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Toxicity Assessment of Ground Water in Different Aquifers of Khagrachari in Bangladesh

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Abstract: A study was conducted to evaluate the water quality at Matiranga Upazilla under Khagrachari Hill District of Bangladesh. pH values (6.72-7.54) indicated that groundwater was slightly acidic to neutral. Ca (0.4-6.90 mg L^{-1}) Mg (0.55-6.60 mg L^{-1}), Na (4.00-44.00 mg L^{-1}), K (4.75-13.50 mg L^{-1}), HCO_3 (0.15-1.20 me L^{-1}) and CI (0.30-1.60 me L^{-1}) were predominant along with Zn, Mn and P in lesser amounts. Fe, Cu, As, B and SO_4 were found trace to very little amounts. Total dissolved solids (TDS) and sodium adsorption ratio (SAR) values were 35-200 mg L^{-1} and 0.36-3.40 respectively and indicated that all water were under freshwater' and excellent' class respectively. In terms of soluble sodium percentage (SSP), most water was doubtful. SAR (0.36-3.40) and EC (52-300 μS cm^{-1}) values classified the water as CI-SI except one as C2-S1. All water was under the category of soft regarding hardness with 'suitable' RSC. Based on As, Fe, Mn, Zn, SO_4, NO_3 and CI all water was within the safe limit for drinking except 3 samples for Mn and one for As.

Key words: Toxicity, groundwater, chemical elements, irrigation, Khagrachari, Bangladesh

Introduction

Groundwater is an important source of freshwater for agricultural, drinking and domestic uses in many regions of the world and also in Bangladesh. Demand of groundwater has been increasing day by day for irrigation by bringing more area under cultivation. Water generally contains different species of cation and anions in varying amounts. The concentration and comparison of dissolved constituents in water is an important determinant concerning its quality. Among the chemical constituents Ca, Mg, Fe, Na, Cl, HCO_3, SO_4 and B are of prime importance in determining the quality and suitability of irrigation water. The assessment of waterquality indicates their potential to foster soil conditions determental to crop growth. The dominance of HCO^{-}_{3}, CO_3^{-2}, Na^{+}, Ca^{+2}, Mg^{+2} and CI^{-} ions were detected in groundwater collected from different regions of Bangladesh (Rahman and Zaman, 1995; Quddus and Zaman, 1996). Currently 16% of the cultivated area are irrigated from different sources.

Among the sources hand tubewell (HTW) water was used for irrigating vegetable crops and driniking. It is mentionable that in the study area there is no shallow or deep tubewell. In the near future groundwater will be the main source of irrigation and domestic uses in this remote hilly region. Therefore, the present study was conducted to assess the level of different chemical constituents present HTW's water and to compare them with the standards of acceptable quality for irrigation and drinking.

Materials and Methods

The study was conducted at some parts of Matiranga Upazilla during the month of March, 2001. Within the study area, 21 sites were selected for collecting water samples. The dates of sinking and commissioning of different tubewells has been presented in Table 1, which indicated duration of use. In order to assess their suitability for irrigation and drinking uses, the important inorganic constituents of groundwater were determined. Water samples were collected following the techniques as outlined by Hunt and Wilson (1986) and Anonymous (1989).

The pH and EC were determined electrometrically (Anonymous, 1989). Total dissolved solids (TDS) were estimated after Chopra and Kanwar (1980). Ca and Mg were analyzed by complexometric titration (Page *et al*., 1982). Whereas K and Na were estimated by flame emission spectrophotometer (Ghosh *et al*., 1983). Sulfate was determined turbidimetrically (Wolf, 1982) while CO_3 and HCO_3 were analyzed titrimetrically (Ghosh *et al*., 1983; Chopra and Kanwar, 1980). Chloride was estimated by argentometric titration (Anonymous, 1989; Ghosh *et al*., 1983) and P, B and NO_3 were determined colorimetrically. Arsenic (As) was determined by absorption spectrophotometer equipped with hydride generator situated at Soil Resources Development Institute (SRDI) Laboratory in Bangladesh (Anonymous, 1989). Iron, zinc, copper and manganese were analyzed by atomic absorption spectorphotometer (Anonymous, 1989) in the

Laboratory of Soil Chemistry Division, Bangladesh Rice Research Institute (BRRI), Joydebpur, Bangladesh. Water under test was classified using few standard equations as per the results obtained from the data generated out of chemical analysis.

1) Sodium adsorption ratio

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

2) Soluble sodium percentage (SSP)

$$SSP = \frac{\text{Soluble Na concentration}}{\text{Total cation concentration}} \times 100$$

3) Residual sodium carbonate (RSC)

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$

4) Hardness or total hardness (H_T)

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

Where, concentration unit of ionic constituents for SAR, SSP and RSC are in me L^{-1} and in case of hardness as mg L^{-1}.

Results and Discussion

The pH varied from 6.72 to 7.54 indicating slightly acidic to neutral nature of water. EC ranged from 52 to 300 μS cm^{-1} (Table 2) and water was under 'low' (100-250 μS cm^{-1}) salinity class except sample No. 11 under 'medium salinity' (250-750 μS cm^{-1}) according to Richards (1968). The amount of total dissolved solids (TDS) in the study area was reported to very from 35 to 200 mg L^{-1}. Water containing TDS less than 1000 mg L^{-1} could be considered good quality for irrigation uses (Freez and Cherry, 1979) and would not affect the osmotic pressure of the soil solution.

The ionic concentrations of Ca, Mg, K and Na were found to vary from 0.40-6.90, 0.55-6.60, 4.75-13.50 and 4.00-44.00 mg L^{-1} with the respective average values of 1.66, 2.04, 6.78 and 14.42 mg L^{-1} (Table 3). According to Todd (1989) irrigation water generally contains less than 100 mg L^{-1} Ca and 50 mg L^{-1} Mg and higher amounts may not suitable for irrigation.

Recommended maximum concentrations of Na and K for long-term irrigation use on all soils are 40 and 2 mg L^{-1} respectively (Ayers and Wastcot, 1985). Based on K none of the water should be used for long-term irrigation in the study area. The recorded Na concentration was far below the recommended limit for irrigation except sample No. 11. The status of Fe, Zn, Mn and Cu of all water was in between trace to 0.30, 0.02-0.26, trace to 0.375 and trace to 0.05 mg L^{-1}, respectively and all the values were far below the maximum recommended limits for irrigation and could be safely used without harmful effects on soil and crops (Todd, 1980).

Table 1: Information regardint different sources of waters

Sample No.	Sampling location: Villages	Sampling location: Union	Depth of sinking (m)	Date of sinking
1	South Achalong	Taindong	101	30.3.78
2	North Achalong	,,	76	30.3.78
3	South Taindong	,,	87	25.7.89
4	North Taindong	,,	87	17.7.92
5	Thailapru chowdhury para	Barnal	29	2.9.81
6	Thailafang jamini	,,	54	25.8.80
7	Thailafang jamini chairman para	,,	61	15.6.86
8	Barabil	Tablachari	49	2.6.82
9	Gargarianala North	Gomti	53	30.12.80
10	Gomti North	,,	92	20.3.79
11	Gomti South	,,	109	25.3.80
12	Karaillachari	,,	64.6	5.5.88
13	Belchari	Belchari	45.7	15.7.78
14	Chandrakapa	,,	50.3	16.6.86
15	Dargiling Tilla	Guimara	93	18.2.79
16	Muslim Para	,,	36.6	6.12.80
17	Taimatai North	,,	42.7	12.12.80
18	Taimatai South	,,	45.7	16.8.89
19	East Billachari	,,	75	15.6.76
20	West Billachari	,,	97.2	17.6.82
21	Charpara	Matiraanga	41.1	17.2.92

The concentration of B was within the range of trace to 0.007 mg L^{-1} with a mean value of 0.006 mg L^{-1} and the co-efficient of variation was 23.57%. Boron content of water was under 'excellent' class (<0.33 mg L^{-1}) for sensitive crops after Wilcox (1955). Concentration of P (0.001 to 0.11 mg L^{-1}) also indicated that it had a little influence on irrigation water quality. The sulfur concentration was found trace. The presence of chloride was within the range 0.30 to 1.60 me L^{-1} with a mean value of 0.57 me L^{-1} and the co-efficient of variation was 51.19% (Table 2). For irrigation use Cl^{-} would not be problematic because the recommended limit is 4.00 me L^{-1}. The groundwater contained HCO^{-}_3 and CI^{-} abundantly along with sulfate in smaller quantities (Table 1) and also reported by Rao *et al.* (1982). All samples contained small amount of nitrate (0.10 to 1.50 mg L^{-1}) hence its concentration had little influence on irrigation water quality. The presence of HCO_3 was within the range of 0.15-1.20 me L^{-1} and the percent co-efficient of variation was 67. Irrigation water containing HCO_3 higher than 1.50 me L^{-1} is not generally recommended (Ayers and Westcot, 1985) and all of the samples were within the suitable limit. The results were at per with that of Rahman and Zaman (1995) and Quddus and Zaman (1996).

Sodium adsorption ratio (SAR) varied from 0.36 to 3.40 (Table 4). Todd (1980) classified irrigation water with SAR values less than 10 as 'excellent'. SSP values reflected that the water was under the category of 'good' (20-40% Na), 'permissible' (40-60% Na) and 'doubtful' (60-80% Na) class according to Wilcox (1955). Residual sodium carbonate (RSC) values ranged from -0.001 to 0.418. As per Eaton's (1950) classification on RSC three samples

Table 2: pH, EC, TDS, As and anionic concentration of groundwater at Matiranga

Sample No.	pH	EC ($\mu S\ cm^{-1}$)	TDS ($mg\ L^{-1}$)	As ($mg\ L^{-1}$)	SO_4^{-2} ($me\ L^{-1}$)	NO_3^- ($mg\ L^{-1}$)	HCO_3^- ($me\ L^{-1}$)	CL^- ($me\ L^{-1}$)
1	6.72	110	70	Trace	Trace	0.28	0.30	0.60
2	6.92	77	50	Trace	Trace	0.15	0.25	0.50
3	6.90	84	55	Trace	Trace	0.36	0.25	0.40
4	7.00	92	60	Trace	Trace	0.29	0.30	0.50
5	6.94	90	55	0.05	Trace	0.40	0.35	0.40
6	7.27	246	160	Trace	Trace	1.20	1.20	0.80
7	6.88	52	35	Trace	Trace	0.65	0.15	0.30
8	7.02	110	70	Trace	Trace	0.50	0.30	0.60
9	7.12	105	70	0.10	Trace	0.43	0.30	0.60
10	7.04	85	55	Trace	Trace	1.00	0.30	0.40
11	7.54	300	200	Trace	Trace	0.22	1.05	1.60
12	7.28	105	70	0.04	Trace	0.12	0.30	0.60
13	7.09	98	65	Trace	Trace	0.44	0.35	0.40
14	7.06	85	55	Trace	Trace	0.68	0.30	0.40
15	7.15	145	100	0.02	Trace	0.10	0.25	0.80
16	7.32	150	90	Trace	Trace	1.50	0.45	1.00
17	7.26	110	70	Trace	Trace	0.75	0.40	0.50
18	7.17	100	70	Trace	Trace	0.08	0.35	0.40
19	7.08	85	55	Trace	Trace	0.23	0.30	0.40
20	7.07	92	60	Tarce	Trace	0.71	0.30	0.40
21	7.08	92	60	Tarce	Trace	1.45	0.30	0.40
Range	6.72 to 7.54	52 to 300	35 to 200	Trace to 0.01	–	0.10 to 1.50	0.15 to 1.20	0.30 to 1.60
Mean		114.90	75	0.014	–	0.55	0.38	0.57
SD		57.26	37.98	0.025	–	0.43	0.25	0.29
CV(%)		49.83	50.64	178.57	–	78.18	67.00	51.19
Recommended limit for irrigation	–	0-750	0-1000	0.10	0-20	–	1.50	4.00
Recommended limit for drinking	6.5-8.5	–	500	0.01	5.20	5.00	–	250.00

Traces for sulfate and As were considered <0.001 me L^{-1} and <0.01 mg L^{-1} respectively
TDS= Total dissolved solids, EC= Elecrical conductance

Table 3: Cationic compositon of groundwater at Matiranga

Sample No.	Fe^{+3} ($mg\ L^{-1}$)	Zn^{+2} ($mg\ L^{-1}$)	Mn^{+2} ($mg\ L^{-1}$)	Cu^{++} ($mg\ L^{-1}$)	P^{5+} ($mg\ L^{-1}$)	B^{3+} ($mg\ L^{-1}$)	Ca^{++} ($mg\ L^{-1}$)	Mg^{++} ($mg\ L^{-1}$)	K^+ ($mg\ L^{-1}$)	Na^+ ($mg\ L^{-1}$)
1	Trace	0.06	0.050	Trace	0.020	Trace	1.50	1.85	6.50	13.50
2	0.15	0.08	0.050	Trace	0.045	Trace	0.50	1.10	5.00	12.50
3	0.15	0.06	0.460	Trace	0.020	Trace	0.70	1.10	6.00	9.75
4	0.15	0.06	0.050	Trace	0.030	0.005	1.00	1.55	6.25	12.75
5	Trace	0.26	0.007	Trace	0.035	Trace	0.80	1.85	4.75	10.50
6	Trace	0.06	0.050	Trace	0.035	Trace	6.90	6.60	11.25	22.50
7	0.15	0.06	0.050	Trace	0.035	Trace	0.70	0.55	5.00	6.50
8	0.30	0.04	0.050	0.05	0.045	Trace	1.00	1.80	6.25	13.00
9	Trace	0.08	0.050	Trace	0.055	Trace	1.00	1.60	6.00	14.50
10	Trace	0.08	0.050	0.05	0.080	Trace	0.40	0.70	5.00	12.75
11	Trace	0.06	0.050	Trace	0.110	Trace	3.30	5.70	13.50	44.00
12	Trace	0.02	0.375	Trace	0.020	Trace	1.00	1.60	6.25	14.75
13	Trace	0.02	0.125	Trace	0.001	0.007	1.00	1.40	5.00	12.5
14	Trace	0.02	0.050	Trace	0.010	Trace	0.60	1.05	5.00	12.25
15	Trace	0.04	0.050	Trace	0.005	Trace	1.80	4.10	6.25	14.00
16	Trace	0.04	Trace	Trace	0.010	Trace	1.90	4.35	9.25	21.00
17	0.15	0.04	Trace	Trace	0.020	Trace	0.90	2.05	7.25	14.75
18	Trace	0.06	0.050	Trace	0.015	Trace	7.50	0.85	9.00	4.00
19	Trace	0.02	Trace	Trace	0.020	Trace	0.40	0.55	6.50	11.50
20	0.15	0.04	0.150	Trace	0.010	Trace	1.00	1.35	6.50	12.75
21	0.15	0.02	Trace	Trace	0.005	Trace	0.90	1.25	6.00	13.00
Range	Trace to 0.30	0.02 to 0.26	Trace to 0.375	Trace to 0.05	0.001 to 0.110	Trace to 0.007	0.40 to 6.90	0.55 to 6.60	4.75 to 13.50	4.00 to 44.00
Mean	0.168	0.058	0.141	0.05	0.029	0.006	1.66	2.04	6.78	14.42
SD	0.053	0.050	0.188	0.00	0.026	0.001	1.95	1.68	2.23	7.83
CV(%)	31.56	87.17	133.71	0.00	91.44	23.57	117.70	82.34	32.90	54.30
Recommended limit for irrigation	5.00	2.00	0.20	0.20	0-2.0	<0.75	100.00	50.00	2.00	40.00
Recommended limit for drinking	0.30	5.00	0.05	1.00	–	–	75	–	–	–

Trace for Fe, Mn, Cu and B were considered <0.01, <0.01, <0.01 and <0.001 mgL^{-1}, respectively

Table 4: Quality classification of water samples for irrigation

Sample No.	SAR	SSP	RSC	Hardness	Water class based on TDS	B^{3+}	SAR	SSP	RSC	Hardness	Alkali and salinity hazard class
1	1.74	59.72	0.074	11.33	FW	Ex	Ex	Doubtful	Suit.	Soft	C1-S1
2	2.28	68.62	0.136	5.76	,,	,,	,,	,,	,,	,,	C1-S1
3	1.70	60.15	0.126	6.26	,,	,,	,,	,,	,,	,,	C1-S1
4	1.87	61.98	0.124	8.85	,,	,,	,,	,,	,,	,,	C1-S1
5	1.47	58.94	0.159	9.58	,,	,,	,,	Permissible	,,	,,	C1-S1
6	1.47	45.39	0.314	44.31	,,	,,	,,	,,	,,	,,	C1-S1
7	1.42	57.13	0.071	4.00	,,	,,	,,	,,	,,	,,	C1-S1
8	1.79	60.74	0.103	9.88	,,	,,	,,	Doubtful	,,	,,	C1-S1
9	2.10	64.82	0.120	9.06	,,	,,	,,	,,	,,	,,	C1-S1
10	2.85	71.95	0.224	3.87	,,	,,	,,	,,	,,	,,	C1-S1
11	3.40	65.79	0.418	31.62	,,	,,	,,	,,	,,	,,	C1-S1
12	2.13	65.19	0.120	9.06	,,	,,	,,	,,	,,	,,	C1-S1
13	1.89	65.10	0.186	8.24	,,	,,	,,	,,	,,	,,	C1-S1
14	2.22	68.59	0.185	5.80	,,	,,	,,	,,	,,	,,	C1-S1
15	1.31	50.92	-0.176	21.31	,,	,,	,,	Permissible	,,	,,	C1-S1
16	1.92	57.00	-0.001	22.58	,,	,,	,,	,,	,,	,,	C1-S1
17	1.97	61.56	0.188	10.65	,,	,,	,,	Doubtful	,,	,,	C1-S1
18	0.36	20.39	-0.093	22.23	,,	,,	,,	Good	,,	,,	C1-S1
19	2.80	66.38	0.216	3.25	,,	,,	,,	Doubtful	,,	,,	C1-S1
20	1.96	62.84	0.146	8.03	,,	,,	,,	,,	,,	,,	C1-S1
21	2.09	65.06	0.154	7.37		,,		,,	,,	,,	C1-S1

Legend: FW= Fresh water, Ex= Excellent, Suit.= Suitable, SAR= Sodium adsorption ratio, SSP= Soluble sodium percentage RSC= Residual sodum carbonate, TDS= Total dissolved solids

were free fro RSC and 18 were categorized 'suitable' for irrigation as they were well within the limit (<1.25). Hardness values were within the range of 3.25 to 44.31 mg L^{-1} and were categorized as 'soft' (0-75 mg L^{-1} as $CaCO_3$) reported by Sawyer and McCarty (1967) and this is due to in abundance of divalent cations such as Ca and Mg (Todd, 1980). According to Richards (1968) all irrigation water was under C1S1 categories except sample No. 11(C2S1). C1 and C2 indicated 'low' salinity (EC=100-250 μS cm^{-1}) and 'medium' salinity (EC=250-750 μS cm^{-1}), respectively. S1 also indicated 'low sodium' with respect to SAR. Finally it can be concluded that the water under test can safely be used for irrigation in all types of crops usually grown in Matiranga without any harmful effects on soil and crops.

As the water was collected from hand tubewells it may be worth enough to find their suitability for drinking purposes. According to drinking water standards on the basis of Cl, Fe, Cu, NO_3 and SO_4 contents as per Anonymous (1975), all water was found 'suitable'. Based on As and Mn, some of water was found 'unsuitable' for drinking.

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