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ASSESSMENT OF IRRIGATION WATER QUALITY OF BOGRA DISTRICT IN BANGLADESH

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Abstract

Some important physio-chemical parameters of surface and groundwater of Bogra District were evaluated for the criteria of irrigation water quality. Forty four water samples were collected in the peak dry season (December-April) from different areas of Bogra District. The study revealed that temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), sodium adsorption ratio (SAR), soluble sodium percentage (SSP), residual sodium carbonate (RSC), total hardness (Ht) and Kelly's ratio of waters were found within the permissible limits for irrigation purposes. Any initiative for surface and groundwater development for planned irrigation practices is highly encouraged.

Key Words: Irrigation water (surface and groundwater), quality, Bogra District.

Introduction

Irrigated agriculture is dependent on adequate water supply of usable quality. Water quality concerns have often been neglected because good quality water supplies have been plentiful and readily available (Shamsad and Islam, 2005; Islam *et al.*, 1999). This situation is now changing in many areas. Intensive use of nearly all good quality supplies means that new irrigation projects, and old projects seeking new or supplemental supplies, must rely on lower quality and less desirable sources (Cuena, 1989).

Irrigation water quality is related to its effects on soils and crops and its management. High quality crops can be produced only by using high-quality irrigation water keeping other inputs optimal. Characteristics of irrigation water that define its quality vary with the source of the water. There are regional differences in water characteristics, based mainly on geology and climate. There may also be great differences in the quality of water available on a local level depending on whether the source is from surface water bodies (rivers and ponds) or from groundwater aquifers with varying geology, and whether the water has been chemically treated. The chemical constituents of irrigation water can affect plant growth directly through toxicity or deficiency, or indirectly by altering plant availability of nutrients (Ayers and Westcot, 1985; Rowe *et al.*, 1995).

Water used for irrigation can also vary greatly in quality depending upon the type and quantity of dissolved salts. In irrigated agriculture, the hazard of salt

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water is a constant threat. Poor-quality irrigation water becomes more concern as the climate changes from humid to arid conditions. Salts are originated from dissolution or weathering of rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. These substances are carried with the water to wherever it is used (UCCC, 1974; Tanji, 1990).

To evaluate the quality of irrigation water, we need to identify the characteristics that are important for plant growth, and their acceptable levels of concentrations. Having the water tested by a reputable laboratory is the first step in this process. A knowledgeable interpretation of the results can help to correct water quality problems and/or choose fertilizers and irrigation techniques to avoid crop damage. To avoid problems when using these poor quality water supplies, there must also be sound planning to ensure that the quality of water available is put to the best use.

Bogra district lies in the northern part of Bangladesh with a coordinate of 24° 51´ N and 89°22´ E. It covers an area of 2919.9 sq. km. with annual average maximum temperature of 34.6° C and the minimum of 11.90 ^{0}C. The annual total rainfall is 1610 mm. It comprises twelve upazillas, namely Bogra Sadar, Shibgonj, Dupchachia, Adamdhighi, Kahalu, Nandigram, Sherpur, Dhunot, Sajahanpur, Sariakandi, Gabtoli and Sonatola. Its agriculture is mainly dependent on irrigation. But a detailed investigation regarding the irrigation water quality and its suitability for crops has no yet been done. Keeping these in mind, the present research reports the bench mark survey of irrigation water quality of Bogra District.

Materials and Method

A field research was conducted to evaluate the suitability of groundwater for irrigated agriculture of Bogra District. A total of 44 ground water samples representing extensively used STW and DTW area were collected from various sites in the cropping period of the peak dry season (January, 2007). Samples were collected from 12 deep tube wells, 19 shallow tube wells, 5 rivers and 8 canals. Each sample was a composite of 20 sub-samples to minimize error and heterogeneity. The high density PVC bottles were used for sampling. They were thoroughly cleaned by rinsing with 8N HNO_3 and deionized water followed by repeated washing with water sample as suggested by De (1989). Before sampling from a well, water was pumped out sufficiently so that the sample represents the groundwater from which the well is fed (Raghunath, 1990). The bottles were kept air tight and labeled properly for identification. Aeration during sampling was avoided by stoppering the bottle quickly. Various determinants, such as EC, pH and temperature of the samples were measured on the spot using portable EC-meter, pH-meter and thermometer, respectively. Ionic TDS was simply determined by multiplying the measured EC values (in µS/cm) by 0.64 as there exists an approximate relation between EC and TDS for most natural water in the range of 100 to 5000 µS/cm leading to the equivalencies 1 meq/l of cations = 100 µS/cm and 1 meq/l = 1.56 µS/cm (Todd, 1980). Samples collected from study area were carefully transported to the laboratory and were preserved in a refrigerator for analysis.

The analysis for the physico-chemical parameters of the samples were carried out following the established analytical methods. Na^+ and K^+ were determined by flame photometry (Jackson, 1967); Ca^{2+}, Mg^{2+}, Fe and B by visible spectrophotometry (Jackson, 1967 and Page *et al.*, 1982); $C1^-$ and HCO^-_3 by titration method (Jackson, 1967); the sodium adsorption ratio (SAR) was estimated by the equation using the values obtained for, Ca^{2+}, Mg^{2+} in me/I (Richards, 1954); the soluble sodium percentage (SSP) was determined by the equation using the values obtained for Na^+, K^+, Ca^{2+}, Mg^{2+} in me/l (Todd, 1980); the residual sodium carbonate (RSC) was determined by the equation using the values obtained for CO^{2-}_3, HCO^-_3 in me/l (Eaton, 1950) and the Kelly's ratio was determined by the equation using the values obtained for Na^+, Ca^{2+} and Mg^{2+} in me/l (Kelly, 1953).

Results and Discussion

Table 1 represents the results of physico-chemical parameters of the irrigation water samples of the study area of Bogra District, while Table 2 shows the suitability of water quality for irrigation purposes.

Table 1 reveals that the average temperature of irrigation water samples of the study area was 20°C and in the range of 18 to 23 °C. The pH value of irrigation water of the study area ranges from 6.7 to 7.9 with an average value of 7.22, which is within the permissible limit for irrigated agriculture (DOE, 1997 and UCCC, 1974).

The EC value of irrigation water of the study area ranges from 317 to 769 µS/cm with an average value of 549.5 µS/cm, which according to Wilcox (1955) falls within the irrigation water quality classification stand 'excellent to good'. In terms of the 'degree of restriction on use', EC value of < 700 µS/cm refers the water to 'none'; 700-3000 µS/cm 'slight to moderate' and 3000 µS/cm 'severe' (UCCC, 1974). It is easily presumable from the data in Table 2 that in terms of EC value, the irrigation water of the study area is suitable for irrigation purpose as it falls under category 'none' (UCCC, 1974).

In addition to above parameters, it is also important to consider the TDS in water, because many of the toxic solid materials may be imbedded in the water which may cause harm to the plants (Matthess, 1982). As EC and TDS values of groundwater are interrelated, both the values are indicative of saline water in absence of non-ionic dissolved constituents (Michael, 1992). The TDS values range from 218 to 529 mg/l. It indicates that some values are quite suitable but some are suitable under some restrictions as the higher values exceeded 450 mg/l (Table 1). In terms of ‘Degree of restrictions on use’, the TDS values <450, 450-2000 and >2000 mg/l represent the irrigation water as ‘none’; ‘slight to moderate’ and ‘severe’, respectively (Table 2). So, like EC, the irrigation water of the study area, in term of TDS, is suitable for irrigation purpose.

Irrigation water that has high sodium (Na^{+}) content can bring about a displacement of exchangeable cations Ca^{2+} and Mg^{2+} from the clay minerals of the soil, followed by the replacement of the cations by sodium. Sodium-saturated soil peptizes and loses their permeability, so that their fertility and suitability for cultivation decrease (Matthess, 1982). High SAR in any irrigation water implies hazard of sodium (Alkali) replacing Ca and Mg of the soil through cation exchange process, a situation eventually damaging to soil structure, namely permeability which ultimately affects the fertility status of the soil and reduce crop yield (Gupta, 2005). The values of SAR of the collected water samples range from 0.13 to 0.45 with an average value of 0.23 (Table 1). According to Richards (1954), all the irrigation water samples fell under ‘excellent’ class and as per salinity classification (Fig. 1); all the irrigation water samples fell under low sodium hazards (S_1) class.

Salinity classification was done using a quality diagram (Fig. 1) given by the U. S. Salinity Laboratory (Richards, 1954). The diagram classifies 16 classes, with reference to SAR as an index of sodium hazard and EC as an index of salinity hazard (Mirsha and Ahmed, 1987; Michael, 1992). By plotting the obtained results in the diagram (Fig. 1), it was found that out of 44 irrigation water samples, the water of a canal near Bolua village under Sonatola upazilla (sample no. 36) was categorized into “C_1-S_1” and the rest of 43 samples fell under “C_2-S_2” class. Such water can be used safely for irrigation purposes (Richards, 1954). According to the quality diagram (Richards, 1954), all but one water samples in the study area fall in class C_2 that indicates “medium salinity”. But when value of EC is in concern, the classification of the water samples of the study area comes under “excellent to good” (Wilcox, 1955). And in terms of “degree of restriction on use” the value of water samples of the study area refers to ‘none’ when salinity is in concern (UCCC, 1974).

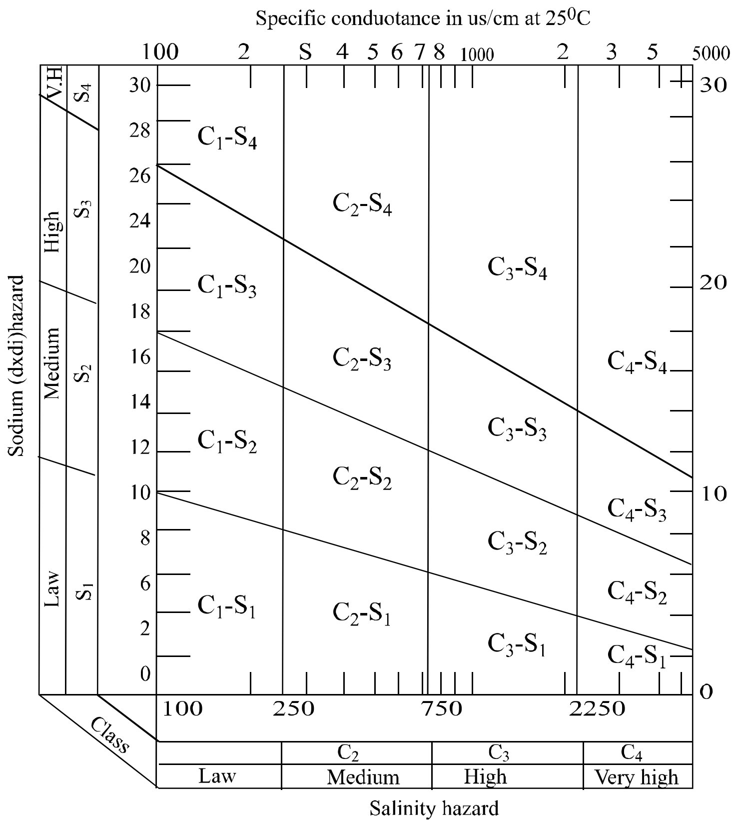

Fig. 2. Satinity alassification of irrigation water samples (Richards. 1954)

The soluble sodium percentage (SSP) values were found to vary from 14.79 to 41.99% with an average value of 24.42 % (Table 1) depending upon locations. Based on the classification after Wilcox (1955) for SSP, out of 44 irrigation water samples, 14 samples fell under "Excellent class" and 26 samples fell under "Good" class.

Table 1. Physico-chemical properties of irrigation water of the study area.

Water sample No.	Sampling area (village, Upazilla)	Sources of sample	Temper -ature (^oC)	EC µs/ cm	pH	TDS mg/l	SAR	SSP (%)	RSC me/l	Kelly's Ratio	Feme/l	$C1^-$ me/l	HCO^-_3 me/l	B mg/l
1	Pirob, Shibgonj	STW	18	320	7.5	349	0.14	16.56	2.06	0.137	0.00	1.24	5.10	0.32
2	Majihatta, Shibgonj	Canal	20	480	7.3	365	0.15	19.83	2.27	0.176	0.013	3.48	5.33	0.32
3	Shibgonj Sadar	Nagor River	20	497	6.9	329	0.18	17.89	1.31	0.187	0.00	1.66	5.21	0.30
4	Mokamtola, Shibgonj	STW	18	317	6.8	317	0.14	17.29	1.69	0.163	0.009	1.28	5.14	0.27
5	Rainagar, Shibgonj	STW	18	698	8.2	369	0.29	19.14	0.17	0.193	0.00	1.90	3.17	0.29
6	Dhunot Sadar	Bangali River	21	565	7.4	218	0.20	21.63	2.66	0.208	0.00	1.24	4.09	0.23
7	Kuthibari, Dhunot	STW	21	530	7.6	298	0.17	18.44	2.13	0.61	0.112	0.59	4.90	0.29
8	Khaduli, Dhunot	DTW	22	547	7.7	468	0.13	14.79	1.07	0.137	0.007	2.19	4.33	0.34
9	Goshaibari, Dhunot	Ichamoti River	21	491	7.8	350	0.14	16.43	0.5	0.153	0.20	3.21	4.19	0.38
10	Sabgram, Bogra Sadar	STW	18	465	7.6	319	0.18	21.95	2.03	0.218	0.004	1.02	4.66	0.36
11	Namuja Bogra Sadar	DTW	18	543	6.7	364	0.22	31.00	2.91	0.330	0.007	0.99	4.98	0.36
12	Nungola, Bogra Sadar	STW	20	581	6.9	347	0.39	34.41	3.27	0.477	0.00	1.20	5.87	0.29
13	Bogra Sadar	Karatoa River	19	537	6.7	361	0.17	19.57	2.32	0.187	0.00	1.03	5.47	0.30
14	Sahjahanpur Sadar	DTW	19	629	6.7	320	0.27	26.34	2.54	0.297	0.00	1.04	5.28	0.29
15	Chupnagar, Sahjahanpur	STW	19	489	7.1	312	0.26	26.27	2.11	0.289	0.002	1.30	5.00	0.30
16	Mirzapur, Sherpur	Canal	20	687	7.7	302	0.27	32.12	3.87	0.389	0.00	1.11	5.94	0.32
17	Kusumdi, Sherpur	DTW	21	709	7.3	309	0.43	38.21	3.35	0.556	0.00	2.01	6.10	0.32
18	Bhabanipur, Sherpur	DTW	24	586	7.6	299	0.33	28.33	2.83	0.350	0.005	1.05	3.97	0.29
19	Sudha, Sherpur	Bhadrabati River	20	493	7.5	307	0.34	28.05	2.12	0.348	0.019	1.00	3.59	0.34

Table 1. Cont'd.

Water sample No.	Sampling area (village, Upazilla)	Sources of sample	Temper -ature (°C)	EC µs/ cm	pH	TDS mg/l	SAR	SSP (%)	RSC me/l	Kelly's Ratio	Feme/l	$C1^{-}$ me/l	HCO^{-}_{3} me/l	B mg/l
20	Shihari, Adamdhighi	Canal	21	739	6.7	529	0.20	22.86	3.5	0.240	0.00	1.20	4.79	0.32
21	Santahar, Adamdhighi	STW	19	728	7.9	379	0.22	20.00	1.8	0.218	0.00	0.97	5.29	036
22	Bihigram, Adamdhighi	STW	19	684	7.0	314	0.19	21.19	3.02	0.218	0.017	1.66	5.91	0.37
23	Kundagram, Adamdhighi	DTW	17	439	6.9	318	0.22	28.34	3.29	0.328	0.028	1.24	6.09	0.32
24	Karamji, Dupchachia	Canal	21	698	6.8	340	0.17	17.46	1.27	0.181	0.021	1.31	5.20	032
25	Talora, Dupehachia	Canal	23	654	69	350	0.17	18.00	2.14	0.186	0.00	1.41	5.34	0.37
26	Jianagar, Dupchachia	DTW	22	625	7.4	304	0.33	41.99	2.69	0.380	0.00	1.09	6.22	0.31
27	Chararul, Dupchachia	DTW	22	581	70	307	0.17	21.94	1.87	0.222	0.007	1.71	3.75	0.38
28	Murail, Kahalu	STW	19	586	6.8	318	0.16	18.92	1.56	0.193	0.016	1.08	4.68	0.30
29	Durgapur, Kahalu	STW	18	537	7.6	314	0.27	28.60	4.21	0.35 1	0.014	1.35	5.49	0.30
30	Malancha, Kahalu	Canal	19	739	7.9	321	0.27	29.96	2.13	0.369	0.023	1.61	5.99	0.29
31	Jaguli, Gabtoli	Canal	21	734	7.8	327	0.18	18.94	1.92	0.182	0.00	5.63	5.18	0.36
32	Hosenpur, Gabtoli	STW	22	467	6.8	319	0.17	20.32	1.95	0.188	0.00	3.22	5.34	0.32
33	Durgahata, Gabtoli	STW	22	529	6.7	410	0.35	30.94	1.59	0.381	0.00	0.99	5.71	037
34	Modhupur, Sonatola	DWT	22	543	6.8	419	OM	29.50	4.63	0.617	0.004	2.19	6.94	0.17
35	Tekni, Sonatola	STW	22	627	6.7	342	0.17	19.05	1.64	0.222	0.008	1.51	3.55	032
36	Bolua, Sonatola	Canal	20	*235*	7.4	322	0.22	25.52	1.62	0.285	0.00	1.26	*4.25*	0.39
37	Digdaib, Sonatola	DWT	20	481	7.6	312	0.19	19.74	2.06	0.210	0.026	1.66	6.11	0.39
38	Kutubpur, Sariakandi	STW	18	367	7.6	314	0.13	15.95	2.03	0.149	0.00	1.24	5.02	035
39	Chandabaisha, Sariakandi	DTW	19	349	7.3	311	0.19	19.52	2.42	0.203	0.00	1.09	5.60	0.36

Table 1. Cont'd.

Water sample No.	Sampling area (village, Upazilla)	Sources of sample	Temper -ature (^oC)	EC µs/ cm	pH	TDS mg/l	SAR	SSP (%)	RSC me/l	Kelly's Ratio	Feme/l	C1$^-$ me/l	HCO$^-_3$ me/l	B mg/l
40	Sariakandi	Jamuna River	19	519	7.1	316	0.26	30.62	2.58	0.376	0.013	1.30	5.21	039
41	Nandigram Sadar	STW	20	541	7.2	300	028	31.32	1.84	0.396	0.017	1.04	5.66	0.32
42	Vatgram, Nandigram	DWT	18	641	6.9	310	0.20	25.55	2.75	0.269	0.00	2.13	5.42	0.39
43	Majhgram, Nandigram	STW	21	512	7.1	321	0.45	39.92	1.53	0.222	0.008	1.26	5.01	0.37
44	Vatra, Nandigram	STW	23	468	6.8	351	0.27	26.87	2.4	0.193	0.00	1.39	5.03	0.38
	Average		20	549.5	7.22	335.70	0.23	24.42	2.26	0.27	0.013	1.57	5.12	0.33
	Range		18-23	317- 769	6.7- 7.9	218-529	0.13 - 0.45	14.79-41.99	0.17-4.63	0.137-0.396	0.00-0.112	0.59 -5.63	3.17-6.94	0.17-0.39
	SD		1.41	164.40	0.37	83.2 3	0.0 7	6.81	1.48	0.09	0.07	0.69	1.38	0.11
	CV (%)		7.78	26.06	5.96	28.03	29.90	39.01	91.60	101.97	23.41	27.60	19.08	48.09

Table 2. Guideline for interpretation of water quality for irrigation (UCCC, 1974).

Potential irrigation problem	Units	Degree of restrictions on use			Obtained results
		None	Slight to Moderate	Severe	
Salinity (affects crop water availability)					
EC	μS/cm	<7000	700-3000	>3000	317-769
TDS	mg/I	<450	450-2000	>2000	218-529
Infiltration (affects infiltration rate of water into the soil. Evaluate using EC and SAR together)					
SAR = 0.3 and EC =		> 700	700-200	<200	SAR = 0.323-4.52
=3-6 =		>1200	1200-300	<300	
=6-12 =		>1900	1900-500	<500	
=12-20 =		>2900	2900-1300	>1300	
=20-40 =		>500	5000-2900	<2900	
Specific Ion Toxicity					
Sodium (Na)	meq/1	<3	3-9	>9	0.69-3.09
Chloride (Cl)	meq/l	<4	4-10	>10	0.59-5.63
Boron (B)	mg/I	<0.7	0.7-3.0	>3.0	0.17-0.77
Miscellaneous effect					
Bicarbonate ($HC0_3$) (me/I)		<1.5	1.5-8.5	>8.5	3.17-6.94
pH		Normal Range 6.5-8.5			6.7-7.9

The water sample (sample no. 26) of a deep tube well (DTW) near Jianagar village under Dupchachia upazilla fell under "Permissible" class, which indicates that all the samples fell under the allowable range (Excellent to permissible) for irrigation use (Wilcox, 1955).

Table 1 shows that the highest residual sodium carbonate (RSC) value of the irrigation water was 4.63 which was collected from a deep tube well (DTW) (Sample no. 34) near Modhupur village under Sonatola Upazilla. The average value of RSC of the collected irrigation water samples was 2.26. Based on Eaton (1950), out of 44 irrigation water samples, 3 samples fell under "Good" class, 41 samples under "Marginal" class.

The Kelly's ratio of collected irrigation water samples ranged from 0.137 to 0.396 with an average value of 0.27 (Table 1) which showed all values were under acceptable range and suitable for irrigation purposes (Kelly, 1953).

Iron (Fe) content of irrigation water samples of the study area was from 0.00 to 0.112 me/l with an average value of 0.013 me/l. No Fe was detected in some samples (about 20 samples). Highest Fe concentration was recorded in Kuthibari village under Dhunot upazilla (sample no. 7) from a shallow tube well (STW).

Chloride ($C1^-$) content of the 44 irrigation water samples of the study area varied considerably ranging from 0.69 to 5.63 me/l with an average value of 1.57me/l (Table 1). The water sample of a canal (Sample no.31) near Jaguli village under Gabtoli upazilla showed the highest value of $C1^-$. Higher $C1^-$ values of concentration in a canal of Jaguli village might be due to the impact of settlement and anthropogenic effect (Islam *et al.,* 1999). It is evident that the values of Cl of the study area were within the recommended limit (BWPCB, 1976; WHO, 1984; Ayers and Westcot, 1985) and suitable for irrigation (Marschner, 1989; UCCC, 1974).

Table 1 shows that the range of bicarbonate (HCO^-_3) of irrigation water samples of the study area was between 3.17 and 6.94 me/l with an average value of 5.12 me/l. All the water was suitable for irrigation (Ayers and Westcot, 1985). Most of the values of both ground and surface water samples of the study area fell into 'slight to moderate' degree of restrictions on use (UCCC, 1974).

The concentration of boron (B) of irrigation water samples of the study area varied from 0.17 and 0.77 mg/l with an average value of 0.33 mg/i (Table 1). Out of 44 irrigation water samples, 25 samples showed 'Excellent' and the other 19 samples showed 'Good' with respect to B classification for sensitive crops after Wilcox (1955). The results are within the permissible limits (UCCC, 1974; Wilcox, 1955; Ayers and Westcot, 1985).

Conclusion

Different physico-chemical properties of irrigation water of Bogra District were compared with the national and international water quality standards set for irrigation. Electrical Conductivity (EC) of collected irrigation water samples fall in the class 'Good' except one sample which falls in the 'Excellent' class of EC; SAR, in 'Excellent', SSP in 'Good to Excellent' RSC in 'Good to Marginal' and B and CI^-contents within the maximum allowable concentration (MAC). Groundwater and surface water of Bogra district had no salinity problem. On the basis of SAR, RSC, and SSP values, no permeability problem was found to exist in Bogra District. Irrigation water quality in the other districts of Bangladesh needs to be assessed.

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