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Quality Assessment of Well and Pond Water for Irrigation in Different Remote Aquifers of Khagrachari in Bangladesh

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Abstract: A study was conducted to evaluate the pond and well water quality at Matiranga Upazilla under very remote areas of Khagrachari Hill District of Bangladesh. The chemical analyses of water included pH, EC, total cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Zn^{++}, Cu^{++}, Mn^{++}, Fe^{+++}, As^{+++}, P^{+5} and B^{+3}), total anions (CO_3^{--}, HCO_3^{-}, SO_4^{--}, NO_3^{-}, Cl^{-}), TDS, SAR, SSP, RSC and hardness (H_T). pH values (6.01-7.17) indicated that the waters were slightly acidic to neutral. Waters contained Ca^{++}, Mg^{++}, Na^{+}, K^{+}, HCO_3^{-} and Cl^{-} predominantly along with Zn^{++}, P^{+5} and B^{+3} in lesser amounts. Mn^{++}, Cu^{++} and Fe^{+++} were found trace to very little amount. As^{+3} and SO_4^{--} were found trace. TDS and SAR values indicated that all water were under 'freshwater' and 'excellent' class respectively. SSP of most waters were under 'good' 'permissible' and 'doubtful' class. SAR and EC categorized the waters as C1-S1. All waters were found under 'soft' class regarding hardness with 'suitable' RSC. Based on As^{+3}, Fe^{+3}, Mn^{++}, Zn^{++}, SO_4^{--}, NO_3^{-} and Cl^{-} all waters were within the 'safe' limit for drinking.

Key words: Quality, pond and well water, irrigation, Khagrachari, Bangladesh

INTRODUCTION

All natural waters irrespective of the surface and sub-surface sources contain different ions in varying amounts. And, thus the concentration and composition of dissolved constituents in water is an important determinant concerning its quality. Among the chemical constituents Ca^{++}, Mg^{++}, Fe^{+3}, Na^{+}, Cl^{-}, HCO_3^{-}, SO_4^{--} and B^{+3} are of prime importance in determining the quality and suitability of irrigation and domestic usage. The assessment of water quality indicates their potential to foster soil conditions detrimental to crop growth. The dominance of HCO_3^{-}, Na^{+}, Ca^{++}, Mg^{++} and Cl^{-} ions were detected in surface water collected from different regions of Bangladesh (Rahman and Zaman, 1995; Quddus and Zaman, 1996; Shah Md. Helal Uddin *et al*., 2003). Currently 16% of the cultivated area is irrigated from different sources. Among the sources well and pond waters are widely used for irrigation and drinking purposes. It is mentionable that in the study area there is no shallow or deep tube well. Limited use of groundwater for irrigation from hand tube well is observed in the vegetable fields. Therefore, the present study has been conducted to assess the quality of so far major utilized irrigation and drinking from ponds and wells in different sites of Matiranga Upazilla under Khagrachari Hill District of Bangladesh 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, 23 sites were selected for collecting representative water samples. Information regarding different sampling locations/ sites is given in Table 1. In order to assess their suitability for irrigation and drinking uses, the important inorganic constituents of groundwater were pH, electrical conductance (EC), total dissolved solids (TDS), Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Zn^{++}, Cu^{++}, Mn^{++}, Fe^{+++}, As^{+3}, P^{+5}, B^{+3}, CO_3^{--}, HCO_3^{-}, SO_4^{--}, NO_3^{-} and Cl^{-}. Water samples were collected following the techniques as outlined by Hunt and Wilson (1986) and APHA(1989).

The pH and electrical conductance was determined electrometrically (APHA, 1989). TDS was estimated after Chopra and Kanwar (1980). Ca^{++} and Mg^{++} were analysed 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 analysed titrimetrically (Ghosh *et al*., 1983; Chopra and Kanwar, 1980). Chloride was estimated by

Table 1: Information regarding different sources of waters

Sample No.	Sampling location: Village	Union	Sources of water	Duration of irrigation
1	Tabalchari	Tabalchari	Well	25
2	Barabil	Tabalchari	,,	25
3	Thailapru Chowdhury Para	Barnal	,,	10
4	Thailafang	Barnal	,,	10
5	Karaillachari	Gomti	,,	25
6	Gomti	Gomti	,,	25
7	Gargarianala North	Gomti	,,	25
8	Belchari	Belchari	,,	25
9	Khadachara East	Belchari	,,	25
10	Khadachara West	Belchari	,,	25
11	Guimara East	Guimara	,,	25
12	Sadua Para	,,	,,	25
13	East Billachari	Guimara	,,	25
14	West Alutilla	Matiranga	,,	10
15	North Achalong	Taindong	Pond	56
16	South Achalong	Taindong	,,	46
17	South Taidong	Taindong	,,	46
18	Tabalchari	Tabalchari	,,	25
19	Thailafang	Barnal	,,	10
20	Thailapru Chowdhury Para	Barnal	,,	10
21	Gomti North	Gomti	,,	25
22	Gomti South	,,	,,	25
23	Karaillachari	,,	,,	25

argentometric titration (APHA, 1989 and Ghosh *et al.*, 1983) and P^{+5}, B^{+3} and NO_3^- were determined colorimetrically. Arsenic was determined by atomic absorption spectrophotometer equipped with hydride generator situated at Soil Resources Development Institute (SRDI) laboratory in Bangladesh (APHA, 1989). Fe^{+++}, Zn^{++}, Cu^{++} and Mn^{++} were analysed by atomic absorption spectrophotometer (APHA, 1989) in the laboratory of Soil Chemistry Division, Bangladesh Rice Research Institute (BRRI), Joydebpur, Bangladesh. Waters under test were classified using few standard equations as per the results obtained from the data generated out of chemical analyses. These equations are as follows:

Sodium adsorption ratio (SAR)

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

Soluble sodium percentage (SSP)

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

Residual sodium carbonate (RSC)

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

Hardness or Total Hardness (H_T)

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

Where, concentrations of ionic constituents for calculating all parameters except hardness are in me L^{-1} and in case of hardness as mg L^{-1}.

RESULTS AND DISCUSSION

The results of chemical analyses and quality classification of irrigation waters have been presented in Table 2, 3 and 4. pH varied from 6.01 to 7.17 indicating slightly acidic to neutral nature of waters. EC ranged from 30 to 220 µS cm^{-1} (Table 2) and waters were under 'low' (100-250 µS cm^{-1}) salinity class according to Richards (1968). The amount of total dissolved solids (TDS) in the study area was reported to vary from 20 to 140 mg L^{-1}. Waters containing TDS less than 1000 mg L^{-1} could be considered to be of 'good' quality for irrigation uses (Freeze and Cherry, 1979) and would not affect the osmotic pressure of the soil solution. Toxic element As^{+3} was found trace. Although As^{+3} is not an essential nutrient element for plant growth and development but high concentration of As^{+3} in water or soil may lead to plant to uptake excess amount of As^{+3} which is not desirable.

The ionic concentrations of Ca^{++}, Mg^{++}, K^+ and Na^+ were found to vary from 0.10-8.40, 0.17 –7.00, 2.00- 16.50 and 3.50-19.00 mg L^{-1} with the respective average values of 1.55, 1.92, 7.75 and 8.62 mg L^{-1}. According to Todd (1980) 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. The recorded Na^+ and K^+ concentrations were far below the recommended limits for irrigation after Ayers and Westcot (1985). The status of

Table 2: pH, EC, TDS, As^{+3} and anionic concentration of well and pond water at Matiranga

Sample No.	pH	EC µS cm^{-1}	TDS mg L^{-1}	As^{+3} mg L^{-1}	SO_4^{--} me L^{-1}	NO_3^- mg L^{-1}	HCO_3^- me L^{-1}	Cl^- me L^{-1}
1	6.52	120	80	Trace	Trace	0.30	0.45	0.60
2	6.40	70	45	Trace	Trace	0.50	0.17	0.40
3	6.35	110	70	Trace	Trace	0.90	0.35	0.50
4	5.80	30	20	Trace	Trace	1.50	0.10	0.10
5	6.01	64	40	Trace	Trace	0.80	0.20	0.30
6	6.03	38	25	Trace	Trace	0.45	0.10	0.20
7	6.38	105	70	Trace	Trace	0.80	0.30	0.60
8	6.36	38	25	Trace	Trace	0.90	0.10	0.20
9	6.18	130	80	Trace	Trace	1.20	0.30	0.80
10	6.37	73	50	Trace	Trace	1.10	0.25	0.30
11	6.46	30	20	Trace	Trace	1.40	0.10	0.15
12	6.33	38	26	Trace	Trace	0.45	0.10	0.20
13	6.24	75	45	Trace	Trace	0.65	0.25	0.30
14	6.32	30	20	Trace	Trace	0.85	0.10	0.15
15	7.17	220	140	Trace	Trace	1.60	0.90	1.00
16	7.07	165	110	Trace	Trace	1.80	0.60	0.80
17	7.15	190	120	Trace	Trace	2.00	0.50	1.20
18	6.78	45	30	Trace	Trace	1.95	0.15	0.20
19	6.63	95	60	Trace	Trace	1.85	0.35	0.40
20	6.54	88	60	Trace	Trace	0.55	0.30	0.40
21	6.48	55	35	Trace	Trace	1.35	0.15	0.30
22	6.39	125	80	Trace	Trace	1.20	0.55	0.60
23	6.52	70	45	Trace	Trace	1.30	0.25	0.40
Range	6.01 to 7.17	30 to 220	20 to 140	-	-	0.30 to 2.00	0.10 to 0.90	0.10 to 1.20
Mean		83.17	56.38	-	-	1.10	0.29	0.44
SD		52.60	33.51	-	-	0.52	0.20	0.29
CV (%)		63.24	59.43	-	-	47.27	68.96	65.91
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^{+3} were considered <0.001 me L^{-1} and <0.01 mg L^{-1}, respectively

Table 3: Cationic composition of well and pond water at Matiranga

Sl. No.	Fe^{+++} mg L^{-1}	Zn^{++} mg L^{-1}	Mn^{++} 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	2.00	0.34	Trace	0.05	0.007	Trace	3.40	1.40	9.00	12.75
2	Trace	0.04	Trace	Trace	0.003	Trace	0.70	1.35	5.00	8.00
3	Trace	0.04	0.05	Trace	Trace	Trace	1.00	1.55	9.00	12.00
4	Trace	0.46	Trace	Trace	0.010	Trace	0.10	0.25	2.00	3.50
5	Trace	0.06	0.05	Trace	Trace	Trace	0.60	0.50	6.50	7.00
6	Trace	0.02	Trace	Trace	0.005	Trace	0.20	0.25	4.75	4.50
7	Trace	0.02	Trace	Trace	0.007	Trace	0.60	2.30	8.50	12.50
8	Trace	0.02	Trace	Trace	0.015	Trace	0.40	0.20	4.50	4.00
9	Trace	0.10	Trace	Trace	0.015	0.007	3.40	2.05	8.50	14.00
10	Trace	0.02	Trace	Trace	0.035	0.005	0.50	0.55	8.75	7.50
11	Trace	0.06	Trace	Trace	0.010	Trace	0.30	0.35	2.50	3.50
12	Trace	0.06	Trace	Trace	0.030	0.006	0.10	0.30	2.50	5.00
13	Trace	0.06	Trace	Trace	0.025	Trace	0.90	0.90	6.00	7.75
14	Trace	0.04	Trace	Trace	0.015	Trace	0.40	0.17	2.75	4.00
15	Trace	0.08	Trace	Trace	0.020	Trace	6.50	7.00	16.00	19.00
16	Trace	0.06	Trace	Trace	0.030	Trace	2.90	5.00	14.00	14.50
17	Trace	0.08	Trace	Trace	0.025	Trace	8.40	5.85	16.50	14.00
18	Trace	0.06	Trace	Trace	0.030	Trace	0.60	0.80	4.75	3.50
19	Trace	0.04	Trace	Trace	0.010	Trace	1.00	0.85	11.50	9.50
20	Trace	0.06	Trace	Trace	0.020	Trace	2.20	2.10	9.75	5.50
21	Trace	0.06	Trace	Trace	0.020	Trace	0.80	5.85	4.50	7.00
22	Trace	0.04	Trace	Trace	0.010	Trace	2.20	2.70	15.00	14.25
23	Trace	0.04	Trace	Trace	Trace	Trace	1.50	1.90	6.00	5.00
Range	Trace to 2.00	0.02 to 0.34	Trace to 0.05	Trace to 0.05	Trace to 0.035	Trace to 0.007	0.10 to 8.40	0.17 to 7.00	2.00 to 16.50	3.50 to 19.00
Mean	0.09	0.08	0.004	0.002	0.014	0.0007	1.55	1.92	7.75	8.62
SD	0.42	0.10	0.01	0.010	0.010	0.002	2.08	2.04	4.41	4.56
CV(%)	466.67	125.00	250.00	500.00	71.43	285.71	134.19	106.25	56.90	52.90
Recommended limit for irrigation	5.00	2.00	0.20	0.20	0-2.00	<0.75	100	50.00	2.00	40.00
Recommended limit for drinking	0.30	5.00	0.05	1.00	-	-	75	-	-	-

Traces for Fe^{+3}, Mn^{++}, Cu^{++} and B^{+3} were considered < 0.01, < 0.01, < 0.01 and < 0.001 mg L^{-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	1.47	51.81	0.166	14.24	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
2	1.28	56.02	0.025	7.28	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
3	1.76	56.20	0.174	8.85	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
4	1.39	66.49	0.076	1.27	FW	Ex.	Ex.	Doubtful	Suit.	Soft	C1S1
5	1.62	56.29	0.193	3.55	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
6	1.62	56.39	0.071	1.52	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
7	1.64	55.45	0.082	10.93	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
8	1.31	53.16	0.065	1.82	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
9	1.48	52.21	-0.040	16.90	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
10	1.76	52.27	0.181	3.50	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
11	1.05	58.77	0.058	2.18	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
12	1.83	67.37	0.072	1.48	FW	Ex.	Ex.	Doubtful	Suit.	Soft	C1S1
13	1.38	54.99	0.132	5.94	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
14	1.35	62.14	0.067	1.71	FW	Ex.	Ex.	Doubtful	Suit.	Soft	C1S1
15	1.23	38.64	0.001	44.95	FW	Ex.	Ex.	Good	Suit.	Soft	C1S1
16	1.19	40.70	0.005	27.75	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
17	0.90	31.61	-0.490	44.98	FW	Ex.	Ex.	Good	Suit.	Soft	C1S1
18	0.70	40.88	0.056	4.78	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
19	1.70	49.96	0.232	5.98	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
20	0.63	30.95	0.019	14.11	FW	Ex.	Ex.	Good	Suit.	Soft	C1S1
21	1.31	57.33	0.042	5.48	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
22	1.52	46.38	0.219	16.57	FW	Ex.	Ex.	Permissible	Suit.	Soft	C1S1
23	0.64	36.16	0.020	11.54	FW	Ex.	Ex.	Good	Suit.	Soft	C1S1

Legend: FW= Fresh water, Ex = Excellent, Suit. = Suitable

Fe^{+++}, Zn^{++}, Mn^{++} and Cu^{++} of all waters were in between trace to 2.00, 0.02 to 0.34, trace to 0.05 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).

The concentration of B^{+3} was within the range of trace to 0.007 mg L^{-1} with a mean value of 0.0007 mg L^{-1} and the co-efficient of variation was 285.71%. Boron content of waters was under 'excellent' class (<0.33 mg L^{-1}) for sensitive crops after Wilcox (1955). Concentration of P^{+5} (trace to 0.035 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 0.10 to 1.20 me L^{-1} with a mean value of 0.44 me L^{-1} and the co-efficient of variation was 65.91% (Table 2). For irrigation use chloride ion would not be problematic because the recommended limit is 4.00 me L^{-1}. The groundwater contained HCO_3^- and Cl^- abundantly along with sulfate in smaller quantities (Table 1) and also reported by Rao *et al.*, (1982). All samples contained small amount of nitrate (0.30 to 1.40 mg L^{-1}) hence its concentration had little influence on irrigation water quality. The presence of HCO_3^- was within the range of 0.10 to 0.90 me L^{-1} and the percent co-efficient of variation was 68.96. Irrigation waters 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 0.63 to 1.83 (Table 4). Todd (1980) classified irrigation waters with SAR values less than 10 as 'excellent'. SSP values reflected that the waters were 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 –0.040 to 0.232. As per Eaton (1950) classification on RSC, 2 samples were free from RSC and 21 were categorized 'suitable' for irrigation as they were well within the limit (<1.25). Hardness values were within the range of 1.27 to 44.98 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 inabundance of divalent cations such as Ca^{++} and Mg^{++} (Todd, 1980). According to Richards (1968) all irrigation waters were under C1S1 categories. C1 indicated 'low' salinity (EC= 100-250 μS cm^{-1}) and S1 indicated 'low sodium' with respect to SAR. Finally it can be concluded that the water under test can safely be used for irrigating all types of crops usually grown in Matiranga without any harmful effects on soil and crops.

As the waters were used for drinking it may be worth enough to find their suitability for drinking purposes. According to drinking water standards on the basis of Cl^-, Fe^{+++}, Cu^{++}, Zn^{++}, Mn^{++}, As^{+3}, NO_3^- and SO_4^{--} contents, all waters were found 'suitable' for drinking and domestic usage.

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