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Groundwater and Surface Water Quality Assessment for Irrigation and Drinking Purposes of Khulna District, South-Western, Bangladesh.

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Abstract—This research deals with the Water Quality of Khulna District, South-western Bangladesh according to WHO standard. The water analyses show that, Na+, Cl-, and HCO3- are dominant ions but as far as the water quality is concerned, except some locations, the water is not suitable for drinking purpose.The competency of groundwater for drinking varies from place to place with depth but shallow water is totally unsuitable for drinking.Most of the samples exceeds the WHO and Bangladesh standard. Approximately all the groundwater is moderate to very hard and the surface water is soft to moderately hard. Maximum water samples are mixed type of Ca-HCO3- andNa-HCO3- . Some shallow and surface water are Ca-HCO3- type and rest of deep water samples are Na-HCO3- type. The groundwater electrical conductivity (EC) of the study area shows some spatial variation and highest SEC value was found in southern part which gives indication of water quality deterioration. It also indicates the salinity of groundwater. Based on sodium absorption ratio (SAR) values it is observed that, the water is suitable for irrigation development

Index Terms—Water Quality, Concentration, WHO Standard, SAR, KR, Chloride Toxicity, Hardness and EC.

1 INTRODUCTION

ALMOST two billion people of the world depend directly upon aquifers for drinking water, and 40 per cent of the world's food is produced by irrigation that relies largely on groundwater. In the future, aquifer development will continue to be fundamental to economic development and reliable water supplies will be needed fordomestic, industrial and irrigation purposes. Numerous water quality problems exist in GW and surface water (SW) systems in Bangladesh, especially in its southwestern coastal belt, where salinity is a very alarming issue at present (Elahi and Hossain, 2011). The salinity started to increase in Khulna after the commencement of Farrakka Barrage operation of India in 1975, which significantly reduced the Ganges flow. Main objective of this study is quality assessment of ground water and surface water for irrigation and drinking purposes. Total Dissolved Solids (TDS), Electrical Conductivity (EC), Hardness. Sodium Adsorption Ratio (SAR) and Kelly's Ratio (KR) are studied for quality assessment of the research area.The Study area lies in the south-western part of Bangladesh between latitude 22˚ and 23˚ North and longitudes 89˚15' and 89˚45' East (Figure: 1). The study area covers an area of about 2250 km², comprising eight Upazila, namely, Rupsa, Terokhada, Dighalia, Phultala, Dumuria, Batiaghata, Paikgacha, Dacope.

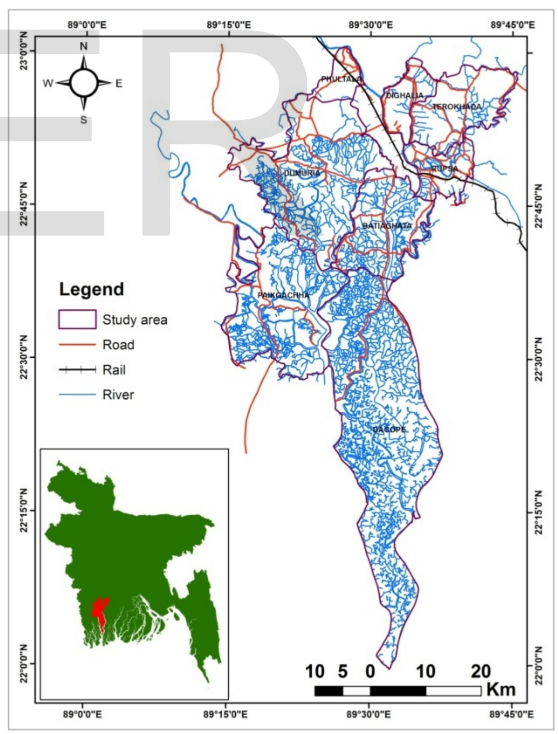

Fig. 1. Location Map of the study area.

2 MATERIALS AND METHODOLOGY

For hydro-geochemistry study, thirty nine groundwater samples and six surface water samples were collected from selected locations of the study area (Figure: 2) . For the chemical analysis of water samples, concentration of some major cations

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(Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (HCO_3^-, Cl^-)(Table: 1) are determined. Concentration of Fe^{2+} is also determined which is usually present in low concentration. The calculation principle of determining Ionic Balance is:

Ionic Balance (%) = {(Σ Cation – Σ Anion)/ (Σ Cation + Σ Anion)} ×100

Where cations and anions are expressed in meq/l. The acceptable limit of this balance is $\pm$10%.

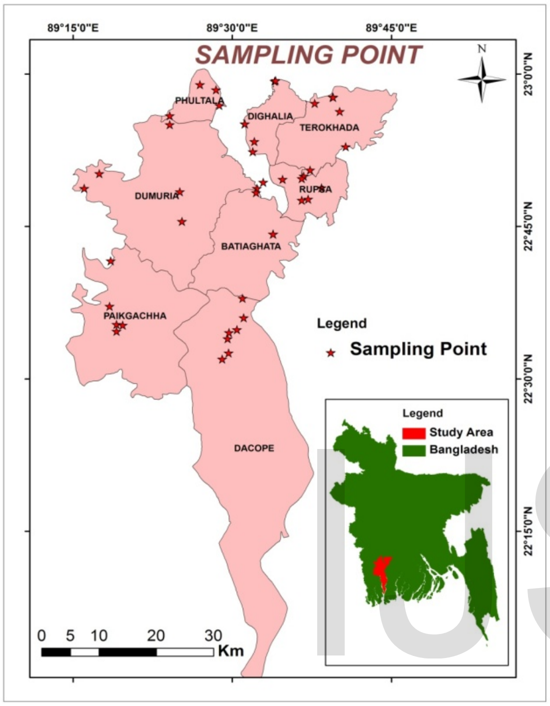

Fig. 2. Sampling Point of the study area.

TABLE 1

IONIC BALANCE OF THE WATER SAMPLES.

Sam-ID	Location	Major Cations in (meq/l)				Major Anions in (meq/l)			Ionic Balance
		Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}	
STW-1	Beyara	1.9203	0.0191	10.71	3.492	1.491	7.8733	0.0223	26.4682932
STW-2	Dighalia	2.1365	0.0167	6.509	2.754	0.746	8.2483	0.0264	11.7241552
DTW-3	Barakpur-1	7.2397	0.118	6.569	2.781	7.207	5.4988	0.0229	13.5175195
STW-4	Barakpur-2	24.038	0.0497	30.29	8.572	39.76	6.1237	0.1407	15.5284006
STW-5	Gazirhat	14.949	0.0336	11.88	4.089	18.02	6.8736	0.0223	10.8124582
STW-6	Gazirhat(BS)	15.425	0.0453	14.5	4.379	19.88	7.8733	0.0229	10.5774227
DTW-7	Phultala Baz	3.6258	0.0993	4.906	2.166	1.367	6.3737	0.0223	16.3487499
DTW-8	Bejerdanga	3.8466	0.0778	3.874	1.778	0.87	5.9987	0.0223	16.3060255
DTW-9	Damudarpur	5.0402	0.0655	2.424	1.114	0.746	6.6236	0.0223	7.80883502
DTW-10	Jamira Baz	3.8929	0.0458	2.639	1.02	0.249	5.9987	0.0243	9.5621998
STW-11	Beside Baz	25.321	0.184	26.9	9.462	75.79	6.7486	0.227	14.4481449
DTW-12	Atlia-1	63.557	1.175	15.2	14.7	89.46	10.248	0.025	2.62716831
DTW-13	Atlia-2	11.22	0.1971	10.37	4.362	17.4	5.9987	0.0236	5.51640581
DTW-14	Barasat	24.554	0.3421	29.89	26.93	49.7	6.4986	0.2147	18.3182262
DTW-15	Thana Schl	13.501	0.2528	24.84	8.426	31.68	5.4988	0.0572	11.6031398
DTW-16	Sagladah	8.4086	0.1567	8.52	3.007	9.94	5.4988	0.0339	12.9880288
DTW-17	Ajugara	16.695	0.2742	17.08	7.085	28.58	4.749	0.1353	10.2866527
DTW-18	Sefaltala	19.828	0.3511	20.54	9.656	38.52	5.2489	0.1024	6.90641514
DTW-19	Ajiganti	10.23	0.1415	11.62	3.645	16.15	5.9987	0.0483	7.18655059
DTW-20	Pitavog	35.939	0.3004	30.36	10.6	64.61	4.999	0.0907	5.10694542
DTW-21	Elatpur	30.889	0.3618	20.68	10.32	57.16	5.2489	0.0229	0.14089055
STW-22	Kamarkhula	53.997	0.8842	33.11	18.28	86.98	8.7482	0.1702	5.12932608
STW-23	Saheberabad	48.353	0.6737	15.4	11.38	69.58	11.748	0.0346	3.54114805
STW-24	Baroikhali	47.832	0.2531	5.28	4.258	47.22	14.622	0.0764	3.58882407
DTW-25	Chalna	35.498	0.3902	3.286	3.016	39.14	8.6232	0.0305	6.22515579
STW-26	Budrapara	30.194	0.4114	8.519	5.317	37.28	10.248	0.051	3.40458668
DTW-27	Hatbati	6.5081	0.0989	0.075	0.11	3.479	6.7486	0.0243	20.2968904
DTW-28	Kuriya(Amirp)	9.0557	0.1202	6.391	2.224	11.43	4.749	0.0243	4.66598848
STW-29	Beside Kuriya	10.306	0.0391	5.316	2.22	9.692	5.8738	0.0223	6.85435028
DTW-30	Gallamari Bz	6.9035	0.0835	1.935	1.137	3.976	6.2487	0.025	0.94077087
STW-31	Betaga	0.6393	0.039	8.394	1.887	0.994	5.4988	0.0243	25.4199703
DTW-32	Nasirpur	64.729	0.4724	24.39	16.88	90.7	10.998	0.0277	2.27867572
DTW-33	Matbari	1.0053	0.0967	7.421	2.689	0.497	5.7488	0.0264	28.2543787
STW-34	Paikgacha DP	21.832	0.525	27.1	9.233	32.31	10.498	0.138	15.500054
STW-35	Romardanga	32.364	0.2942	56.87	25.19	64.61	3.4993	0.4828	25.1647153
DTW-36	Chukannagar	11.186	0.0392	1.352	0.773	4.722	8.8731	0.0353	1.03796054
DTW-37	Sajira(Dumuria)	1.739	0.0507	4.864	1.557	0.994	4.749	0.0223	17.4951181
DTW-38	Dumuria Bazar	2.2195	0.0524	5.151	1.804	1.243	5.2489	0.0223	17.2369779
DTW-39	Islamnagar	2.4318	0.0554	1.525	0.676	1.988	6.4986	0.0243	28.9583116
SW-40	Ajugara-SW	2.4784	0.1263	3.148	1.112	3.728	3.4993	0.0791	3.11549423
SW-41	Elatpur-SW	0.8295	0.1637	6.375	2.414	1.491	3.4993	0.0962	31.5772787
SW-42	Romard-SW	31.737	0.2995	10.36	4.085	47.22	8.1233	0.0271	8.72502789
SW-43	Beside-K-SW	5.0449	0.1481	5.171	1.949	6.213	3.7492	0.1366	9.87903906
SW-44	Saheber-SW	0.5517	0.0455	3.076	0.68	1.243	1.9996	0.075	13.5065361
SW-45	Kamark-SW	5.0053	0.2319	0.624	2.788	13.92	2.4995	0.3281	31.8763206

For irrigation purpose, water is classified on the basis of electric conductivity (EC), sodium absorption ratio (SAR), Kelly's ratio (KR), Chloride toxicity and Salinity Hazard.

2.1 Sodium absorption ratio (SAR)

The sodium adsorption ratio (SAR) is commonly used as an index for evaluating the sodium hazard associated with irrigation water supply determined on the basis of table 2.It is calculated by using the following equation where Cations are expressed in meq/l.

$$Sodium\ Absorption\ Ratio = \frac{N_a}{\sqrt[2]{\left(\frac{N_a + M_g}{2}\right)}}$$

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TABLE 2
WATER QUALITY CLASSIFICATION FOR IRRIGATION (WILCOX, 1955)

Water Class	Percent Sodium	Specific conductance (µS/cm)
Excellent	<20	<250
Good	20-40	250-750
Permissible	40-60	750-2000
Doubtful	60-80	2000-3000
Unsuitable	>80	>3000

2.2 Kelly's ratio (KR)

Na^{+} measured against $Ca^{2+}$and Mg^{2+} is used to calculate Kelley's ratio. The formula used to estimate Kelley's ratio is expressed as

$$Kelly's\ Ratio = \frac{N_a^{+}}{C_a^{+2}+M_g^{+2}} \quad ,$$

Where cations are expressed in mg/l.SAR& KR value of ground water and surface water of the study area are shown in table 3.

TABLE 3
SAR & KR VALUE OF GROUND WATER AND SURFACE WATER OF THE STUDY AREA

Sample ID	Location	EC (µS/cm)	KR	TDS (mg/l)	Hardness (mg/l)	SAR (meq/l)
STW-1	Beyara	1060	0.17421683	3960	708.137	1.019117651
STW-2	Dighalia	780	0.304144221	4488	461.488	1.40396752
DTW-3	Barakpur-1	1570	1.021136584	4686	465.8	4.735270146
STW-4	Barakpur-2	5410	0.788462623	4554	1937.748	7.711977482
STW-5	Gazirhat	2800	1.21184816	4752	796.016	7.481751461
STW-6	Gazirhat(BS)	3040	1.046685341	4752	941.216	7.100119776
DTW-7	Phultala Baz	860	0.678858385	5082	352.285	2.726859202
DTW-8	Bejerdanga	790	0.904601072	5214	281.497	3.235980876
DTW-9	Damudarpur	770	1.89358643	5214	176.222	5.359186261
DTW-10	Jamira Baz	660	1.391301675	5214	182.339	4.070258939
STW-11	Beside Baz	5460	0.90303337	4752	1812.6	8.398214594
DTW-12	Atlia-1	10200	3.072931393	4290	1485.86	23.24651158
DTW-13	Atlia-2	2370	1.003461272	4752	734.13	5.846446737
DTW-14	Barasat	5620	0.619134102	4554	2824.804	6.514808172
DTW-15	Thana Schl	3700	0.524839529	4752	1658.032	4.681614411
DTW-16	Sagladah	1720	0.946413706	4950	574.518	4.953310383
DTW-17	Ajugara	3630	0.909316596	4818	1204.026	6.79239634
DTW-18	Sefaltala	4470	0.874630121	4818	1504.144	7.216625981
DTW-19	Ajiganti	2260	0.860881523	5016	761.122	5.236694336
DTW-20	Pitavog	6750	1.137266641	4752	2041.716	11.2309375
DTW-21	Elatpur	6030	1.335412329	4818	1543.808	11.09565635
STW-22	Kamarkhula	9200	1.423257395	4092	2558.07	15.06469414
STW-23	Saheberabad	7400	2.527227778	4422	1331.655	18.68736782
STW-24	Baroikhali	6020	7.089738687	4092	474.33	30.97561067
DTW-25	Chalna	4790	8.088820302	5016	313.294	28.28099476
STW-26	Budrapara	4620	2.995137349	4620	688.596	16.23474119
DTW-27	Hatbati	1160	53.48091873	4950	9.203	30.26205031
DTW-28	Kuriya(Amirp)	1680	1.362124054	4818	429.389	6.170557185
STW-29	Beside Kuriya	1730	1.801157286	4818	375.475	7.508439554
DTW-30	Gallamari Bz	1020	3.064458866	5016	152.895	7.877505574
STW-31	Betaga	670	0.077998111	4026	512.934	0.398764989
DTW-32	Nasirpur	9150	2.177850116	4224	2053.36	20.15169859
DTW-33	Matbari	790	0.129299856	4752	503.89	0.632339193
STW-34	Paikgacha DP	4330	0.777153615	4554	1811.284	7.243907381
STW-35	Romardanga	5580	0.522332334	4422	4088.032	7.145398128
DTW-36	Chukannagar	1420	7.15647868	4950	105.771	15.34706539
DTW-37	Sajira(Dumuria)	560	0.348547789	4950	320.091	1.372550217
DTW-38	Dumuria Bazar	630	0.413755511	4884	346.659	1.683203315
DTW-39	Islamnagar	850	1.463208279	5148	109.665	3.278293469
SW-40	Ajugara-SW	570	0.754905043	4818	212.315	2.401577447
SW-41	Elatpur-SW	480	0.123203679	4884	437.953	0.559598644
SW-42	Romard-SW	1590	2.878773695	4554	719.702	16.70079305
SW-43	Beside-K-SW	280	0.924603988	4719	354.793	3.781312418
SW-44	Saheber-SW	950	0.184062545	4290	187.379	0.569338022
SW-45	Kamark-SW	4950	2.526633384	4752	168.9215	5.419454783

2.3 Chloride Toxicity

Chloride toxicity of groundwater is determined on the basis of table 4.

TABLE 4
CHLORIDE TOXICITY AYERS AND WESTCOT (1989).

Term	Chloride (meq/l)
No toxicity	< 4
Slightly toxicity	4-10
Severe toxic	> 10

2.4 Salinity Hazard

Based on the Electrical Conductivity (EC), water is classified by the table 5.

TABLE 5
WATER CLASSIFICATIONS FOR SALINITY HAZARD

Term	EC (µS/cm)
Unrestricted use	< 700
Restricted use	700-3000
Not suitable	> 3000

2.5 Hardness

Hardness (HT) is customarily expressed as the equivalent of calcium carbonate (Todd, 1980). Thus:

HT = {Ca^{2+} (mg/l) × Molecular Weight of $CaCO_3$ / Atomic Weight Ca}+ {Mg^{2+} (mg/l) × Molecular Weight of $CaCO_3$ / Atomic Weight Mg}
= {Ca^{2+} (mg/l) × 100.08 / 40.08} + {Mg^{2+} (mg/l) × 100.08 / 24.31}

Where, HT, Ca^{2+} and Mg^{2+} measured in milligram per litter and the ratios are in equivalent weights. Thus the above equation reduced to

$$HT = 2.5\ Ca^{2+} + 4.1\ Mg^{2+}$$

Hardness of water is determined on the basis of table 6 shown below:

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TABLE 6

QUALITY CLASSIFICATION OF WATER FOR DRINKING (SAWYER AND CARTY, 1967)

Hardness (mg/l)as $CaCO_3$	Water Class
0-75	Soft
75-150	Moderately Hard
150-300	Hard
>300	Very hard

For drinking water quality assessment, Drinking water standard of World Health Organization (WHO_1983) and Government Republic of Bangladesh (DOE_1997) were used shown in table 7.

TABLE 7

CORRELATION CHART FOR DRINKING WATER.

Parameters	*Unit*	*WHO Std. 1983*	*DOE Std. 1997*	*B'desh Std. 1997*	*Obtained results for DW*		*Number of samples exceeding-BS*
		Drinking water recom. limit	**Drinking water recom. limit**	**Drinking water recom. limit**	**Min.**	**Max.**	
Calcium	mg/l	200	75	75	1.50	1137	35
Magnesium	mg/l	50	30-35	30-35	1.33	324	25
Sodium	mg/l	200	200	200	12.83	1505	25
Potassium	mg/l	-	12	12	0.65	45	11
Iron	mg/l	0.3	.03-1.0	0.3-1.0	0	10	15
Chloride	mg/l	250	150-600	150-600	8.88	3239	21
Total Hardness	mg/l	500	200-500	200-500	9.2	4088	24
TDS	mg/l	1500	1000	1000	184.8	6732	28

3 RESULTS AND DISCUSSION

3.1 Electrical Conductivity (EC)

The Electrical Conductivity (EC) value of groundwater of the study area ranges from 0.56 mS/cm to 10.2 mS/cm. Maximum Electrical Conductivity (EC) was recorded at Atlia-1 at Terokhada (Sample ID: DTW-12) and minimum at Sajira at Dumuria (Sample ID: DTW-37)(Figure: 3).

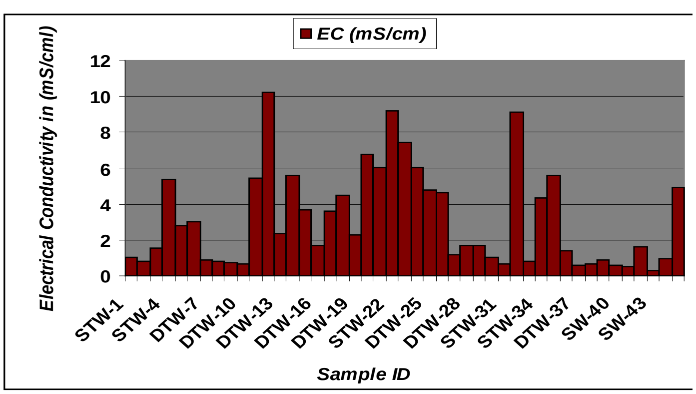

Fig. 3. EC hydrograph in groundwater samples of the study area.

3.2 Total Dissolved Solid (TDS)

TDS in groundwater at different locations of the study area ranges from 369.6 mg/l to 6732 mg/l where the maximum TDS value was found in Atlia, Terokhada (Sample ID: DTW-12) and the minimum in Sajira, Dumuria (Sample ID: DTW-37) (Figure: 4). The range of surface water TDS is from 184.8 mg/l to 3267 mg/l where the maximum TDS value was observed at Kamarkhula (Sample ID: SW-45) and the minimum at Kuriya (Sample ID: SW-43).

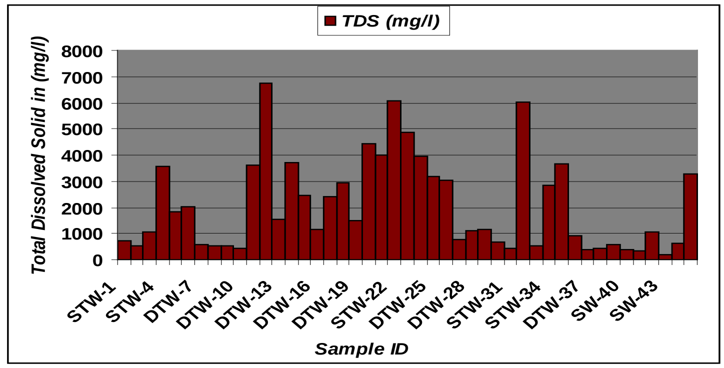

Fig. 4. TDS hydrograph in groundwater samples of the study area.

3.3 Sodium (Na^+)

Maximum Na^+ ion concentration of 1505.33 mg/l was observed in Nasirpur, Paikgacha (Sample ID: DTW-32) and minimum of 14.868 mg/l in Betaga, Dumuria (Sample ID: STW-31). The Na+ ion concentration ranges in surface water from 122 mg/l to 495.63 mg/l where the highest Na+ ion concentration was found in Romardanga, (Sample ID: SW-42) and minimum in Shaheberabad, Dacope (Sample ID: SW-44) (Figure: 5).

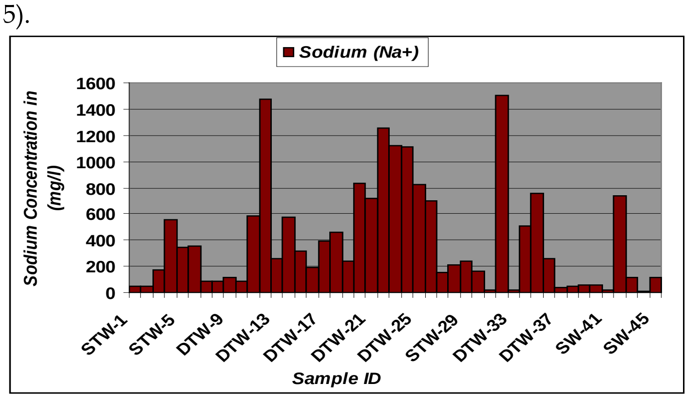

Fig. 5. Diagram representing Na^+ concentration of sampled groundwater.

3.4 Potassium (K^+)

The K^+ ion concentration of the study area ranges from 0.652 mg/l to 45.825 mg/l in groundwater. Maximum K^+ ion con-

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centration was found in Atlia, at TerokhadaUpazila (Sample ID: DTW-12) and the minimum in DighaliaUpazila (Sample ID: STW-2). The maximum K^+ ion concentration of surface water is 11.682 mg/l in Romardanga, at Paikgacha (Sample ID: SW-42) and 1.776 mg/l is the lower limit of K^+ ion concentration in Saheberabad, at Dacope (Sample ID: SW-44) (Figure: 6).

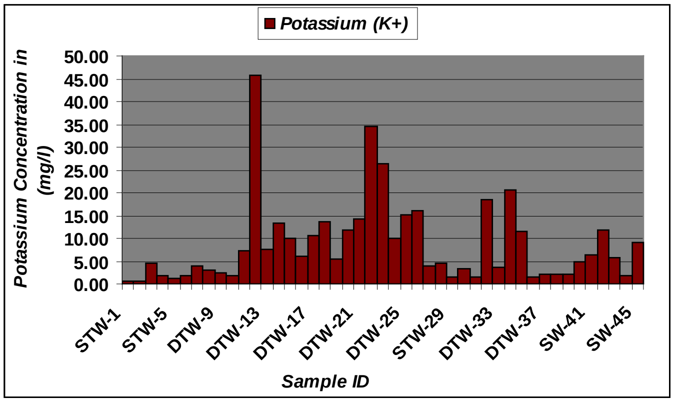

Fig. 6. Bar Diagram representing K^+ concentration of sampled groundwater.

3.5Calcium (Ca^{2+})

The Ca^{2+} ion concentration of the study area ranges from 1.5 mg/l to 1137.44 mg/l in groundwater. Maximum Ca^{2+} ion concentration was found in Romardanga, Paikgacha (Sample ID: STW-35) and the minimum in Hatbati, Batiagata (Sample ID: DTW-27). The maximum Ca^{2+} ion concentration of surface water is 207.16mg/l in Romardanga, Paikgacha (Sample ID: SW-42) and 12.48 mg/l is minimum in Kamarkhula, Dacope (Sample ID: SW-45) (Figure: 7).

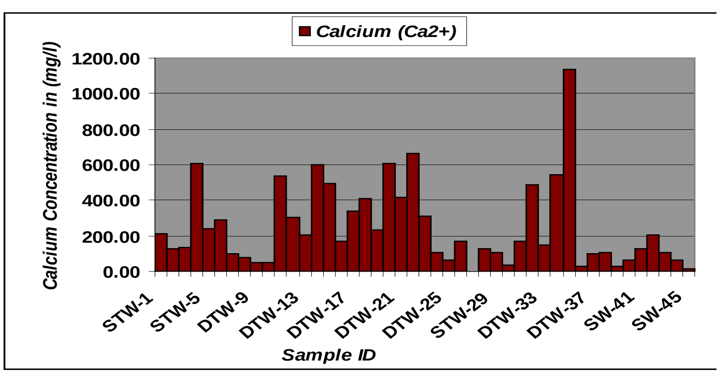

Fig. 7. Diagram representing Ca^{2+} ion concentration of groundwater samples.

3.6Magnesium (Mg^{2+})

The Mg^{2+} ion concentration of the study area ranges from 1.33mg/l to 324.44 mg/l in groundwater. Maximum Mg^{2+} ion concentration was found in Barasat, Terokhada (Sample ID: DTW-14) and the minimum in Hatbati, Batiaghata (Sample ID: DTW-27). The Mg^{2+} ion concentration of surface water ranges from 8.19 mg/l to 33.59 mg/l where the maximum concentration was found in Kamarkhula (Sample ID: SW-45) and in Saheberabad (Sample ID: SW-44) (Figure: 8).

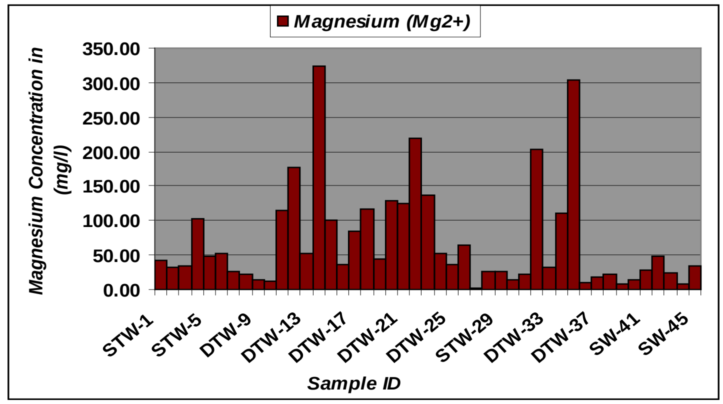

Fig. 8. Bar Diagram representing Magnesium concentration of water samples.

3.7Bicarbonate (HCO_3^-)

HCO_3^- ion concentration in groundwater range from 213.5 mg/l to 892.125 mg/l. The maximum HCO_3^- ion concentration 892.125 mg/l was observed in Baroikhali, in Dacope (Sample ID: STW-24) and the minimum of 213.5 mg/l in Romardanga, in Paikgacha (Sample ID: STW-35). In surface water HCO_3^- ion concentration ranges from 122 to 495.625 mg/l (Figure: 9).

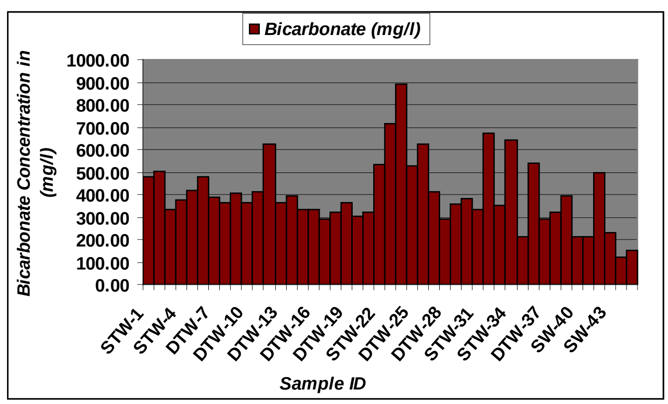

Fig. 9. Bar Diagram representing HCO_3^- concentration of sampled groundwater

3.8Chloride (Cl^-)

The Cl^- ion concentration of the study area ranges from 8.875mg/l to 3239.375 mg/l. The highest ion concentration of 3239.375 mg/l was observed in Nasirpur, at PaikgachaUpazila (Sample ID: DTW-32) and the lowest of 8.875 mg/l in Jamira Bazar, at PhultalaUpazila (Sample ID: DTW-10) (Figure: 10).

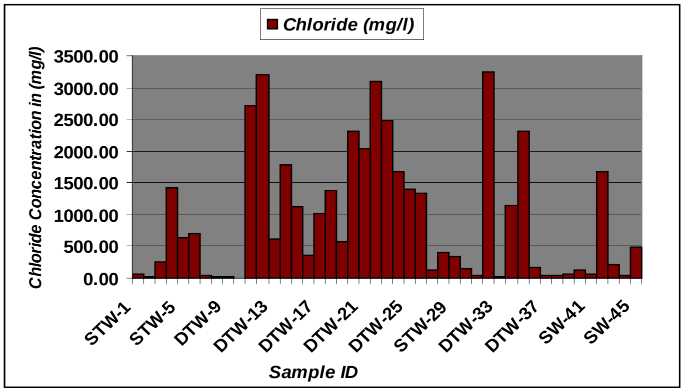

Fig. 10. Bar Diagram representing Cl^{-} concentration of sampled groundwater.

3.9Iron (Fe^{2+})

The Fe^{2+} ion concentration of the study area ranges from 0.0 to 5.574 mg/l in groundwater. Maximum concentration was found in Paikgacha DPHE Office, Paikgacha (Sample ID: STW-34) and the minimum in Barakpur-1, Dighalia (Sample ID: DTW-3). The maximum Fe^{2+} ion concentration range of surface water is 0.481 mg/l in Kuriya (Sample ID: SW-43) and 0.025 mg/l is the lower limit in. Saheberabad-Surface water (Sample ID: SW-44) (Figure 11).

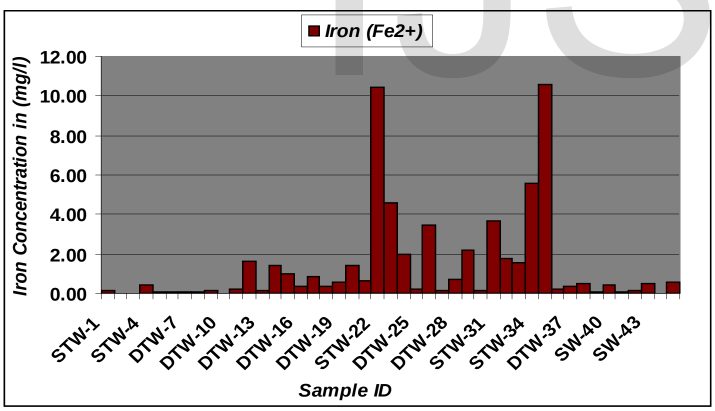

Fig. 11. Diagram representing Iron concentration of sampled groundwater

3.10Hardness

The presence of Hardness results from divalent metallic cations, of which calcium and magnesium are the most abundant in groundwater. Total hardness in groundwater at different locations of the study area ranges from 9.203 mg/l to 4088.032 mg/l (Figure: 12). Maximum samples are very hard type and the highest was found at Romardanga, Paikgacha (Sample ID: STW-35) and the minimum at Hatbati, Batiagata (Sample ID: DTW-27). Only one groundwater sample is soft at Hatbati, Batiagata (Sample ID: DTW-27). However for surface water total hardness varies from 168.921 mg/l to 719.702 mg/l where the maximum value was found at Romardanga (Sample ID: SW-42) and the minimum at Kamarkhula (Sample ID: SW-45).

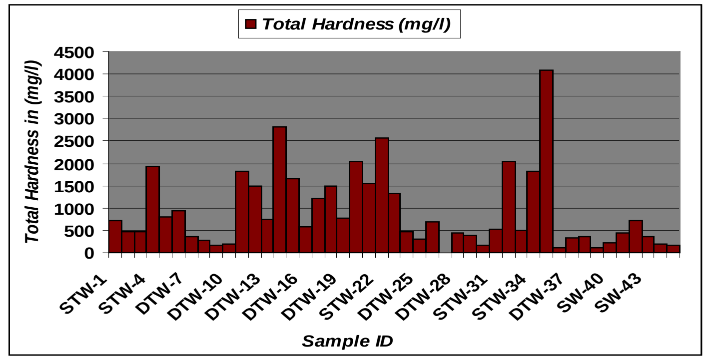

Fig. 12. Diagram representing Total Hardness (mg/l) concentration of groundwater samples.

3.11Sodium Adsorption Ratio

For typical irrigation waters, the quality of irrigation water depends primarily on the presence of dissolved salts and their concentrations. Sodium Absorption Ratio (SAR) is one of the most important quality components, which influence the water quality and its suitability for irrigationAverage Sodium Absorption Ratio (SAR) ranges from 0.28 to 21.90 in groundwater and from 0.39 to 11.80 in surface water.

3.12Kelley's Ratio (KR)

A Kelley's Ratio (KR) of more than one, indicates an excess level of sodium in waters. Hence, waters with a Kelley's Ratioless than one are suitable for irrigation, while those with a ratio more than one are unsuitable. KR ranges from 0.12320 to 2.8787 in surface water and 0.17421 to 53.480913 in ground water.

3.13Chloride Toxicity

Chloride toxicity of groundwater is showed in the figure: 13 according to Ayers and Westcot (1989). From the figure it is observed that Cl^{-} concentration exceed the toxicity level in 24 samples. Five samples are slightly toxic. Others are not toxic.

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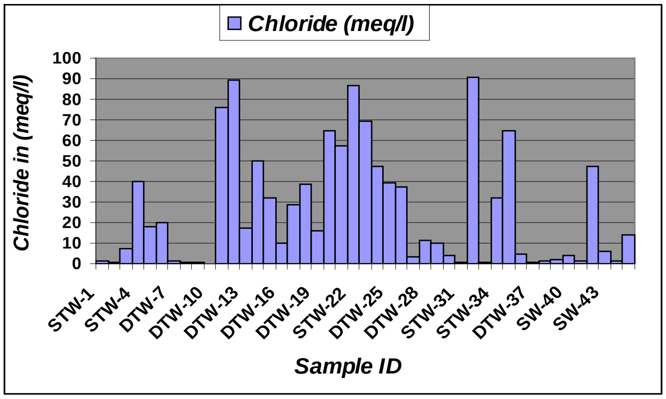

Fig. 13. Chloride Toxicity in the groundwater samples.

3.14Salinity Hazard

According to the FAO guidelines (Ayers and Wescott, 1989) for irrigation water quality, water with less than 700 µS/cm that is suitable for unrestricted use. The salinity hazard is presented in figure: 17 which show that, 19 samples exceed the restricted use. Rest are suitable for use in irrigation.

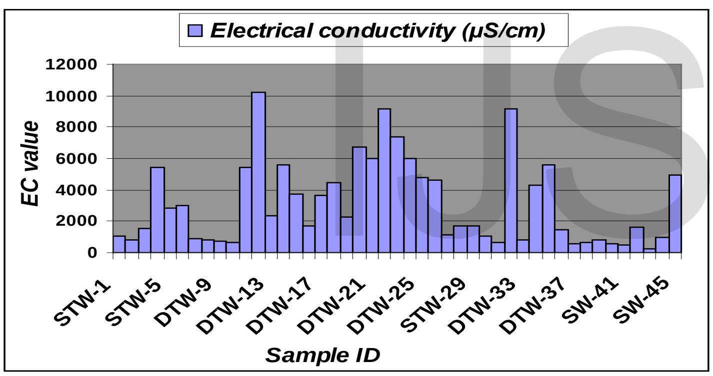

Fig. 14. Salinity Hazard in the groundwater and surface water samples.

Hydrochemical characteristics of the study area are represented in Piper Trilinear Diagram and Box and Whisker diagram. The Piper Trilinear Diagram is constructed by plotting major ions in two triangles using HYDROCHEM, ascations and anions percentage in mg/l. Total cations and anions are each considered as 100% (Figure: 15). Maximum water samples are mixed type of Ca-HCO_3^- and Na-HCO_3^-. Some shallow and surface water are Ca-HCO_3^- type and rest of deep water samples are Na-HCO_3^- type.

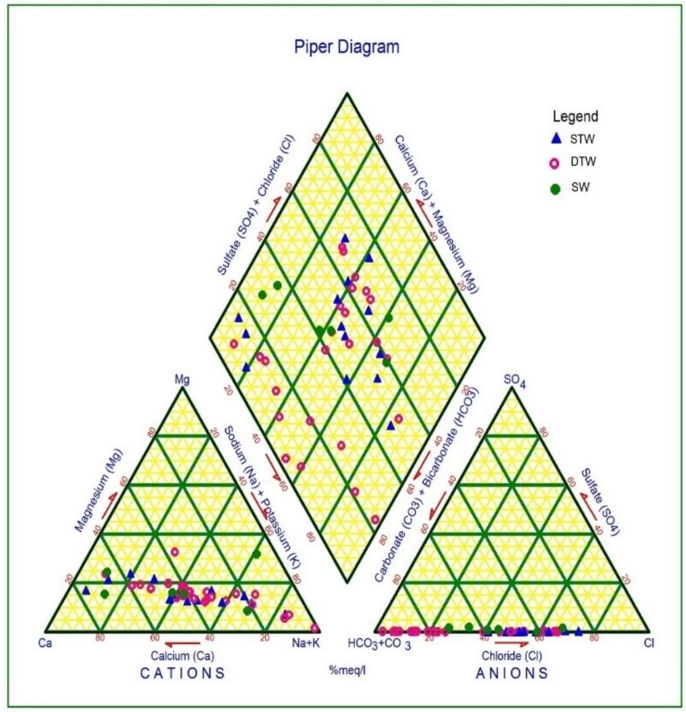

Fig. 15. Plots of groundwater samples (Khulna) on Piper Diagram.

In Box and Whisker diagram, vertical axis represents the concentration of Cations and Anions (Figure: 16) in milligram per liter. Box and Whisker Diagram for the studied groundwater samples have been constructed by using AQUACHEM Software. It shows that Cl^-, Na^+ and Ca^{2+} have the higher concentration in water sample.

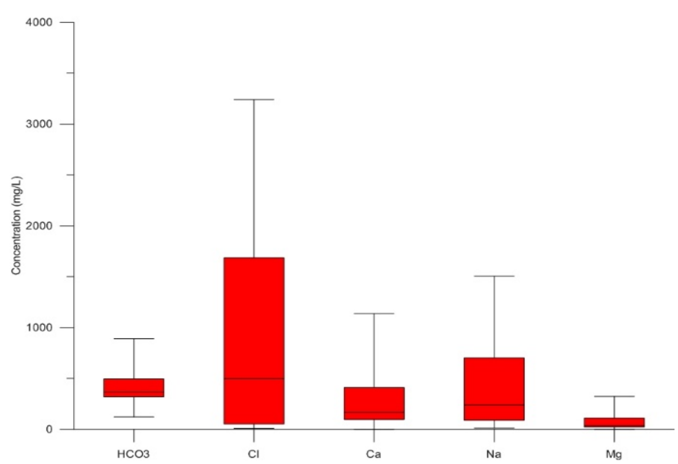

Fig. 16. Plots the major ions concentration (mg/l) in Box and Whisker diagram.

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4 Conclusion

According to the chemical characteristics, comparative charts, and hydro-chemical facies analyses it is concluded that the physical and chemical parameters of Deep water, Shallow water and surface water are unlike to each other. The value of Electrical conductivity, Total dissolved solid, and hardness of the water samples proved that, maximum water samples were not suitable for drinking purposes. The concentration value of major elements, trace element in the water samples indicates that, most of the samples are saline water where Cl-, Na+ and Ca2+ have the higher concentration. Because of the minimum value of Sodium Absorption Ratio (SAR), and as about 50 % Kelly's ratio values for the GW and SW of the study area are less than 1 indicate good quality for irrigation. The majority of the groundwater samples are mixed type.Hardness of the all groundwater sample ranges from 9.203 mg/l to 4088mg/l in groundwater and 68.92 mg/l to 719.709 mg/l in surface waterwhich indicate maximum groundwater is hard type and the surface water is less hard than groundwater. According to Bangladesh, WHO, DOE drinking water standards some ground water and surface water of the study area is not suitable for human consumption and mostly be used for irrigation purpose only.

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