Journal of Science and Technology 11(June 2013): 25-31

QUALITY ASSESSMENT OF GROUNDWATER AND SURFACE WATER FOR DOMESTIC AND IRRIGATION USES IN COMILLA DISTRICT OF BANGLADESH

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Received 07 August 2012, revised 25 August 2012, accepted 26 August 2012

ABSTRACT

Twenty seven Water quality assessment for drinking and irrigation groundwater and three surface water samples were collected from Homna Upazila of Comilla District, Bangladesh. The chemical properties of these samples were analyzed to assess the suitability for domestic and irrigation purposes. Most of the samples were alkaline in nature ranging pH from 6.81 to 7.8. The dominant ions were Na, Cl, Ca, Mg and HCO_3 with the average values of 4.70, 6.35, 3.18**,** 5.11 and 4.60 meq L^{-1}, respectively. The other ions like K, Fe, Mn, Zn, Cu, B, SO_4 and NO_3 were within acceptable limit for irrigation and drinking purposes. Arsenic (As) contamination was found in 46.66% water samples. Electrical conductivity (EC), pH, total dissolved solid (TDS), sodium adsorption ratio (SAR), and soluble sodium percentage (SSP) of the waters were used to classify determining their suitability. Some waters might be used for domestic and drinking as well as irrigation purposes. Water contaminated with As should be purified before human consumption to save public health.

Key words: domestic uses, irrigation uses, water quality

INTRODUCTION

Natural water is essential for every living organism. For domestic and irrigation, the major sources of waters are surface water (river water) and ground water (hand pressure tube well and deep tube well). Hand pressure tube well water is frequently used in country side for domestic purposes especially in drinking, cooking, washing clothes, utensils, bathing, etc. But the presence of ionic constituents in waters (water quality) over the country are not within the safety limit especially in the southern part of Comilla district (Islam *et al*. 2009). Most of the area of the southern part of Bangladesh is an As contaminated Commila district is also an As contaminated area. Both ground and surface water of the area were contaminated by As (Islam *et al*. 2009). As contaminated water affects skin, mainly hand and leg and its severe infection causes skin cancer. People had died from As contamination in the study area, and this situation is deteriorating day by day (Roy *et al.* 2010). Agricultural crops and soils are also contaminated by As which already reported alarming conditions in southern part like Gopalganj, Jessore and Jhinedah districts of Bangladesh.

There are several factors such as ions, salts, heavy metals, toxic elements, fertilizers, pesticides, insecticides, industrial wastages etc. that affect water quality and make the water quality poor. Using this poor quality water, it might deteriorate soil properties, crops yield and quality (Sarker *et al.* 2000). Alfalfa yield decreased by irrigating with poor quality water was reported by Prunty *et al.* (1991). High concentration of Na, B, Cl and HCO_3 ions of water affects directly the soils and crop yield (Sarker *et al.* 2000). Osmotic effects of excessive salinity cause adverse soil physical properties and reduce crop growth. Salts from the irrigation water accumulate in the soil profile and cause soil dispersion and surface seal development during irrigation, thus decreasing infiltration rate and amount (Sarker 2001). Davies *et al*. (1993) reported that 20% crop production loss occurred due to high concentration (20 ppm) of As in plant body. So,

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water quality assessment is necessary prior to its safe use for domestic and irrigation purposes. The present study was designed to investigate the chemical properties of groundwater and surface water for assessing the suitability for domestic and irrigation purposes.

MATERIALS AND METHODS

Thirty water samples were collected from different locations at Homna thana of Comilla district in April, 2007. Samples were collected from two different sources: hand tube well and river. After collection, the samples were immediately brought to the laboratory of Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University, Dinajpur; for chemical analysis. The pH and EC of sampled waters were determined by using pH meter (Hanna instrument-211) and EC meter (Hanna instrument-H18033). The values of TDS of waters were estimated by evaporating a measured aliquot of filtered samples. The Na and K ions were estimated by flame photometer, and Ca and Mg ions were determined by complexometric titration method. The other cations like Fe, Mn, Cu, Zn, B, and anions like Cl, NO_3-N, SO_4-S, HCO_3, and CO_3 were determined as per standard procedure. The toxic element, As was detected qualitatively. Irrigation water quality parameters viz. SAR, SSP, and H_T were used to classify the suitability of waters, along with pH, EC, and TDS. The values of SAR, SSP and H_T were calculated from the analyzed data using following formula:

a) Sodium Adsorption Ratio, $SAR = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})\ /2}}$

b) Soluble Sodium Percentage,

$$SSP = \frac{Soluble\ Na\ concentration\,(meq\ L^{-1})}{Total\ cation\ concentration\,(meq\ L^{-1})} \times 100$$

c) Hardness or Total Hardness,
$H_T = 2.5 \times Ca^{2+} + 4.1 \times Mg^{2+}$

Correlation coefficient analysis was done for all possible combinations among the quality parameters.

RESULTS AND DISCUSSION

Chemical properties of groundwater and surface water: The pH values of waters were ranged from 6.81 to 7.8 with an average value of 7.20. It indicates that the pH of all sources of waters were within the normal range 6.5 to 8.4 for irrigation (Ayers and Westcot 1985) and these waters might not be harmful for domestic uses (WHO, 1971). The higher pH values were probably due to the alkalinity, i.e., the presence of higher amounts of Ca, Mg, Na and HCO_3 (Micheal 1987). Regarding pH values, water samples are might not be harmful for soils and crops. Similar observations were revealed by Sarker (2001), Hassanuzzaman *et al.* (2007) and Nasirullah *et al.* (2007).

The major ions such as Ca, Mg, Na, K, Cl and HCO_3 distributed at various concentrations in the water samples. The concentrations of major ions have been presented in Table 1. According to WHO (1971) standard, all waters ware within acceptable limits and were suitable for domestic and irrigation purposes with respect to these major ions. The concentrations of SO_4 and B were found within the range of 0.02 to 0.26 and 0.05 to 0.19 mg L^{-1}, respectively which were in acceptable limits (Ayers and Westcot, 1976; Acceptable limit: <0.75 mg L^{-1}; WHO 1971).

The concentrations of Mn, Zn, and Cu were nil and was very low in case of Fe. So, the waters were free from the toxic effect of heavy metals and suitable for domestic use and crop production. A semi-heavy toxic metal As was tested qualitatively using $AgNO_3$. In the study area, both surface and ground waters contain As at different levels. Out of 30 samples, 14 (46.66%) were As contaminated by different levels. Arsenic concentration in different places varies might be due to As containing parent material. Among 30 samples, 16 samples were As free; 9 samples contained low level which were not harmful for domestic and irrigation purpose. High level of As contamination was found in 5 samples in both sources. High level of As increases skin lesions, cardiovascular and cancer death. So, it needs careful use of As contaminated water.

EC, TDS, SAR, SSP, RSC, B, and H_T: Electrical conductivity of waters varied between 660 and 1800 μScm^{-1} with an average value of 1084 $\mu S\ cm^{-1}$. TDS of waters varied from 466 to 1305 mg L^{-1} with an average value of 741 mg L^{-1}. Most of the waters (25 samples) contained less than 1000 mg L^{-1} TDS and were suitable for drinking (WHO 1971) and irrigation purpose (Carroll 1962; Freeze and Cherry 1979). Few samples (5) contained high amounts of TDS. The high TDS in water affects primarily on crops productivity. The important quality parameter viz. SAR, SSP and H_T computed from the analyzed data are depicted in Table 2. The computed SAR of water samples were within the range from 0.70 to 4.79 with the mean value of 2.35. A high SAR can disperse soil aggregations, which in turn deduce the number of large pores in the soil which are responsible for aeration and drainage resulting soil sealing and crust formation (Gratton 2002). The water with SAR less than 10.00 might not be toxic for agricultural crops (Todd, 1980). The SAR values of the waters were far less from 10.0. So, the waters of all sources were safe for irrigation purpose. The calculated SSP values of all water samples were varied from 12.04 to 71.39 with the average of 40.79. Wilcox (1955) categorized that SSP with >80 are unsuitable for irrigation. So, the waters contained less than 80 SSP were not harmfully affect irrigated crops and soil. The calculated H_T values of all water samples varied from 114.70 to 923.29 mg L^{-1} which were in acceptable limit (>3000 mg L^{-1}) (Saweyer and McCarty 1967).

Specific ions: In the present study, the ions like Ca, Mg, Na, K, Cl, SO_4, HCO_3 and As were in dominant quantities but the remaining detected ions (Fe, Mn, Zn, Cu, B, NO_3 and CO_3) were also recorded in trace amounts. The ions having excess quantity reduce crop growth, production, quality and/or cause specific injure due to ionic toxicity. The level of Ca in water is related closely to the geology of the source areas, the Ca being derived by weathering of processes from minerals such as gypsum, limestone and dolomite (Nasirullah *et al.* 2007). Calcium contributes to the hardness of the water which may cause soil crust and infiltration problems. Chemical reactions of Mg in the water are similar to those of Ca and cause water hardness. A considerable amount of K was present in the water. This might be due to the presence of K bearing mineral in the parent material in soils like sylvite (KCl), nitre (KNO_3) in the aquifers (Karanth 1994). The high concentrations of Na and Cl ions were found in hand tube wells. The presence of high Na and Cl ions are considered potential threat for sodium hazard and salt problem. Thus, the soils of this area are assumed to cause sodicity and salinity problem in future. Irrigation water containing high Na ion might induce K deficiency. Where Na/Ca ions ratio is high, some cereals, such as, rice, wheat, maize and barley showed severe deficiency of Ca ion (Grieve and Mass 1988; Grieve and Fujiyama 1987). Sodium ion causes disturbance of Ca nutrition. On the other hand, the beneficial effects of Ca and/or Mg ions are well known for controlling the negative role of Na toxicity. The high amount of Cl ion can contribute osmotic stress and some cultivars of soybean that tend to accumulate excessive and toxic amounts of Cl ion (Parker *et al.* 1983). Many woody species and fruit cultivars are also susceptible to Cl ion toxicity. The presence of heavy metal Fe was found in very low concentration and had no toxic effect. The other heavy metals, like, Mn, Zn and Cu were in trace. The NO_3-N, SO_4-S, and B played an important role for crop nutrition but their relative concentrations were very low. So, the heavy metals, Mn, Zn and Cu and other ionic groups, NO_3-N, SO_4-S and B had no effects on agricultural crops. Considering CO_3, only 2 samples contained high amount. The presence of high concentration of CO_3 in water due to high residual sodium carbonate must be given special attention because of its tendency to precipitate Ca and Mg as carbonates in the soil. High bicarbonate water has been shown to induce iron chlorosis (Finkel 1993). Arsenic contamination was found in different levels and was found more in the groundwater than on the surface water. The occurrence of As in groundwater is considered to be a process by weathering of As containing parent materials and by changing redox conditions whereby As is selectively desorbed in response to the reduction of Fe^{3+} to Fe^{2+} (Bhattacharya *et al.* 1999). High concentration of

Table1. Chemical composition and computed parameters for suitability classification of the study water.

S/N	Source	pH	Ca	Mg	Na	K
			meq L^{-1}			
1	River	7.28	1.00	1.61	6.10	0.001
2	HTW	7.05	1.00	2.93	6.30	0.003
3	HTW	7.11	6.21	8.8	5.80	0.003
4	HTW	7.05	2.60	4.04	6.10	0.003
5	River	6.96	1.30	1.92	5.80	0.001
6	HTW	6.81	3.00	3.64	5.20	0.002
7	HTW	7.80	2.20	3.13	4.10	0.002
8	HTW	7.32	0.60	1.72	5.80	0.003
9	HTW	7.34	7.11	11.13	2.50	0.003
10	HTW	7.00	7.01	11.63	5.30	0.002
11	HTW	7.23	2.20	3.54	5.90	0.002
12	HTW	7.18	3.50	5.36	4.80	0.004
13	River	7.24	1.00	2.12	5.10	0.001
14	HTW	7.17	6.41	11.23	2.80	0.003
15	HTW	7.27	6.01	10.32	3.60	0.002
16	HTW	7.46	3.80	5.56	2.80	0.003
17	HTW	7.56	1.10	1.92	5.60	0.002
18	HTW	7.24	6.21	2.02	5.50	0.003
19	HTW	7.10	4.00	7.99	2.13	0.003
20	HTW	7.73	4.50	6.47	2.34	0.002
21	HTW	7.01	1.90	7.69	4.80	0.002
22	HTW	6.97	1.70	2.73	5.10	0.001
23	HTW	7.10	2.30	2.12	5.30	0.002
24	HTW	7.16	2.40	4.55	5.10	0.002
25	HTW	7.22	3.50	3.54	4.80	0.003
26	HTW	7.09	3.50	2.32	4.60	0.002
27	HTW	7.16	3.60	5.36	4.20	0.004
28	HTW	7.21	3.20	10.01	2.30	0.003
29	HTW	7.16	0.10	4.75	5.80	0.001
30	HTW	7.19	2.40	3.13	5.60	0.001
Mean		7.20	3.18	5.11	4.70	0.002
SD		0.21	2.00	3.23	1.29	0.001
CV		2.95	63.0	63.34	27.4	33.31

Key: HTW = hand pressure tube well, H= high, L= low, ND= not detected.

Contd….

Table 1. Contd.

S/N	B	Cl	SO_4	HCO_3	Arsenic
		meq L^{-1}			
1	0.19	5.20	0.08	2.00	H
2	0.11	4.80	0.18	4.10	ND
3	0.11	8.70	0.15	8.60	L
4	0.13	6.00	0.03	4.60	L
5	0.12	5.20	0.09	2.40	H
6	0.11	6.80	0.18	3.40	ND
7	0.14	5.60	0.09	2.10	ND
8	0.08	4.60	0.08	2.40	ND
9	0.13	8.30	0.09	8.80	ND
10	0.11	12.4	0.09	7.60	ND
11	0.05	5.20	0.02	4.80	H
12	0.14	6.00	0.04	5.40	H
13	0.05	4.80	0.07	2.20	H
14	0.05	8.60	0.04	8.50	ND
15	0.11	8.40	0.26	9.00	ND
16	0.11	5.20	0.04	5.00	ND
17	0.13	5.30	0.03	2.30	ND
18	0.19	6.00	0.03	6.10	L
19	0.05	6.20	0.14	5.40	ND
20	0.12	5.60	0.02	5.40	ND
21	0.12	5.80	0.18	6.20	ND
22	0.08	5.60	0.09	2.20	L
23	0.11	5.20	0.18	3.10	ND
24	0.15	6.60	0.26	3.40	L
25	0.13	6.50	0.14	3.40	L
26	0.12	5.60	0.18	3.40	ND
27	0.11	6.80	0.02	4.20	L
28	0.10	6.80	0.02	6.20	L
29	0.05	6.40	0.23	2.80	L
30	0.08	6.40	0.14	3.10	ND
Mean	0.10	6.35	0.11	4.60	
SD	0.03	1.60	0.07	2.19	
CV	33.5	25.2	66.7	47.74	

As might be problematic for long-term irrigation and crops, like rice, vegetables, and human beings. Arsenic is getting into rice, Bangladesh's staple crop, through irrigation water pumped from contaminated soils. People of that area are contaminated severely by having those crops and drinking As contaminated water.

Table 2. Chemical composition and computed parameters of groundwater and surface water.

S/N	EC	TDS	H_T	SAR	SSP
	µS cm^{-1}	mg L^{-1}	mg L^{-1}		
1	660	485	129.76	4.53	69.93
2	860	624	194.49	4.01	61.53
3	1660	1200	743.79	1.78	27.86
4	1010	731	329.42	2.83	47.82
5	710	513	159.73	3.85	64.25
6	920	677	329.54	2.37	43.88
7	820	504	264.57	2.11	43.41
8	720	475	114.70	4.80	71.39
9	1660	1168	903.40	0.70	12.05
10	1780	1305	923.29	1.48	22.12
11	940	696	284.48	2.96	50.65
12	1210	785	439.24	1.93	35.10
13	690	466	154.66	3.55	61.98
14	1680	1151	873.31	0.81	13.69
15	1800	1184	808.46	1.08	18.06
16	1040	698	464.22	1.09	22.99
17	670	500	149.71	3.89	64.91
18	1160	858	410.20	2.04	40.03
19	1240	781	593.74	0.75	15.07
20	1260	751	544.11	0.84	17.55
21	1280	831	473.59	2.00	33.34
22	700	518	219.60	2.91	53.47
23	820	573	219.79	2.88	54.46
24	1000	671	344.29	2.35	42.28
25	1020	665	349.61	2.09	40.50
26	860	616	289.86	2.13	44.07
27	1200	730	444.25	1.67	31.88
28	1220	858	653.24	0.80	14.81
29	920	597	239.02	3.68	54.42
30	1020	635	274.59	2.81	50.25
Min.	660	466	114.70	0.70	12.05
Max.	1800	1305	923.29	4.79	71.39
Mean	1084	741	410.75	2.36	40.79

Suitability classification:
For the irrigation water, EC, SAR and SSP are considered to be the major criteria for assessing suitability classification, whereas TDS and B are minor. On the basis of EC values following Richards (1954), 6 samples belonged to *good* (C2) class and 24 were in *permissible* (C3) class.

Table 3. Quality classification and suitability of groundwater and surface water for irrigation purpose.

S/N	Suitability classification						
	EC	TDS	SAR	SSP	Boron	Alkalinity and salinity hazard	Proposed suitability classification
1	Good	Free	Excellent	Doubt	Excellent	C2S1	Moderate suitable
2	Permissible	Free	Excellent	Doubt	Excellent	C3S1	Permissible
3	Permissible	Brackish	Excellent	Good	Excellent	C3S1	Permissible
4	Permissible	Free	Excellent	Permissible	Excellent	C3S1	Permissible
5	Good	Free	Excellent	Doubt	Excellent	C2S1	Permissible
6	Permissible	Free	Excellent	Permissible	Excellent	C3S1	Permissible
7	Permissible	Free	Excellent	Permissible	Excellent	C3S1	Permissible
8	Good	Free	Excellent	Doubt	Excellent	C2S1	Moderate suitable
9	Permissible	Brackish	Excellent	Excellent	Excellent	C3S1	Permissible
10	Permissible	Brackish	Excellent	Good	Excellent	C3S1	Permissible
11	Permissible	Free	Excellent	Permissible	Excellent	C3S1	Permissible
12	Permissible	Free	Excellent	Good	Excellent	C3S1	Permissible
13	Good	Free	Excellent	Doubt	Excellent	C2S1	Moderate suitable
14	Permissible	Brackish	Excellent	Excellent	Excellent	C3S1	Permissible
15	Permissible	Brackish	Excellent	Excellent	Excellent	C3S1	Permissible
16	Permissible	Free	Excellent	Good	Excellent	C3S1	Permissible
17	Good	Free	Excellent	Doubt	Excellent	C2S1	Permissible
18	Permissible	Free	Excellent	Permissible	Excellent	C3S1	Permissible
19	Permissible	Free	Excellent	Excellent	Excellent	C3S1	Permissible
20	Permissible	Free	Excellent	Excellent	Excellent	C3S1	Permissible
21	Permissible	Free	Excellent	Good	Excellent	C3S1	Permissible
22	Good	Free	Excellent	Permissible	Excellent	C2S1	Moderate suitable
23	Permissible	Free	Excellent	Permissible	Excellent	C3S1	Permissible
24	Permissible	Free	Excellent	Permissible	Excellent	C3S1	Permissible
25	Permissible	Free	Excellent	Permissible	Excellent	C3S1	Permissible
26	Permissible	Free	Excellent	Permissible	Excellent	C3S1	Permissible
27	Permissible	Free	Excellent	Good	Excellent	C3S1	Permissible
28	Permissible	Free	Excellent	Excellent	Excellent	C3S1	Permissible
29	Permissible	Free	Excellent	Permissible	Excellent	C3S1	Permissible
30	Permissible	Free	Excellent	Permissible	Excellent	C3S1	Permissible

The suitability classification was based on Wilcox (1955), Freeze and Cherry (1979), Todd (1980), Wilcox (1955), Eaton (1950), Richards (1954), and Sawyer and McCarty (1967), respectively. C1, C2, C3, and C4 represent low, medium, high, and very high salinity hazard; and S1, S2, S3, and S4 represent low, medium, high, and very high sodium hazard, respectively.

All water samples were classified *permissible* to *good* for EC. So, these sources of water might not cause any harm for agriculture purpose. As per TDS values, 25 samples out of 30 were *fresh* (Carrol 1962; Freeze and Cherry 1979) and 5 were *brackish* which were not suitable for irrigation. TDS can increase through the continual addition of salts by both natural weathering process and human activities, such as discharges of domestic and industrial effluents and runoff from urban and rural areas. The value of TDS is directly proportional with that of total soluble mineral ions and other dissolved substances in water bodies (Sarker *et al.* 2000; Sarker *et al.* 2003). In addition to this, Puntamkar *et al.* (1988) indicated that the degree of soil properties deterioration depends on the total dissolved salt contents in irrigation water. With respect to SAR, all samples were graded as *excellent* class.

All the samples were rated as low alkalinity hazard (S1) class for irrigation as per SAR value (Table 3). In the study area, alkalinity problem might not occur using this water. From the calculated value of SSP, 12 samples were *permissible*, 6 were *good* and other 6 were *excellent* in class. Based on suitability class of B, all waters were graded as *excellent* for irrigation and can safely be used for successful crop production.

The EC, SAR, and SSP belonged to the *excellent* to *good* category water are considered as suitable class. No water was found in this class. The waters were categorized as *moderate suitable* when SAR, EC and SSP for *excellent*, *good* and *permissible*, respectively. In the study area, only 4 water samples (S/N. 1, 8, 13 and 22) were categorized in this class. The *permissible* category comprised the samples that were *excellent*, *good* and *permissible* for SAR, EC and SSP, respectively. Most of the waters (26) ware in the *permissible* category.

Relations among pH, EC, SAR and SSP: Correlation coefficient was determined amongst the parameters viz. pH, EC, SAR and SSP in all possible combinations (Table 4). It was evident that pH value was not significantly correlated with EC, TDS, SAR and SSP. EC value was significantly correlated with TDS, SAR and SSP at 1% level of significance. It indicates that EC had influence on TDS, SAR and SSP. TDS value was significantly correlated with SAR and SSP at 1% level of significant. SAR value showed a close relationship with SSP at 1% level of significant. There were significant correlations among EC-TDS, -SAR, EC-SSP; TDS-SAR, TDS-SSP; and SAR-SSP. This results support that the quality of free soil solution may indicate the distribution of Na ions in the absorbed phase. The presence of Na in irrigation water influences the physical properties of the soil, particularly the permeability by affecting the swelling and dispersion of the clay (Finkel 1993). Besides, when the excess carbonate (residual) concentration becomes too high, they combine with Ca and Mg to form a solid material which settles out of the water. The end result is an increase in both the Na percentage and SAR (Johnson and Jhang, 2003). At the same time as per result, it may create alkali hazard in soil and may encumber successful crop production. On the other hand insignificant correlation coefficient among pH-EC, pH-TDS, pH-SAR and pH-SSP indicated that the increase of one parameter will result in the decreasing of the aforementioned parameters.

Table 4. Correlation matrix among the water quality parameters.

	pH	EC	TDS	SAR
EC	-0.052^{NS}			
TDS	-0.1372^{NS}	0.978^{**}		
SAR	-0.124^{NS}	-0.771^{**}	-0.707^{**}	
SSP	-0.104^{NS}	-0.852^{**}	-0.791^{**}	0.978^{**}

Legend: NS, and ** indicate not significant, and 1% level, respectively

CONCLUSION

Chemical analysis of different water samples show good for domestic and irrigation purposes. Some water samples contained undesirable level of EC, TDS, and SSP but the SAR and B contents were within safety limit. Undesirable level exerted a significant impact on the crop production and the soil properties. In the study area, the suitable and moderately suitable waters could be used for domestic and irrigation purposes without any detrimental effects. Higher EC value helps to the development of soil salinity that has deleterious effect on soil properties if uses for prolonged period. In this study, 53% water samples were As free and can be used safely; but 47% contained As in different levels which have harmful effects on domestic and irrigation uses.

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