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Evaluation of groundwater quality for irrigation and drinking purposes in Barishal district of Bangladesh

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Abstract

A study was conducted to evaluate the quality of groundwater in Barishal district of Bangladesh for both irrigation and drinking purposes. Sixty water samples were collected and analyzed in the Biochemistry laboratory of Bangladesh Agricultural University for the assessment of their quality based on a number of parameters, *viz.* total dissolved solids (TDS), electrical conductivity (EC), sodium adsorption ratio (SAR), Kelly's ratio (KR), residual sodium carbonate (RSC), soluble sodium percentage (SSP), pH and magnesium absorption ratio (MAR), salinity and alkalinity hazard, total cation and anion. Most of the water samples were found as acceptable in terms of TDS, EC, SAR and TH values, but unacceptable based on pH. Though the water samples were demonstrated as 'good' and 'satisfactory' water class in terms of SSP and KR, respectively, they were categorized as 'harmful' water class in term of MAR. However, in terms of salinity and alkalinity hazard, most of the water samples were found as 'good water' class for irrigation. In case of drinking purpose, most of the samples were found as 'permissible', 'good' and 'safe' based on EC, pH, and TDS, respectively. Though the samples were demonstrated as 'suitable' and 'good' water class in terms of TH and nitrate, respectively, they were classified as 'unsatisfactory' based on sulphate. Overall for the groundwater samples, SSP–KR and pH–TH had a very strong correlation with a correlation coefficient around 1, and EC, TH and pH showed a negative correlation with most of the parameters. The study revealed that the quality of groundwater for most of the locations in the area was permissible and good for irrigation and drinking purposes.

Keywords: Groundwater, irrigation, drinking water, quality parameters

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1 Introduction

Water, vital input to life, is one of the most important and essential resources widely available in this world. Almost 40% of the world's food is produced by irrigation that highly depends on groundwater. Groundwater is considered one of the most significant components of the natural resources. About one-third of the world's population utilizes groundwater for drinking purpose with or without treatment (Nickson et al., 2005). It is an important natural source of water for irrigation, domestic and industrial use, and the competition of water use is increasing among these sectors. In Bangladesh, groundwater is the main source of drinking and irrigation water, and approximately 90% of drinking water and 75% of irrigation water come from groundwater sources without any treatment (Shahid et al., 2006; Shariot-Ullah, 2018). The groundwater may be contaminated with the presence of excess amount of different cations, anions, and salts. The type and concentration of salts normally depend on the environment, movement, and source of groundwater (Todd, 1980). If the groundwater gets polluted, it threatens the safe use of groundwater. Hence, control of groundwater pollution is of great importance.

Irrigated agriculture depends on sufficient water supply of usable quality. However, a few years ago, water quality had often been neglected because the supply of good quality water had been plentiful in Bangladesh, but this situation has been changing. Irrigated agriculture in Bangladesh has been experiencing problems regarding water quality. Irrigation with poor quality water reduces soil productivity and changes soil physical and chemical properties (Talukder et al., 1989). Hasan et al. (2016) carried out a study to evaluate the groundwater quality for irrigation purpose; finally, they found that the enhanced dissolution of calcium ions may be expected to block the filter of the pumping well and deteriorate the quality of groundwater for irrigation purposes. Roy et al. (2016) conducted a study on groundwater quality assessment for both irrigation and drinking purposes in Comilla district of Bangladesh; finally they found that the physiochemical properties (*viz.* EC, TDS, TH, SAR, and SSP) of the analyzed groundwater samples were classified as 'permissible' class and very few samples as 'unsuitable' class. Actually, irrigation water quality testing is very important for the estimation of the percentage of different salts, ions and other pollutants, which may affect the public health and food production.

In Barishal district of Bangladesh, specific research work relating the quality of groundwater has not been conducted yet. For this reason, an attempt was taken to assess the groundwater quality for both irrigation and drinking purposes covering the entire area of the Barishal district and also to evaluate the correlations among various water quality parameters.

2 Materials and Methods

2.1 Study location

The Barishal district in Bangladesh was selected as the study area (22°42′5.6″N, 90°21′13.7″E) (Fig. 1). The topography of the study area is flat, comprising of high land and medium high land. The soils of Barishal district fall under local general soil types of noncalcareous grey floodplains soil (non-saline). The textural family of the soils ranges between silty clay to clay loam having highly acidic to the slightly alkaline reaction, and the soils are also slightly poor drained to poorly drained. Groundwater is an important source for irrigation, drinking, and household purposes in the area.

2.2 Water quality parameters

For irrigation and drinking purposes, water is classified on the basis of a number of important quality parameters, *viz.* sodium absorption ratio (SAR), total dissolved solids (TDS), pH, electrical conductivity (EC), total hardness (TH), soluble sodium percentage (SSP), kelly's ratio (KR), magnesium adsorption ratio (MAR), residual sodium carbonate (RSC), salinity and alkalinity hazard, total cation and anion.

A ratio of soil extracts and irrigation water used to express the relative activity of sodium ions in an exchange reaction with soil is called SAR. It was calculated by the following equation (Richards, 1954):

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++}+Mg^{++}}{2}}} \tag{1}$$

Total hardness is the hardness of the mineral content of water that is irreversible by boiling. It is the sum of calcium and magnesium hardness. TH (ppm) was calculated by the following equation (Raghunath, 1987):

$$TH = (Ca^{++} + Mg^{++}) \times 50 \tag{2}$$

Soluble sodium percentage (SSP) is a term used in concentration with irrigation water and soil extract to indicate the proportion of sodium ions in solution in relation to the total cation concentration. It was calculated by the following equation (Todd, 1980):

$$SSP = \frac{Na^+ + K^+}{Ca^{++} + Mg^{++} + Na^+ + K^+} \times 100 \tag{3}$$

The Kelly's ratio was calculated using the equation (Kelly, 1963):

$$KR = \frac{Na^+}{Ca^{++} + Mg^{++}} \tag{4}$$

The magnesium adsorption ratio was calculated by the equation (Szabolces and Darab, 1968):

$$MAR = \frac{Mg^{++}}{Ca^{++} + Mg^{++}} \times 100 \tag{5}$$

Cations are positively charged ions including calcium, magnesium, sodium, potassium, etc. Total cation was calculated by the following equation:

$$\begin{aligned}\text{Total cation} = Na^+ + Ca^{++} + Mg^{++} + K^+ \\ + Fe^{++} + P^{+++} + Na^+\end{aligned} \tag{6}$$

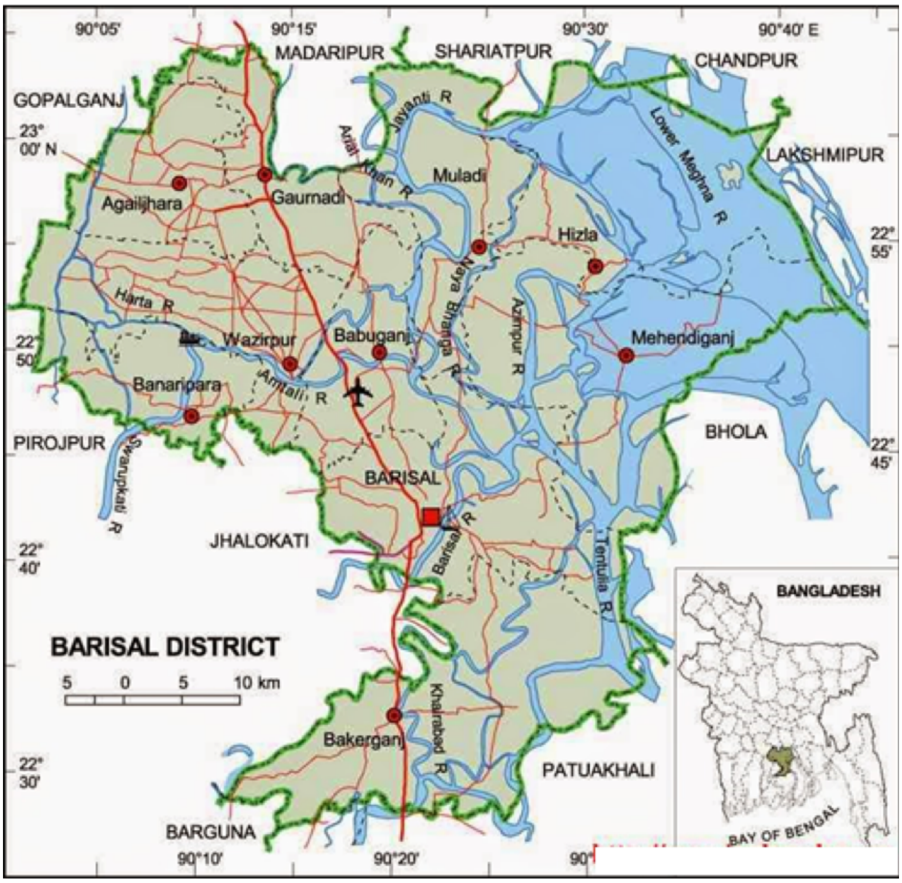

Figure 1. Location of the study area

Anions are negatively charged ions including sulphate, chloride, fluoride, nitrate and those contributing to alkalinity which is usually in term of an equivalent amount of carbonate and bicarbonate. Total anion was calculated by the following equation:

$$\text{Total anion} = SO_4{}^{--} + Cl^- + PO_4{}^{3-} + NO_3{}^- + NO_2{}^- \quad (7)$$

where all the ions in the above equations are expressed in epm.

2.3 Data collection and preparation

In order to analyse groundwater quality, 60 groundwater samples data had been collected from different locations of Barishal district. The water samples were analyzed in the Biochemistry laboratory of Bangladesh Agricultural University for the assessment of EC, pH, TDS, major cations like as calcium, iron, magnesium, sodium, potassium, phosphorous and anions such as chloride, nitrate, nitrite, and sulphate. The groundwater locations were selected to cover the entire study area and attention had been given to the area where contamination was expected. EC and pH of the samples were analyzed using portable EC-meter and pH-meter, respectively, and the other quality parameters were calculated by different equations using different cations and anions concentration present in the water samples, already discussed in the previous section. In this study, the concentrations of Ca and Mg ions were determined by a complex metric titration method using Na_2EDTA (Disodium Ethylenediaminetetraacetic Acid) as titrant. The concentrations of chloride and arsenic were determined by performing a titration test using $AgNO_3$ (Silver Nitrate), and the concentrations of other ions were determined as per standard procedure.

3 Results and Discussion

3.1 Groundwater chemistry

Understanding the chemistry of groundwater is important as it is the main factor in determining it's suitability for drinking, domestic, agricultural and industrial purposes (Subramani et al., 2005). The average values of the physical and chemical parameters of the collected groundwater samples are given in Table 1. The groundwater quality parameters are discussed in the next sections based on their observed and standard values.

3.2 Irrigation water quality

3.2.1 Sodium Adsorption Ratio (SAR)

The SAR values varied from 3.81 to 10.63 with an average value of 5.89 (Table 1). Among the water samples (Table 2), 98.33% low sodic hazard and 1.67% (only one sample) medium sodic hazard as categorized by Wilcox (1955). Almost similar results were obtained in Mahadebpur Upazila of Naogaon district (Zaman, 2000), Dhalia-Randia site of Mymensingh district and Kamalbhog site of Kishoregonj district (Adham et al., 2003). In the study area, the observed value of SAR for the water samples may cause a positive effect on soil hydraulic conductivity and crop yield.

3.2.2 Total Dissolved Solids (TDS)

Total dissolved solids present in the groundwater samples were also considered for judging the quality of irrigation water. All the samples were suitable for irrigation purpose (Davis and Dewiest, 1966) (Table 2) and were in the freshwater category. Todd (1980) reported that it is considered undesirable if the value of TDS exceeds 500 ppm. In the current study, 24 samples had exceeded this TDS limit. Puntamkar et al. (1988) reported that the degree of soil deterioration depends on the degree of TDS content in irrigation water. The soil and plants can thus be affected due to irrigation water in 24 locations within the entire study area.

3.2.3 pH

Based on pH values 0, 48.33, 31.67, 11.67 and 8.33% of the groundwater samples were in the categories of acidic, slightly acidic, practically neutral, slightly alkaline and alkaline, respectively for irrigation purpose according to Ayers and Westcot (1985) (Table 2). Biswas and Khan (1976) reported that the use of waters having pH value of 7.69 to 8.33 did not create any problem for normal use. Values of pH of most of the water samples were less than 8.33, indicating their suitability for irrigation.

3.2.4 Electrical Conductivity (EC)

The EC value ranged from 405 to 2400 μS cm^{-1} with an average value of 857.05 μS cm^{-1} in the study area (Table 1). According to the EC values (Wilcox, 1955), 65, 25 and 10% of the groundwater samples were found as good, medium and bad water class, respectively, for irrigation purposes (Table 2).

Again, according to WHO (1993), 83.33% of the samples showed EC values within the permissible limit, but the rest of the samples were not in the permissible limit, and there was no hazardous sample (Table 2).

3.2.5 Soluble Sodium Percentage (SSP)

The SSP value of the groundwater samples ranged from 15.14 to 50.66. It was observed that 11.67, 75 and 13.33% samples were in the excellent, good and permissible category according to Wilcox (1955) (Table 2).

The Wilcox (1955) diagram (Fig. 2), relating sodium percentage and EC, indicates that 65, 18.3 and 16.66% of the groundwater samples fell in the category of excellent to good, good to permissible, and doubtful to unsuitable, respectively, for irrigation. The Na% for groundwater was much higher than the present finding, reported by Adham et al. (2003) in Kamalbhog, Kishoreganj, and Zaman (2000) in the barind area of Bangladesh.

3.2.6 Kelly's Ratio (KR)

Kelly's ratio for the water samples ranged from 0.15 to 0.94. Kelly (1963) suggested that this ratio should not exceed unity for irrigation water. Not a single sample in the entire study area was found to exceed the limit.

3.2.7 Magnesium Adsorption Ratio (MAR)

The MAR of the water samples was between 83.31 and 83.37. Gupta and Gupta (1987) observed a harmful effect on soils while MAR exceeded the limit of 50. In the present study, all of the samples demonstrated the MAR values higher than 50, which may harm the soil. Almost similar result on the MAR value of the water samples was also reported by Adham et al. (2003).

3.2.8 Residual Sodium Carbonate (RSC)

Based on RSC values, 86.67, 5 and 8.33% of the groundwater samples fell in the category of good, doubtful and unsuitable for irrigation, respectively (Table 2).

3.2.9 Salinity and alkalinity hazard

Sodium adsorption ratio is an important parameter for determining the suitability of groundwater for irrigation as it is a measure of alkali or sodium hazard to crop. According to the classification of irrigation waters (Richards, 1954), 63.33% of the groundwater samples fell in the field of C2-S1, indicating medium salinity and low sodium content/hazard and suitable for irrigation for all types of soil; 25% of the samples were in the category of C3-S1, indicating medium-high salinity and low sodium and suitable for irrigation in almost all types of soil with little danger of exchangeable sodium; and 10% of the samples were in the field of C4-S1, indicating high salinity and low alkalinity hazard. Only 1.67% of groundwater

Table 1. Average values of the quality parameters of groundwater samples

Water quality parameters	Average	Range
Arsenic (ppm)	0.01	0–0.5
Calcium (ppm)	20.57	9.72–57.6
Cal + Mg (ppm)	4.37	2.02–8.6
Chloride (ppm)	122.12	20–203
EC (μs/cm)	857.05	405–2400
Hardness (ppm)	218.4	101–430
Iron (ppm)	0.93	0.1–5
Magnesium (ppm)	102.85	48.6–288
Nitrate (ppm)	3.85	0–5.4
Nitrate + Nitrogen (ppm)	0.33	0–0.5
Nitrite (ppm)	0	0–0
Nitrogen (ppm)	0	0–0
pH	6.88	6.1–8.6
Phosphate (ppm)	4.27	0.2–7.5
Phosphorous (ppm)	7.74	0–50
Potassium (ppm)	9.22	5–20
Residual sodium carbonate (epm)	0.56	0–5.52
Sodium adsorption ratio (SAR)	5.89	3.81–10.63
Sodium (ppm)	42.29	28–77
Sulphate (ppm)	197.68	0–404
Total dissolved solids (TDS) (ppm)	458.92	295–818
TH (ppm)	256.58	101–485

samples fell in the field of C2-S2, indicating water of medium salinity and medium sodium hazard. The present findings on salinity and alkalinity hazard partially agreed by Arumugam and Elangovan (2008), conducted a study on hydrochemical characteristic and groundwater quality assessment in Tirupur region, Coimbatore district, Tamil Nadu, India. Excess salinity reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil.

3.3 Drinking water quality

The physical and chemical parameters of the groundwater samples were compared with the standard guideline values given by the World Health Organization (WHO, 1993) and Bangladesh drinking and public health standards (MoEF, 1977) (Table 3). The table shows the most desirable limits and maximum allowable limits of various parameters based on WHO and acceptable drinking limit based on Bangladesh standard. It was found that 18.33 and 16.67% of the samples had higher K^+ and Mg^{2+} concentrations, respectively, compared to the WHO limits, and 48.33% of the sample locations exceeded the standard limits for SO_4^{2-}. According to the Bangladesh standard, it was observed that 18.33 and 93.33% of the samples exceeded the concentration limit of K^+, Mg^{2+}, and 48.33% of the sample locations had the standard limits for SO_4^{2-}.

3.3.1 pH

The pH value of the groundwater samples ranged from 6.1 to 8.6 with an average value of 6.88 in the study area (Table 1). On the basis of pH value of groundwater in the study area, 1.66% samples exceeded the acceptable limit of Bangladesh standard and there was no sample to exceed the allowable limit of WHO standard (Table 3).

3.3.2 Total Dissolved Solids (TDS)

The value of TDS of the samples in the study area ranged from 295 to 818 ppm with an average value of 458.92 ppm (Table 1). It was found that the groundwater was in the range of fresh water. The study also showed that 60% of the groundwater samples contained less than 500 ppm of TDS, which can be used for drinking without any risk, and 40% of the samples was permissible for drinking, and there was no sample which was unfit for drinking according to Davis and Dewiest (1966) (Table 4).

3.3.3 Total Hardness (TH)

The hardness values of the groundwater samples ranged from 101 to 430 ppm (Table 1). The classification of groundwater based on total hardness (Raghunath, 1987) showed that a majority of the groundwater samples fell in the moderately hard water category (Table 4).

Table 2. Classification of groundwater samples based on different parameters

Classification parameter and range	Water class and its developer	No. of sample	% of sample
Sodium adsorption ratio (SAR)	Wilcox (1955)		
0 – 10	Low sodic hazard (S1)	59	98.33
10 – 18	Medium sodic hazard (S2)	1	1.67
18 – 26	High sodic hazard (S3)	0	0
>26	Very high sodic hazard (S4)	0	0
Total dissolved solids (TDS) (ppm)	Davis and Dewiest (1966)		
<500	Desirable for drinking	36	60
500 – 1000	Permissible for drinking	24	40
1000 – 3000	Useful for irrigation	0	0
>3000	Unfit for drinking & irrigation	0	0
pH	Ayers and Westcot (1985)		
<5.5	Acidic	0	0
5.6 – 6.4	Slightly acidic	29	48.33
6.5 – 7.5	Practically neutral	19	31.67
7.6 – 8.0	Slightly alkaline	7	11.67
8.1 – 9.0	Alkaline	5	8.33
Electrical conductivity (EC) (μS cm^{-1})	Wilcox (1955)		
<250	Excellent (C1)	0	0
250 – 750	Good (C2)	39	65
750 – 2250	Medium (C3)	15	25
2250 – 4000	Bad (C4)	6	10
4000 – 6000	Very Bad (C5)	0	0
Electrical conductivity (EC) (μS cm^{-1})	WHO (1993)		
<1500	Permissible	50	83.33
1500 – 3000	Not permissible	10	16.67
>3000	Hazardous	0	0
Soluble Na (%)	Wilcox (1955)		
<20	Excellent	7	11.67
20 – 40	Good	45	75
40 – 60	Permissible	8	13.33
60 – 80	Doubtful	0	0
>80	Unsuitable	0	0
Residual sodium carbonate (RSC) (epm)	Raghunath (1987)		
<1.25	Good	52	86.67
1.25 – 2.5	Doubtful	3	5
>2.5	Unsuitable	5	8.33

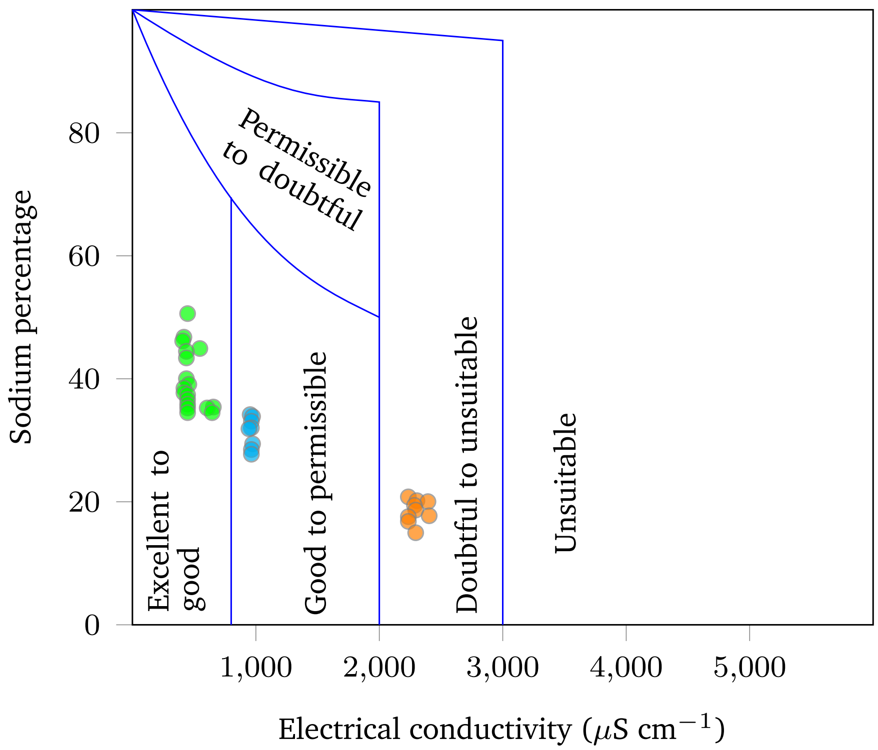

Figure 2. Suitability groundwater samples for irrigation according to Wilcox (1955) classification

The maximum allowable limit of TH for drinking purpose is 500 ppm and the most desirable limit is 100 ppm as per the WHO international standard. For total hardness, the most desirable limit is 80–100 ppm (Freeze and Cherry, 1979). Groundwater exceeding the limit of 300 ppm is considered to be very hard (Sawyer and McMcartly, 1967). A majority of the groundwater samples was in the moderately high water category for drinking purpose (Table 4) and all the data were within the maximum allowable limit of 500 ppm.

3.3.4 Chloride

The chloride concentration varied between 20 ppm to 203 ppm with an average value of 122.12 ppm (Table 1). There was no chloride ion concentration which exceeds the maximum allowable limit of 600 ppm based on WHO and acceptable drinking limit of 150–600 ppm according to Bangladesh standard (Table 3).

3.3.5 Nitrate

The nitrate ion concentration varied from 0 to 5.4 ppm with an average value of 3.85 ppm (Table 1). There was no nitrate ion concentration which exceeded the most desirable limit of WHO (45 ppm) and acceptable drinking water limit of Bangladesh standard (10 ppm) (Table 3). As all nitrate ion concentrations in the entire study area were below the acceptable limit, there was no risk of using water for domestic purposes.

3.3.6 Sulphate

The sulphate ion concentration varied from 0 to 404 ppm with an average value of 197.68 ppm (Table 1). The concentration of sulphate is likely to react with human organs if the value exceeds the maximum allowable limit of 400 ppm. It was found that 48.33% of the total sample exceeded the maximum allowable limit of WHO and acceptable drinking limit of Bangladesh standard (Table 3).

3.3.7 Magnesium

The magnesium ion concentration of the samples varied from 48.6 to 288 ppm with an average value of 102.85 ppm (Table 1). Excess magnesium with excess sulphate causes a laxative effect on the human system. It was revealed that 16.67% of total samples exceeded the maximum allowable limit of WHO and 93.33% samples had concentrations within the acceptable drinking water limit of Bangladesh standard (Table 3).

3.3.8 Arsenic

Arsenic is poisonous when its intake exceeds the limit of tolerance. People suffer from arsenicosis after consuming arsenic-contaminated water year after year. The arsenic concentrations varied from 0 to 0.5 ppm

Table 3. Groundwater quality standard (permissible and acceptable limits) prescribed by WHO and Bangladesh for domestic purposes

Quality parameter	WHO standard			Bangladesh standard	
	Most desirable limit	Max. allowable limit (MAL)	Sample exceed MAL (%)	Acceptable drinking limit	Sample exceed acceptable limits (%)
pH	6.5 – 8.5	9.2	0	6.5 – 8.5	1.66
TDS (ppm)	500	1500	0	1000	0
Calcium (ppm)	75	200	0	75	0
Magnesium (ppm)	50	150	16.67	30 – 50	93.33
Potassium (ppm)	–	12	18.33	12	18.33
Sodium (ppm)	–	200	0	200	0
Chloride (ppm)	200	600	0	150 – 600	0
Nitrate (ppm)	45	–	0	10	0
Sulphate (ppm)	200	400	48.33	400	48.33

Table 4. Classification of drinking water samples based on different parameters

Classification parameter and range	Water class and its developer	No. of sample	% of sample
Total dissolved solids (TDS) (ppm)	Davis and Dewiest (1966)		
<500	Desirable for drinking	36	60
500 – 1000	Permissible for drinking	24	40
1000 – 3000	Useful for irrigation	0	0
>3000	Unfit for drinking and irrigation	0	0
Hardness (epm)	Raghunath (1987)		
0 – 50	Soft	0	0
56 –100	Slightly hard	0	0
101 – 200	Moderately hard	33	55
201 – 500	Very hard	27	45
Hardness (TH as $CaCO_3$ (ppm))	Sawyer and McMcartly (1967)		
<75	Soft	0	0
75 – 150	Moderately high	33	55
150 – 300	Hard	4	6.67
>300	Very hard	23	38.33

Table 5. Correlation matrix of different water quality parameters

Parameters	EC	TH	pH	RSC	TDS	SAR	MAR	KR	SSP	Total anion	Total cation
EC	1										
TH	0.50	1									
pH	0.52	0.87	1								
RSC	–0.22	–0.31	–0.31	1							
TDS	0.59	0.47	0.63	–0.24	1						
SAR	–0.46	–0.13	–0.08	0.01	–0.35	1					
MAR	0.19	0.08	0.23	–0.20	0.29	–0.12	1				
KR	–0.90	–0.66	–0.63	0.21	–0.62	0.68	–0.18	1			
SSP	–0.92	–0.50	–0.45	0.18	–0.51	0.63	–0.19	0.94	1		
Total anion	–0.60	–0.87	–0.85	0.33	–0.80	0.23	–0.16	0.67	0.49	1	
Total cation	0.58	0.46	0.63	–0.23	1	–0.34	0.29	–0.61	–0.50	–0.8	1

with an average value of 0.01 ppm (Table 1). Based on Bangladesh standard (MoEF, 1977), the maximum allowable limit of arsenic for drinking water is 0.05 ppm., Among 60 groundwater samples in the present study, only one sample exceeded the limit and 3 water samples showed presence of arsenic beyond the safe limit (0.05 ppm), and other samples were found to be arsenic free. Finally, it was found that almost all the water samples were safe for drinking purpose.

3.4 Interrelationship among different water quality parameters

The correlation for physiochemical parameters of the groundwater samples was done by bivariate technique. The correlation coefficient (R) was calculated to find out the relationship between the quality parameters of the groundwater samples, presented in Table 5.

R identifies the correlation between the parameters, and its value ranges between -1 and 1. The value of R around zero shows no relationship between the parameters (Srivastava and Ramanathan, 2007). Its value around 1 represents a very strong correlation between the parameters. If the value of R is more than 0.7, then it is considered as strongly correlated for the geochemical study. If its value varies from 0.5 to 0.7, the parameters are moderately correlated. If its value is negative, it shows that the value of one parameter is decreasing with the increase in another parameter (Giridharan et al., 2007). Besides very strong correlation (R = 0.94) between SSP and KR, a strong correlation (R = 0.87) was also found between pH and TH. In this study, EC, TH and pH showed a negative correlation with most of the parameters. Overall in the study area, TH–EC, pH–EC, TDS–EC, TDS–pH, KR–SAR, total anion–KR, total cation–EC and total cation–pH were moderately correlated with correlation coefficient from 0.5 to 0.7, and other pairs of the parameters had a weak correlation with a correlation coefficient less than 0.5.

4 Conclusions

The most of the groundwater samples of the study area were good with respect to EC, low sodic hazard in case of SAR, slightly acidic based on pH and good with respect to SSP as long as irrigation is a concern. In case of drinking purpose, the most of the groundwater samples were permissible, good and safe with respect to EC, pH and TDS, respectively. Maximum hardness and arsenic concentrations were found within the acceptable limit and therefore, the water was suitable for drinking. All samples were in a good category with respect to nitrate and magnesium, but the samples were not so satisfactory in case of sulphate ion concentration. Overall for the groundwater samples, SSP–KR and pH–TH had a very strong correlation, and TH–EC, pH–EC, TDS–EC, TDS–pH, KR–SAR, total anion–KR, total cation–EC and total cation–pH were moderately correlated, and other pairs of the parameters had a weak correlation. Therefore, the quality of groundwater in the study area was almost permissible and good for irrigation and drinking purposes based on their physical and chemical properties analysis.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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