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Water quality analysis and suitability assessment for irrigated agriculture in Dinajpur sadar, Dinajpur district of Bangladesh

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ABSTRACT

Water quality bears an utmost importance in irrigated agriculture, domestic uses, industrial and some other purposes for productivity, quality, public health and environmental issues. A laboratory experiment was performed to determine the chemical constituents of groundwater for crop production in Dinajpur sadar upazila under Dinajpur district of Bangladesh. Thirty groundwater samples were collected from different areas of sadar upazila for the evaluation of chemical constituents. Groundwater samples collected from selected areas were classified by examining chemical constituents present therein. Several parameters like pH, EC, TDS, Ca, Mg, Na, K, SO_4, PO_4, HCO_3, Fe, Cu, Zn, Mn, and calculated parameters like SAR, SSP and H_T, respectively, were considered for the suitability assessment. The pH value of all the water samples fluctuated from 6.16 to 7.51 indicating slightly acidic to slightly alkaline and found suitable for irrigation. EC and TDS values of water samples were found suitable. In the study areas, the water contained an appreciable amount of Ca, Mg, Na and K. The concentrations of SO_4 and PO_4, Fe, Cu, Zn and Mn, were found within safe limit for irrigating crops. On the basis of EC and SAR, all the waters were found excellent for irrigated agriculture. SSP values of all samples were rated as excellent, five samples were good, 15 samples were permissible and 10 samples were doubtful classes for crop prediction. On the basis of H_T, three samples were moderately hard, 16 samples were hard and the rest 11 samples were very hard categories. Finally, water samples were suitable for crop production. It is advised that water should be analyzed systematically for understanding the impact of dissolved ions in water on the quality crops for prolonged uses.

Keywords: Irrigated agriculture, ionic concentration, water quality

INTRODUCTION

Water is the most important in shaping the land and regulating the climate and most important compounds that profoundly influence life (Gorde and Jadhav2013). Water is one of the main important abiotic components of the environment also. Approximately, 97% of the total water is found in oceans, which is not appropriate for drinking and irrigation, and only 3% is considered as fresh water, out of which 2.97% is found as glaciers and ice caps (Mishra and Dubey 2015). Only the remaining little portion, 0.03%, is obtainable as surface and ground water for human use (Mohsin et al. 2013). There are several factors such as ions, salts, heavy metals, toxic elements, fertilizers, pesticides, insecticides, and industrial wastages etc. that affect to deteriorate water quality. Using this poor quality water, it might decline soil properties, crops yield and quality (Sarker et al. 2000). 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 (Islam

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et al. 1999).

Irrigation water quality is important for successful crop production. The poor quality of the irrigation water may affect crop yields and soil physical conditions (Talukder et al. 1998). For example, the average yield of wheat decreased by 24% (Datta and Dayal 2000), rice decreased by 39% (Bai 1988), vegetables decreased by 30% (Chang et al. 2001), and corn decreased by 21% (Lindhjem 2008) over normal yield when poor quality water was used. The major irrigation water is judged by four important measures of salinity hazard, sodium hazard, toxicity hazard and residual sodium carbonate hazard (Michael 1978). The generally accepted view is that in most parts of Bangladesh, the present levels of surface water abstraction for irrigation during dry season are very close to the accepted maximum limits. Irrigated agriculture in Bangladesh has already started showing problems regarding water quality and fertilization. The concentration and proportion of these dissolved ions among other things determine the suitability of water for irrigation (Ajayi et al. 1990). Therefore, groundwater quality should have free from toxic elements as well as within safe limit for quality crop production. Keeping this view in mind, the present research was undertaken to appraise water quality analysis and suitability assessment for irrigated agriculture.

MATERIALS AND METHODS

For the study, 30 groundwater samples were collected from different locations at Dinajpur sadar upazila of Dinajpur district in August, 2017. Groundwater sampling sites were selected from different places under Dinajpur sadar upazila in Dinajpur district, Bangladesh. All the water samples were collected from different deep tube wells used for the study purposes from the selected sites (Figure 1 and Table 1). The studied waters have widely been used for producing major agricultural crops such as cereals, pulses, fibers, spices and vegetable crops. Water samples were collected in cleaned liter plastic bottles and carried to the laboratory of the Department of Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology, Dinajpur for analyses. The major chemical constituents or compounds both ionic and nonionic forms which all essentially can take part in water pollution. The pH and EC of sampled waters were determined by using pH meter (Model: Hanna instrument-211) and Conductivity bridge (Hanna instrument-H18033), respectively. The values of total dissolved solid (TDS) of water were estimated by evaporating a measured aliquot of filtered samples.

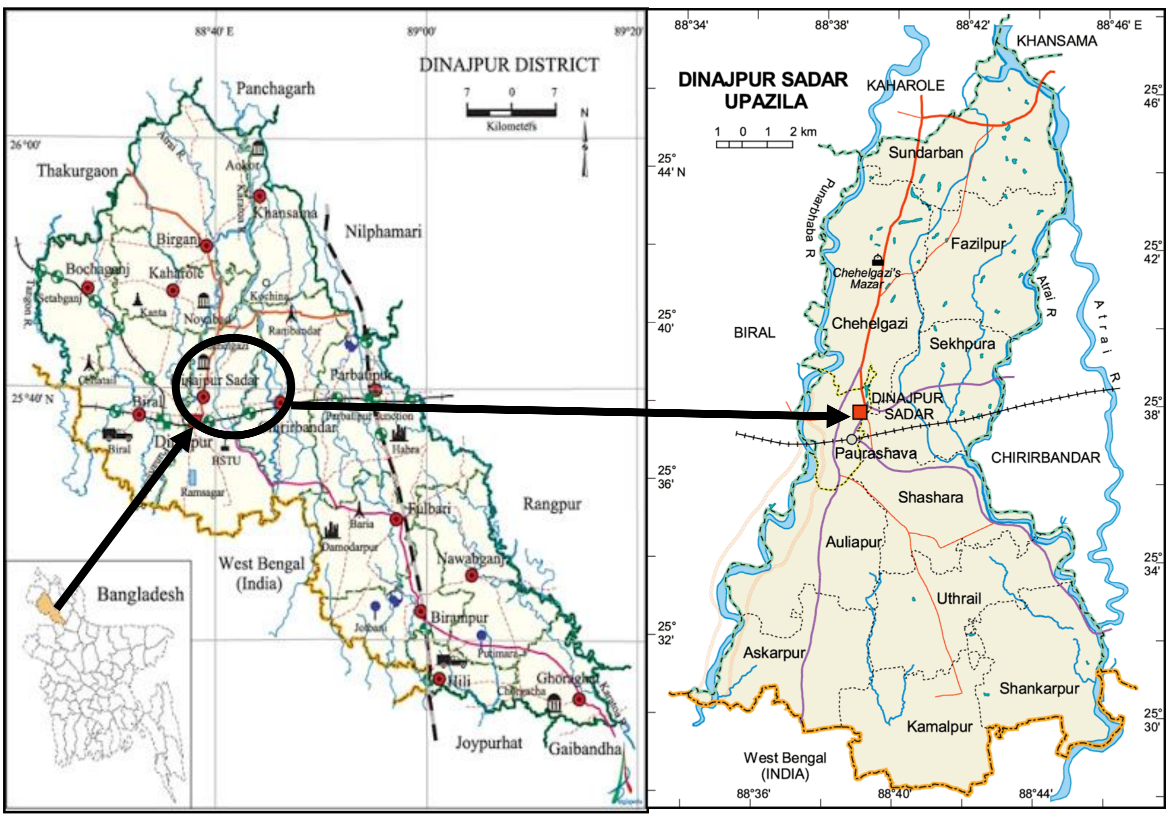

Figure 1: Map of study area at Dinajpur district in Bangladesh with sampling sites

Table 1. Information regarding water sampling from deep tube well

Sl/No.	Source	Location (DinajpurSadar)		Depth (m)	Date of collection
		Union/Paurashava	Village		
1	Deep Tube well	Sundarban	Khasalpur	80	25/08/2017
2	Deep Tube well	Sundarban	Sundarban	70	25/08/2017
3	Deep Tube well	Sundarban	Kalikapur	95	25/08/2017
4	Deep Tube well	Chehelgazi	Chehelgazi	70	25/08/2017
5	Deep Tube well	Chehelgazi	Nayonpur	70	25/08/2017
6	Deep Tube well	Fazilpur	Purustoma	70	25/08/2017
7	Deep Tube well	Fazilpur	Xanzira	80	25/08/2017
8	Deep Tube well	Fazilpur	North Horirampur	70	25/08/2017
9	Deep Tube well	Sekhpura	Sekhpura	65	25/08/2017
10	Deep Tube well	Sekhpura	Laxmipur	80	25/08/2017
11	Deep Tube well	Paurashava	Balubari	90	25/08/2017
12	Deep Tube well	Paurashava	Suihari	80	25/08/2017
13	Deep Tube well	Sankarpur	Damudorpur	70	27/08/2017
14	Deep Tube well	Sankarpur	South Durgapur	70	27/08/2017
15	Deep Tube well	Sankarpur	Narayanpur	80	27/08/2017
16	Deep Tube well	Askarpur	Saraswatipur	95	27/08/2017
17	Deep Tube well	Askarpur	Jalalpur	90	27/08/2017
18	Deep Tube well	Askarpur	Sreechandrapur	60	27/08/2017
19	Deep Tube well	Kamalpur	Kamalpur	90	27/08/2017
20	Deep Tube well	Kamalpur	Danihari	85	27/08/2017
21	Deep Tube well	Kamalpur	South Bhowanipur	80	27/08/2017
22	Deep Tube well	Shashara	Mohammadpur	70	28/08/2017
23	Deep Tube well	Shashara	Shashara	90	28/08/2017
24	Deep Tube well	Shashara	Jopeya	90	28/08/2017
25	Deep Tube well	Auliapur	Mohobbotpur	70	28/08/2017
26	Deep Tube well	Auliapur	Auliapur	90	28/08/2017
27	Deep Tube well	Auliapur	Mohonpur	70	28/08/2017
28	Deep Tube well	Uthrail	South Sadipur	67	28/08/2017
29	Deep Tube well	Uthrail	South Gosaipur	70	28/08/2017
30	Deep Tube well	Uthrail	Danihari	60	28/08/2017

Sodium (Na) and potassium (K) were estimated by flame-photometer. Calcium (Ca) and Magnesium (Mg) were determined by complexometric titration using Na_2EDTA as the titrant. The other cations like Fe, Mn, Cu, Zn were analysed using atomic absorption spectrophotometer (AAS) and anions like SO_4 and PO_4were determined by colorimetrically and HCO_3 were determined titrimetrically. 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 formulae:

$$SAR=[Na^+]/[\{(Ca^{2+})+[Mg^{2+}]\}/]^{1/2}$$

$$SSP=\text{Soluble Na concentration (me}L^{-1})\times 100/\text{Total cation concentration (me } L^{-1})$$

$$H_T\,(mg\ L^{-1})=2.5\times Ca^{2+}+4.1\times Mg^{2+}$$

Correlation coefficient analysis was done for all possible combinations within the quality parameter.

RESULTS AND DISCUSSION

Groundwater rating for irrigation

pH: The pH value of water sample within the range of 6.16 to 7.51 with the average value was 7.01 (Table 2). Out of 30 samples, the pH of 10 samples (33.3 %) was found from 6.16 to 6.99 and the rest 20 samples (66.7%) water varied 7.00 to 7.51. The pH of water varied from 6.16 to 7.51 indicated that the water were slightly acidic to alkaline. Out of 30 samples, 10 samples were below pH 7 and were slightly acidic in nature and might be due to the presence of lower concentration of Ca, Mg, Na and HCO_3. These 10 water samples would be suitable for acid loving crops. The remaining 17 samples under the study showed higher pH values above 7 and were slightly alkaline in nature and this might be due to the presence of higher amount of Ca, Mg, Na and HCO_3. Ayers and Westcot (1985) mentioned that normal pH range of irrigation usually varied from 6.0 to 8.5. It indicated that pH of all water samples under test were within the normal range and this water might not be harmful for soils and crops. Similar observations were also reported by Quayum (1995) and Razzaque (1995).

Electrical Conductivity (EC): The electrical conductivity (EC) of all water samples was within the limit of 275 to 624 µS cm-^{1} with the mean value of 460 µS cm^{-1} (Table 2). The EC of 15 samples (50 %) were less than the mean value and the remaining 15 samples (50 %) were higher than the average value. The highest amount (624 µS cm^{-1}) was obtained from the sample no. 1 and the lowest amount (275 µS cm^{-1}) was obtained from the sample no. 13. According to the Richards (1968) as illustrated that all the groundwater under test were rated as 'medium salinity' (C2). Therefore, groundwater of such quality can be used for irrigation purpose without harmful effects on soils and crops but moderate leaching will be required.

Table 2. Temperature, pH, EC and TDS of groundwater samples

Sl. No.	Temp.	pH	EC (µS cm^{-1})	TDS (mg L^{-1})
1	28.60	7.00	624	370
2	28.80	6.47	583	349
3	29.00	7.00	618	371
4	29.20	7.02	464	275
5	29.30	6.66	348	207
6	29.30	7.00	545	328
7	29.20	7.37	379	227
8	29.10	7.08	521	311
9	29.10	7.05	562	337
10	29.00	7.22	515	307
11	28.90	7.46	435	362
12	28.90	7.32	296	169
13	28.90	6.96	275	164
14	28.80	7.11	356	214
15	28.90	7.31	431	260
16	28.90	6.92	418	251
17	28.90	7.51	482	291
18	28.90	7.03	375	227
19	28.80	7.12	475	285
20	28.80	6.99	560	338
21	28.60	6.63	306	186
22	28.70	6.93	408	245
23	28.70	6.99	460	274
24	28.80	7.04	445	268
25	28.90	7.01	443	290
26	28.90	7.01	443	264
27	28.90	7.05	552	330
28	29.00	6.51	614	369
29	29.00	6.16	350	212
30	28.90	7.30	529	317
Mean	28.92	7.01	460.40	280
Minimum	28.60	6.16	275.00	164
Maximum	29.30	7.51	624.00	371

Total dissolved solids (TDS): The amount of total dissolved solids (TDS) of groundwater samples in the investigated area varied from 164 to 371 mg L^{-1} with mean value of 280 mg L^{-1} (Table 2). Out of the 30 samples, 50 % TDS values (15 samples) were found bellow the mean value and the remaining 50% samples were found above the average value. The highest TDS values (371 mg L^{-1}) was detected in a deep tube well sample no. 3 and the lowest TDS value was detected in sample no. 13. Sufficient qualities of bicarbonate, sulphates and chloride are of Ca, Mg and Na caused high TDS values (Karanth 1994). According to Freeze and Cherry (1979) all the groundwater's under investigation contained less than 1,000 mg L^{-1} TDS and were classified 'fresh water' in quality. These waters would not affect the osmotic pressure of soil solution and cell sap of the plants when applied to soil as irrigation water.

Ionic constituents: In present study, major ions like Ca, Mg, K, Na, CO_3, and HCO_3 were dominant quantities but the remaining detected ions Fe, Mn, Zn and Cu were also recorded in minor amounts. The estimated amounts of these ions present in all the samples in relation to irrigation water quality have been described and discussed as follows:

Table 3. Cationic constituents of the collected groundwater samples

Sl. No.	Ca	Mg	Na	K (mg L^{-1})	Fe	Mn	Zn	Cu
1	16.03	17.012	5.0	10.0	0.38	0.021	0.07	0.079
2	12.02	21.87	5.0	5.0	0.45	0.022	0.04	0.085
3	10.42	15.06	7.5	5.0	0.55	0.035	0.07	0.092
4	12.02	13.61	10.0	7.5	0.39	0.011	0.07	0.086
5	16.03	16.52	5.0	10.0	0.38	0.021	0.07	0.055
6	16.03	16.52	7.5	15.0	0.49	0.018	0.04	0.065
7	14.43	11.66	10.0	12.5	0.19	0.054	0.05	0.088
8	14.43	13.12	10.0	10.0	0.25	0.061	0.04	0.097
9	12.02	15.06	10.0	5.0	0.33	0.029	0.06	0.076
10	14.43	15.55	5.0	2.5	0.35	0.036	0.06	0.09
11	16.03	24.79	5.0	5.0	0.43	0.037	0.04	0.092
12	16.03	24.79	5.0	10.0	0.38	0.018	0.04	0.099
13	12.02	19.93	7.5	10.0	0.22	0.021	0.07	0.077
14	10.42	20.9	10.0	5.0	0.25	0.022	0.07	0.072
15	10.42	16.52	12.5	5.0	0.27	0.029	0.06	0.073
16	10.42	17.01	10.0	5.0	0.18	0.033	0.07	0.077
17	11.22	17.01	10.0	5.0	0.43	0.044	0.06	0.076
18	14.43	20.9	10.0	10.0	0.55	0.032	0.05	0.066
19	16.03	24.79	10.0	10.0	0.49	0.053	0.07	0.071
20	14.43	24.3	10.0	10.0	0.37	0.021	0.07	0.072
21	14.43	18.95	12.5	10.0	0.28	0.022	0.08	0.081
22	12.02	18.47	7.5	5.0	0.40	0.026	0.04	0.081
23	18.44	18.47	10.0	7.5	0.47	0.022	0.05	0.089
24	12.02	24.79	10.0	7.5	0.31	0.02	0.04	0.088
25	16.03	24.79	10.0	10.0	0.36	0.02	0.06	0.08
26	16.03	22.36	10.0	5.0	0.44	0.018	0.07	0.073
27	12.02	21.87	7.5	5.0	0.45	0.017	0.07	0.059
28	12.83	18.47	10.0	5.0	0.61	0.019	0.07	0.056
29	14.43	17.98	10.0	7.5	0.52	0.023	0.04	0.088
30	15.23	18.95	10.0	7.5	0.41	0.024	0.05	0.087
Mean	13.76	19.07	8.75	7.58	0.39	0.03	0.06	0.08
Minimum	10.42	11.66	5.00	2.50	0.18	0.01	0.04	0.06
Maximum	18.44	24.79	12.50	15.00	0.61	0.06	0.08	0.10

Calcium (Ca): The concentration of Ca was found within the range of 10.42 to 18.44 mg L^{-1} with the mean value of 13.76 mg L^{-1} (Table 3). Out of 30 samples, 13 samples (43.33%) were found below the mean value and the rest 17 samples (56.67%) were above the mean value. The highest concentration (18.44 mg L^{-1}) was found at Shahapara village of Shashara union (sample no. 23). The lowest value (10.42 mg L^{-1}) was observed the sample no. 15 and 16. The concentration of Ca content in groundwater was largely dependent on the solubility of $CaCO_3$, $CaSO_4$ and rarely on $CaCl_2$ (Karanth 1994). Irrigation water containing less than the 20 meq L^{-1}Ca was suitable for irrigating crops plants (Ayers and Westcot1985). On the basis of Ca content, the entire water samples can safely be used for irrigation and would not affect the soils.

Magnesium (Mg): In groundwater samples collected from Dinajpur sadar upazila under Dinajpur District, Mg content was found within the range of 11.16 to 24.79 mg L^{-1} with the mean value of 19.07 mg L^{-1} (Table 3). Out of 30 samples, about 53.33% (16 samples) were found below the average value and the rest 46.67% (14 Samples) recorded above the mean value. The highest value 24.79 mg L^{-1} of magnesium was found in sample no. 11 and the lowest value (11.16 mg L^{-1}) were found in sample no 7. According to the Ayers and Westcot (1985), all the irrigation water was within the safety limit. All the groundwater samples were 'suitable' for irrigation with respect of Mg content in this study area.

Sodium (Na): Table 3 showed the Na content of collected groundwater samples in Dinajpur sadar upazila. The concentration of Na in different water samples were within the range of 5.00 to 12.50 mg L^{-1} and the mean value was 8.75 mg L^{-1}. About 37% values (11 samples) were below the mean and the remaining 63% values (19 samples) were above the mean. The highest value of sodium found in sample no 15 and 21 but the lowest was found the sample numbers 2, 3, 10, 11 and 12, respectively. The recorded Na content in all the groundwater samples under the test was far below this specified limit (Ayers and Westcot, 1985). Hence, as per 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.

Potassium (K): The concentration of K in the collected water samples was within the range from 2.50 to 15.00 mg L^{-1} with 7.58 mg L^{-1} as mean value (Table 3). It was found that 60% values (18 samples) were below the mean and 40% (12 samples) were above the mean value. The presence of higher quantity of K in some groundwater samples might be due to the presence of some potash bearing minerals like sylvite (KCl) and nitre (KNO_3) in the aquifers (Karanth 1994). The detected quantity of K in all the collected ground water samples had no significant influence on water quality for irrigation. The presence of higher K content in the groundwater might have beneficial effect as it acts as an essential nutrient element for plant growth and development.

Iron (Fe): Table 3 showed A marked variation of Fe content water samples was observed in Dinajpur sadar upazila. All water samples contained small amount of Fe and varied from 0.18 to 0.61 mg L^{-1}. The obtained mean value was 0.39 mg L^{-1}. About 53 % values (16 samples) were below the mean and 47 % (14 samples) were above the mean. The recorded iron concentration of all groundwater samples was far below the acceptable limit (Fe = 5 mg L^{-1}).

Zinc (Zn): All water samples contained very small amount of Zn and varied from 0.04 to 0.08 mg L^{-1} (Table 3). The obtained average value was 0.06 mg L^{-1} and 53% values (16 samples) were below the mean and in where 47% (14 samples) were above the mean. According to Ayers and Westcot (1985) the acceptable limit of zinc in irrigation water is less than 2.0 mg L^{-1}. On the basis of this limit water under investigation was not toxic or problematic for continuous irrigation. The more Zn concentration in groundwater is suitable for crop growth as it helps in many enzymatic reactions

Copper (Cu): Table 3 showed Cu content of collected ground water samples in Dinajpur sadar areas. All water samples contained very small amount of Cu and varied from 0.06 to 0.10 mg L^{-1}. The obtained mean value was 0.08 mg L^{-1}. About 50% values (15 samples) were below the mean and 50% (17 samples) were above the mean. According to Ayers and Westcot (1985), the acceptable limit of copper in irrigation water is less than 0.20 mg L^{-1}. On the basis of this limit all the water under investigation was not problematic for continuous irrigation.

Manganese (Mn): Manganese was present in little amount 0.01 to 0.06 mg L^{-1} and the obtained mean value was 0.03 mg L^{-1} (Table 3). Out of 30 samples, 9 water samples (30%) were above the mean but 21 samples (70%) was found below the mean. According to Ayers and Westcott (1985), the maximum recommended content of Mn for water used for irrigation is 0.20 mg L^{-1}. On the basis of Mn content, all the waters but one under test was not toxic for long-term irrigation.

Sulphate (SO_4): Table 4 showed the SO_4-S content of collected groundwater samples in Dinajpur sadar upazila. In all the ground waters, sulphate content varied from 0.44 to 3.19 mg L^{-1} with the mean value of 1.26 mg L^{-1} (Table 4). Out of 30 samples, 50% (15 samples) were within the range of 0.44 to 0.972 mg L^{-1} and the rest 50% (15 samples) were greater than that of the average value for the range of 1.305 mg L^{-1} and 3.194 mg L^{-1}. According to Ayers and Westcot (1985), the acceptable limit of SO_4 for irrigation water is less than 20 mg L^{-1}. 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 area of this study.

Phosphorus (P): Table 4 showed the P content of collected groundwater samples in Dinajpur sadar upazila. The phosphorus content of all collected groundwaters varied from 2.88 to 6.10 mg L^{-1} with the mean value of 4.17 mg L^{-1} (Table 4). Out of the 30 samples, about 53.33% samples (16 samples) were less than the mean value and the rest 46.67% samples (16 samples) were higher than the mean value. The status of PO_4 of all tested groundwater samples were found within the recommended limit as per Ayers and Westcot (1985).

Bicarbonate (HCO_3): The concentration of HCO_3 in water samples was within the range of 2.00 to 2.80 mg L^{-1} and the mean value was 2.37 mg L^{-1} (Table 4). Out of 30 samples, 50% samples (15 samples) were below the mean value and rest 50% (15 samples) were above the mean value. Bicarbonate content was recorded comparatively higher among the ionic constituents. In respect of HCO_3 content, fifty percent of the groundwater samples were not toxic for irrigation because HCO_3 content were within the recommended limit.

Table 4: Anionic constituents of the collected groundwater samples

S/l	SO_4-S mg L^{-1}	PO_4-P mg L^{-1}	HCO_3 mg L^{-1}
1	1.67	4.23	2.20
2	1.58	4.43	2.80
3	0.78	4.34	2.40
4	0.44	3.98	2.60
5	0.55	3.63	2.20
6	1.89	3.98	2.20
7	1.94	5.14	2.20
8	0.64	4.37	2.60
9	0.70	4.09	2.60
10	0.78	3.23	2.20
11	1.42	4.2	2.00
12	0.61	3.35	2.40
13	3.19	4.02	2.60
14	2.83	4.09	2.60
15	1.44	4.39	2.80
16	0.72	5.55	2.60
17	0.53	5.20	2.20
18	2.58	6.10	2.20
19	0.50	2.88	2.20
20	0.94	3.46	2.20
21	1.50	3.74	2.00
22	1.44	3.62	2.00
23	1.89	3.39	2.60
24	1.58	2.90	2.20
25	0.67	3.98	2.40
26	0.58	3.70	2.40
27	0.64	4.30	2.60
28	0.97	4.44	2.60
29	1.47	5.00	2.20
30	1.30	5.37	2.20
Mean	1.26	4.17	2.37
Minimum	0.44	2.88	2.00
Maximum	3.19	6.10	2.80

Correlation coefficient analysis: Correlation coefficient analysis was performed amongst the parameters viz. pH, EC, SAR and SSP in all possible combinations (Table 5). 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 indicated that EC had influence on TDS, SAR and SSP. TDS value had significantly correlated with SAR and SSP at 1% level of significant. SAR value showed a close relationship with SSP at 1% level of significant. Table 5 indicated that the correlation matrix of analyzed cations and anions of water samples. A significant positive relation was observed between Ca and Mg but negative relation was between Na and Fe.

Proposed suitability classification: In irrigated agriculture, EC, SAR, and SSP are considered to be the major criteria for assessing suitability classification. All water samples were classified ‘permissible’ to ‘good’ based on EC. So, these sources of water might not cause any harm for agriculture purpose. With respect to SAR, all samples were graded as ‘excellent’ and permissible in class (Table 6). All the tested water samples were classified as C3S1 regarding alkalinity and salinity hazard indicating suitable. Therefore, it is evident that 28 samples were graded as permissible and remaining two were moderately suitable for irrigated agriculture.

Table 5: Correlation matrix for the major ions in the collected ground water samples

Parameter	Mg	Na	K	Fe	Mn	Zn	Cu	SO_4	PO_4	HCO_3
Ca	.895**	-.074	.039	.114	-0.222	.297	.168	-.195	.068	.087
Mg		-.086	.038	.151	-0.226	.322	.158	-.271	.015	.228
Na			.073	-.501**	-0.260	-.233	-.238	-.145	-.098	-.106
K				-.060	0.322	.062	.000	-.307	-.251	-.007
Fe					0.127	.319	.392*	-.128	-.139	.158
Mn						.329	.204	-.137	-.126	-.174
Zn							.233	-.315	.030	-.160
Cu								-.162	-.027	-.032
SO_4									.204	-.005
PO_4										.095

* and ** indicated significant at 5% and 1% level of profitability at 28 df

Table 6: Quality classification and suitability of groundwater and surface water for irrigation purpose.

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

Key: C2 and C3 represent medium and high salinity hazard and S1 represent low sodium hazard.

CONCLUSION

The concentrations of total cations and total anions under study were within the safe limit for soils and crops. According to Fe content, all the groundwater samples contained Fe which was within safe limit (5.0 mg L^{-1}). The concentrations of SO_4 and PO_4 of thirty samples were found suitable for irrigation. The cationic concentrations of water samples analyzed were in the descending order of magnitude as: Mg>Ca>K>Na>Fe>Cu>Zn>Mn. Likewise cationic concentrations, the anion of water samples analyzed were in the descending order of magnitude as: PO_4>SO_4>HCO_3. It may be suggested that groundwater samples were suitable and permissible for irrigating major crops but should be treated for intense monitoring quality for prolonged uses. In addition to the chemical quality of water, biological and radiological qualities should also be assessed for the efficient water management in irrigated agriculture.

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