Major Ion Chemistry of the Groundwater under Jhenaidah District of Bangladesh for Irrigation, Drinking and Industrial Uses

Md. Enamul Haque[1], Jahidul Islam[1], Shah Md. Shakil Ahmed[2], K. M. Manirul Islam[2*] and Noor Muhammad[3]

[1]*Department of Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh.*
[2]*Faculty of Agriculture, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh.*
[3]*Department of Agricultural Extension, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh.*

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ABSTRACT

Aims: The study was carried out to determine the baseline cation and anion concentrations of the groundwater of Kaliganj Upazila of Jhenaidah district of Bangladesh and to evaluate the suitability of these water sources for irrigation, drinking and industrial uses.
Study Design: The research was carried out in laboratory and field.

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*Corresponding author: E-mail: mani12hstu@gmail.com

Place and Duration of Study: Samples of water were collected from Kaliganj Upazila of Jhenaidah district during July-September 2013.

Methodology: A total of 45 groundwater (6 deep tube-wells, 19 shallow tube-wells, 20 hand tube-wells) samples were collected from existing wells in the study areas. The collected water samples were carried to the laboratory of the Department of Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh for testing. The samples were analyzed as quickly as possible on arrival at the laboratory. All reagents were analytical grade. For SO_4^{2-} and PO_4^-, samples were refrigerated and analyzed within 24 hrs.

Results: The pH values indicated that the waters were mostly acidic in nature. Among the chemical budget of ions, magnesium and chloride were found to be the most predominant ions. The average amount of Ca, Na, K and HCO_3. were safe for crop production. The mean values of TDS and SAR indicated the excellent category for irrigation. Based on SSP all waters were excellent classes. In respect to hardness, water was moderately hard to very hard classes. Based on the total hardness, most ground waters were moderately hard. All waters were free from RSC and belong to the suitable category. Most of the major ionic constituents were detected below the acceptable level for drinking. All water samples are more or less suitable for industrial uses. Other micronutrients like Fe, Zn, Mn, Cu and Cl were within the safe limit for irrigating agricultural crops. Iron and Mn exceeded the drinking standard in some waters.

Conclusion: All water samples are more or less suitable for industries like brewery, ice manufacture purpose, dairy farm and carbonate beverage. But almost all waters were unsuitable for textile and laundering. All waters were suitable for drinking and irrigation uses; although some samples were rated to be unsuitable for some specific ions.

1. INTRODUCTION

Water is the most essential natural resource on the earth. The water resources, about 97.2% are saline water mainly in oceans and only 2.8% is available as freshwater. Out of 2.8%, about 2.2% is available as surface water and 0.6% as groundwater [1]. At present one fifth of all the water used in the world is obtained from groundwater sources. Around 80% of it is used in agricultural field. Water quality for irrigation is a prime factor for successful crop production as it contains different ionic constituents at various concentrations. Groundwater is fresh and very important for agricultural, industrial and drinking purposes in Bangladesh. Water of adequate quantity and quality is required to meet growing household, industrial and agricultural need [2]. Increasing populations, food insecurity, growing economies and poor water management are putting unprecedented pressure on the world's freshwater resources. Groundwater irrigation demand has been growing steadily over the past decades, for many reasons including the unreliability of the traditional large canal schemes, and the increasing need of farmers for intensive cultivation. In addition, unpredictability in climate has forced some farmers, particularly in southern Bangladesh, to exploit groundwater, in order to combat drought.

Groundwater is becoming essential input for increasing crop production for the sustainable agricultural development. The quality of water can be directly affected by the infiltration of pollutants in the recharge area due to anthropogenic activities [3]. In addition to natural sources, groundwater quality could be affected by urbanization, agricultural waste, land cover, indiscriminate application of fertilizers, pesticides, utilization of waste water for irrigation, leakage from waste water lagoons, landfill disposal sites, septic tanks and industrial discharge [4]. The groundwater in different countries was contaminated probably due to lack of proper waste management [5]. However, specific water may be suitable for irrigation but may not be suitable for drinking and industrial uses due to the presence of some other ions at toxic level.

Bangladesh is located in sub-tropical area with an average annual precipitation of 203 cm. Spatial and temporal distribution of the regional precipitation is not integrated and also these resources are at greater risk to contamination. Yet few studies related to groundwater quality and irrigation practices are available for this region. HCO_3^-, Na^+, Ca^{2+}, Mg^{2+} and Cl^- were the dominant ions in groundwater collected from different regions of Bangladesh [6]. Intensive agricultural practices demand on groundwater resources in southern region of Bangladesh. In

addition, nitrate, chloride, phosphorus and pesticide residues may cause significant temporal and spatial variability in groundwater beneath agricultural land. Groundwater quality is important factor to assess its suitability for drinking, domestic, agricultural and industrial purposes. The management of groundwater requires an understanding of hydro-chemical properties of the aquifer.

i.   To determine the baseline cation and anion concentrations of the groundwater of Kaliganj Upazila of Jhenaidah district of Bangladesh.
ii. To evaluate the suitability of these water sources for irrigation, drinking and industrial uses.

2. MATERIALS AND METHODS

2.1 Site of Research

Kaliganj Upazila under Jhenaidah District of Bangladesh was selected as the locale of the research. The average rainfall of this district during monsoon period ranges from 1110 mm to 5690 mm. Another feature characterizing the precipitation in the study site is its irregular yearly distribution. The area has a sub-tropical climate, with mean maximum summer temperature (July) about 42°C and minimum winter temperature (January) of 7°C. The area has complicated land use characteristics, mainly consisting of agricultural and residential areas. The lithology of most southern region of Bangladesh, especially this study area, consists predominantly of medium to coarse grained, poorly sorted sands and gravels with thin surface clays. We collected the water samples from the deep aquifer due to that it is the main water bearing zone and occurs at depths ranging from greater than 5 m in the southern region of Bangladesh. This aquifers either semi-confined or leaky, and consists of stratified interconnected unconfined water bearing zones. The detailed information regarding of sampling site, location, well type and depth is presented in Table 1.

2.2 Sampling Methods

The study was conducted at the laboratory of Department of Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh. A total of 45 groundwater (6 deep tube wells, 19 shallow tube wells and 20 hand tube wells) samples were collected during July-September, 2013 (Table 1). Samples were collected in one liter plastic bottles that had been cleaned and rinsed with tap water followed by rinsing with distilled water. Before collecting each sample, bottles were rinsed 3 to 4 times with sample water. The collected water samples were carried to the laboratory of the Department of Agricultural Chemistry, HSTU, Dinajpur for testing. The samples were analyzed as quickly as possible on arrival at the laboratory. All reagents were analytical grade. For SO_4^{2-} and PO_4^-, samples were refrigerated and analyzed within 24 hrs. For heavy metal analysis, samples were filtered immediately using 0.45 µm filter paper. The filtrates were acidified to pH = 2 with nitric acid in order to keep the metals in solution.

Table 1. Information regarding sampling site, location, type and depth of well

Sl. no.	Location	Union	Type of well*	Depth (m)
1	Gopinathpur	Trilachanpur	STW	67
2	Gorga	Trilachanpur	STW	61
3	Boromath	Trilachanpur	DTW	115
4	Mamatpur	Rakhalgasi	HTW	37
5	Pukiria	Rakhalgasi	STW	34
6	Mallacua	Rakhalgasi	HTW	30
7	Bokargasy	Rakhalgasi	HTW	37
8	Ragunathpur	Rakhalgasi	HTW	43
9	Sadikpur	Borobazaar	STW	30
10	Ghoppara	Kastovagga	HTW	47
11	Golacata	Borobazaar	STW	46
12	Gopinathpur	Kastovagga	STW	55
13	Gopinathpur	Kastovagga	STW	35
14	Kastovagga	Kastovagga	STW	43
15	Fatapur	Trilachanpur	STW	45
16	Niamathpur	Niamathpur	STW	58

Sl. no.	Location	Union	Type of well*	Depth (m)
17	Dabna	Niamathpur	STW	55
18	Kochatola	Niamathpur	HTW	43
19	Bolashad	Niamathpur	HTW	46
20	Mollikpur	Niamathpur	HTW	49
21	Monoharpur	Maliath	HTW	41
22	Maliath	Maliath	HTW	40
23	Uttorpara	Maliath	HTW	37
24	Hudabari	Maliath	DTW	120
25	Bathuli	Maliath	HTW	55
26	Jamal	Jamal	HTW	55
27	Boraioti	Jamal	HTW	43
28	Bashudabpur	Jamal	HTW	37
29	Ullapara	Jamal	STW	67
30	Raigram	Raigram	STW	40
31	Dulalminda	Raigram	STW	37
32	Hajeepara	Raigram	DTW	116
33	Uttorpara	Niamathpur	STW	58
34	Niamathpur	Niamathpur	DTW	118
35	Bolorampur	Kola	STW	58
36	Kola	Kola	HTW	55
37	Majrpara	Kola	STW	40
38	Tilla	Borobazaar	HTW	42
39	Monoharpur	Borobazaar	HTW	50
40	Rakonpur	Kamalhat	DTW	130
41	Bocha	Kamalhat	STW	61
42	Kishepur	Shibnagar	HTW	50
43	Fotapur	Shibnagar	HTW	55
44	Shibnagar	Shibnagar	STW	65
45	Biharimor	Shibnagar	DTW	110

STW= Shallow tube well, HTW =Hand tube well, DTW= Deep tube well

2.3 Statistical Analysis

Statistical analysis of the data generated out of the chemical analyses of water samples, were done using MSTATC and MS Excel software. Correlation studies were also computed following the standard procedure as described by Gomez and Gomez [7].

2.4 Checking the Correctness of Analysis

There are various species of cations and anions present in natural water. This cations and anions must have in equal quantity as the natural water is electrically neutral. The quality of natural water may vary with their sources, movement etc. The analysis of water sample must be checked for determining the characteristics of water quality. Some of the properties indicate the quality criteria whether it is either suitable for drinking, irrigation, domestic, livestock, industrial or other purposes or not. The accuracy of chemical analyses of water samples were checked using ionic balance as suggested by Clesceri [8].

3. RESULTS AND DISCUSSION

Natural waters contain ionic constituents in different concentration and composition which is dependent on sources and spaces. Ionic constituents of Ca, Mg, Na, K, HCO_3, SO_4, PO_4, Cl, Cu, Mn, Zn and Fe were analyzed and variable amounts were present in different water sources. The results have been discussed in the following heading.

3.1 Chemical Properties of Water

3.1.1 pH

The pH of the solution is very important in plant nutrition and out of range can lead to problems. In the study area, the pH of ground waters fluctuated from 6.40 to 7.59 with a mean value of 6.79 and CV was 3.47% (Table 2). Almost all samples were acidic in nature. The highest result was observed in sample no.14 (7.59) and the lowest in sample no.28 (6.4), which indicates that

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the waters were slightly acidic in reaction. The pH directly affects the availability of many plant nutrients, especially micronutrients. Too low (<4.0) pH can result in increased micronutrient availability that can lead to phototoxic responses in some plant species. The normal pH range for irrigation water is 6.5 to 8.4 [9]. Therefore, the water of different sources and locations under study would be suitable for normal crop production except sample no. 28.

3.1.2 Electrical conductivity (EC)

EC is assessment of all soluble salts in a sample. This includes negatively and positively charged ions (e.g. Cl^-, NO_3^-, Ca^{2+}, Na^+). The electrical conductivity i.e. total concentration of soluble salts in all water samples ranged within the limit of 518 to 925 µS cm^{-1} at 25°C with the mean value of 763.53 µS cm^{-1} (Table 2). The standard deviation and coefficient of variation were 94.9 µS cm^{-1} and 12.43 µS cm^{-1}, respectively. High EC value reflected the higher amount of salt concentration which affect on irrigation water quality related to salinity hazard.

The present findings revealed that the higher EC value was probably due to the accumulation of high amount of salt concentration. On the basis of EC values, the irrigation waters were classified into four groups such as low salinity, medium salinity, high salinity and very high salinity respectively [10] which is presented in Fig. 1. The result showed that the samples were found in 'good' and 'permissible' in higher value of EC.

3.1.3 Total dissolved solids (TDS)

The TDS of ground waters were fluctuated between 31 mg L^{-1} to 555mg L^{-1} (Table 2). Among the collected samples, the mean TDS value is 450.44 mg L^{-1}. The computed standard deviation (SD) was 82.37 and coefficient of variation was 18.28%. The primary effect of high TDS in water on crop productivity is the inability of the plant to complete with ions in the soil solution for water (physiological drought). The higher TDS value might be due to the release of polluted water bodies.

3.2 Cationic Constituents

3.2.1 Calcium

The concentration of Ca in water samples were found to vary from 2.16 to 5.92 meq L^{-1}. The mean value was 4.31 meq L^{-1} (Table 3). Out of

the 45 samples, the computed CV% obtained from the analyses was 16.66% (Table 3). The highest concentration was found in sample no. 39 (5.92 meq/L) and the lowest value was exhibited in sample no. 14 (2.16 meq/L).

3.2.2 Magnesium

The concentration of Mg in water samples were found to vary from 3.80 to 5.52 meq L^{-1}. The mean value was 4.61 meq L^{-1} (Table 3). The computed CV% obtained from the analyses was 8.12% (Table 3). The highest concentration was found in sample no. 29 (5.52 meq/L) and the lowest concentration was shown in sample no. 19 (3.80 meq/L).

3.2.3 Sodium

The concentration of Na was observed within the range of 0.21 to 0.33 meq L^{-1} with the mean value of 0.26 meq L^{-1} (Table 3). The co-efficient of variation (CV) was 13.16%.

3.2.4 Potassium

The concentration of K was found within the range of 0.19 to 0.44 meq L^{-1} with the mean value of 0.29 meq L^{-1} (Table 3). Out of the 45 samples, 16 samples found below the mean value and 25 samples were found at above the mean value. The coefficient of variation (CV) was 28.16%.

3.2.5 Zinc

The concentration of zinc in different sources of water in the study areas were within the range of 0.003 to 0.095 mg L^{-1} (Table 3). The mean value was 0.029 mg L^{-1}. Out of 45 samples, most samples were found within below the mean value and few samples were found above the mean value. The computed standard deviation (SD) was 38.26% (Table 3). Karanth [11] reported that Zn is found in groundwater in indeterminate quantities or traces generally not exceeding 1 mg L^{-1}. In the present study, Zn was recorded in very little quantities.

3.2.6 Copper

The concentration of Cu in different sources of water in the study areas were within range 0.00 to 0.08 mg L^{-1} and mean value was 0.027 mg L^{-1} (Table 3). The computed standard deviation (SD) was 34.20.

Table 2. pH, EC, TDS, anionic constituents and hardness of groundwater during the study period

Sl. no.	pH	EC (µScm^{-1})	TDS mg L^{-1}	PO$_4^{3-}$ (meqL^{-1})	SO$_4^{2-}$ (meqL^{-1})	HCO$_3^-$ (meqL^{-1})	Cl$^-$ (meqL^{-1})	Hardness (mgL^{-1})
1	6.7	773	464	0.06	4.10	0.64	3.65	491.63
2	6.78	659	395	0.01	5.53	0.44	2.46	407.63
3	6.78	655	393	0.01	3.77	0.62	2.97	413.62
4	6.67	702	421	0.02	3.25	0.51	4.64	505.61
5	6.76	824	494	0.00	3.54	0.68	3.74	447.46
6	6.79	810	485	0.01	2.27	0.57	3.79	385.51
7	6.56	768	461	0.02	2.60	0.64	3.4	385.51
8	6.73	711	427	0.03	2.84	0.73	4.5	461.61
9	6.83	790	473	0.04	1.92	0.82	4.2	397.53
10	6.79	806	483	0.04	3.25	0.55	3.76	453.75
11	6.57	715	429	0.01	5.20	0.38	2.5	385.35
12	7.06	805	484	0.03	3.77	0.36	3.2	401.60
13	6.99	895	537	0.04	2.52	0.55	4.76	449.59
14	7.59	518	31	0.02	3.19	0.36	2.3	323.46
15	6.71	727	376	0.05	2.58	0.61	4.6	457.71
16	6.79	752	406	0.02	3.32	0.73	3.41	425.59
17	6.56	676	451	0.02	3.71	0.49	3.4	461.44
18	6.63	698	419	0.10	2.34	0.64	4.7	465.55
19	6.88	713	428	0.03	2.93	0.67	3.85	417.79
20	6.99	793	555	0.01	3.77	0.36	4.2	10.92
21	6.68	925	400	0.01	2.01	0.24	4.95	6.00
22	7.19	668	476	0.02	2.32	0.36	4.63	7.30
23	7.25	818	491	0.05	2.84	0.78	3.9	10.31
24	6.67	919	552	0.10	2.47	0.48	4.96	8.15
25	6.7	765	459	0.03	2.27	0.89	4.75	9.34
26	6.58	619	371	0.00	2.66	0.79	4.92	9.90
27	6.62	868	520	0.01	2.93	0.73	3.89	10.29
28	6.4	765	550	0.03	3.71	0.67	3.76	12.02
29	6.78	918	415	0.05	2.93	0.82	4.21	10.67
30	6.83	696	435	0.02	2.97	0.64	4.37	10.03
31	6.76	913	548	0.09	2.95	0.54	4.66	9.57
32	6.56	815	489	0.01	2.34	0.50	4.65	7.88
33	6.43	716	430	0.03	5.66	0.13	2.7	14.70
34	6.62	918	551	0.01	2.53	0.64	4.38	8.95
35	6.71	898	506	0.00	2.52	0.64	4.64	8.90
36	6.93	889	539	0.04	3.01	0.45	3.95	9.40
37	6.52	821	493	0.04	3.28	0.36	4.54	9.68
38	6.89	700	420	0.01	5.66	0.15	3.6	14.76
39	7.08	715	429	0.03	5.66	0.56	3.67	16.46
40	7.19	608	395	0.02	5.02	0.24	2.6	13.53
41	7.11	702	442	0.01	5.66	0.33	3.2	15.49
42	6.93	765	459	0.03	4.55	0.36	4.32	12.87
43	6.82	790	473	0.03	4.42	0.78	3.42	14.26
44	6.68	677	407	0.04	5.66	0.56	3.12	16.46
45	6.49	681	408	0.03	2.39	0.45	4.76	7.83
MIN	6.4	518	31	0.00	1.92	0.13	2.3	323.46
MAX	7.59	925	555	0.10	5.66	0.89	4.96	535.67
MEAN	6.79	763.53	450.44	0.03	3.44	0.54	3.924	452.01
SD	0.23	94.90	82.37	0.02	1.14	0.18	0.74	0.84
CV(%)	3.46	12.43	18.28	79.15	33.18	33.78	18.99	0.001

Table 3. Concentrations of cationic constituents of groundwater during the study period

SI no.	Ca^{2+} (meq/L)	Mg^{2+} meq/L	Na^+ meq/L	K^+ meq/L	Mn^{2+} (mg/L)	Fe^{2+} (mg/L)	Cu^{2+} (mg/L)	Zn^{2+} (mg/L)
1	4.92	4.07	0.25	0.19	0.010	0.02	0.022	0.01
2	4.84	4.32	0.25	0.22	0.040	0.05	0.060	0.00
3	3.88	4.40	0.25	0.44	0.007	0.00	0.070	0.03
4	4.56	5.12	0.33	0.25	0.060	0.02	0.040	0.03
5	3.72	5.24	0.21	0.34	0.080	0.03	0.057	0.02
6	3.12	4.60	0.25	0.28	0.030	0.09	0.008	0.01
7	3.12	4.60	0.25	0.28	0.007	0.01	0.004	0.02
8	4.44	4.80	0.25	0.38	0.008	0.03	0.025	0.01
9	3.36	4.60	0.33	0.19	0.003	0.06	0.035	0.02
10	4.88	4.20	0.29	0.28	0.030	0.01	0.002	0.007
11	3.56	5.16	0.29	0.19	0.060	0.00	0.030	0.008
12	3.64	4.40	0.33	0.19	0.022	0.03	0.030	0.003
13	4.24	4.76	0.25	0.38	0.060	0.03	0.080	0.030
14	2.16	4.32	0.25	0.31	0.070	0.02	0.030	0.060
15	4.76	4.40	0.29	0.28	0.040	0.01	0.007	0.022
16	3.92	4.60	0.21	0.22	0.040	0.02	0.008	0.060
17	3.84	5.40	0.25	0.19	0.080	0.01	0.003	0.070
18	4.28	5.04	0.29	0.25	0.010	0.02	0.030	0.040
19	4.56	3.80	0.25	0.44	0.020	0.02	0.030	0.021
20	4.28	4.72	0.25	0.38	0.004	0.02	0.001	0.020
21	3.36	4.52	0.21	0.22	0.013	0.03	0.008	0.06
22	3.80	4.44	0.25	0.25	0.023	0.01	0.020	0.022
23	4.08	4.60	0.25	0.31	0.025	0.02	0.050	0.004
24	5.16	4.32	0.29	0.28	0.035	0.00	0.020	0.07
25	4.60	4.36	0.25	0.44	0.041	0.02	0.030	0.03
26	4.12	5.10	0.29	0.28	0.013	0.00	0.020	0.07
27	3.68	4.52	0.25	0.19	0.026	0.02	0.000	0.03
28	3.88	4.88	0.25	0.41	0.037	0.00	0.07	0.02
29	3.68	5.52	0.25	0.28	0.021	0.01	0.03	0.008
30	4.76	4.64	0.29	0.22	0.020	0.03	0.02	0.003
31	5.04	4.56	0.29	0.41	0.06	0.00	0.04	0.03
32	4.32	4.44	0.33	0.38	0.022	0.00	0.03	0.00
33	4.92	4.24	0.25	0.25	0.004	0.08	0.03	0.03
34	4.76	4.36	0.21	0.19	0.07	0.02	0.01	0.040
35	5.02	4.07	0.25	0.28	0.03	0.03	0.02	0.040
36	4.54	4.08	0.25	0.22	0.07	0.03	0.01	0.080
37	4.60	4.51	0.33	0.38	0.03	0.02	0.02	0.010
38	5.64	4.44	0.25	0.22	0.02	0.01	0.02	0.020
39	5.92	4.60	0.25	0.25	0.04	0.02	0.02	0.004
40	4.12	4.61	0.25	0.41	0.03	0.02	0.01	0.03
41	4.48	5.16	0.21	0.44	0.02	0.03	0.07	0.09
42	4.52	5.12	0.25	0.22	0.008	0.03	0.01	0.01
43	5.40	4.36	0.25	0.28	0.003	0.03	0.08	0.03
44	4.96	4.92	0.29	0.38	0.03	0.00	0.02	0.06
45	4.44	4.48	0.21	0.25	0.03	0.02	0.01	0.01
MIN	2.16	3.80	0.21	0.19	0.003	0.001	0.000	0.003
MAX	5.92	5.52	0.33	0.44	0.080	0.095	0.080	0.095
MEAN	4.31	4.61	0.26	0.29	0.031	0.022	0.027	0.029
SD	0.71	0.37	0.03	0.08	38.94	22.74	34.20	30.26
CV(%)	16.66	8.12	13.16	28.16	125000	105512.4	125000	105512.4

3.2.7 Iron

The concentration of Fe was found within the range of 0.001 to .095 mg L^{-1} with the mean value of 0.022 mg L^{-1} (Table 3). Out of 45 samples, 32 samples found below the mean value and 13 samples were found above the mean value. The computed standard deviation (SD) was 22.74 (Table 3).The recorded Fe concentration of all waters were far below the acceptable limit (Fe = 5.0 mg L^{-1}) and may be 'suitable' for crop production.

3.2.8 Manganese

The concentration of Mn was found within the range of 0.003 to 0.08 mg L^{-1} with the mean value of 0.031 mg L^{-1} (Table 3). Out of 45 samples, 18 samples were found within below the mean value and 27 samples found above the mean value. The computed standard deviation (SD) was 38.94 (Table 3).

3.3 Anionic Constituents

3.3.1 Bicarbonate

The concentration of HCO_3^- was found within the range of 0.13 to 0.89 meq L^{-1} with the mean value of 0.54 meq L^{-1} (Table 2). Out of 45 samples, 17 samples were found within below the mean value and the rest samples found above the mean value. The co-efficient of variation (CV) was 33.78%. The highest value was found in sample no. 25 and the lowest was in sample no. 33. Similar finding was described by Uddin [12].

3.3.2 Sulphate

The concentration of SO_4^{2-} was found within the range of 1.92 to 5.66 meq L^{-1} (Table 2) with the mean value of 3.44 meq L^{-1}. Out of 45 samples, 28 samples were found within below the mean value and 17 samples found above the mean value. The co-efficient of variation (CV) was 33.18% (Table 2).

3.3.3 Phosphorus / Phosphate

The concentration of PO_4^- was found within range of 0 to 0.1 meq L^{-1} with the mean value of 0.03 meq L^{-1} (Table 2). Out of 45 samples, 21 samples were found within below the mean value and 24 samples found above the mean value. The co-efficient of variation (CV) was 79.15%.

3.3.4 Chloride

The concentration of Cl^- was found within the range of 2.30 to 4.96 meq L^{-1} (Table 2) with the mean value of 3.92 meq L^{-1}. Out of 45 samples, 25 samples were found within above the mean value and rest samples found below the mean value. The coefficient of variation (CV) was 18.99% (Table 2).

3.4 Quality Determining Indicates for Irrigation Water

3.4.1 Sodium Adsorption Ratio (SAR)

All the samples were rated as 'low' alkalinity hazard (S1) class for irrigation as per SAR value (Table 4). Waters under test were rated as 'low salinity' (C1), 'medium salinity' (C2) and 'high salinity' (C3). On the basis of salinity classification, 20 samples were found in 'medium salinity' (C2; EC = 250-750 µS cm^{-1}), 25 samples were of 'high salinity' (C3; EC = 750-2250 µS cm^{-1}) and 'low salinity' (C1; EC = 0-250 µS cm^{-1}) category of water not found in any samples (Table 4). Alkalinity and salinity class was done using the diagram for classification of irrigation waters given by Richards, 1968 [10] demonstrated in Fig. 1.

3.4.2 Soluble Sodium Percentage (SSP)

The calculated SSP values of all water samples were varied from 2.01 to 3.87 with the mean value of 2.75 and the standard deviation was 0.41 (Table 4). All samples were in 'excellent' (SSP=>2).

3.4.3 Residual Sodium Carbonate (RSC)

The calculated RSC values of all water samples were varied from -9.96 to -6.12 with the mean value of -8.38 and the standard deviation was 0.74 (Table 4).

3.4.4 Total hardness (H_T)

The calculated H_T values of all water samples varied from 323.46 to 535.67 mg L^{-1} with the mean value of 452.01 mg L^{-1} and the standard deviation was 84 (Table 2).

3.4.5 Permeability index and potential salinity

The range of the value of Permeability Index (PI) for all water samples were varied from 3.90 to 6.60 and the mean value was 5.64 (Table 5). The

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range of calculated values for the Permeability salinity of water samples was 0.26 to 0.44. The average value of this term was 0.34 (Table 5). Relative proportions of other different cations or balance of some cations and anions defined by SAR, SSP, KR, MAR, TH, RSBC etc. also the indicators of permeability problem.

3.4.6 Gibbs ratio

The ranges of Gibbs ratio [13] for anions and cations varied from 0.81 to 0.96 and 0.08 to 0.21 (Table 5). The average values for both ratios were 0.88 (for anions) and 0.12 (for cations).

3.4.7 Kelly's ratio

The Kelly's ratio for all water samples were ranged from 0.02 to 0.04 with the mean value 0.03 (Table 5). Therefore, according to Kelly's ratio, all of the water samples were suitable for irrigation.

3.5 Correlation between Quality Factors and Major Ionic Constituents of Groundwater

The relationship of water quality factors in computed regression line recorded among the EC-TDS, EC-SSP, EC-SAR, EC-RSC,EC -H_T,pH-EC, pH- H_T,SSP-SAR , SAR-RSC, SSP-RSC and pH-TDS demonstrated the positive relation (Table 6). This reflected a significant relation between the above conditions. On contrary pH-H_T, EC- H_T and SAR-RSC were found inversely relegated representing an antagonistic behavior (Table 6).The relationship between all dominant cations and anions were highly significant. Among them relationship between EC-TDS(r = 0.501) are graphically presented in Fig. 2 whereas the relationship between SSP-SAR (r =0.924) presented in Fig. 3.These results indicated that a synergistic relationship existed between the dissolved ions present in various sources of water presented in Table 6.

Table 4. Quality classification of water samples for irrigation

Sl. no	EC	TDS	SAR	SSP	RSC	Water class based on					Alkalinity
						EC	TDS	SAR	SSP	RSC	Salinity class
1	773	464	0.12	2.62	-8.36	Per.	Fre.	Ex.	Ex.	Suit.	C3S1
2	659	395	0.12	2.57	-8.72	Good	Fre.	Ex.	Ex.	Suit.	C2S1
3	655	393	0.12	2.76	-7.66	Good	Fre.	Ex	Ex.	Suit.	C2S1
4	702	421	0.15	3.20	-9.17	Good	Fre.	Ex.	Ex.	Suit.	C2S1
5	824	494	0.10	2.17	-8.28	Per.	Fre.	Ex.	Ex.	Suit	C3S1
6	810	485	0.13	3.00	-7.15	Per.	Fre.	Ex.	Ex.	Suit.	C3S1
7	768	461	0.13	3.00	-7.08	Per.	Fre.	Ex	Ex.	Suit.	C3S1
8	711	427	0.12	2.51	-8.51	Good	Fre.	Ex.	Ex.	Suit.	C2S1
9	790	473	0.16	3.87	-7.14	Per.	Fre.	Ex.	Ex.	Suit.	C3S1
10	806	483	0.14	2.98	-8.54	Per.	Fre.	Ex.	Ex.	Suit.	C3S1
11	715	429	0.14	3.13	-8.34	Good	Fre.	Ex.	Ex.	Suit.	C2S1
12	805	484	0.16	3.84	-7.68	Per.	Fre.	Ex.	Ex.	Suit.	C3S1
13	895	537	0.12	2.57	-8.46	Per.	Fre.	Ex	Ex.	Suit.	C3S1
14	518	31	0.14	3.51	-6.12	Good	Fre.	Ex.	Ex.	Suit.	C2S1
15	727	376	0.13	2.96	-8.55	Good	Fre.	Ex.	Ex.	Suit	C2S1
16	752	406	0.10	2.31	-7.79	Per.	Fre.	Ex.	Ex.	Suit.	C3S1
17	676	451	0.12	2.56	-8.75	Good	Fre.	Ex	Ex.	Suit.	C2S1
18	698	419	0.13	2.92	-8.68	Good	Fre.	Ex.	Ex.	Suit.	C2S1
19	713	428	0.12	2.73	-7.69	Good	Fre.	Ex.	Ex.	Suit.	C2S1
20	793	555	0.12	2.57	-8.64	Per.	Fre.	Ex.	Ex.	Suit.	C3S1
21	925	400	0.10	2.49	-7.64	Per.	Fre.	Ex	Ex.	Suit.	C3S1
22	668	476	0.12	2.83	-7.88	Good	Fre.	Ex.	Ex.	Suit.	C2S1
23	818	491	0.12	2.68	-7.90	Per.	Fre.	Ex.	Ex.	Suit	C3S1
24	919	552	0.13	2.86	-9.00	Per.	Fre.	Ex.	Ex.	Suit.	C3S1
25	765	459	0.12	2.56	-8.07	Per.	Fre.	Ex	Ex.	Suit.	C3S1
26	619	371	0.13	2.94	-8.43	Good	Fre.	Ex.	Ex.	Suit.	C2S1
27	868	520	0.12	2.86	-7.47	Per.	Fre.	Ex.	Ex.	Suit.	C3S1

Sl. no	EC	TDS	SAR	SSP	RSC	Water class based on					Alkalinity
						EC	TDS	SAR	SSP	RSC	Salinity class
28	765	550	0.12	2.63	-8.09	Per.	Fre.	Ex.	Ex.	Suit.	C3S1
29	918	415	0.12	2.54	-8.38	Per.	Fre.	Ex.	Ex.	Suit.	C3S1
30	696	435	0.13	2.90	-8.76	Good	Fre.	Ex.	Ex.	Suit.	C2S1
31	913	548	0.13	2.80	-9.06	Per.	Fre.	Ex.	Ex.	Suit.	C3S1
32	815	489	0.16	3.47	-8.26	Per.	Fre.	Ex	Ex.	Suit.	C3S1
33	716	430	0.12	2.56	-9.03	Good	Fre.	Ex.	Ex.	Suit.	C2S1
34	918	551	0.10	2.17	-8.48	Per.	Fre.	Ex.	Ex.	Suit	C3S1
35	898	506	0.12	2.57	-8.46	Per.	Fre.	Ex.	Ex.	Suit.	C3S1
36	889	539	0.12	2.72	-8.17	Per.	Fre.	Ex	Ex.	Suit.	C3S1
37	821	493	0.15	3.35	-8.74	Per.	Fre.	Ex.	Ex.	Suit.	C3S1
38	700	420	0.11	2.34	-9.93	Good	Fre.	Ex.	Ex.	Suit.	C2S1
39	715	429	0.11	2.24	-9.96	Good	Fre.	Ex.	Ex.	Suit.	C2S1
40	608	395	0.12	2.64	-8.49	Good	Fre.	Ex	Ex.	Suit.	C2S1
41	702	442	0.09	2.01	-9.31	Good	Fre.	Ex.	Ex.	Suit.	C2S1
42	765	459	0.11	2.45	-9.28	Per.	Fre.	Ex.	Ex.	Suit	C3S1
43	790	473	0.11	2.40	-8.98	Per.	Fre.	Ex.	Ex.	Suit.	C3S1
44	677	407	0.13	2.73	-9.32	Good	Fre.	Ex	Ex.	Suit.	C2S1
45	681	408	0.10	2.21	-8.47	Good	Fre.	Ex.	Ex.	Suit.	C2S1
MIN	518	31	0.09	2.01	-9.96						
MAX	925	555	0.16	3.87	-6.12						
MEAN	763.53	450.44	0.12	2.75	-8.38						
SD	94.90	82.37	0.02	0.41	0.74						
CV	12.43	18.28	0.14	2.62	-0.09						

* Per=permissible, Fre=Fresh, Ex=Excellent, Suit=Suitable
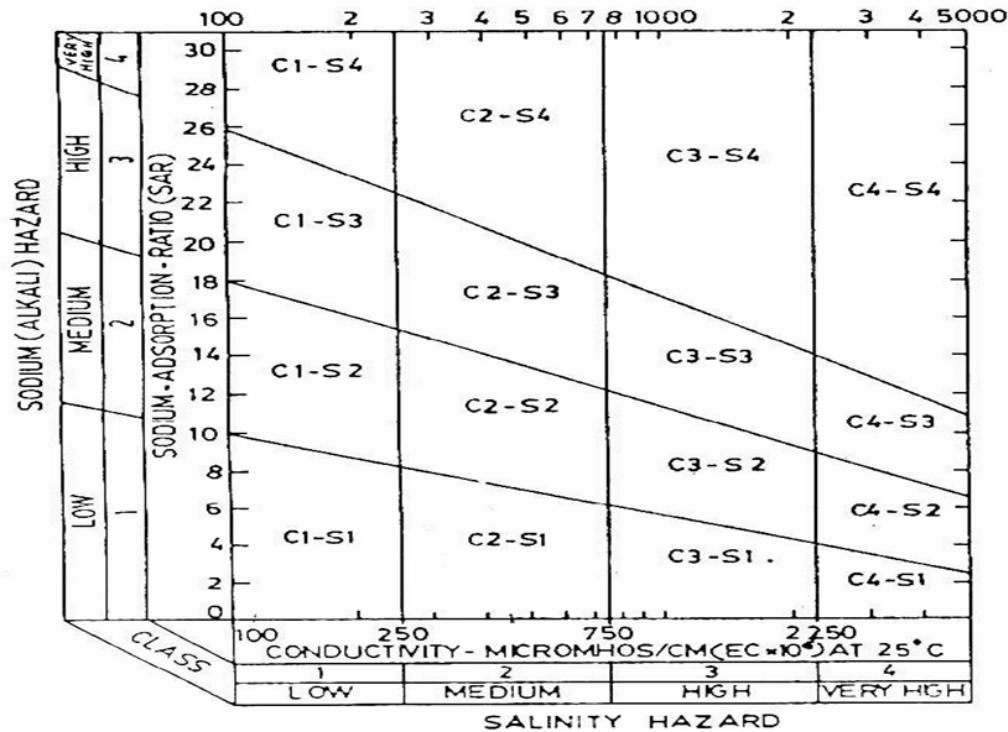

Fig. 1. Diagram for classification of irrigation waters (Richards, 1968)

Table 5. Permeability Index (PI), Potential Salinity (PS), Kelly's ratio and Gibbs ratio of the groundwater

Sl. No.	PI	PS	Gibbs ratio (anion)	Gibbs ratio (cation)	Kellys ratio
1	5.70	0.33	0.85	0.08	0.03
2	5.22	0.32	0.85	0.09	0.03
3	4.86	0.34	0.83	0.15	0.03
4	6.27	0.40	0.90	0.11	0.03
5	5.51	0.30	0.85	0.13	0.02
6	4.93	0.34	0.87	0.14	0.03
7	4.70	0.35	0.84	0.14	0.03
8	5.92	0.34	0.86	0.12	0.03
9	5.16	0.44	0.84	0.13	0.04
10	5.39	0.37	0.87	0.10	0.03
11	5.10	0.36	0.87	0.12	0.03
12	5.09	0.40	0.90	0.12	0.04
13	6.02	0.33	0.90	0.13	0.03
14	3.90	0.34	0.86	0.21	0.04
15	5.89	0.37	0.88	0.11	0.03
16	5.07	0.30	0.82	0.10	0.02
17	5.25	0.32	0.87	0.10	0.03
18	5.87	0.37	0.88	0.11	0.03
19	5.31	0.34	0.85	0.13	0.03
20	6.09	0.31	0.92	0.13	0.03
21	5.96	0.27	0.95	0.11	0.03
22	5.79	0.32	0.93	0.12	0.03
23	5.32	0.35	0.83	0.12	0.03
24	6.19	0.36	0.91	0.10	0.03
25	5.89	0.35	0.84	0.13	0.03
26	6.25	0.38	0.86	0.12	0.03
27	5.35	0.35	0.84	0.11	0.03
28	5.61	0.34	0.85	0.14	0.03
29	5.67	0.34	0.84	0.13	0.03
30	5.85	0.37	0.87	0.10	0.03
31	6.13	0.36	0.90	0.12	0.03
32	5.82	0.41	0.90	0.14	0.04
33	5.53	0.29	0.95	0.09	0.03
34	5.65	0.29	0.87	0.08	0.02
35	5.90	0.33	0.88	0.10	0.03
36	5.46	0.32	0.90	0.09	0.03
37	6.18	0.39	0.93	0.13	0.04
38	6.43	0.28	0.96	0.08	0.02
39	6.50	0.32	0.87	0.08	0.02
40	5.11	0.30	0.92	0.14	0.03
41	6.03	0.26	0.91	0.13	0.02
42	6.60	0.31	0.92	0.09	0.03
43	5.63	0.34	0.81	0.09	0.03
44	5.95	0.36	0.85	0.12	0.03
45	5.95	0.28	0.91	0.09	0.02
Min	3.90	0.26	0.81	0.08	0.02
max	6.60	0.44	0.96	0.21	0.04
Mean	5.64	0.34	0.88	0.12	0.03
SD	0.53	0.04	0.04	0.02	0.00
CV(%)	0.09	0.11	0.04	0.21	0.15

Table 6. Correlation co-efficient and regression equation of different parameters

Parameters	Correlation co-efficient (r)	Regression equation $Y = a + bx$
EC - TDS	0.501**	y = 0.614x-19.03
EC - SAR	0.003 [NS]	y= -1E - 05x + 0.130
EC - SSP	0.006 [NS]	y= .000x + 3.019
EC - RSC	0.000 [NS]	y= -0.000x-8.266
EC - H_T	0.058 [NS]	y= 0.115x+ 363.9
pH - EC	0.062 [NS]	y = -101.0x + 1449
pH - H_T	0.047 [NS]	y = - 41.68x + 736.3
SSP-SAR	0.924**	y= 0.039x+.015
SAR - RSC	0.056 [NS]	y= 10.58-9.676
SSP – RSC	0.223 [NS]	y **=** 0.858x-10.73
pH -TDS	0.145 [NS]	y=-133.3x+1356

*Legends: NS = Not Significant, * = Significant at 1 % level and ** = Significant at 5 % level, Tabulated value of r with 44df = 0.291 at 5% level and 0.376 at 1%level of significance*
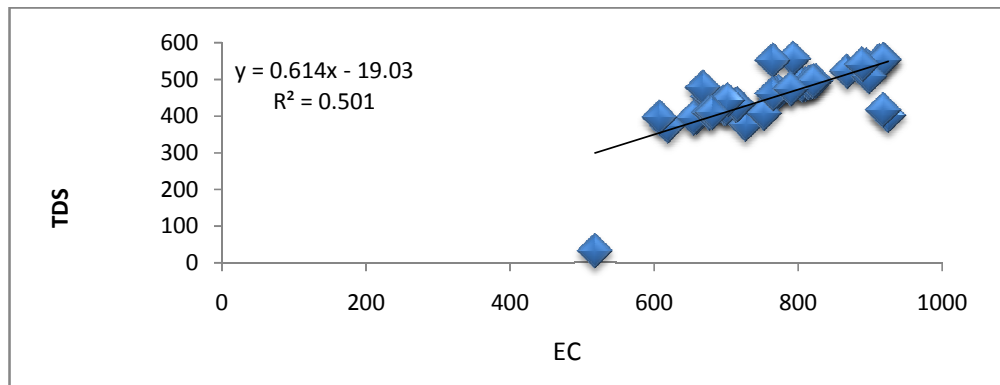
Fig. 2. Relationship between EC and TDS
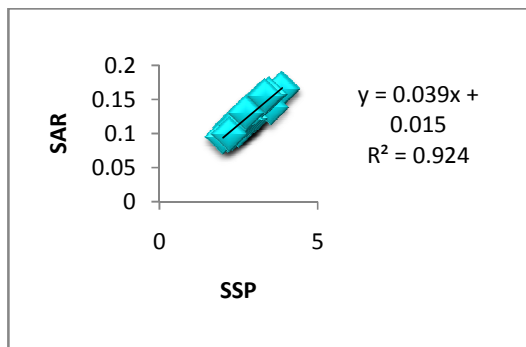
Fig. 3. Relationship between SSP and SAR

3.6 Suitability of Groundwater for Specific Uses

3.6.1 Irrigation uses

The EC value of all samples varied from 518 to 925 µScm^{-1} and mean value was 763.53 µScm^{-1} and these values were reported in Table 4. The

pH values of water samples were varied from 6.4 to 7.59 (Table 2). The mean value of samples is 6.79. The pH value of all samples indicated that these samples of water were slightly acidic to neutral or slightly alkaline in nature. The important factors that control the pH solution during crop production are: 1) pre-plant substance such as dolomite limestone put into the substance and substrate component themselves, 2) the alkalinity of irrigation water, 3) the acidity or basicity of the fertilizer used during crop production.

The values of total dissolved solids (TDS) of collected water samples varied from 31 to 555 mg/L and mean value was 450.4 mg/L (Table 2). All samples were considered as 'fresh' for irrigation. Because of TDS values of all samples were less than 1000 mg/L (Table 2).

The value of Hardness for all samples was ranged from 323.5 to 535 mg/L and the mean value of the hardness was 452 mg/L (Table 2).
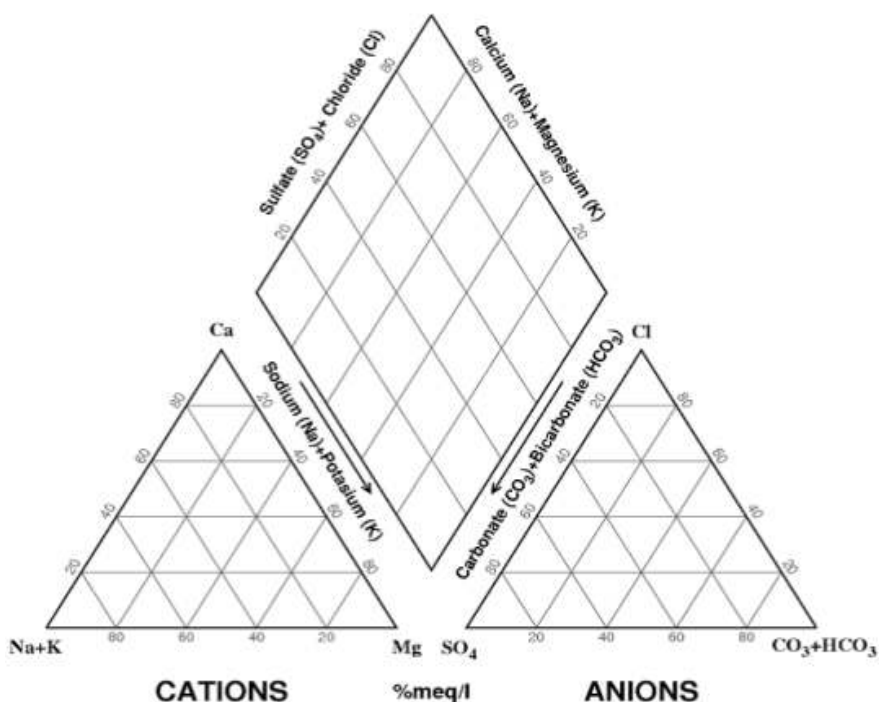
Fig. 4. Piper diagram

According to [14] water was classified into four groups on the basis of hardness. By following this classification, all samples were considered 'very hard' for irrigation.

Results of Sodium Adsorption Ratio (SAR) for all groundwater samples were ranged from 0.09 to 0.16 meq/L (Table 4). All water samples for SAR were 'excellent' for irrigation indicated in (Table 4). The value of RSC for all samples was ranged from from -9.96 to -6.12 meq/L and the mean value was -8.38 me/L (Table 4).

3.6.2 Groundwater quality for drinking and domestic uses

Most chemicals arising in drinking water are of health concern only after extended exposure of years, rather than months. It should be noted that there is a difference between "pure water" and "safe drinking water". The problems associated with chemical contaminants of drinking water arise primarily from their ability to cause adverse health effects after prolonged periods of exposure. Of particular concern are contaminants which have cumulative toxic properties, such as some heavy metals and carcinogenic substances. Water should preferably be soft, low in dissolved solids and free from poisonous constituents for drinking and domestic uses.

3.6.3 Groundwater quality for industrial uses

TDS is important properties in ground water. It creates scaling problem in industrial pipes and reservoirs. All water samples are suitable for brewing, ice manufacture purpose, dairy farm and carbonate beverage.

3.7 Piper Diagram

In the diagram the concentrations are plotted as percentages with each point representing a chemical analysis (Fig. 4) above.

4. CONCLUSION

If salts accumulate on the surface in irrigated fields, they can leach through the soil zone by recharge water and reach the water table. Further, recycling of groundwater for irrigation increase soil and groundwater salinity based on the patterns we observed, it can be concluded that all the hand tube well, shallow tube well and deep tube well water samples of the Kaliganj Upazila in the district of Jhenaidah, Bangladesh were suitable for drinking, irrigation and industrial uses; although some samples were rated to be unsuitable for some specific industries for some specific ions. Spatial variability is caused by aquifer heterogeneities, non-uniform cropping

patterns, and runoff of agricultural chemicals to topographically low points in the landscape.

From the present study, it is concluded that some water sample were exceeded the standard limit (ground water) in respect of Cl, Ca ions for irrigation purposes. So, the chemical assessment of groundwater should be taken into account for irrigated agriculture with due care. Results illustrate the necessity of improving the knowledge of groundwater quality for the study area. Especially for drinking and industrial water use, continuous monitoring of chemical and bacteriological indicators of water quality is needed.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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