Assessing groundwater pollution for irrigation in Puthia upazila, Rajshahi

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Abstract: Groundwater samples were collected from Puthia upazila under the district of Rajshahi to determine ionic concentration as pollutant in order to classify them on the basis of their suitability for irrigation usage. Water samples were slightly alkaline (pH = 7.10-7.24) and were not problematic for crop production. TDS of all water samples were classified as fresh water (TDS<1,000 mg L^{-1}). EC and SAR showed medium salinity (C2) and low alkalinity (S1) hazards combinedly expressed as C2S1. EC values of the collected water samples were in medium salinity hazard and could be safely used for crops growing on soils with moderate level of permeability and leaching. SAR values were excellent in quality for irrigating soils and crops. Out of 15 water samples, 12 samples were classified as excellent and the rest 3 samples were rated as good in quality based on SSP. Waters were free from RSC and belonged to suitable in category. All water samples were hard in quality. The concentrations of HCO_3, Fe, Mn, BO_3, SO_4, PO_4 and Cl were below the toxic levels as irrigation water and might not pose threat to soil environment as pollutants. The relationship between different water quality criteria like EC, TDS, SAR, SSP, RSC and H_T were established and combinations such as EC vs TDS, EC vs RSC, EC vs H_T, SAR vs SSP, SSP vs RSC SSP vs H_T and RSC vs H_T exhibited significant positive correlation.
Key words: Groundwater, pollution and irrigation.

Introduction

Water is one of the precious renewable vital natural resource for survival of all kinds of life on planet earth. With the ever increasing demand of water, the importance of utilization of groundwater is increasing at an accelerated rate in Bangladesh. Water quality is equally important as quantity in the evaluation of water resources potentially for irrigation usage in successful crop production. All groundwater contains dissolved ionic constituents and its quality depends on the amounts and different species of ions. Among the ions, Ca, Mg, Na, Cl, Fe, B and HCO_3 are of prime importance in assessing the water quality for irrigation (Michael, 2008). The usual toxic ions such as B, Na and Cl in groundwater for irrigation are sensitive to plants at relatively low concentrations (Bohn *et al*., 2001). When the polluted groundwater is applied to soil for long-term irrigation, dissolved ionic constituents containing toxic elements may accumulate in the soil thus affecting soil qualities as well as crop growth and becomes less suitable for irrigation in relation to soil properties and crop growth. Intensive farming has the potential to contaminate groundwater. Different agrochemicals used in farming system are leached downward out of soil zone to groundwater. As a consequence of these different agricultural activities, the potential contaminants can result in groundwater pollution and have the potential to produce problems in agroecosystem (Schwartz and Zhang, 2012).

The study area has different water sources but groundwater is mainly used for irrigation. The chemical analysis of water is commonly used to determine whether water meets standards for irrigation use of agricultural crops or for support of the health of human. The cropping patterns like HYV rice, vegetables and *rabi* crops are cultivated under irrigation. Systematic study on groundwater quality is necessary to grow public awareness in rural areas of Bangladesh. Keeping the above facts in mind, the present study was aimed towards evaluation of groundwater pollution for irrigation purpose.

Materials and Methods

Water sampling: Groundwater sampling sites consisted of six unions *viz*., Bhalukgachhi, Shilmaria, Puthia, Baneshwar, Belpukuria and Jeopara under Puthia upazila of Rajshahi district in Bangladesh. Exactly 15 water samples were randomly collected from tube wells of the investigated area during 11 March to 10 April, 2013 following the sampling techniques as outlined by Hunt and Wilson (1986) and APHA (2012). The depth of tube wells ranged from 49.0 to 55.0 m and the duration of irrigation usage was from 5 to 12 years. During sampling, all water samples were colorless, odorless, tasteless and also free from turbidity. All water samples were filtered and tightly sealed immediately to avoid air exposure and thereafter, analyzed.

Water analysis: pH and EC values were determined electrometrically (Gupta, 2013). The amount of total dissolved solids (TDS) was measured by evaporating water samples to dryness after Chopra and Kanwar (1991). Ca and Mg were estimated by EDTA titrimetric method while the concentrations of K and Na were determined by flame photometric method (APHA, 2012). Chloride was analyzed by titrimetric method (Singh *et al*., 1999) and CO_3 and HCO_3 were determined by titrimetric method (Tandon, 1995). The concentrations of BO_3 and PO_4 were determined by spectrophotometric method and SO_4 was determined by turbidimertic method (Tandon, 1995). Fe and Mn contents were determined by atomic absorption spectrometric method (APHA, 2012).

Water pollution rating: The following chemical parameters generated from the analytical results were considered for judging the pollution of groundwater - (i) Sodium adsorption ratio (SAR) = $Na^+ \div [\sqrt{\{(Ca^{2+} + Mg^{2+}) \div 2\}}]$, (ii) Soluble sodium percentage (SSP) = $\{(Na^+ + K^+) \div (Ca^{2+} + Mg^{2+} + Na^+ + K^+)\} \times 100$, (iii) Residual sodium carbonate (RSC) = $(CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$, (iv) Hardness ($H_T$) = $2.5 \times Ca^{2+} + 4.1 \times Mg^{2+}$, Where, ionic concentrations were expressed as me L^{-1} but in hardness, cationic concentrations were expressed as mg L^{-1}.

Statistical analysis: The statistical analyses were done following the standard method as mentioned by Gomez and Gomez (1984).

Results and Discussion

The chemical composition and the extent of groundwater pollution have been presented in Tables 1-3. The major ions like Ca, Mg, K, Na, HCO_3 and Cl were dominant but

the remaining ions were also detected in minor amounts. None of the samples was responded to CO_3 test.

Water pollution assessment

pH, EC and TDS status: pH of all groundwater samples ranged from 7.10 to 7.24 indicating slightly alkaline and were not problematic for crop production (Table 1) where the recommended limit of pH in water for irrigation is from 6.50 to 8.40 (Ayers and Westcot, 1985). This might be due to the presence of major ions like Ca, Mg, Na and HCO_3 in water as mentioned by Rao *et al*. (1982). Electrical conductivity (EC) varied from 320.0 to 460.0 µS cm^{-1} with mean value of 392.3 µS cm^{-1} (Table 1). According to Richards (1968), all water samples were classified as medium salinity (C2, EC= 250-750 µS cm^{-1}) class and could safely be used for crops growing on soils with moderate level of permeability and leaching. The total dissolved solids (TDS) ranged from 220.0 to 270.0 mg L^{-1} with average value of 246.2 mg L^{-1} as reported in Table 1. All waters were rated as fresh water (TDS <1,000 mg L^{-1}) in quality (Freeze and Cherry, 1979). Similar results on TDS in groundwater pollution were reported by Rahman *et al*. (2005) and Rahman and Rahman (2006).

Table 1. pH, EC, TDS, Ca, Mg and K levels of groundwater samples

Sample No.	Sampling site		pH	EC	TDS	Ca	Mg	K
	Union	Village		µS cm^{-1}	mg L^{-1}	-------- me L^{-1} ---------		
1	Bhalukgachhi	Majhpara	7.14	390.0	240.0	2.90	2.20	0.059
2		Gaenpara	7.18	368.0	227.0	3.00	2.40	0.046
3		Ghatia	7.10	320.0	220.0	2.70	1.90	0.072
4	Shilmaria	Jogopara	7.18	448.0	266.0	2.90	2.30	0.084
5		Kajupara	7.16	377.0	245.0	2.60	2.20	0.086
6		Kartikpara	7.18	338.0	231.0	2.30	2.20	0.072
7	Puthia	Bashupara	7.20	383.0	246.0	2.20	2.50	0.085
8		Kanthalbaria	7.14	413.0	251.0	2.90	2.70	0.072
9		Palopara	7.12	358.0	236.0	3.30	1.60	0.059
10	Baneshwar	Maipara	7.20	430.0	256.0	2.80	2.40	0.074
11		Polashbari	7.18	382.0	243.0	2.10	1.70	0.072
12	Belpukuria	Belpukuria	7.16	406.0	253.0	3.30	2.00	0.086
13		Bashpukuria	7.20	460.0	270.0	2.90	2.90	0.088
14	Jeopara	Dhopapara	7.15	388.0	250.0	3.50	1.50	0.072
15		Gaopara	7.24	424.0	259.0	2.50	2.80	0.074
		Min.	7.10	320.0	220.0	2.10	1.50	0.046
		Max.	7.24	460.0	270.0	3.50	2.90	0.088
		Mean	-	392.3	246.2	2.79	2.22	0.074
		SD	-	38.84	14.00	0.40	0.42	0.012
		CV (%)	-	9.90	5.68	14.34	18.92	16.22

Ca, Mg, K and Na status: The concentrations of Ca, Mg, K and Na ions in all samples fluctuated from 2.10 to 3.50, 1.50 to 2.90, 0.046 to 0.088 and 0.84 to 1.24 me L^{-1} with the average values of 2.79, 2.22, 0.074 and 1.05 me L^{-1}, respectively (Tables 1 & 2). Ca and Mg levels were comparatively higher than that of K and Na in groundwater. The contribution of Ca and Mg ions in water was mainly dependent on the solubility of these cations bearing minerals (Karanth, 1994). According to Ayers and Westcot (1985), the accepted usual ranges of Ca, Mg and Na ions are 20.0, 5.0 and 40.0 me L^{-1}, respectively and the usual limit of K ion for irrigation is 2.0 mg L^{-1}. On the basis of these cationic contents, all groundwater samples could safely be applied for irrigation without hazard.

Fe and Mn status: The results in Table 2 revealed that all groundwaters contained trace amount of Fe and Mn (<0.01 mg L^{-1}). As per this detected level, these ions were not considered as pollutants for irrigation in relation to soil properties and crop growth.

Cl and HCO_3 status: Cl and HCO_3 ions in the collected water samples were within the limit of 0.28 to 0.52 and 0.70 to 1.40 me L^{-1} with the average values of 0.37 and 0.96 me L^{-1}, respectively. On the basis of guideline for interpretation of water quality for irrigation, Cl ion was suitable for irrigating soils and crops because its concentration did not exceed the specified limit (4.00 me L^{-1}) as mentioned by Ayers and Westcot (1985). According to Evangelou (1998), the recommended maximum concentration of HCO_3 for irrigation water used continuously on soil is 1.50 me L^{-1}. As per this acceptable range, HCO_3 status of all waters was not considered as pollutant for continuous irrigation.

BO_3, SO_4 and PO_4 status: The content of BO_3 in water samples ranged from 0.010 to 0.092 mg L^{-1} with the mean value of 0.044 mg L^{-1} (Table 2). The level of BO_3 in samples showed no problematic threat for irrigating soils and crops, where the specified limit for irrigation is <1.00 mg L^{-1} (Ayers and Westcot, 1985) and all samples were excellent for sensitive crops. PO_4 in all water samples varied from 0.06 to 0.24 mg L^{-1} and these waters were not problematic for long-term irrigation showing no hazardous impact on soil properties and crop growth because the detected anion did not exceed the permissible limit (2.0 mg L^{-1}) in irrigation water (Ayers and Westcot, 1985). SO_4 content of the waters varied from 0.76 to 2.60 mg L^{-1} with the mean value of 1.32 mg L^{-1} and was not hazardous when applied as irrigation water, where the recorded values of SO_4 ion were below the recommended limit (20 me L^{-1}) for irrigation (Ayers and Westcot, 1985).

Water quality determining indices:

SAR, SSP, RSC and Hardness status: The results in Table 3 showed that the calculated SAR, SSP and RSC

values of water samples varied from 0.54 to 0.78, 15.20 to 21.46% and -4.70 to -3.10 me L^{-1}, respectively. SAR was less than 10 and were considered as excellent class indicating low alkalinity hazard (S1) but on the basis of SSP, 12 samples were excellent (SSP<20%) and the rest 3 were in good (SSP = 20-40%) classes (Todd and Mays, 2004). RSC of water samples were rated as suitable (RSC<1.25 me L^{-1}) for irrigation (Schwartz and Zhang, 2012) because RSC values were negative and all samples were also free from RSC. Hardness (H_T) values varied from 188.78 to 287.82 mg L^{-1}. All groundwater samples were hard (H_T = 150-300 mg L^{-1}) in quality (Sawyer and McCarty, 1967). Similar result was observed by Rahman and Rahman (2007). Hardness of waters resulted due to the abundant of divalent ions such as Ca and Mg (Todd and Mays, 2004; Manahan, 2010).

Table 2. Cationic and anionic constituents of groundwater samples

Sample No.	Na	HCO_3	Cl	BO_3	PO_4	SO_4	Fe	Mn
	---------- me L^{-1} ----------			---------- mg L^{-1} ----------				
1	0.84	0.80	0.42	0.012	0.16	2.14	Trace	Trace
2	0.92	0.70	0.35	0.014	0.12	2.50	Trace	Trace
3	0.94	0.90	0.28	0.048	0.10	0.80	Trace	Trace
4	1.24	1.00	0.49	0.010	0.08	0.78	Trace	Trace
5	1.10	1.10	0.40	0.048	0.06	1.10	Trace	Trace
6	1.08	1.20	0.28	0.018	0.18	0.88	Trace	Trace
7	1.20	0.80	0.35	0.026	0.20	0.76	Trace	Trace
8	0.98	1.40	0.52	0.034	0.24	2.10	Trace	Trace
9	0.96	1.00	0.42	0.056	0.22	1.84	Trace	Trace
10	1.12	0.90	0.32	0.040	0.14	2.60	Trace	Trace
11	0.90	0.70	0.28	0.078	0.08	0.78	Trace	Trace
12	1.04	0.80	0.35	0.092	0.12	0.80	Trace	Trace
13	1.08	1.10	0.42	0.048	0.22	1.00	Trace	Trace
14	1.22	0.80	0.35	0.070	0.12	0.86	Trace	Trace
15	1.16	1.20	0.30	0.072	0.24	0.94	Trace	Trace
Min.	0.84	0.70	0.28	0.010	0.06	0.76	-	-
Max.	1.24	1.40	0.52	0.092	0.24	2.60	-	-
Mean	1.05	0.96	0.37	0.044	0.15	1.32	-	-
SD	0.12	0.21	0.07	0.026	0.06	0.69	-	-
CV (%)	11.42	21.88	18.92	60.00	40.00	52.27	-	-

Legend: Trace amount of Fe or Mn was <0.01 mg L^{-1}.

Table 3. Quality classification of groundwater for irrigation usage

Sample No.	SAR		SSP (%)		RSC (me L^{-1})		H_T (mg L^{-1})		Alkalinity and Salinity Hazards
	Value	Class	Value	Class	Value	Class	Value	Class	
1	0.54	Ex.	15.20	Ex.	-4.30	Suit.	253.37	Hard	C2S1
2	0.58	Ex.	15.32	Ex.	-4.70	Suit.	268.21	Hard	C2S1
3	0.60	Ex.	17.90	Ex.	-3.70	Suit.	228.61	Hard	C2S1
4	0.75	Ex.	19.98	Ex.	-4.20	Suit.	258.29	Hard	C2S1
5	0.70	Ex.	19.32	Ex.	-3.70	Suit.	238.37	Hard	C2S1
6	0.72	Ex.	20.38	Good	-3.30	Suit.	223.37	Hard	C2S1
7	0.78	Ex.	21.46	Good	-3.90	Suit.	233.13	Hard	C2S1
8	0.58	Ex.	15.76	Ex.	-4.20	Suit.	277.97	Hard	C2S1
9	0.60	Ex.	17.02	Ex.	-3.90	Suit.	243.85	Hard	C2S1
10	0.62	Ex.	17.36	Ex.	-4.30	Suit.	258.21	Hard	C2S1
11	0.66	Ex.	20.90	Good	-3.10	Suit.	188.78	Hard	C2S1
12	0.65	Ex.	17.64	Ex.	-4.50	Suit.	263.53	Hard	C2S1
13	0.63	Ex.	16.73	Ex.	-4.70	Suit.	287.82	Hard	C2S1
14	0.64	Ex.	17.73	Ex.	-4.20	Suit.	248.93	Hard	C2S1
15	0.68	Ex.	17.21	Ex.	-4.10	Suit.	267.81	Hard	C2S1
Min.	0.54	-	15.20	-	-4.70	-	188.78	-	-
Max.	0.78	-	21.46	-	-3.10	-	287.82	-	-
Mean	0.65	-	18.00	-	-4.10	-	249.35	-	-
SD	0.067	-	2.00	-	0.46	-	24.72	-	-
CV (%)	10.30	-	11.10	-	11.22	-	9.92	-	-

Legend: Ex.= Excellent; Suit. = Suitable; C2= Medium Salinity & S1= Low Alkalinity

Relationship between chemical parameters for water quality: The relationship between six quality parameters such as EC, TDS, SAR, SSP, RSC and hardness was established and out of 15 combinations, 6 combinations were significant at 1% level and only 1 combination was significant at 5% level (Table 4). Significant correlations existed between EC vs TDS, EC vs RSC, EC vs H_T, SAR vs SSP, SSP vs RSC SSP vs H_T and RSC vs H_T. The relationship between chemical parameters did not reflect any negative signal on water quality for irrigation.

Table 4. Correlation matrix among the chemical parameters of groundwater quality

Parameters	TDS	SAR	SSP	RSC	Hardness
EC	0.955**	0.071 NS	0.158NS	0.646**	0.624*
TDS		0.255NS	0.032NS	0.534NS	0.507 NS
SAR			0.931**	0.356NS	0.395 NS
SSP				0.663**	0.694**
RSC					0.996**

Legend: **Significant at 1% level; *Significant at 5% level & NSNot significant, Tabulated values of r with 13 df are 0.514 at 5% and 0.641 at 1% level of significance

It is concluded from the above findings that all groundwater samples could be safely applied for irrigation without any hazardous impacts on crops growing on soils with moderate level of permeability and leaching in the investigated area.

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