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Assessment of Groundwater Quality in A Selected Area of Bangladesh

S.M. Shahidullah[1], M.A. Hakim[2], M.S. Alam[3] and A.T.M. Shamsuddoha[4]
[1]RFS Division, BRRI, Gazipur 1701, Bangladesh,
[2]Horticulture Research Centre, BARI, Gazipur 1701, Bangladesh
[3]Department of Agricultural Extension, Khamarbari, Dhaka, Bangladesh,
[4]Department of Soil Science, BAI, Sher-E-Bangla Nagar, Dhaka, Bangladesh

Abstract: A study was conducted to evaluate the groundwater quality at Phulpur thane of Mymensingh district in Bangladesh. Water samples from 14 deep tubewells were analyzed for pH, EC, TDS, Na^+, K^+, Ca^{++}, Mg^{++}, Fe, P, B, NO_3-N, SO_4^-, Cl^-, CO_3^- and HCO_3^-. In addition SAR, SSP and RSC were calculated following standard equations. The range of EC was 180-380 μScm^{-1} and SAR 0.22-0.80 and these two parameters indicated that three samples were in 'low salinity-low alkali' and 11 were in 'medium salinity-low alkali' hazard class. There was no chloride toxicity in the area. The presence of SO_4^-, NO_3^- and P were negligible. As regards boron and SSP, all waters were of 'good' to 'excellent' class. In respect of TDS all were 'fresh water'. On the basis of RSC values all samples were of 'suitable' class. As a whole, groundwater of the area can safely be used for long-term irrigation. But some of those may not be suitable for drinking and industrial uses in consideration of Fe concentration, TDS and pH values. Among the quality determining factors SSP and SAR were highly correlated where correlation coefficient was 0.97.

Key word: Groundwater, irrigation

Introduction

Bangladesh is a land of rivers. Annual rainfall of the country is over 200 cm but its distribution is uneven. About 85 percent of the total rainfall occur during April-October. In winter rain water is unusual and the rivers also dry. So, the groundwater has become the prime source of irrigation in dry period. About 70 percent irrigation water and 90 percent of total potable water in Bangladesh is supplied from groundwater source (Mridha *et al.*, 1996). The water quality is important for long-term irrigation system because it influences the soil properties. The toxicity or suitability of groundwater is determined by varying amounts and different species of ions. The usual toxic elements in irrigation water are chlorine, boron and sodium. These ions are toxic to sensitive crops at low concentrations (Ayers and Westcot, 1985). Irrigation water quality is judged by some determining factors like sodium adsorption ratio (SARI, soluble sodium percentage (SSP), residual sodium carbonate (RSC) and electrical conductance (EC) (Richards, 1968). Intensive irrigated agriculture with HYV crops under high inputs has already started showing problems in different regions of Bangladesh. Mridha *et al.* (1996) reported the quality of groundwater for irrigation use in Natore district. This study was conducted on regional basis. People of Phulpur thane in Mymensingh district are of the pioneer users of deep tubewells. Most of the arable land is usually irrigated by groundwater to grow crops mainly HYV rice during winter season at the area. Therefore, the present study was undertaken to investigate the ionic toxicity (if there is any) and also to categorize the groundwater for irrigation, drinking and industrial uses on the basis of chemical composition.

Materials and Methods

The study was conducted at Phulpur thana of Mymensingh district in Bangladesh during the month of January to February, 1993. Within the study area 14 groundwater samples were collected from 14 deep tubewells. The depth of wells were within 220 to 330 feet and were commissioned during 1970-1980. The water samples were collected after 30 minutes of pumping to avoid stagnant and contaminated water. One litre white plastic containers were rinsed out 3-4 times with sampling water. Then the containers were filled up to the mouth and were immediately sealed to avoid exposure to air (Clesceri *et al.*, 1981). The containers were labeled far proper identification and those were brought to the laboratory of Agricultural Chemistry in Bangladesh' Agricultural University, Mymensingh, for analyses.

The groundwater samples were analyzed for pH, EC, total dissolved solids (TDS), sodium (Na^+), potassium (K^+), calcium (Ca^{++}), magnesium (Mg^{++}), soluble iron (Fe), phosphorus (P), boron (B), nitrate-nitrogen (NO_3-N), sulphate (SO_4^-), chloride (Cl^-), carbonate (CO_3^-) and bicarbonate (HCO_3^-). The pH and electrical conductance were determined electrometrically (Clesceri *et al.*, 1981). TDS was estimated after Chopra and Kanwar (1980). Calcium and magnesium were determined by complexometric titration (Page *et al.*, 1982), whereas, potassium and sodium were estimated by flame emission spectrophotometer (Ghosh *et al.*, 1983). Sulphate was determined turbidimetrically (Wolf, 1982). Carbonate and bicarbonate were determined by titration method (Ghosh *et al.*, 1983). Chloride was estimated by argentometric titration (Clesceri *et al.*, 1981). Phosphorus, nitrate and boron were determined calorimetrically. Iron was analyzed by atomic absorption spectrophotometer (Clesceri *et al.*, 1981). Waters under test were classified as per results obtained from chemical analyses. SAR, SSP and RSC were calculated on the basis of few standard equations as outlined by Richards (1968), Todd (1980) and Wolf (1982). These equations are as follows:

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

$$SSP = \frac{\text{Soluble Na concentration (meq L}^{-1}\text{)}}{\text{Total cation concentration (meq L}^{-1}\text{)}}$$

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

Correlation analyses between the different combination of quality indicators, such as SAR versus SSP, SSP versus RSC etc. were done to establish relationship between them.

Results and Discussion

The chemical compositions of the collected groundwater samples are presented in Table 1. Major cations and anions are expressed in milliequivalent per litre (meq L^{-1}), the nitrate-nitrogen content, phosphorus, boron and iron concentrations are in milligram per litre (mg L^{-1}). The unit used for measuring EC is micro-siemens percentimeter (μScm^{-1}). The results have mainly been discussed in the light of irrigation use, in addition to drinking and industrial usage. The high pH value of samples (8.1-8.3) indicated the alkalinity of water, possibly due to the presence of appreciable amounts of sodium, calcium, magnesium, carbonate and bicarbonate ions (Rao *et al*., 1982). These water could safely be used for irrigation but might not be suitable for brewing, laundering and tanning where the recommended pH are 6.5-7.0, 6.0-6.8 and 6.0-6.9, respectively (Anonymous, 1971). The estimated amounts of TDS ranged from 115 to 247 mg L^{-1}. Waters containing TDS less than 1000 mg L^{-1} could be considered to be 'fresh water' for irrigation uses and would not affect the osmotic pressure of soil solution. But as per the detected values none of these waters were not found suitable for confectionery, rayon and pulp production where recommended limit of TDS is 50-100 mg L^{-1} (Todd, 1980). The range of electrical conductivity was 180-380 μS cm^{-1}. This is an agreement with the findings of Ahmed *et al*. (1993) who reported EC values ranging 150-480 μS cm^{-1} for Muktagacha thana in Mymensingh district. According to Wilcox (1955) the water samples were classified into 'excellent' to 'good'. Out of 14 groundwater samples, three were in 'excellent' and the rest 11 were in 'good' class. The SAR values were between 0.22 and 0.80, all of which are under 'excellent' class (Richards, 1968). The similar SAR value was reported by Ahmed *et al*. (1993) for Muktagacha thane. EC and SAR based combined classification from the U.S. Salinity Laboratory (Richards, 1968) showed that three samples were categorized into low salinity-low alkali hazard' or 'C1-S1' class. The rest 11 samples fell under 'C2-S1' class indicating medium salinity-low alkali hazard (Table 2). All these waters could be safely used for irrigation purposes. The SSP values were found from 6.99 to 23.31. Khan *et al*. (1989) found 14.50-37.55 SSP for the North-West region of Bangladesh. Based on the classification after Wilcox (1955) for SSP, 12 groundwater samples fell under 'excellent' class and only two under 'good' class.

The concentrations of Ca^{++}, Mg^{++}, Na^{+} and K^{+} in water samples varied in the ranges of 1,40-2.65, 0.05-1.08, 0.23-1.00 and 0.04-0.10 meq L^{-1}, respectively (Table 1). Recommended maximum concentrations of Ca^{++}, Mg^{+} Na^{+} and K^{+} for long-term irrigation use on all soils are 20, 5, 40 and 2 meq L^{-1}, respectively (Ayers and Westcot, 1985). Therefore, all the waters in the study area can be used, for long-term irrigation. The concentration of soluble iron was found to vary within a wide range of 0.40 to 1.90 mg L^{-1} with and average of 0.80 mg L^{-1} and the computed CV was 47 percent. These waters would not be problematic for irrigation but most of them would be unsuitable for drinking, baking, brewing, confectionery, dairy, carbonated beverages, food processing laundering, paper and pulp industries, where the recommended maximum limit is 0.3 mg L^{-1} (Todd, 1980).

The upper limit of NO_3-N was 0.49, phosphorus 0.10 and boron 0.43 mg L^{-1} in the waters. These values are comparatively low and 1 might not be problematic for irrigation and industrial uses. Out of the samples, nine were 'excellent' and five 'good' with respect to boron based classification of Wilcox (1955). The Cl^{-} content of groundwater samples varied from 0.14 to 0.42 meq L^{-1}. Most tree, crops under sprinkler irrigation are sensitive to chloride having values more than 4 meq L^{-1} (Mridha *et al*., 1996). This indicate that there was no chloride toxicity problem in the area. The SO_4^{-} concentration (0.03-0.15 meq L^{-1}) in the samples were negligible Carbonate and bicarbonate concentrations in all the samples were, relatively high and were found in the ranges of 0.16-0.54 and 1.784-3.14 meq L^{-1}, respectively. Irrigation water containing CO_3^{-} higher than 0.1 meq L^{-1} and bicarbonate more than 10 meq L^{-1} are not generally recommended (Ayers and Westcot, 1985). The highest value of RSC was 0.36 meq L^{-1}. Based on RSC criteria after Eaton, (1950) all groundwater samples were found in 'suitable' class. Out of 14 samples, three showed negative values which indicated the dissolved Ca^{++} and Mg^{++} contents were higher than CO_3^{-} and HCO_3^{-} contents for these three samples.

While checking the correctness of chemical analyses of theee waters, the differences between sum total of cations and anion were within the acceptable limit (3.0-5.0%) showed in Table 3. According to Clesceri *et al*. (1981) this difference should be ≤5 percent.

Table 1: Chemical compositions of deep tubewell waters

Sl.#	Location	pH	EC μS cm^{-1}	TDS mg L^{-1}	Na^{+} meq L^{-1}	K^{+} meq L^{-1}	Ca^{++} meq L^{-1}	Mg^{++} meq L^{-1}
1	Sanchur	8.1	340	247	0.52	0.05	2.20	1.08
2	Kuturakanda	8.1	320	204	0.52	0.10	2.00	1.02
3	Dhanarvita	8.2	275	175	0.3	0.04	2.06	0.75
4	Ramsona	8.2	330	211	0.39	0.08	2.48	0.95
5	Basati	8.1	185	118	0.24	0.05	1.53	0.72
6	Chhotosonoi	8.2	180	115	0.23	0.05	1.50	0.75
7	Barasonoi	8.2	350	224	1.00	0.05	2.08	1.05
8	Goadanga	8.2	345	221	0.90	0.05	2.16	1.02
9	Charpara	8.3	380	243	0.52	0.08	2.65	1.05
10	Poyari	8.3	325	208	0.39	0.08	2.48	0.95
11	Shahapur	8.3	186	119	0.30	0.05	1.40	0.50
12	Bongaon	8.2	330	211	0.64	0.05	2.05	1.05
13	Kaziakanda	8.1	275	175	0.57	0.07	1.85	0.75
14	Fateypur	8.2	340	217	0.39	0.06	2.45	1.05
Range		8.1	180-380	115-243	0.23-1.00	0.04-0.10	1.40-2.65	0.05-1.08
Mean			297	192	0.49	0.06	2.06	0.91
CV (%)			22	23	45	27	18	19

Table 1: (Contd.....)

S.#	FE mg L^{-1}	P_1 mg L^{-1}	B mg L^{-1}	NO_3^- mg L^{-1}	SO_4^- mg L^{-1}	Cl^- mg L^{-1}	CO_3^- mg L^{-1}	HCO_3^- mg L^{-1}
1	0.70	0.08	0.35	Trace	0.07	0.28	0.48	2.82
2	0.60	0.08	0.25	0.14	0.11	0.42	0.42	2.42
3	0.60	0.08	0.38	0.05	0.15	0.35	0.32	2.28
4	0.60	0.10	0.43	Trace	0,08	0.24	0.48	2.98
5	0.90	0.08	0.23	Trace	0.04	0.14	0.35	1.92
6	0.80	0.08	0.24	Trace	0.05	0.14	0.34	1.92
7	0.60	0.08	0.28	Trace	0.04	0.35	0.45	3.04
8	0.70	0.08	0.25	0.05	0.04	0.36	0.48	3.02
9	1.30	0.10	0.35	0.05	0.08	0.42	0.32	3.00
10	1.90	0.10	0.43	Trace	0.03	0.24	0.48	2.98
11	1.00	0.07	0.23	0.05	0.04	0.21	0.16	1.78
12	0.40	0.10	0.25	Trace	0.03	0.20	0.54	2.80
13	0.60	0.06	0.28	Trace	0.03	0.21	0.42	2.36
14	0.50	0.09	0.43	0.49	0.04	0.28	0.40	3.14
Range	0.40-1.90	0.06-0.10	0.23-0.43	Trace-0.49	0.03-0.15	0.14-0.42	0.16-0.54	1.78-3.14
Mean	0.80	0.08	0.31	0.06	0.06	0.27	0.40	2.60
CVC%)	47	14	24	212	58	32	33	18

Table 2: Qualit classification of deep tubewell waters based on different criteria for irrigation

	TDS		EC		Boron		SAR		SSP		RSC		
Sl.#	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class	Hazard class
1	217	FW	340	Good	0.35	Good	0.41	Exl.	13.07	Exl.	0.02	Suit.	C2-51
2	204	FW	320	Good	0.25	Exl.	0.42	Exl.	14.61	Exl.	-0.18	Suit.	C2-51
3	175	FW	275	Good	0.38	Good	0.25	Exl.	6.99	Exl.	-0.21	Suit.	C2-51
4	211	FW	330	Good	0.43	Good	0.30	Exl.	9.61	Exl.	0.03	Suit.	C2-51
5	118	FW	185	Exl.	0.23	Exl.	0.23	Exl.	9.02	Exl.	0.02	Suit.	C1-51
6	115	FW	180	Exl.	0.24	Exl.	0.22	Exl.	8.71	Exl.	0.01	Suit.	C1-51
7	224	FW	350	Good	0.28	Exl.	0.80	Exl.	23.31	Good	0.36	Suit.	C2-S1
8	221	FW	345	Good	0.25	Exl.	0.71	Exl.	21.28	Good	0.32	Suit.	C2-S1
9	243	FW	380	Good	0.25	Exl.	0.38	Exl.	11.61	Exl.	-0.38	Suit.	C2-S1
10	208	FW	325	Good	0.43	Good	0.30	Exl.	9.56	Exl.	0.03	Suit.	C2-51
11	119	FW	186	Exl.	0.23	Exl.	0.31	Exl.	1 2.61	Exl.	0.04	Suit.	C1-51
12	211	FW	330	Good	0.25	Exl.	0.47	Exl.	16.45	Exl,	0.24	Suit.	C2-S1
13	175	FW	275	Good	0.28	Exl.	0.50	Exl.	17.07	Exl.	0.18	Suit.	C2-51
14	217	FW	340	Good	0.43	Good	0.45	Exl.	13.69	Exl.	0.14	Suit.	C2-51

Note: FW = Fresh water, Exi. = Excellent, Suit. = Suitable

Table 3: Checking the correctness of analyses for irrigation waters

Sl.#	Anion-Cation balance		
	ΣCation (meq L^{-1})	ΣAnion (meq L^{-1})	Difference (%)
1	3.98	3.65	4.3
2	3.56	3.37	3.0
3	3.29	3.00	4.6
4	4.06	3.78	3.6
5	2.66	2.45	4.1
6	2.64	2.45	3.7
7	4.29	3.88	5.0
8	4.23	3.90	4.0
9	4.43	3.82	3.9
10	4.08	3.73	4.5
11	2.38	2.19	4.2
12	3.89	3.57	4.3
13	3.34	3.03	4.9
14	4.31	3.97	4.1

Table 4: Correlation coefficient (r) for relationship between different combination of water quality determining factors

Parameters	pH	EC	SAR	SSP	RSC	Boron
pH	1.00	-	-	-	-	-
EC	0.11	1.00	-	-	-	-
SAR	0.10	0.56	1.00	-	-	-
SSP	0.15	0.44	0.97	1.00	-	-
RSC	0.16	0.05	0.66	0.70	1.00	-
Boron	0.14	0.38	0.18	0.33	0.14	1.00

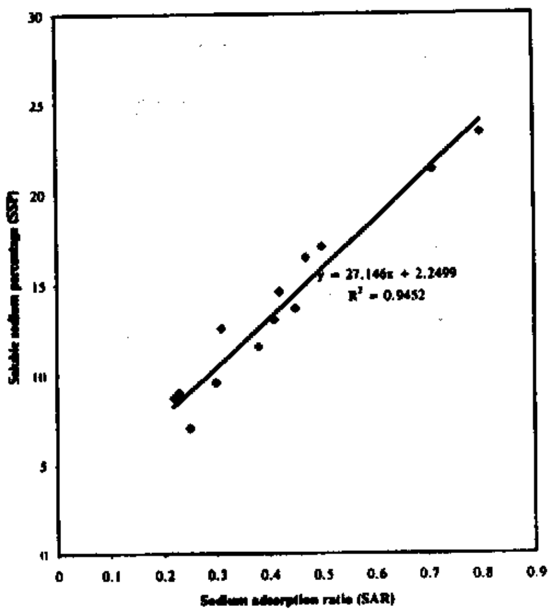

Fig. 1: Relationship between soluble sodium percentage (SSP) and sodium adsorption ratio (SAR)

Table 4 showed the interrelationship between pH, EC, SAR, SSP, RSC and boron in terms of correlation coefficient. The relationship between any two variables was assumed to be good with correlation coefficient higher than 0.80. From this analysis, it can be observed that only SSP was found to be dependent on SAR. All other quality determining indicators produced correlation coefficient less than 0.80. The correlation coefficient between SAR and SSP was 0.97. A linear relationship between SAR and SSP was found with $r^2 = 0.95$ (Fig. 1).

There was neither salinity nor toxicity problem of irrigation water. In respect of all evaluating criteria groundwater of the area can safely be used for long-term irrigation. But some of those may not be suitable for drinking and industrial uses in consideration of Fe concentration. TDS and pH values. Among the quality determining factors, a linear relationship between SSP and SAR was observed.

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