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Research Article

ASSESSMENT OF GROUNDWATER QUALITY FOR DRINKING PURPOSES IN SOME PARTS OF JHENAIDAH DRISTRICT, BANGLADESH

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ABSTRACT

This Research project deals with the groundwater quality with the special emphasis to drinking uses of Shailakupa Upazila, Jhenaidah District and covers the area of about 572.91 Sq. Km. The study area is finely communicated with Kustia, Magura and Jhenaidah District. The major objectives of the research work are as follows to collect the water sample from different sites in the area for proper geo-chemical assessments. To assess the groundwater quality for different uses. To identify the nature and extent of the health hazard due to toxic elements. From the shallow tube-wells and Tara pumps, water samples were collected and analyzed for the chemical composition according to their suitability for drinking purposes. The physical and chemical analysis of groundwater in the study area included cations (Ca, Mg, Na, K) anions (HCO_3, Cl, SO_4, PO_4) and trace elements (Fe total, B) also included pH, EC, TDS, SAR, RSBC,SSP,TH, PI, for the classification of water based on different uses especially on drinking purses. All the cations, anions and the trace elements were analyzed in the Soil Research Development Institute (SRDI) Shampur, Rajshahi and science Laboratory, Shampur, Rajshahi. Major cations were analyzed through EDTA Titrimetric Method and Flame photometric Method. Major anions were analyzed through Titration Method and Calcium-bi-phosphate extraction method. And Trace elements were analyzed through Phenanthroline method and cucurmin mathod. The concentration of Mg, Na, HCO_3, Cl, SO_4, PO_4 and B in groundwater of the study area does not exceed WHO and DOE drinking water standard value. As such, groundwater of the study area can be considered suitable for drinking purposes. But the concentration of Ca and Fe total were slightly higher than the permissible limit suggested by DOE for drinking purposes and TH of groundwater is very hard. From graphical analysis of water samples, it is observed that alkaline earths (Ca, Mg) exceeded alkaline (Na, K) and weak acid (HCO_3) exceeded strong acids (Cl, SO_4 and PO_4). From the Piper Trilinear, Collin's bar graph and Facies mapping diagram shows that the groundwater of the study area is good. Also the values of pH, TH were within permissible limit. So the groundwater of the study area is suitable for drinking purposes. The groundwater of the study is ironically balanced water.

Key Words: *Chemical Analysis, Health Hazard, Shallow Tube-Wells, Drinking, Permissible Limit*

INTRODUCTION

Water is absolutely the most necessary commodity for the substance and well being for mankind. Most of the available sources and of fresh water lies underground. With the ever increasing demand of water, the importance of utilization of water is increasing at an accelerated rate throughout the world. So the quality of ground water is very much essential as well as quantity. Water quality refers to the characteristics of the water supply that will influence its suitability for a use i.e. how well the quality meets the needs of the user. The desired quality of groundwater supply depends on its purpose of uses i.e. for drinking, agricultural, industrial and municipal purposes.

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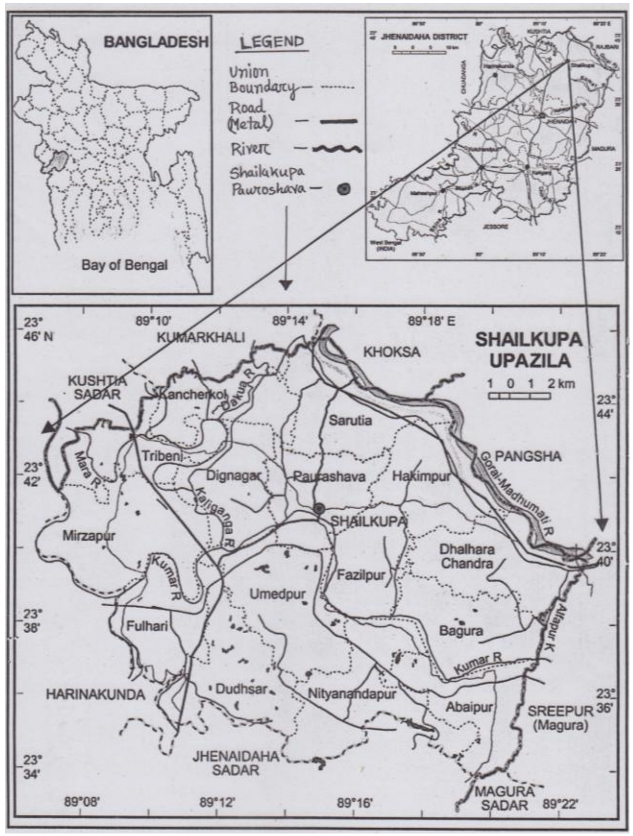

Figure 1: Location map of the study area

The study area covered the entire area of shailakupa upazila, Jhenaidah, Bangladesh. It is located between the geographical co-ordinates 23°46′N to 23°34′N latitude and 89°08′E to 89°22′E longitude and covers the area of about 572.91 Sq. Km. The study area bounded in the North by Kustia Sadar, in the South by Jhenaidah Sadar, in the East by Sreepur Upazila of Magura District and in the west by Harinakundu Upazila of Jhenaidah District. The River Gorrai-Madhumati is passing through the North-Eastern part of study area. Groundwater is highly important and dependable source of water for drinking, industrial, irrigation and domestic purposes in Bangladesh. The habitants of shailakupa upazila supper to get pure drinking and Irrigation water, there were insufficient work in this area especially for drinking purposes. In this regards a research work was under taken to analysis the quality of groundwater for drinking purpose. The detail and precise hydrological investigation has not been carried out in the study area. But some partial works carried out by Department of Public Health Engineering (DPHE), Jhenaidah. Bangladesh water Development Board (BWDB), Jhenaidah.

MATERIALS AND METHODS

The steps necessary for the completion of the research work may be classified as

Data Collection: Data were collected from different organizations.

Field investigation: Water samples were collected by random sampling in the field. It was decided to collect water samples from shallow tube-wells, hand tube wells and Tara pumps. These were collected from all over the union. Total 28 wells were selected for collecting water samples. Water samples were collected in sterilized plastic bottles from a well only after it has been pumped for some times (Minimum 15 minutes). The bottles were cleaned two times with pumping water before collecting the samples and tightly sealed after collection. For field measurement of p, a portable pH meter (HANNA pocket pH meter) was used. EC and temperature of water samples were measured by EC meter (HANNA HI 7039p) and thermometer respectively. During sampling one un-acidified sample was collected for major cation and anaion analysis. The other one sample was acidified to low pH with hydrochloric acid (HCl) for determination of iron (Fe) concentration.

Laboratory Analysis: All the ground water samples were analyzed to determine the concentration level of different ions such as actions (Ca, Mg, Na, K); anaions (HCO_3, Cl, SO_4, PO_4) and the trace elements (Fe total, B).

Data Presentation and Interpretation: The results of chemical analyses of ground water were presented by the program of One-Way ANOVA of SPSS 16.0 version in accordance with the objectives of the study.

Literature Review

Ahmed *et al.*, (2001) investigated the quality of groundwater of Samta village, Sharsha Upazila, Jessore district. The quality of groundwater of that area shows partially suitable for drinking purpose and public health; good for irrigation and not suitable for industrial purpose. Iron content of groundwater varies from 0.07 to 3.53mg/l which was not suitable for drinking purposes. Satter and Yeasmin (2002) shows the groundwater quality of Ishawardi and Atgharia Upazila, Pabna district. Results of chemical analysis reveals that the water of the study area was within compatible limit for all purposes as well as drinking, domestic and irrigation uses.

RESULTS AND DISCUSSION

Aquifer System of the Study Area

The aquifer system of the study area has been divided on the basis of bore log data collected from DPHE, Shailakupa, Jhenaidah. The aquifer system is classified as aquitard **w**hich covers the uppermost layer of the study area and comprises of mainly clay to fine sand materials. Aquifer is the main underground water sources comprise of medium to coarse grained sandy sediments. The thickness of the main aquifer is more than 30m.Hence this aquifer is potentially good for water availability and most of the tube-wells and Tara pumps are installed in this unit.

Analysis and Results of the Quality of Groundwater Samples

The analytical results are very much important to determine the groundwater quality of the study area. The results of chemical analysis of groundwater samples are represented in the Table 1.

In the field, the physical parameters such as Hydrogen ion concentration (pH), Electric Conductance (EC), Temperature (°C), Total Dissolved Solids (TDS), and total Hardness (TH) were measured. The values ranges from pH; 6.4 to 8.2 average 7.02, EC; 395.1μs/cm to 568.7μs/cm average 479.6, Temperature (°C); 26°C to 32°C, Total Dissolved Solids (TDS); ranges from 263.7 mg/l to 369.1mg/l and Total Hardness (TH); 243.2 mg/l to 303.1 mg/l which are suitable for drinking purposes.

Determination of Major Cations

Calcium(Ca++)

Calcium is the most abundant element of the alkaline-earth metals and major constituents of common rock minerals. The calcium concentration ranges from 71.6mg/l to 97.5mg/l in Rajnagar and Fulhari union respectively.

The upper limit of calcium for drinking purpose is 75mg/l (DOE, 1997). In the study area, the concentration of Ca++ is higher than permissible limit. Magnesium (Mg++): Magnesium is abundant element in the nature, it causes hardness of water. The maximum and minimum Magnesium content of the study area is 19.7mg/l and 10.2mg/l in Mirzapur and Hakimpur Union respectively. The average value is 14.1mg/l. Magnesium contents are within the acceptable limit for drinking purposes.

Sodium(Na^{++})

Sodium is the most abundant element of water. In the study area the concentration of Na^+ ranges from 13.8mg/l to 40.2mg/l in Umedpur and Dhalahara Chandra Union respectively. The average value is 26.5mg/l. Sodium content is generally within the safe limit.

Potassium(k^+)

Potassium is slightly less common than sodium in ground water. The tolerable limit of k^+ for drinking water is 12mg/l. In the study area Potassium content varies from 2.1mg/l to 3.3mg/l. in Bogura Union and Dignagar union respectively and is suitable for drinking purposes.

Determinations of Major Anions

Bicarbonate(HCO_3): More than 200mg/l bicarbonate is common in ground water. In Most samples concentration of HCO^-_3 is higher than 200mg/l and ranges from 245mg/l (Kacherkol) to 365mg/l (Dignagar). From the analyzed data it can be stated that the bicarbonate content in groundwater of the investigated area is suitable for drinking, purposes.

Chloride(Cl): According to Johnson's(1996) Chloride classification, the concentration of Chloride in water samples of the study area have been grouped.

Chloride concentration of the study area ranges from 14.7mg/l to 35.2mg/l in Umedpur and Dhalahara Chandra Union respectively.

Sulphate(SO_4): More Sulphate dissolved in groundwater is bad for health. The Sulphate concentration ranges from 0.16mg/l to 7.8mg/l in Kacherkol and Tribeni Union respectively. The Sulphate concentration is within the permissible limits for drinking as well as other purposes.

Phosphate(PO_4^{-3}): Phosphorus is a common element in igneous rocks. The range of the study area is 0.01 to 2.3 mg/l in Hakimpur and Nittanadapur respectively.

Minor and Trace Elements

Iron(Fe): Iron is an Important trace elements in ground water that occurs in all natural waters both in the form of oxidized (ferric)as well as reduced (ferrous). Ferrous iron is solution oxidized on exposure to air and deposited as ferric hydroxide. The maximum acceptable limits of iron are 0.3mg/l as recommended by WHO (Todd D.K 1980).The iron content in the study area was measured which varies from 0.04mh/l (Kacherkol) to 4.2mg/l (Fulhari). So the iron concentration of the study area is not acceptance limit and good for drinking usages.

Boron(B^-): In the study area, the Boron content ranges from 0.01mg/l to 0.1 mg/l in Fulhari and Dudsar Union respectively.

Graphical Representation of Geo-chemical Data

The Geo-chemical Characteristics of groundwater in an area play an important role in any hydrological investigation. The qualitative analysis of ground water is based on different graphical models. There are different profound geo-chemical schemes such as Piper's (1953) Diagram, Facies mapping approach (Black, 1960), Colllin's (1923) Bargrph and Mauch's (1940) Radial Vector Diagram etc. Some of the important method's are described below.

a) Piper's Trilinear Diagram

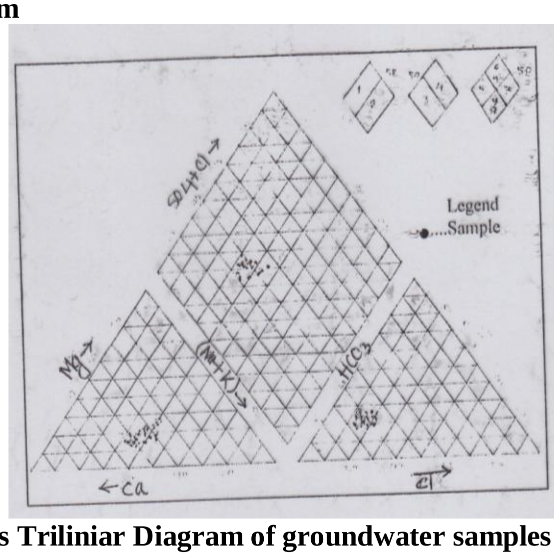

Figure 2: Piper's Triliniar Diagram of groundwater samples of the study area

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Table 1: The results of chemical analysis of groundwater samples

No	Well Location (Union)	Source	Depth in m.	Temp.°c	pH (Mean± st.dav.)	ECμs/cm (Mean± st.dav.)	TDS mg/l (Mean ± st.dav.)	TH mg/l (Mean ± st.dav.)	Major Cations(mg/l) (Mean ± st.dav.)				Major Anions(mg/l) (Mean ± st.dav.)				Trace Element (mg/l) (Mean ± st.dav.)	
									Ca++	Mg++	Na+	K+	Cl¯	HCO3-	SO4--	PO4--	Fe	B
1	Dhalahachandra1	STW	51.8	27	7.6±0.2cd	576.6 ±0.2a	369.1 ±0.1b	295.5 ±0.4d	88.1±0.2f	18.2 ±0c	40.2 ±0a	3.12±0.1ab	35.2±0.2a	351±0.5ab	0.2±0.1m	1.0±0.1e	1.1±0.1ef	0.05±0.01b
2	Dha (Karunakar)	STW	54.2	26	7.2±0.2ef	525.0 ±0.1e	336.0 ±0.3e	295.5 ±0.2d	89.2±0.2c	17.3 ±0d	37.2 ±0b	3.12±0.09ab	30.1±0.1d	322±0.3cd	0.21±0.02m	0.72±0.04f	0.5±0.1hi	0.04±0.01b
3	Hakim1 (Chamtai)	STW	54.8	27	7.4±0.1de	524.8 ±0.1e	335.9 ±0.2f	265.0 ±0.1r	81.7±0.2m	14.7 ±0g	35.5 ±0c	2.6±0.1def	34.4±0.1b	337±0.4bc	1.7±0.2f	0.01±0.0k	0.2±0.1jk	0.07±0.01b
4	Hakim2 (Doharo)	STW	36.5	29	6.8±0.1ghi	519.0 ±0.1f	332.2 ±0.2f	243.2 ±0.3z	80.3±0.2n	10.2 ±0p	34.2 ±0e	2.5±0.2ef	31.9±0.1c	328±0.2cd	1.72±0.03f	0.11±0.03jk	0.5±0.1hi	0.08±0.02b
5	Sarutia1 (Kirtinag)	Tara	51.8	28	6.6±0.2ij	538.2 ±0.2c	344.5 ±0.1c	270.5 ±0.1L	89.2±0.1c	11.4 ±0o	34.7 ±0f	2.2±0.1gh	26.2±0.2f	364±0.3a	0.9±0.02ghijklm	0.2±0.1ijk	1.3±0.3e	0.04±0.02b
6	Sarutia2 (Katlagar)	STW	57.9	28	6.7±0.2hij	532.6 ±0.1d	340.9 ±0.5	273.7 ±0.1i	88.7±0.1d	12.5 ±0L	31.7 ±0h	2.7±0.2def	26.7±0.2e	357±0.5a	0.98±0.01fghijkl	0.25±0.03hijk	2.4±0.1d	0.06±0.01b
7	Dignag1 (Aganiapa)	STW	41.1	28	6.6±0.1ij	524.8 ±0.1e	335.9 ±0.2f	274.0 ±0.3i	87.1±0.1g	13.6 ±0i	31.5 ±0h	2.8±0.1cde	24.3±0.1k	358±0.1a	0.49±0.02jklm	0.3±0.1hij	0.4±0.2ij	0.08±0.01b
8	Dignag2 (Gopalpu)	STW	36.5	27	6.8±0.1ghi	532.8 ±0.2d	340.5 ±0.4d	276.0 ±0.4g	85.3±0.0h	15.2 ±0f	30.2 ±0i	3.3±0.1a	25.1±0.1h	365±0.5a	0.52±0.04jklm	1.2±0.1de	0.8±0.1g	0.07±0.02b
9	Kacher1 (Kachua)	STW	53.3	27	6.4±0.3jk	545.9 ±0.3b	385.4 ±0.3a	268.0 ±0.2n	84.7±0.1i	13.6 ±0i	40.2 ±0a	3.0±0.1a	24.7±0.2i	270±0.4ijk	1.59±0.02fg	1.3±0.25d	0.04±0.01k	0.06±0.01b
10	Kacher2 (Mirjapur)	STW	36.5	26	6.4±0.05jk	436.8 ±0.1u	279.6 ±0.3v	258. ±0.1w	83.2±0.1L	12.1 ±0m	21.2 ±0s	2.7±0.1b	18.6±0.1n	285±0.2fghi	0.16±0.01m	1.98±0.01c	0.05±0.02k	0.04±0.01b
11	Tribeni1 (Nichhint)	STW	42.6	32	6.9±0.1fghi	466.8 ±0.2n	298.8 ±0.2n	267.6 ±0.1o	88.4±0.1e	11.2 ±0o	23.2 ±0p	2.6±0.1d	20.1±0.1l	310±0.3de	0.018±0.01m	1.2±0.1de	0.05±0.02k	0.02±0.01b
12	Tribeni2 (Basanta)	STW	18.2	27	6.8±0.1ghi	493.3 ±0.3i	316.4 ±0.3i	3031. ±0.2b	90.1±0.1b	18.7 ±0b	22.3 ±0q	2.4±0.1c	19..3±0.2m	312±0.3de	7.8±0.1a	2.2±0.2ab	0.7±0.2gh	0.02±0.01b
13	Mirjapur1(Mirjap)	STW	18.2	27	6.6±0.2ij	412.0 3±0x	263.7 ±0.2y	359.0 ±0.1a	72.8±0.2o	18.5 ±0b	19.3 ±0t	2.8±0.1d	15.1±0.1p	257±0.1k	6.2±0.2b	2.3±0.2a	0.8±0.2g	0.04±0.00b
14	Mirjapur2(Rajnaa)	STW	18.2	27	6.8±0.1ghi	417.0 ±0.2w	266.9 ±0.1x	261.0 ±0.1t	71.4±0.1p	25.7 ±0a	18.4 ±0u	3.1±0.1s	15.2±0.1p	263±0.4jk	5.2±0.2c	2.1±0.2ab	2.7±0.2c	0.05±0.03b

15	Fulhari1 (Fulhari)	STW	39.6	27	7.0±0.4ef	468.9 ±0.1m	300.1 ±0.1m	274.5 ±0.2h	90.3±0.1b	11.7 ±0n	26.4 ±0L	2.9±0.2e	24.6±0.3j	278±0.3hij	4.2±0.2d	0.4±0.1ghi	3.4±0.1b	0.06±0.01b
16	Fulhari2 (Chandpu)	STW	36.5	27	7.1±0.2efg	508.5 ±0.3g	325.5 ±0.3g	300.4 ±0.1c	97.5±0.2a	13.6 ±0i	31.5 ±0h	2.6±0.2f	24.4±0.2jk	298±0.6efg	3.2±0.1e	0.5±0.1fgh	4.2±0.1a	0.01±0.0b
17	Dudhsar1 (Tripura)	STW	48.76	27	7.2±0.1ef	477.3 ±0.3k	305.0 ±0.3k	287.0 ±0.2e	87.3±0.2g	16.6 ±0e	27.2 ±0j	2.7±0.2d	24.3±0.2k	296±0.4efgh	1.7±0.2f	0.6±0.2fg	0.05±0.01k	0.01±0.00b
18	Dudhsar2 (Bhatai)	STW	51.76	28	7.1±0.1efg	466.1 ±0.4o	294.5 ±0.2q	272.0 ±0.1k	85.3±0.2h	14.2 ±0g	26.6 ±0Lk	2.6±0.3c	24.2±0.1k	285±0.3fghi	1.5±0.1fgh	0.3±0.1ghi	0.04±0.02k	0.03±0.01b
19	Bagura1 (Ratnat)	STW	42.6	26	8.2±0.1a	461.5 ±0.2p	295.4 ±0.2p	251.0 ±0.3y	80.2±0.1n	12.1 ±0m	25.8 ±0m	2.5±0.3cd	25.1±0.1h	300±0.9ef	1.3±0.1fghi	0.4±0.2ghi	0.5±0.2hi	0.05±0.01b
20	Bagura2 (Kamolna)	STW	48.7	27	8.1±0.1ab	483.9 ±0.1j	309.7 ±0.2j	286.0 ±0.1f	88.5±0.1de	13.2 ±0j	26.7 ±0k	2.1±0.1a	25.3±0.1h	309±0.1bc	1.2±0.1fghij	0.5±0.1fgh	0.7±0.1gh	0.1±0.0b
21	Abaipur1 (Jugni)	STW	48.7	27	7.8±0.05bc	497.5 ±0.1h	318.7 ±0.1h	273.0 ±0.2j	89.2±0.1c	12.9 ±0k	24.7 ±0o	2.2±0.1e	25.6±0.2g	324±0.1cd	1.1±0.1fghijk	1.2±0.1de	1.2±0.2e	0.07±0.24a
22	Abaipur2 (Mingra)	STW	51.76	28	7.6±0.1cd	472±0.1L	302.2 ±0.1L	269.5 ±0.2m	83.5±0.1k	14.7 ±0g	21.8 ±0r	2.5±0.2a	15.8±0.2o	325±0.2cd	0.92±0.02ghijklm	1.4±0.1d	2.4±0.1d	0.09±0.01b
23	Nittana1 (Golokn)	STW	48.7	27	6.2±0.1k	448.7 ±0.2s	286.8 ±0.1t	266.5 ±0.1q	84.7±0.2i	13.2 ±0j	25.5 ±0n	2.9±0.1e	15.2±0.1p	290±0.3fgh	0.72±0.2ijklm	2.1±0.2ab	0.4±0.1ij	0.02±0.01b
24	Nittana2 (Nittana)	Tara	48.7	27	7.5±0.1d	452.8 ±0.1q	289.8 ±0.1r	254.0 ±0.2x	88.7±0.1d	11.3 ±0o	22.1 ±0q	2.6±0.1f	15.1±0.2p	310±0.3de	0.82±0.1hijklm	2.3±0.1a	0.9±0.1g	0.04±0.01b
25	Umedp1 (Raera)	STW	54.8	29	6.0±0.1ij	444.2 ±0.1t	284.3 ±0.2u	260.0 ±0.3u	81.5±0.3m	13.6 ±0i	13.8 ±0v	2.6±0.2f	14.7±0.2q	216±0.4l	0.3±0.1lm	1.3±0.1d	1.1±0.1ef	0.05±0.02b
26	Umedp2 (Bahadu)	STW	48.7	28	7.0±0.1fhg	461.7 ±0.1p	295.5 ±0.2o	261.7 ±0.1s	80.3±0.3n	14.7 ±0g	21.2 ±0s	2.7±0.1g	14.9±0.2q	313±0.2cd	0.2±0.1m	1.7±0.2c	2.5±0.1cd	0.07±0.01b
27.	Shailakupa 1(Kabi)	STW	48.7	26	6.7±0.2hij	422.9 ±0.2v	270.5 ±0.2w	259.0 ±0.4v	84.7±0.1i	12.4 ±0L	18.2 ±0u	2.2±0.1h	15.2±0.2p	280±0.3 ghij	0.4±0.2klm	0.2±0.1ijk	0.5±0.2hi	0.04±0.02b
28	Shailap2 (Fazilpu)	STW	42.6	27	7.1±0.1efg	451.4 ±0.1r	288.9 ±0.1s	267.0 ±0.3p	84.1±0.1j	13.7 ±0i	24.7 ±0o	2.4±0.2a	18.4±0.1n	294±0.3 efgh	0.5±1.9f	0.4±0.1ghi	0.7±0.2gh	0.03±0.01b

**The values are calculated as (Mean ± standard deviation)*
The different alphabets in the rows indicate significant variation (significant<0.05)

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Piper's Triliniear Diagram for representing and comparing water quality analysis is developed by Piper (1953) that serve as an important tool in separating hydro-chemical analysis data for critical studies with respect to the source of dissolved constituents(Cations: Ca^{++} Mg^{++},Na^{+} K^{+} and anions HCO_3^{-},Cl^{-},SO_4^{-2},PO_4^{-3}) in water. This diagram serves as for modification in the character of water and related geo-chemical problems. The analyzed chemical parameters were plotted in the two base triangles of the diagram where are expressed in miliequvalent per liter and the cations and anions are each considered as 100 percent. The values were then projected into the rectangle (Diamond Shaped) that represents rapid classification of water into nine areas are summarized in the Table 3.

Table 2: Distribution of ground water samples in the Piper Trilinear diagram

Field	No. of Samples	Interpretation (Liyod *et al.*, 1985)
1	Statino-1 to Station-27.	Alkaline earth exceeds alkalis
2	0	alkalis exceeds Alkaline earth
3	As in Field 1	Weak acids exceeds strong acids
4	0	Strong acid exceeds weak acids
5	As in Field	Carbonate hardness (secondary alkalinity exceeds 50% that is by alkaline earth and weak acid.

From the table it has been found that all the samples fall in the field-1 indicating that alkaline earth's exceeds alkalis. Also, the samples fall in the field-3 indicating that weak acids exceed strong acids. Finally the majority of the groundwater samples have dominant carbonate hardness (secondary alkalinity) as they belong to area-5 of the diamond, exceeds 50% in groundwater. The overall view of the analysis is that the alkaline earth's (Ca^{++} Mg^{++}) and weak acid (HCO_3^{-}) dominate the groundwater in the study area.

b) Facies Mapping Approach:

The Facies Mapping Approach developed by Back (1960) is one of the most significant ways to determine the hydro-chemical facies from chemical data. Here samples are classified according to their facies with the temples for the Piper's Trilinear Diagram. The chemical analysis data measured in meq/l with percentage of each cation and anions were plotted on the fancies mapping approach diagram. The variations and distributions of hydro chemical facies of groundwater throughout the study area are described below.

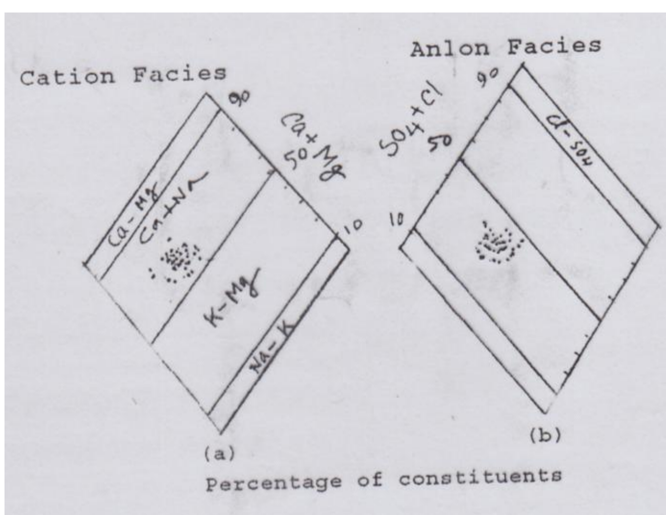

Figure 3: Facies Mapping Approach of groundwater samples

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Cation facies: It has been observed that all the cation facies of groundwater samples of the study area show calcium-Sodium facies.

Anion facies: Among the groundwater samples show Bicarbonate (eight) and Bicarbonate-Chloride-Sulfate (twenty) facies.

d) The Collin's Barograph: The Collin's Barograph represents the concentration of cations and anions of the study area are shown in figure.

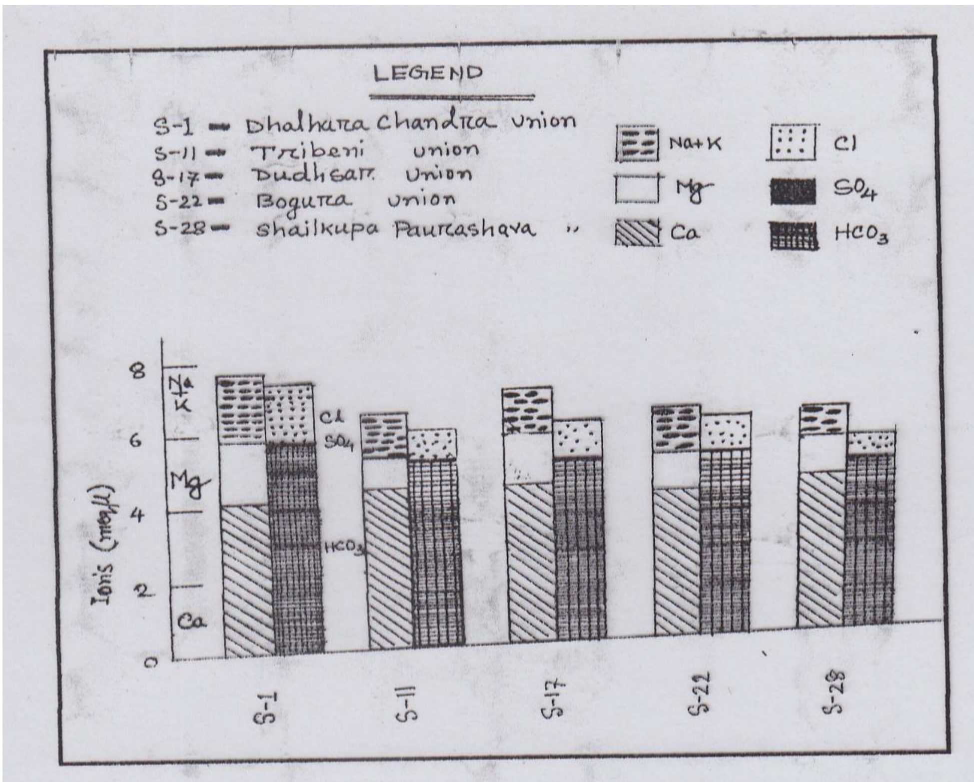

Figure 4: The Collin's Barograph of the study area.

From this Barograph the variation of ionic concentration is determined by the variation of individual height (meq/l) of each cations and anions in the cation and anion bar. The average height of cation and anion are observed that the calcium and bi-carbonate are large amount and the sulfate concentration is small amount. The highest calcium and bi-carbonate content are 4.42 meq/l and 5.75 meq/l in Tribeni and Dhalahara Chandra Union respectively. The lowest sulfate content is 0.004 meq/l (Dhalahara Chandra Union). The Figure indicates that the ground water of the study area is balance.

Classification of Groundwater

On the basis of hydro chemical properties, ground water can be classified to ascertain its suitability for various purposes. The following schemes of classification are made for multipurpose uses of groundwater.

Genetic Classification

According to Scholler (1955) water can be classified genetically from the view point of concentration of Cl^-, SO_4^{--}, HCO_3^-, etc.

a) Classification Based on Cl^-

It has been observed that the groundwater of the study area is "Normal Chloride" water class

Table 3: Classification of groundwater based on Chloride content (Scholler, 1995)

Water Class	Cl^- concentration (meq/l).	Remarks	Study area (meq/l)
Super Chloride	>7	_	
Marine Chloride	700-420	Cl^- content varies about the average sea water content of meq/l (560-140).	
Strong Chloride	420-140	_	
Medium Chloride	140-40	Cl^- content of 40 meq/l corresponds to the upper limit for normal human consumption	
Oligo-Chloride	40-15	_	
Normal Chloride	<15	_	0.63-1.53

b) Classification based on SO_4^{--}:
It may be concluded that the groundwater of the study area is "Normal Sulfate" water class.

Table 4: Classification of groundwater based on Sulfate content (Scholler,1995).

Water Class	SO_4^{--} concentration in meq/l.	Remarks	Study area meq/l
Super Sulfate	>58	58 meq/l is the concentration of sea water.	
Medium Sulfate	58-24	24 meq/l is the upper limit of SO_4^{--}	
Oligo- Sulfate	24-6	for normal use	
Normal Sulfate	<6		0.0032-0.35

c) Classification based on HCO_3^-:
The carbonate content of groundwater samples is measured and groundwater of the area is "Normal Carbonate" water class.

Table 5: Classification of groundwater based on CO_3^{--} and HCO_3^- concentration (Scholler, 1995).

Water Class	Ranges of (CO_3^{--}+ HCO_3^-) concentration in meq/l.	Study area meq/l
Super Carbonate	>7	
Normal Carbonate	2-7	4.21-5.98
Under Sulfate	<2	

Classification Based on Hardness (TH): Hardness of water mainly results from the presence of the bivalent metallic cations; calcium and magnesium (Todd, 1980). Hard water decreases the efficiency of soap by preventing foaming and makes boiler incursions. It has been found recently that, greater incidence of coronary and heart disease in areas with soft water than hard water were identified. The total hardness of water was measured by the standard formula proposed by Raghunath (1987)

Table 6: Classification of ground water based on Hardness (Raghunath, 1987)

Water Class	Ranges of hardness in mg/l as $CaCO_3$	Remarks	Study area
Soft	0-55	Requires little or no softening	
Slight Hard	56-100		
Moderate hard	101-200	Require softening	
Very hard	201-500		243.2-303.1

Drinking Water Quality Standard: The drinking water quality standards are those, which all the limitations of water use criteria recommended by world health organization (WHO, 1983) and Bangladesh water pollution control Board (BWPBC, 1976) which gives the guideline values of chemical constituent in water for drinking standard. The ground water of the study area is compared and correlated with WHO and Bangladesh standard for drinking purposes is given in the table-5.12.From this table it

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may be concluded that, all the parameters have been determined systematically are suitable for drinking and health purposes, because all the samples are within permissible limits except Ca^{++} and Fe^{total} according to DOE (1997).

Table 7: Correlation of the quality of groundwater o the study area with WHO, DOE and BWPBC for drinking purpose

Water quality Parameters	WHO standard (1983)	DOE Bangladesh standard (1997)	BWPCB standard (1976)	Concentration in the study area
pH	6.5-8.5	6.5-8.5	6.5-9	6-8.2
Temperature(°C)	-	20-30	-	26-32
TDS (mg/l)	1000	1000	1500	263.7-369.1
TH (mg/l)	50	200-500	-	243.2-303.1
Ca^{++} (mg/l)	200	75	-	71.6-97.5
Mg^{++} (mg/l)	500	30-35	-	10.2-19.7
Na^{+} (mg/l)	200	200	-	13.8-40.2
K^{+} (mg/l)	-	12	-	2.1-3.3
HCO_3^{-} (mg/l)	-	600	-	285-365
Cl^{-} (mg/l)	250	150-600	600	14.7-35.2
SO_4^{--}(mg/l)	400	400	400	0.16-7.8
PO_3^{---}(mg/l)	-	-	-	0.01-2.3
Fe^{total}(mg/l)	0.3	0.3-1.0	1-5	0.04-4.2
B^{-} (mg/l)	-	-	-	0.01-0.1

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