

## Regular Article

# Ionic Toxicity Assessment of Water Sources and their Suitability for Irrigation, Drinking, Livestock and Industrial Purposes

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**ABSTRACT:** A study was conducted to assess of the degree of ionic toxicity on the basis of standard criteria for irrigation, drinking, livestock, poultry, aquaculture and industrial purposes of 20 ground water sources in Kushtia, Bangladesh. The chemical analysis included pH, electrical conductivity (EC), total dissolved solids (TDS) and major ionic constituents like Ca, Mg, K, Na, Fe, Mn, B, As, Cu, PO<sub>4</sub>, CO<sub>3</sub>, HCO<sub>3</sub>, SO<sub>4</sub> and Cl. sodium adsorption ratio(SAR), soluble sodium percentage (SSP), residual sodium carbonate(RSC) and hardness(HT) were also calculated. The pH (6.93 to 7.63) showed slightly acidic to neutral. Ca (23.8 to 100.2 mg L<sup>-1</sup>), Mg (20.3 to 57 mg L<sup>-1</sup>), Na (16.49 to 52.30 mg L<sup>-1</sup>), K (0.36 to 5.76 mg L<sup>-1</sup>), HCO<sub>3</sub> (132.51 to 347.30 mg L<sup>-1</sup>) and Cl- (36.9 to 76.2 mg L<sup>-1</sup>) were predominant along with Mn, Cu and B in lesser amounts. Fe, As, PO<sub>4</sub>, SO<sub>4</sub> and CO<sub>3</sub> were found trace to little amounts. The TDS was rated as 'fresh water'. EC and SAR were 'medium' and 'high salinity' (C2 and C3) classes and 'low alkali hazard' (S1) class, combinedly expressed as C2S1 and C3S1. SSP was of 'excellent', 'good' and 'permissible' categories. Waters were free from RSC and belonged to 'suitable' category for irrigation. The waters were classified as 'hard', 'very hard' and 'medium hard' based on hardness (HT). The toxicities of B, Mn and Cl were not found in the study area for irrigation but HCO<sub>3</sub>, CO<sub>3</sub>, Fe and As toxicities were found in some sources. Iron content of 7 samples was 'unsuitable' for drinking, livestock, poultry and 7 samples were unsuitable for aquaculture usage. Manganese content of all samples was 'suitable' for drinking and livestock consumption. Both Fe and Mn content of all samples were 'problematic' for industrial usage. Arsenic status of 9 water samples was 'suitable' for drinking. Chloride content most of the samples was 'toxic' for livestock but all samples were 'unfit' for aquaculture. Sulphate of all samples was 'suitable' for drinking, livestock, poultry, aquaculture and industrial usage.

**Key words:** Toxicity, Groundwater, Chemical elements, Irrigation, Ground water

## Introduction

Groundwater is an important source of freshwater for agricultural, drinking and domestic uses in many regions of the world and also in Bangladesh. Water quality is a prime factor for successful crop production because the quality of water for irrigation usually depends on its chemical characteristics. If low quality of water is used for irrigation, toxic elements may accumulate in the soils as well as plants and deteriorates soil properties, which adversely affects on crop production and plant consumers. The principal soluble constituents are Ca, Mg, Na and K as cations and Cl, SO<sub>4</sub>, CO<sub>3</sub> and HCO<sub>3</sub> as anions. Beside these, Cu, PO<sub>4</sub>, Mn, Fe, As, B, Zn, Si and F are present in minor amounts. Out of the soluble constituents, Ca, Mg, Na, Cl, SO<sub>4</sub>, HCO<sub>3</sub> and B are of prime importance in judging the water quality for irrigation (Michael, 1978), especially for rice. Some of these ions are more or less beneficial to plant growth and are also harmful to plant growth beyond the safe limit. Certain soluble ions at relatively high concentrations have a direct toxic effect on sensitive crops. According to Bohn *et al.*, (1985) the concentrations of these toxic ions in irrigation water are particularly important because many

crops are susceptible to even extremely low concentrations of these elements. Moreover, specific water may be suitable for irrigation purpose but may not be suitable for drinking, livestock, poultry, aquaculture and industrial uses due to the presence of some other ions at toxic level. Toxic elements for drinking water are As, Cd, Cl, Cr, Pb, Hg, Fe, Mn and Zn. The troublesome ions for industrial process waters are SO<sub>4</sub>, Cl, Fe, Mn etc. and As, B, Cd, Cu, Pb, Mn, Hg, and Fe are also toxic to livestock consumption (AWWA, 1971 and ESB, 1972). In the global water resources, about 97.2% is salt water mainly in oceans, and only 2.8% is available as fresh water. Out of 2.8%, about 2.2% is available as surface water and 0.6% as ground water (Raghunath, 1987). At present, nearly one fifth of all water used in the world is obtained from ground water resources. Agriculture is the greater user of water accounting for 80% of all consumption. The discovery of arsenic in the ground water of Bangladesh is posing a major threat to people's livelihood in the country. More than 90% of the ground water is used for irrigation although 95% of the population relies on this as the source of drinking water. A recent study of WHO revealed that about 80 million people of 59 districts are at high risk of deadly arsenic poisoning (Hossain *et al.*, 2000). However, arsenic concentration of ground water has recently been realized as a global problem. The quality of water is generally judged by its total salt concentrations and the relative proportions of ions. The chemical composition of water is very important criterion to evaluate its suitability for irrigation, drinking, livestock, poultry, aquaculture and industrial uses. In this context, it becomes a crying need to conduct field level investigations of the existing water management practices in rural areas of Bangladesh.

In some selected areas of Bangladesh most of the chemical analysis pH, EC, Ca, Mg, CO<sub>3</sub>, HCO<sub>3</sub>, Cl, Na, and K were detected (Zaman *et al.*, 2000). For the formulation of a baseline data, an investigation was conducted to assess the groundwater quality for irrigation, drinking, livestock, poultry, aquaculture and industrial usage in Kushtia district. In the study area, there were different water sources, in which waters of shallow tube-well were mainly applied for irrigation. The cropping sequences like HYV rice, vegetables and rabi crops were also found to be cultivated. Some tube-well waters were usually being used for drinking, livestock, poultry, aquaculture and industrial usage. But there is no systemic organization to assess the extent of ground water quality at field level.

## Materials and Methods

An attempt has been taken to analyze ground water samples collected from the district of Kushtia, Bangladesh and the chemical analysis include the estimation of pH, electrical conductivity (EC), total dissolved solids (TDS) and major ionic constituents like Ca, Mg, K, Na, Fe, Mn, B, As, Cu, PO<sub>4</sub>, CO<sub>3</sub>, HCO<sub>3</sub>, SO<sub>4</sub> and Cl. The ground water sampling sites were selected in Kushtia district. Twenty (20) ground water samples were randomly collected to cover most of the investigated area during January, 2008 to February, 2008 following the sampling techniques as outlined by Hunt and Wilson (1986) and APHA (1995). The information regarding groundwater sampling has been presented in Table 1.

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Table 1. Information of Groundwater Sources of Kushtia, Bangladesh

Sample No.	Sampling location			Source	Depth (m)	Date of Installation	Duration (years)
	Village	Union	Upazila				
1	Shymnagar	Chapra	Kumarkhali Upazila	STW	47.65	14-03-1990	19
2	Bhaluka	Jodboira	Kumarkhali Upazila	STW	45.25	05-03-1999	10
3	Mohendrapur	Mohendrapur	Kumarkhali Upazila	STW	49.25	09-06-2003	6
4	Amlabari	Hashimpur	Kumarkhali Upazila	STW	45.23	22-12-1993	16
5	Boira	Jotpara	Kumarkhali Upazila	STW	39.26	11-06-2005	4
6	Ambaria	Ambaria	Khoksa Upazila	STW	38.74	12-06-2001	8
7	Gosaidangi	Dhokrakhol	Khoksa Upazila	STW	41.26	11-06-2003	6
8	Utholi	Mohisbathan	Khoksa Upazila	HTW	42.84	10-05-2005	4
9	Fulbaria	Fulbaria	Khoksa Upazila	STW	37.29	12-07-2000	9
10	Baraichara	Samashpur	Khoksa Upazila	DTW	54.28	10-05-1991	18
11	Joyantihazra	Joyantihazra	Khoksa Upazila	HTW	41.38	21-04-2002	7
12	Mohishakula	Nischintobaria	Khoksa Upazila	STW	39.17	24-06-1997	12
13	Mirzapur	Mirzapur	Khoksa Upazila	STW	42.19	19-04-1996	13
14	Osmanpur	Janipur	Khoksa Upazila	DTW	87.42	24-05-1993	16
15	Taherpur	Taherpur	Khoksa Upazila	HTW	45.26	27-05-2006	3
16	Ranakharia	Talbaria	Mirpur Upazila	STW	38.78	19-01-1998	11
17	Kattlamari	Sadarpur	Mirpur Upazila	STW	37.25	05-03-2007	2
18	Ahmedpur	Poradah	Mirpur Upazila	HTW	47.54	14-03-2003	6
19	Chhatian	Chhatian	Mirpur Upazila	STW	36.45	12-11-1999	10
20	Pagla	Malihad	Mirpur Upazila	STW	34.52	11-06-2008	1

DTW= Deep Tube-well Water; STW= Shallow Tube-well Water, HTW= Hand Tube-well Water

The pH and EC of water samples were determined electrometrically following the procedure mentioned by Ghosh *et al.* (1983) and Tandon (1995). Total dissolved solids (TDS) were determined after Chopra and Kanwar (1980). Sodium and potassium were determined with the help of a flame emission spectrometer (Golterman 1971 and Ghosh *et al.*, (1983). Calcium, magnesium, iron, copper, and manganese were analyzed by atomic absorption spectrophotometer in the analytical laboratory in the department of soil science, Bangladesh Agricultural Research Institute (BARI). Total arsenic content in water was determined from the sample flow injection hydride generation atomic absorption spectrophotometer with UNICAM Model, No. 969 with hydride generator assembly using matrix matched standards (Welsch *et al.*, 1990). Phosphate was analyzed colorimetrically by Stannous Chloride method (APHA 1995). Sulphate was estimated turbidimetrically with the help of spectrophotometer (Wolf, 1982 and Tandon, 1995). Carbonates and bicarbonates of water samples were determined by acidimetric method of titration (Tandon 1995 and Singh *et al.*, 1999). Boron was determined by Azomethine-H method (Page *et al.*, 1982). Chloride of water samples was analyzed by argentometric method of titration (Ghosh *et al.* 1983). The rating of water quality for a specific use depends on some defined quality factors. Some quality factors preferred to evaluate water quality or toxicity:

1) Sodium adsorption ratio (SAR) =

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

2) Soluble sodium percentage (SSP) =  $\frac{Na^+ + K^+}{Ca^{++} + Mg^{++} + Na^+ + K^+} \times 100$

3) Residual sodium carbonate (RSC) =  $(CO_3^{--} + HCO_3^-) - (Ca^{++} + Mg^{++})$

4) Hardness or total hardness (H<sub>T</sub>) =  $2.5 \times Ca^{++} + 4.1 \times Mg^{++}$

Where, concentrations of ionic constituents for calculating all parameters except hardness in me L<sup>-1</sup> and incase of hardness as mg L<sup>-1</sup>.

### Result and Discussion

The pH of waters varied from 6.93 to 7.63 (Table 2) and indicated that waters were slightly acidic to neutral in nature. Out of 20 samples, 1 sample was below 7.0 (i.e. 6.93) and was acidic to slightly acidic in nature. The remaining 19 samples under the study showed higher pH values above 7.0 ranging from 7.05 to 7.63 and were slightly alkaline in nature. Ayers and Westcot (1985) mentioned that the normal pH range of irrigation usually varied from 6.0 to 8.5. It indicated that the pH of all water samples under test were within the normal range and these waters might not be harmful for soils and crops. The electrical conductivity (EC) of all water samples was within the limit of 411 to 980 μS cm<sup>-1</sup> with the mean value of 684.4 μS cm<sup>-1</sup> (Table 2). The EC values of 11 samples were less than the mean value and the rest 9 samples were higher than the average value. The highest value (684.4 μS cm<sup>-1</sup>) was recorded from the sample no.1 and lowest amount (411 μS cm<sup>-1</sup>) was obtained from the sample no.5. According to Richards (1968), all the ground waters under test were rated as 'medium salinity' (C2) and 'high salinity' (C3) waters. Out of 20 samples, 17 samples were of 'medium salinity' and 3 samples were of 'high salinity' water. The amount of total dissolved solids (TDS) of ground water samples in the investigated area varied from 356.49 to 823.03 mg L<sup>-1</sup> with mean value of 555.62 mg L<sup>-1</sup> and CV value 23.47% (Table 2). Out of 20 samples, about 48.78% TDS values

(9 samples) were found below the mean value and remaining 51.22% samples (11 samples) were found above the average value. The highest TDS value (823.03 mg L<sup>-1</sup>) was detected in

shallow tube well (sample no.12). All the ground waters would not affect the osmotic pressure of soil solution (Freeze and Cherry,1997).

Table 2. Concentrations of pH, EC, TDS, Ca, Mg, Na, K, Fe, Mn, Cu, B, As, SO<sub>4</sub>, PO<sub>4</sub>, CO<sub>3</sub>, HCO<sub>3</sub> and Cl in groundwater

Sl. No.	pH	EC (µS cm <sup>-1</sup> )	TDS (mg L <sup>-1</sup> )	Ca (mg L <sup>-1</sup> )	Mg (mg L <sup>-1</sup> )	Na (mg L <sup>-1</sup> )	K (mg L <sup>-1</sup> )	Fe, (mg L <sup>-1</sup> )	Mn (mg L <sup>-1</sup> )	Cu (mg L <sup>-1</sup> )	B (mg L <sup>-1</sup> )	As (mg L <sup>-1</sup> )	SO <sub>4</sub> (mg L <sup>-1</sup> )	PO <sub>4</sub> (mg L <sup>-1</sup> )	CO <sub>3</sub> (mg L <sup>-1</sup> )	HCO <sub>3</sub> (mg L <sup>-1</sup> )	Cl (mg L <sup>-1</sup> )
1	6.93	980	476.39	70.3	52.3	46.46	2.12	0.41	Trace	Trace	0.08	0.03	2.1	3.77	25.3	254.87	41.5
2	7.07	676	387.36	45.5	44.0	36.23	2.42	0.26	Trace	Trace	0.40	0.09	1.3	2.83	Trace	253.40	76.2
3	7.06	730	649.23	40.8	37.1	32.61	1.83	0.20	0.02	Trace	0.08	0.06	2.6	1.57	Trace	317.81	40.1
4	7.05	476	356.49	38.2	35.2	29.84	4.85	0.15	0.04	Trace	0.12	0.04	1.8	5.54	8.6	191.23	62.7
5	7.21	411	477.78	40.4	31.0	47.30	1.81	0.45	Trace	Trace	0.11	0.08	1.6	2.83	6.8	195.35	72.8
6	7.09	843	503.67	59.6	28.5	34.92	1.51	0.35	Trace	Trace	0.15	0.05	2.0	1.78	15.8	180.27	65.4
7	7.11	635	457.52	23.8	20.3	52.30	3.24	0.46	Trace	Trace	0.12	0.07	2.3	3.77	17.5	226.58	63.8
8	7.16	579	602.69	29.5	30.5	38.92	1.52	0.29	Trace	Trace	0.14	0.04	2.0	0.95	9.4	192.87	43.5
9	7.18	925	623.23	100	57.0	49.61	5.76	0.48	Trace	Trace	0.08	0.09	1.5	3.77	Trace	170.35	65.6
10	7.09	545	644.03	90.3	39.3	35.53	1.53	0.32	0.06	Trace	0.06	0.02	0.5	1.69	5.8	210.36	74.6
11	7.37	767	539.10	96.8	41.0	20.23	1.52	0.18	Trace	0.01	0.06	0.08	2.5	1.57	11.4	347.30	36.9
12	7.23	636	823.03	35.9	20.8	23.0	2.12	0.14	Trace	0.03	0.01	0.04	3.0	7.51	13.2	210.52	63.5
13	7.25	658	757.35	100.2	27.0	31.23	2.13	0.34	Trace	Trace	0.10	0.07	5.6	1.87	5.8	143.40	38.9
14	7.24	776	593.08	29.8	23.2	17.38	2.11	0.12	Trace	Trace	0.04	0.02	2.7	1.69	6.8	258.36	41.5
15	7.32	667	471.09	42.6	21.5	16.49	0.36	0.14	0.03	Trace	0.01	0.08	1.8	3.77	9.2	132.51	52.3
16	7.32	703	377.09	44.4	22.0	21.61	1.82	0.20	0.01	Trace	0.02	0.57	4.4	7.51	5.4	183.77	51.8
17	7.25	847	613.97	27.8	27.3	18.33	1.52	0.15	Trace	Trace	0.02	0.08	1.4	0.98	7.6	265.11	48.2
18	7.33	553	552.63	49.6	23.9	26.0	1.49	0.24	Trace	Trace	0.02	0.06	4.5	4.36	6.4	234.65	76.6
19	7.16	581	451.33	49.0	35.8	21.0	1.21	0.17	Trace	Trace	0.04	0.03	3.9	1.69	5.8	216.68	39.7
20	7.63	700	755.28	43.4	34.1	34.92	2.41	0.22	Trace	Trace	0.03	0.05	2.0	3.77	11.2	236.09	42.7
Range	6.53 to 7.63	411.0 to 980.0	356.49 to 823.03	23.8 to 100.2	20.3 to 57.0	16.49 to 52.30	0.36 to 5.76	0.12 to 0.48	Trace To 0.06	Trace To 0.03	0.01 to 0.40	0.02 to 0.57	0.5 to 5.6	0.95 to 7.51	Trace To 25.3	132.51 to 347.30	36.9 to 76.2
S (x <sup>-</sup> )	7.203	684.4	555.62	52.90	32.59	31.70	2.16	0.264	178.6	178.6	0.085	0.083	2.48	3.16	8.05	221.07	54.92
SD	0.151	144.60	130.39	24.97	10.37	11.22	1.22	0.117	0.018	0.017	0.086	0.117	1.25	1.94	2.75	52.98	14.14
CV %	2.09	21.12	23.47	47.20	31.82	35.39	56.48	36.07	0.01	62.18	98.84	140.96	50.40	61.39	34.16	23.97	25.75

The ionic concentrations of calcium Ca, Mg, K and Na were found to vary from 23.8 – 100.2, 20.3 - 57.0, 0.36- 5.76 and 16.49 - 52.30 mg L<sup>-1</sup> with the respective average values 52.90, 32.59, 2.16 and 31.70 mg L<sup>-1</sup> (Table 2). The concentration of Ca content in ground water was largely dependent on solubility of CaCO<sub>3</sub> and CaSO<sub>4</sub>. Irrigation water containing less than 400 mg L<sup>-1</sup> Ca and below 60.75 mg L<sup>-1</sup> of Mg was 'suitable' for crop plants (Ayers and Westcot, 1985). On the basis of Ca and Mg content, all the water samples can safely be used for irrigation and would not affect the soils. Recommended maximum concentrations of Na and K for long- term irrigation use on all soils are 40 and 2 mg L<sup>-1</sup> respectively (Ayers and Westcot, 1985). The recorded Na and K content in all the ground waters under test were far below this specified limit. In respect of

Na content, all the waters of the study area can safely be applied for long –term irrigation without the harmful effects on soils and crops.

The status of Fe, Mn and Cu of all water was in between 0.12 to 0.48, trace to 0.06 and trace to 0.03 mg L<sup>-1</sup> respectively and all the values were far below the maximum recommended limits for irrigation and could be safety used without harmful effects on soil and crops (Todd, 1980).

The concentration of arsenic (As) in ground water samples was within the range of 0.02 to 0.57 mg L<sup>-1</sup> with the mean value of 0.08mg L<sup>-1</sup> (Table 2). Out of 20 samples, about 14 samples were below the mean value (0.08 mgL<sup>-1</sup>), 4 samples were equal to the mean value and rest of 2 samples were above the mean content of

As. The calculated standard deviation (SD) and co-efficient (CV %) were 0.11 and 140.9%, respectively. The status of As in 19 ground water samples were found within the recommended limit (As = 0.1 mg L<sup>-1</sup>) as per Ayers and Westcott (1985) but only 1 sample (no. 16) was problematic for long-term irrigation.

Detected amount of boron (B) varied from 0.01 to 0.4 mg L<sup>-1</sup> having mean value of 0.085 mg L<sup>-1</sup>. About 13 samples were below the mean value and the rest 7 samples value were found above the mean value. The obtained standard deviation (SD) and co-efficient of variation (CV) were 0.086 and 98.84%, respectively (Table 2). The recommended maximum concentration of B for irrigation water used continuously on soil less than 0.75 mg L<sup>-1</sup> (Ayers and Westcot, 1985). In the study area, all the ground water samples were 'suitable' for irrigation based on B content (Wilcox, 1955).

In all the ground waters, sulphate (SO<sub>4</sub>) content varied from 0.5 to 5.6 mg L<sup>-1</sup> with the mean value of 2.48 mg L<sup>-1</sup> (Table 2). Out of 20 samples, 12 samples were below the mean value (2.48 mg L<sup>-1</sup>) and the rest 8 samples were greater than that of mean. The standard deviation and co-efficient of variation were 1.25 and 50.40%, respectively. According to Ayers and Westcot (1985), the acceptable limit of SO<sub>4</sub> in irrigation water is less than 20 mg L<sup>-1</sup>. On the basis of this limit; all the waters under investigation were not problematic for irrigation without any toxic effect on soils and crops grown in the study area.

Groundwater samples collected from the study area contained carbonate (CO<sub>3</sub>) ranging from trace to 25.3 mg L<sup>-1</sup>. Among the collected amount of CO<sub>3</sub> was not detectable in 3 samples. The mean value was 8.05 mg L<sup>-1</sup>. About 9 samples were below the mean and rest 8 samples were above the mean (Table 2). The computed standard deviation was 2.75 and coefficient of variation was 34.16%, respectively. In respect of CO<sub>3</sub> content, 8 ground water samples were toxic for irrigation because CO<sub>3</sub> content exceeded the recommended limit (Ayers and Westcot, 1985).

The concentration of bicarbonate (HCO<sub>3</sub>) in water samples were within the range of 132.51 to 347.30 mg L<sup>-1</sup> and the mean value was 221.07 mg L<sup>-1</sup>. Out of 20 samples, 11 samples were below the

mean value and rest 9 samples were above the mean value. The standard deviation and co-efficient of variation were 52.98 and 23.97%, respectively. Bicarbonate content was recorded comparatively higher among the ionic constituents. In respect of HCO<sub>3</sub> content, all the groundwater samples were toxic for irrigation because HCO<sub>3</sub> content exceeded the recommended limit (Ayers and Westcott, 1985).

Chloride (Cl) content varied from 36.9 to 76.2 mg L<sup>-1</sup>. The mean value was 54.92 mg L<sup>-1</sup>. About 11 samples values were below the mean value and rest 9 samples were above the mean value (54.92 mg L<sup>-1</sup>). The standard deviation and co-efficient of variation were 14.14 and 25.75 %, respectively. Chloride content of all the ground waters collected from the study area was not problematic for irrigation because the concentration was below recommended limit (Appendix VII). Most of the chloride in groundwater was present sodium chloride (NaCl) but chloride content may exceed sodium due to the Base Exchange phenomena (Karanth, 1994).

The computed sodium adsorption ratio (SAR) of groundwater samples was within the range of 2.44 to 11.13 with average value of 4.91 (Table 3). About 10 samples were found below the average value and the rest 10 samples were more than the average value (4.91). The standard deviation (SD) and co-efficient variation were 1.89 and 38.49%, respectively.

On the basis of SAR, Todd (1980) categorized irrigation waters into 4 groups. Considering this classification, all groundwater samples were 'excellent' for irrigation. The present investigation expressed that a good proportion of Ca and Mg existed in waters which was 'suitable' for good structure and tilth condition of soil also would improve the soil permeability. The irrigation water with SAR less than 10 might not be harmful for agricultural crops (Todd, 1980). All the groundwater samples used for irrigation were also classified on the basis of alkalinity hazard as cited diagrammatically in Fig. 3 (Richards, 1968). According to this classification, almost all samples were rated as 'low' alkalinity hazard (SI) class for irrigation as per SAR value (Table 3).

Table 3. Classification of ground waters based on B, EC, TDS, SAR, SSP, RSC and H<sub>t</sub>

Sample No.	B (mg L <sup>-1</sup> )		EC (µS m <sup>-1</sup> )		TDS (mg L <sup>-1</sup> )		SAR		SSP(%)		RSC (me L <sup>-1</sup> )		Hardness (mg L <sup>-1</sup> )		Alkalinity & Salinity hazard class
	Value	Class	Value	Class	Value	Class	Value	Class	Value	Class	Value	Class	Value	Class	
1	0.08	Ex	980	Per	476.39	FW	5.93	Ex	28.38	Good	-2.86	Suit	390.18	VH	C3S1
2	0.40	Good	676	Good	387.36	FW	5.42	Ex	30.16	Good	-1.79	Suit	294.15	H	C2S1
3	0.08	Ex	730	Good	649.23	FW	5.23	Ex	30.65	Good	0.08	Suit	254.11	H	C2S1
4	0.12	Ex	476	Good	356.49	FW	5.93	Ex	32.09	Good	-1.42	Suit	239.82	H	C2S1
5	0.11	Ex	411	Good	477.78	FW	4.92	Ex	40.76	Good	-1.17	Suit	228.10	H	C2S1
6	0.15	Ex	843	Per	503.67	FW	5.26	Ex	29.26	Good	-1.87	Suit	265.85	H	C2S1
7	0.12	Ex	635	Good	457.52	FW	11.13	Good	55.74	Good	1.41	Mar	142.73	MH	C2S1
8	0.14	Ex	579	Good	602.69	FW	7.10	Ex	40.26	Per	-0.55	Suit	198.80	H	C2S1
9	0.08	Ex	925	Per	623.23	FW	5.6	Ex	26.07	Good	-6.95	Suit	483.70	VH	C3S1
10	0.06	Ex	545	Good	644.03	FW	4.42	Ex	18.19	Ex	-4.75	Suit	386.88	VH	C3S1
11	0.06	Ex	767	Per	539.10	FW	2.44	Ex	13.63	Ex	-2.19	Suit	410.10	VH	C3S1
12	0.01	Ex	636	Good	823.03	FW	4.32	Ex	30.70	Good	0.36	Suit	175.03	H	C2S1
13	0.10	Ex	658	Good	757.35	FW	3.92	Ex	20.02	Good	-4.72	Suit	361.20	VH	C3S1
14	0.04	Ex	776	Per	593.08	FW	3.37	Ex	26.90	Good	1.04	Suit	169.62	H	C2S1
15	0.01	Ex	667	Good	471.09	FW	2.91	Ex	20.82	Good	-1.44	Suit	194.65	H	C2S1
16	0.02	Ex	703	Good	377.09	FW	3.75	Ex	26.08	Good	-0.86	Suit	201.20	H	C2S1
17	0.02	Ex	847	Per	613.97	FW	3.5	Ex	51.99	Per	2.58	UnSuit	181.43	H	C2S1
18	0.02	Ex	553	Good	552.63	FW	4.29	Ex	27.44	Good	-0.41	Suit	221.99	H	C2S1
19	0.04	Ex	581	Good	451.33	FW	3.23	Ex	20.76	Good	-0.53	Suit	269.28	H	C2S1
20	0.03	Ex	700	Good	755.28	FW	5.61	Ex	32.50	Good	2.50	Mar	248.31	H	C2S1

Ex= Excellent; FW= Fresh Water; Per = Permissible; Suit = Suitable; UnSuit= Unsuitable Mar = Marginal; H = Hard; VH= Very Hard; C2= Medium Salinity; C3= High Salinity and S1= Low alkalinity.

The soluble sodium percentage (SSP) of all 20 water samples varied from 13.63 to 55.74. The obtained mean value was 30.12 (Table 3). About 11 samples values were below the mean. The standard deviation and co-efficient of variation were 10.53 and 34.96%, respectively. According to the water classification proposed by Wilcox (1955), 2 samples were classified as 'excellent' (SSP<20%),

16 samples were rated as 'good' (SSP = 20 to 40%) and the rest 2 samples were rated as 'permissible' (SSP = 40 to 60%). In the study area, the ground waters might safely be applied for irrigating agricultural crops.

The computed residual sodium carbonate (RSC) of ground water samples ranged from -6.95 to 2.58 me L<sup>-1</sup> with mean value of -1.17

me L<sup>-1</sup> (Table 3). Out of the 20 samples, about 13 samples were below the mean value, 6 samples were above the mean value and rest 1 sample was equal to mean value. The standard deviation and co-efficient of variation (CV) were 2.39 and -204.27%, respectively. 14 groundwater samples under test, contained negative value and rest of 6 groundwater samples contained positive value.

According to Eaton (1950) and Ghosh *et al.* (1983), all the groundwater samples were found to be 'suitable' class (RSC <1.25 me L<sup>-1</sup>), 'marginal' class (RSC 1.25-2.50 me L<sup>-1</sup>) and 'unsuitable' class (RSC >2.50 me L<sup>-1</sup>). For this reason, almost 1 ground water samples (sample No. 17) might be problematic for irrigation purposes but rest all the ground waters might not be problematic for irrigation purposes.

The total hardness (H<sub>T</sub>) of water samples was within the range of 142.73 to 483.70 mg L<sup>-1</sup> with a mean value of 265.86 mg L<sup>-1</sup> (Table 3). About 14 samples were found below the mean and 6 samples were above the mean. The computed standard deviation and co-efficient of variation were 93.55 and 35.19%, respectively. Sawyer and McCarty (1967) classified irrigation water into 4 classes based on hardness. According to this classification, 5 samples were 'very hard' 1 sample was 'moderately hard' and the rest 14 samples were 'hard'. Hardness resulted due to presence of appreciable amount of divalent cations like Ca and Mg (Todd, 1980).

Among the 20 water samples, 9 samples were 'suitable' and the rest 11 samples (Sl. No. 2,3, 5, 7, 9, 11,13,15,16, 17 and18) were found 'unsuitable' for drinking due to the exceeded the tolerance limit of As (0.05 mg L<sup>-1</sup>) and this ion was considered as pollutant in the study area (USEPA, 1975). Considering Mn ion, 19 samples were 'suitable' for drinking (0.05 mg L<sup>-1</sup>) but 1 sample was 'unsuitable' for drinking. Out of the 20 samples, 7 samples (Sl. No. 1, 5, 6, 7, 9, 10, and 13) were unfit for drinking based on Fe content, while the recommended limit of Fe for drinking water is 0.30 mg L<sup>-1</sup> (USEPA, 1975). So these ground water samples were problematic for drinking because Fe content of those waters exceeded the acceptable limit (Fe = 0.30 mg L<sup>-1</sup>). The rest ground water samples were fit for drinking based on Fe content. Among 20 samples, 8 were 'suitable' and the rest 12 samples were found 'unsuitable' for drinking due to the exceeded the recommended limit of TDS (500 mg L<sup>-1</sup>) as per (USEPA, 1975). As regards to B, SO<sub>4</sub> and Cl ions, all waters were suitable for drinking because the concentrations of these ions were less than the recommended limits (USEPA, 1975).

## References

APHA (American Public Health Association) (1995) Standard Methods for the Examination of Water and Wastewater. 19<sup>th</sup> edition published by American Water Works Association (AWWA) & Water Environmental Federation (WEF). pp.1-12.

AWWA (American Water Works Association) (1971) Water quality and treatment. McGraw-Hill, New York. p.654.

Ayers, R. S. and Westcot, D. W. (1985) Water quality for agriculture. FAO irrigation and drainage paper. 29 (Rev.1): 1-144.

Bohn, H. L., Mcneal, B. L. and O-Conner, G. A. (1985). Soil Chemistry. 2<sup>nd</sup> edn. John Wiley and Sons. New York. pp.239-245.

Chopra, S. L. and Kanwar, J. S. (1980). Analytical agricultural chemistry, Kalyani Publishers, Ludhiana, New Delhi. pp.148-289.

Eaton, F. M. (1950). Significance of carbonate in irrigation waters. *Soil Sci.* 67:12-133.

ESB (Environmental Studies Board) (1972) National Academy of Sciences. National Academy of Engineering, USA.

Freeze, A. R. and Cherry, J. A. (1979) Groundwater, Prentice Hall Inc., Englewood Cliffs. New Jersey 07632. pp. 84-387.

Ghosh, A. B., Bajaj, J. C., Hasan, R. and Singh, D. (1983) Soil and testing methods. A laboratory manual, Division of Soil Science and Agricultural Chemistry, IARI, New Delhi-1100012. pp. 1-48.

Hossain, N., Khan, A., Tancer, M. K., Ahmed, M. and Sattar, A. (2000) Suitability of Punjab (Pakistan) underground waters. *J. of Agric. Res.* 28(4): 519-529.

Hunt D. T. E. and Wilson, A. L. (1986) The chemical analysis of water: General principles and techniques. 2<sup>nd</sup> edn. Published by the Royal Society of Chemistry. Thomas Graham Home. The science park, Cambridge CB44 WF. pp. 1-2.

Michael, A. M. (1978) Irrigation: theory and practice. Vikas Pub. House Pvt. Ltd. pp. 448-452.

Raghunath, H.M. (1987). Groundwater. 2<sup>nd</sup> edn. Wiley Eastern Ltd., New Delhi. pp. 344-369.

Richards, L.A., (1968) Diagnosis and improvement of saline and alkali soils. Agricultural Hand Book60, USDA and IBH Publishing Co. Ltd. New Delhi, India, pp: 98-99.

Sawyer, C. N. and McCarty, P. L. (1967) Chemistry of sanitary engineers. 2<sup>nd</sup> edn. McGraw-Hill, New York. p. 518.

Singh, D., Chhonker, P. K. and Pandey, R. N. (1999) Soil, Plant, Water Analysis: A Methods Manual, Indian Agricultural Research Institute (IARI), New Delhi, India. pp.76-78.

Tandon, H. L. S. (1995) Methods of Analysis of Soils, Plants, Waters and Fertilizers. Fertilizer Development and Consultation Organization, New Delhi. pp. 84-90.

Todd, D. K. (1980) Groundwater Hydrology. 2<sup>nd</sup> edn. John Wiley and Sons. Inc., New York 10016. pp. 267-315.

USEPA (United States Environmental Protection Agency) (1975) Federal Register. 40(248): 59566-59588.

Welsch, F. P., Crock, J. G. and Sanzalone, R. (1990) Trace level determination of arsenic and selenium using continuous-flow hydride generation atomoc absorption spectrophotometry (HG-ASS). pp. 38-45. In B.F. Arbogast (ed) Quality Assurance Survey, United States Geological Survey Denver, Company.

Wilcox, L. V. (1995) Classification and use of irrigation water. United States Department of Agriculture Circular No.969. Washington D.C. p.19.

Wolf, B. (1982) A comprehensive system of leaf analysis and its use for diagnostic crop nutrient status. Communication in soil science and plant analysis. 13(12): 1044-1045.