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Full Length Research Paper

Geochemical characterization of groundwater in Bhangamor Union, Fulbari Upazila, Kurigram

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The geochemical status of groundwater quality in Bhangamor Union under Kurigram District was determined on the basis of local geology, hydrogeology and groundwater chemistry. The study reveals that the values of environment sensitive index parameters like p^H, EC, temperature and concentration values of different chemical constituents in groundwater of the study area vary from place to place. The chemical analysis of groundwater in the study area includes cations (Ca^{2+}, Mg^{2+}, Na^+, K^+, Fe^{total}), anions (HCO_3^-, CO_3^-, Cl^-, SO_4^{2-}, I^- , F^-) and trace elements (Mn, Pb, Cr, Cd). The concentrations of Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, Cl^- and SO_4^{2-} in groundwater of the study area do not exceed WHO and DOE drinking water standard values. But the concentrations of I^- and F^- in groundwater of the study area are very low which are not suitable for drinking purposes. Correlating with WHO and DOE guideline values for drinking water and public heath, it may be concluded that the groundwater of the study area except I^- and F^- is suitable for all drinking and domestic purposes. Total Hardness (TH) of groundwater is moderately hard which indicates that it is also good in quality for irrigation purposes but not suitable for some industrial purposes especially for food making industries. From the graphical analysis of water samples, it is observed that alkaline earths (Ca^{2+} and Mg^{2+}) exceed alkalis (Na^+ and K^+) and weak acid (HCO_3^-) exceed strong acids (Cl^-, SO_4^{2-}). This confirms that alkaline earths and weak acids dominate the chemical properties of groundwater of the study area. Based on EC, PI, SAR and Na%, it can be said that the groundwater of the study area is suitable for drinking and irrigation purposes. The groundwater is also very much a satisfactory quality for livestock.

Key words: Bhangamor Union, anion, cation, groundwater.

INTRODUCTION

Water is absolutely the most necessary commodity for the survival and well being of mankind. Bangladesh being an agricultural country, water plays vital role in its economic development. Water quality refers to the characteristics of groundwater that influence its suitability for drinking and domestics uses.

The study area, Bhangamor Union, belongs to Fulbari upazilla under Kurigram district. The study area lies between latitude 25°52′N to 25°58′N and longitude 89°36′E to 89°39′E. It is bounded by Kashipur union in the north, Newashi and Hasnabad union in the east, Fulbari and Borovita union in the west and Holokhana union in the south. The area covers 43.34 km^2. The location map of the study area is shown in Figure 1.

In the study area, goiter is one of the major problems (Figure 2). Goiter is caused due to lack of iodine in groundwater. Some other problems may exist in the study area which is related to water quality.

Bangladesh comprises a major part of the Bengal Basin. Bengal Basin was formed during the Tertiary period as the Indian plate breaks away from Gondwanaland in the late Cretaceous and moved towards a collision with Eurasian plate. The study area falls within the Rangpur Saddle. Several scientific articles have already been published regarding the regional

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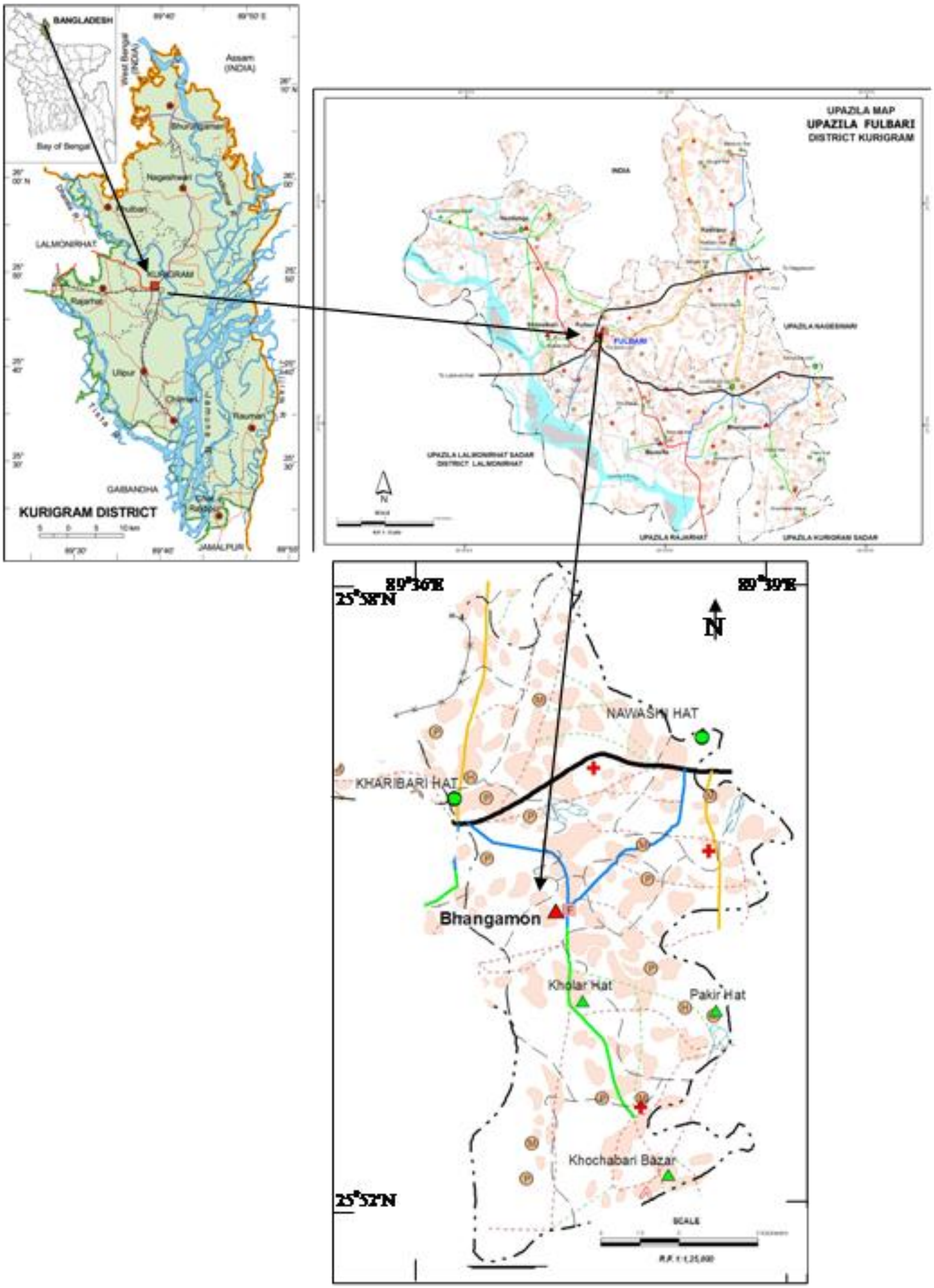

Figure 1. Location map of the study area.

Figure 2. Goiter problem in the study area.

Geology of the Bengal Basin and its surrounding area (Morgan and McIntine, 1959; Khan et al., 1999). Bangladesh is divided into two major tectonic units, one is the Precambrian platform in the northwest, and the other is the Bengal Foredeep on the southeast separated by the Calcutta, Pabna and Mymensing Hinge Zone. The northwest Precambrian Platform is divided into three major elements such as, Bogra shelf, Rangpur Saddle and Dinajpur Slope. The study area is a part of Rangpur Saddle which is a significant tectonic feature of Bangladesh.

The main objectives of this research work are to assess the groundwater quality for drinking and irrigation purposes, to characterize the hydro-geochemical processes which are dominant in the study area, and to delineate the distribution of fluorine and iodine in groundwater of the study area.

METHODOLOGY

Water samples were collected from hand tubewells in the study area. Water samples were collected from 12 designated water wells within the study area. Before collecting samples, each well was pumped for a few minutes and then water samples were collected in a new plastic bottle of 500 ml capacity, which was immediately stopper air light to protect it from air bubbles inside it. Collected samples were acidified with concentrated nitric acid (HNO_3) for determination of trace elements to prevent any reaction; another sample was acidified with 0.5N HCl for determination of iron concentration and another one was unacidified for cations and anions analysis. After collecting samples, they were transported to the laboratory for analysis.

Certain parameters are environmental and sensitive and their values are deteriorating with time and weather. For this reason, the following parameters were measured on site. pH (Hydrogen ion concentration) was measured using pH meter (Hanna). The pH meter was calibrated using the stand any buffer solution prior to sampling. EC (Electrical conductance) was measured with a pocket EC meter (Hanna HI) and the result was displayed in μS/cm. Temperature was measured with the help of scientific thermometer and the result was shown in degree Celsius. A rapid determination of Total dissolved solids (TDS) was made simply by multiplying the measured EC values (μS/cm) by the constant 0.64 (Todd, 1980).

Major cations such as Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^+), Potassium (K^+), Iron (Fe^{total}) and major anions such as Bicarbonate (HCO_3^-), Chloride (Cl^-), Sulfate (SO_4^{2-}), Fluoride (F^-), and Iodide (I^-) were determined by using SP Flame. Some trace elements like Manganese (Mn), Lead (Pb), Chromium (Cr) and Cadmium (Cd) were determined by using Atomic absorption spectrometer (AAS).

RESULTS AND DISCUSSION

The groundwater quality analysis was carried out on the basis of physical parameters and chemical analysis.

Physical parameters

The physical parameters such as hydrogen ion concentration (pH), Electrical Conductance (EC), Temperature (°C) measured in the field. These physical parameters give idea about the present quality of groundwater.

Hydrogen ion concentration

The pH is one of the most important characteristics of water. Water may be acidic, neutral or alkaline. A neutral solution has a hydrogen ion concentration of pH = 7.0,

Table 1. Results of chemical analysis of hand tubewell water samples in the study area (in mg/l).

Sample number	Cation					Anion						Trace element			
	Na^+	K^+	Mg^{2+}	Ca^{2+}	Fe^{Toal}	Cl^-	HCO^-_3	SO_4^{2-}	CO_3^{2-}	F^-	I^-	Mn	Pb	Cr	Cd
HTWS 1	9.78	0.39	3.00	55.24	1.97	10.75	163.78	1.32	3.11	0.05	0.005	1.1564	0.0468	0.0026	0.0074
HTWS 2	12.33	0.29	2.68	54.99	0.56	40.63	148.39	1.53	3.87	0.10	0.002	1.1279	0.0000	0.0136	0.0074
HTWS 3	10.50	0.25	2.58	57.05	1.33	14.82	159.60	1.27	2.93	0.05	0.004	0.8972	0.0134	0.0085	0.0037
HTWS 4	10.62	0.20	3.40	53.53	0.82	12.62	119.29	1.37	3.39	0.03	0.002	1.2987	0.0401	0.0102	0.0092
HTWS 5	9.98	0.21	5.29	52.61	0.79	28.28	105.10	1.44	4.63	0.03	0.001	0.0854	0.0268	0.0149	0.0008
HTWS 6	11.47	0.31	4.90	55.17	0.55	18.95	118.80	1.77	3.60	0.04	0.002	1.1062	0.0669	0.0187	0.0032
HTWS 7	11.03	0.25	3.14	57.12	0.35	12.68	139.73	1.67	3.50	0.09	0.003	1.5114	0.1070	0.0230	0.0032
HTWS 8	12.39	0.33	4.04	58.27	0.20	12.68	143.50	1.12	3.98	0.07	0.003	0.0659	0.0268	0.0225	0.0008
HTWS 9	13.39	0.21	3.93	54.34	0.79	8.47	127.67	1.43	4.05	0.08	0.002	0.8223	0.0134	0.0255	0.0137
HTWS 10	11.47	0.34	3.50	56.25	0.85	14.57	160.70	1.29	3.69	0.05	0.004	0.7235	0.1070	0.0204	0.0074
HTWS 11	10.88	0.30	4.42	56.21	0.34	16.50	130.00	1.55	3.73	0.04	0.002	1.0613	0.0067	0.0302	0.0119
HTWS 12	10.20	0.37	5.37	57.96	0.79	10.93	110.30	1.40	4.48	0.03	0.001	0.0427	0.0803	0.0357	0.0053

Table 2. Calculated saturation indices of mineral in aquifer using FREEQUE Software.

Sample no. / Mineral	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12
Anhydrite	-	-	-	-	-	-	-	-	-	-	-	-
Aragonite	+	+	+	+	+	+	+	+	+	+	+	+
Calcite	+	+	+	+	+	+	+	+	+	+	+	+
Dolomite	+	+	+	+	+	+	+	+	+	+	+	+
$Fe(OH)_2$	-	-	-	-	-	-	-	-	-	-	-	-
Fluorite	-	-	-	-	-	-	-	-	-	-	-	-
Gypsum	-	-	-	-	-	-	-	-	-	-	-	-
Halite	-	-	-	-	-	-	-	-	-	-	-	-
Hematite	+	+	+	+	+	+	+	+	+	+	+	+
Magnesite	-	-	-	-	-	-	-	-	-	-	-	-
Magnetite	+	+	+	+	+	+	+	+	+	+	+	+
Siderite	-	-	-	-	-	-	-	-	-	-	-	-

+ Means precipitated; - Means dissolved.

acidic has pH = 5 and alkaline has pH = 9. The pH value from the study area ranges from 7.4 to 8.7 and it indicates that neutral water (Table 1) is suitable for drinking and irrigation purposes.

Specific electrical conductance (EC)

Electrical conductance of all groundwater samples was measured in the field by a portable EC meter (HANNA pocket EC meter). Electrical conductance is directly related to the abundance of charged ionic species, that is, higher electrical conductance is the reflection of higher ionic concentration and this is especially true in case of chloride (Cl^-) concentration (Hem, 1985). The EC values of groundwater samples in the study area ranges from 163 to 865 μS/cm (Table 1). The EC value gives a good indication of the Total Dissolved Solid (TDS) present in water.

Temperature

Temperature of the study area ranges from 25 to 27°C.

Results of chemical analysis data

Water samples taken from different hand tube wells of the study area were analyzed for detailed description of the hydrochemical changes in the hand tubewell water chemistry. Results of chemical analysis from different wells of the studied area are shown in Table 2. Detailed descriptions of some major elements of these results are given hereunder:

Cations chemistry

Sodium (Na^+): Sodium is the most abundant member of alkali metal group which dissolves in groundwater.

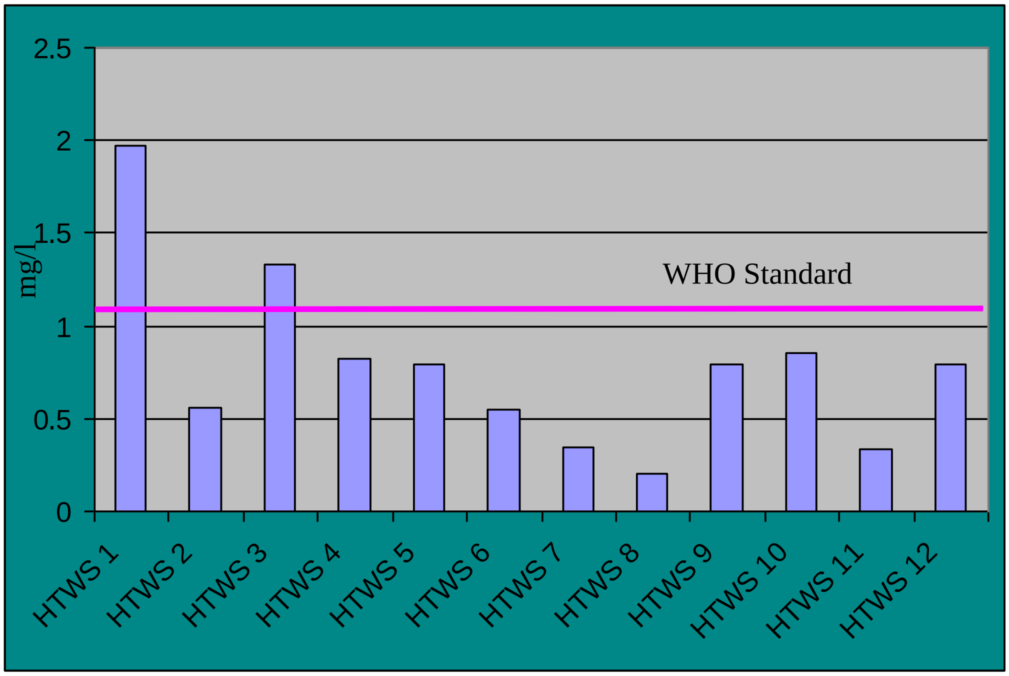

Figure 3. Graphical representation of $Fe^{(Total)}$ concentration with WHO standard.

The presence of Na^+ in groundwater primarily result from the chemical decomposition of feldspar, feldspathoid and some Fe, Mg minerals. The secondary sources of Na^+ in groundwater are agriculture by-products and industrial effluents (Hens, 1985). In the ground water examples of the study area, the concentration of Na^+ ranges from 9.78 to 13.39 mg/L (Table 1). Sodium concentration of more than 50 mg/l makes the water suitable for domestic use; however, Na^+ concentration decreases with increasing depth. The variation is believed to be due to the effect of the agricultural byproducts (Karim et al., 2002). Na^+ concentration in the study area is moderate and hence the water is suitable for domestic application.

Potassium (K^+): Potassium is slightly less common than sodium in igneous rocks but more abundant in all sedimentary rocks. Potassium is also considerably less abundant in groundwater in most fresh water aquifer as Na^+ (Hens, 1985). Potassium plays a vital role as implant metabolism. The tolerable limit of potassium content for drinking purpose is 12 ppm. In the study area, the potassium content in groundwater varies from 0.20 to 0.39 mg/l (Table 1). The potassium concentration in the study area is suitable for drinking purpose.

Magnesium (Mg^{2+}): Magnesium is one of the major cation and is essential for plant and animal nutrition. Magnesium together with calcium in ground water is the main cause of hardness of water (Matthess, 1982). Magnesium concentration of groundwater in the study area varies from 2.58 to 5.37 mg/l (Table 1). In drinking water, the acceptable limit of magnesium in groundwater is 30 to 35 mg/l. So the magnesium concentration is within acceptable limit for drinking and irrigation purposes.

Calcium (Ca^{2+}): Calcium is the most abundant of the alkaline earth metals and is a major constituent of many common rock minerals. Calcium concentration in the study area ranges from 52.61 to 58.27 mg/l (Table 1). The upper limit of calcium for drinking purpose is 75 mg/l (DOE, 1997). In the study area, the concentration of Ca^{2+} is lower than the permissible limit (DOE, 1997).

Iron (Fe^{Total}): Iron is an important element of groundwater that occurs in all natural water both in the form of oxidized (ferric) as well as reduced (ferrous) water. Ferrous ion is solution oxidized on exposure to air and is deposited as ferric hydroxide. As recommended by WHO, the maximum acceptable limit of iron concentration in groundwater used for domestic and irrigation purposes is 1 mg/l (Todd, 1980). The iron concentration in groundwater samples of the study area was measured which varies from 0.20 to 1.97 mg/l (Table 1). Some samples of the study area exceed the permissible limit of iron concentration but not to a greater extent. Graphical representation and distribution of iron are shown in Figures 3 and 4.

Anions chemistry

Alkalinity: Alkalinity and acidity of hand tubewell water

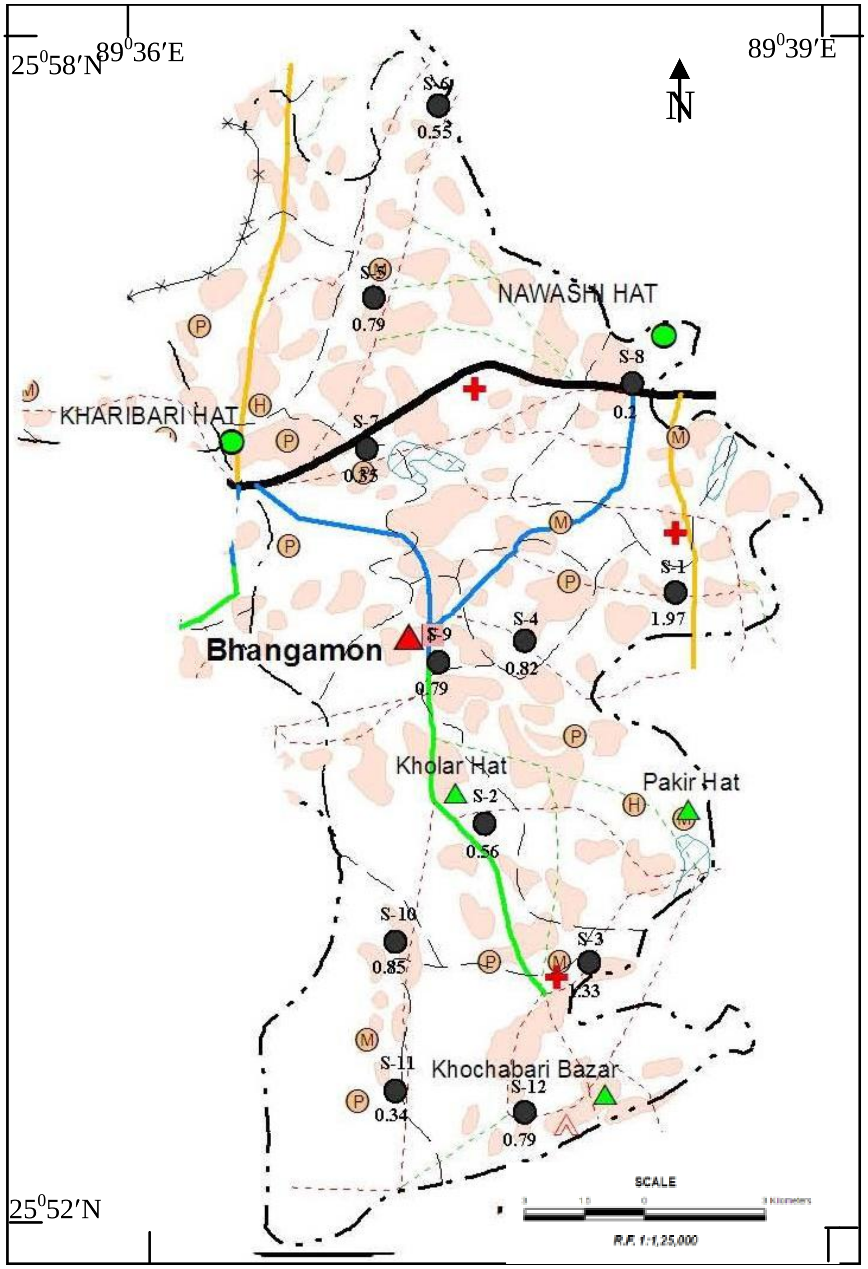

Figure 4. Map showing distribution of iron concentration in the study area.

depends on how much bicarbonate and carbonate ions in hand tubewell water are derived from the carbon dioxide in the soil and solution of carbonate rocks. Other sources of bicarbonate are limestone and dolomite. In the present study, alkalinity in hand tubewell water samples from the study area was measured as CO^{2-}_3 and HCO^-_3. The concentration of CO_3^{2-} and HCO_3^- in the study area of the hand tubewell water ranges from 2.93 to 4.63 mg/l and 105.10 to 163.78 mg/l respectively. These conclude that CO_3^{2-} and HCO_3^- content in groundwater of the study area are suitable for drinking and irrigation purposes.

Sulfate (SO_4^-): The occurrence of sulfate in groundwater results from the oxidation of sulfur in igneous rocks, the solution of the other sulfur bearing minerals and the oxidation of merasite and pyrite (Matthess, 1982). According to the United States public health drinking water standard, the potable water should not contain more than 250 mg/l of sulfate ion. Highest concentration of sulfate in the samples is 1.77 mg/l. The SO_4^{2-} concentration in the study area is well below the recommended limit of drinking water standard by WHO (1984) which indicate very low amount of sulfur bearing

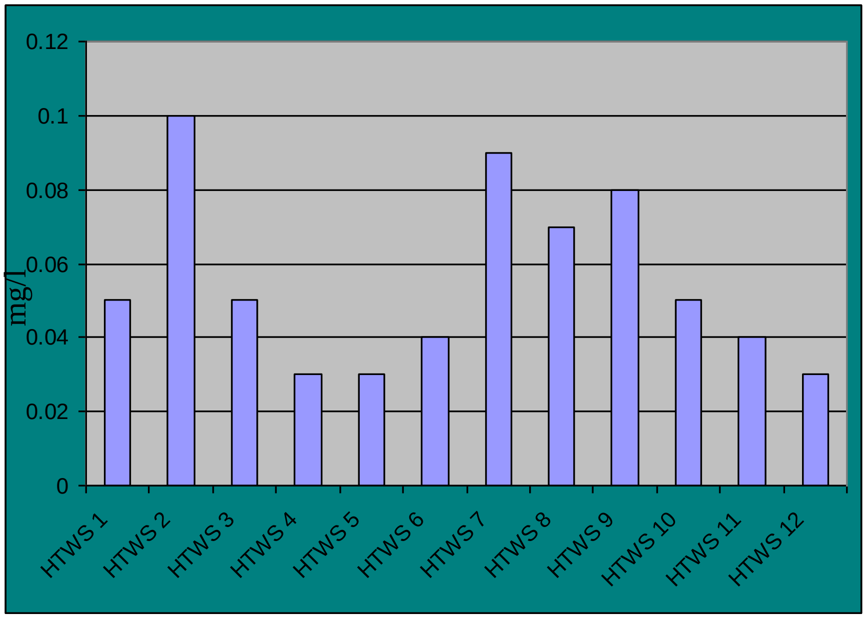

Figure 5. Graphical representation of Fl^- concentration.

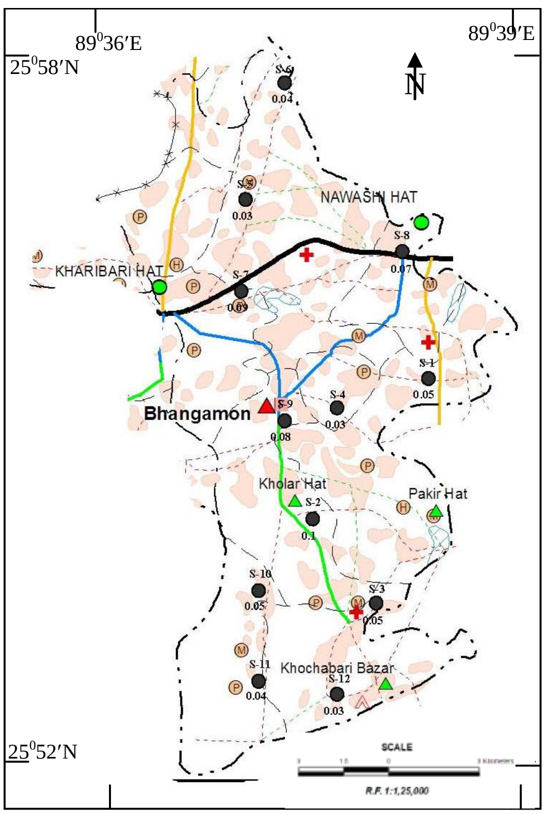

Figure 6. Map showing distribution of Fl^- concentration in the study area.

mineral within the surface and subsurface sediment.

Chloride (Cl^-): Chloride is generally present as disassociated chloride (Cl^-) ions in groundwater. The chloride concentration in excess of 100 mg/l causes physiological damage. A concentration of more than 250 mg/l of chloride in groundwater makes the lesser unsuitable for a number of domestic utilization. In the study area, no definite pattern of chloride variation was observed. The chloride content in the groundwater samples in the study area ranges from 8.47 to 40.63 mg/l (Table 1). So from the findings and discussion, it can be said that the study area is safe from any adverse effect as far as Cl^- concentration.

Fluoride (F^-): The fluoride is the element of halogen. The highest concentration of fluoride in the study area is 0.10 mg/l and lowest concentration is 0.03 mg/l (Table 1). All the values of fluoride concentration in the study area are low. None of the samples exceeds the WHO guideline value for fluoride in drinking water of 1.5 mg/l. Indeed, many are in the range where fluoride deficiency and development of dental caries may become a problem (BGS and DPHE, 2001). Graphical representation and distribution of fluoride are shown in Figures 5 and 6.

Iodide (I^-): The primary cause of iodine deficiency disorders (IDD) is a lack of iodine in the diet. Seafood is a potentially rich source of dietary iodine. In the study area, seafood is little or not available because of its distance from the sea. Crops and vegetables are other sources of dietary iodine (Selinus, 2005). As other inland areas in the study area, these provide only relatively low quantities of iodine. So, drinking water is the main source of dietary iodine in the study area. The highest

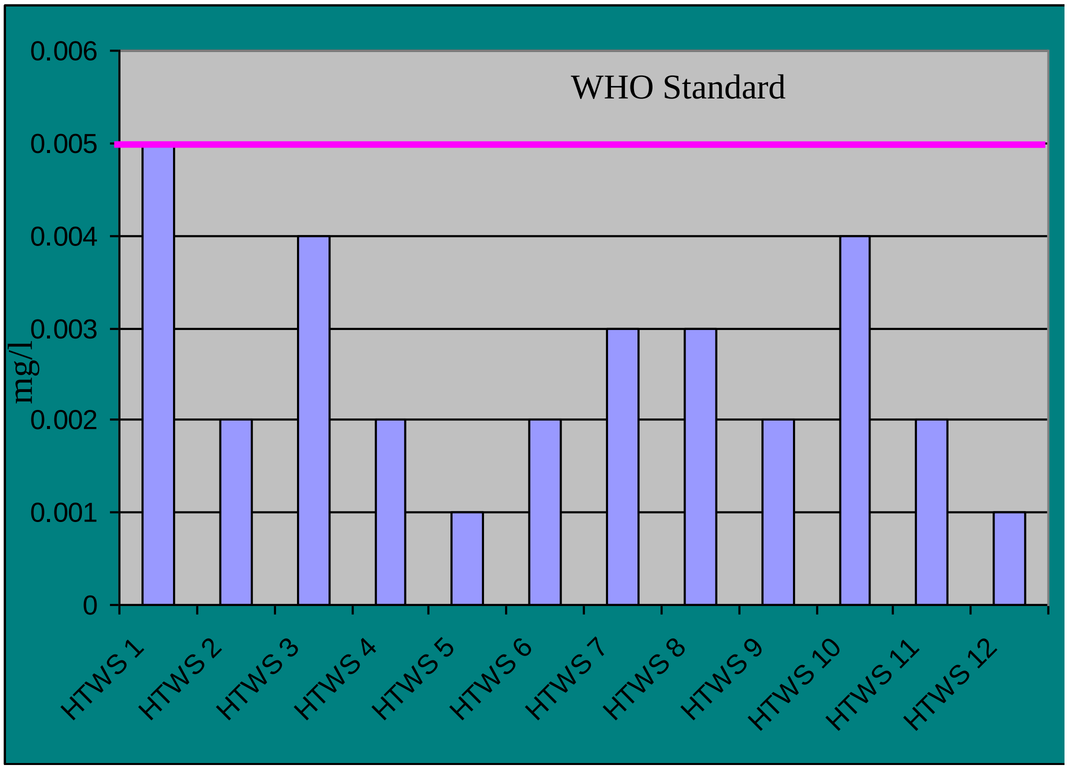

Figure 7. Graphical representation of I^- concentration with WHO standard.

concentration of iodide in the study area is 0.005 mg/l and the lowest concentration of iodide is 0.001 mg/l. The concentration of iodide in the study area is low. The iodide concentration in water in the study area is not sufficient for dietary requirement without other sources of dietary iodine (BGS and DPHE, 2001). Some parts of the study area may be prone to iodine deficiency disorders as a result. Graphical representation and distribution of iodine are shown in Figures 7 and 8.

Trace elements

Common trace elements in groundwater are mainly Manganese (Mn), Lead (Pb), Cromium (Cr) and Cadmium (Cd). Concentrations of Manganese (Mn), Lead (Pb), Cromium (Cr) and Cadmium (Cd) range from 0.042 to 1.511, 0 to 0.107, 0.003 to 0.036 and 0.001 to 0.014 mg/l, respectively. All the values of these trace elements concentration are below the allowable limit of WHO standards. In this case, trace element concentration in the groundwater of the study area is good for human health and purposes.

Graphical representation of chemical analysis data

Graphical representation of chemical analysis is very effective to understand the result of analysis and to provide means for comparing the analysis with each other or to emphasize difference and similarities. To make the interpretation and description of the water quality, variation and geochemical character of chemical analysis of the samples are represented in various graphical forms.

The Piper's Trilinear Diagram (Piper, 1953)

The Piper's Trilinear Diagram (Piper, 1950) is an effective tool in separating hydrochemical analysis data for critical studies with respect to the sources of the dissolved constituents in water. The Piper's Trilinear Diagram (Figure 9) provides rapid classification of water into fields according to the combination of dominant cations and anions. It is an effective tool in separating hydrochemical analysis data for critical studies with respect to the sources of dissolved constituents (major cations: Ca^{+2}, Mg^{+2}, Na^+, K^+ and major anions: HCO_3^-, CO_3^-, Cl^- and SO_4^{2-}) in waters, modifications in the character of water as it passes through an area and related geochemical problems.

In piper diagram, major captions (Ca^{2+}, Mg^{2+}, Na^+, K^+) and anions (HCO_3^-, CO_3^-, Cl^-, SO_4^-) were plotted in the two base triangles of the diagrams as cation and anion percentage of meq/l. Total cations and anions were each considered as 100%. The respective cations and anions locations for analysis were projected into the rectangle that represented the total ion relationships in the present

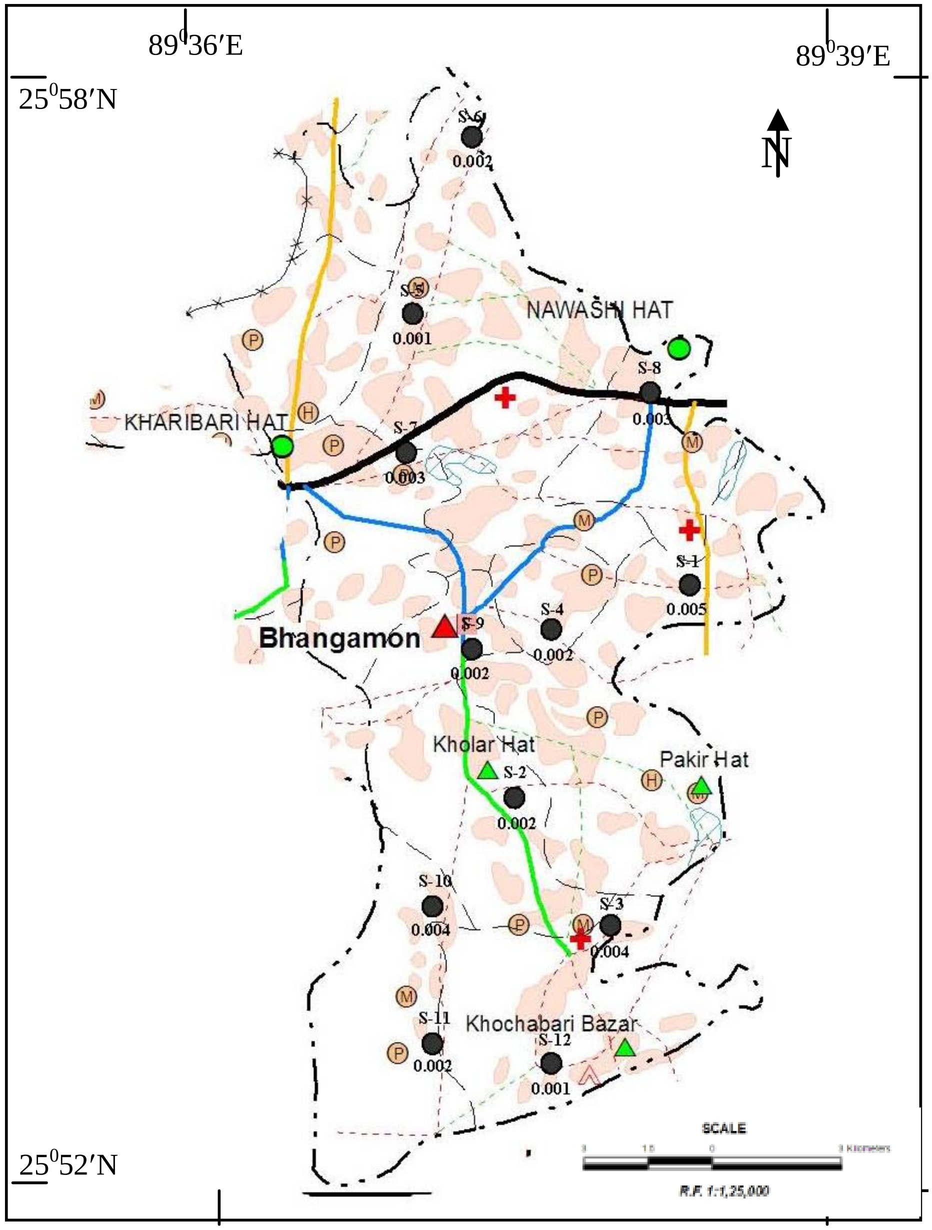

Figure 8. Map showing distribution of I^- concentration in the study area.

study, as shown in Figure 9 by classifying samples on the piper diagram. One can identify geological units with chemically similar water and define the evolution in water chemistry along atlow system. The central plotting field (diamond shaped) of the Trilinear Diagram provides rapid classification of water into nine areas depending upon the one in which the analysis fall. In this classification, alkali cations (Na^+ and K^+) are called primary constituents and the alkali earth cations (Ca^{++} and mg^{++}) are called secondary constituents. The strong acid anions (Cl^- and SO_4^-) are treated as saline constituents and Ca^{++} and HCO_3^- are treated as weak acid. Mutual balancing of these cations and anions determine the chemical characters of water.

The chemical characteristics of the groundwater samples of the study fall in different subdivisions of diamond shaped field of the Piper Diagram. Results of samples are presented in Table 1 and in the graph of Figure 10. The figures show that all the samples fall in field-1 suggesting that alkaline earths exceed alkalis. These entire samples also fall in field-3 indicating that weak acids exceed strong acids. Finally, all the samples that fall in field-5 implied that the groundwaters have an excess of 50% carbonate hardness (secondary alkalinity). It may be concluded that the groundwater samples of the study area is the dominance of alkaline

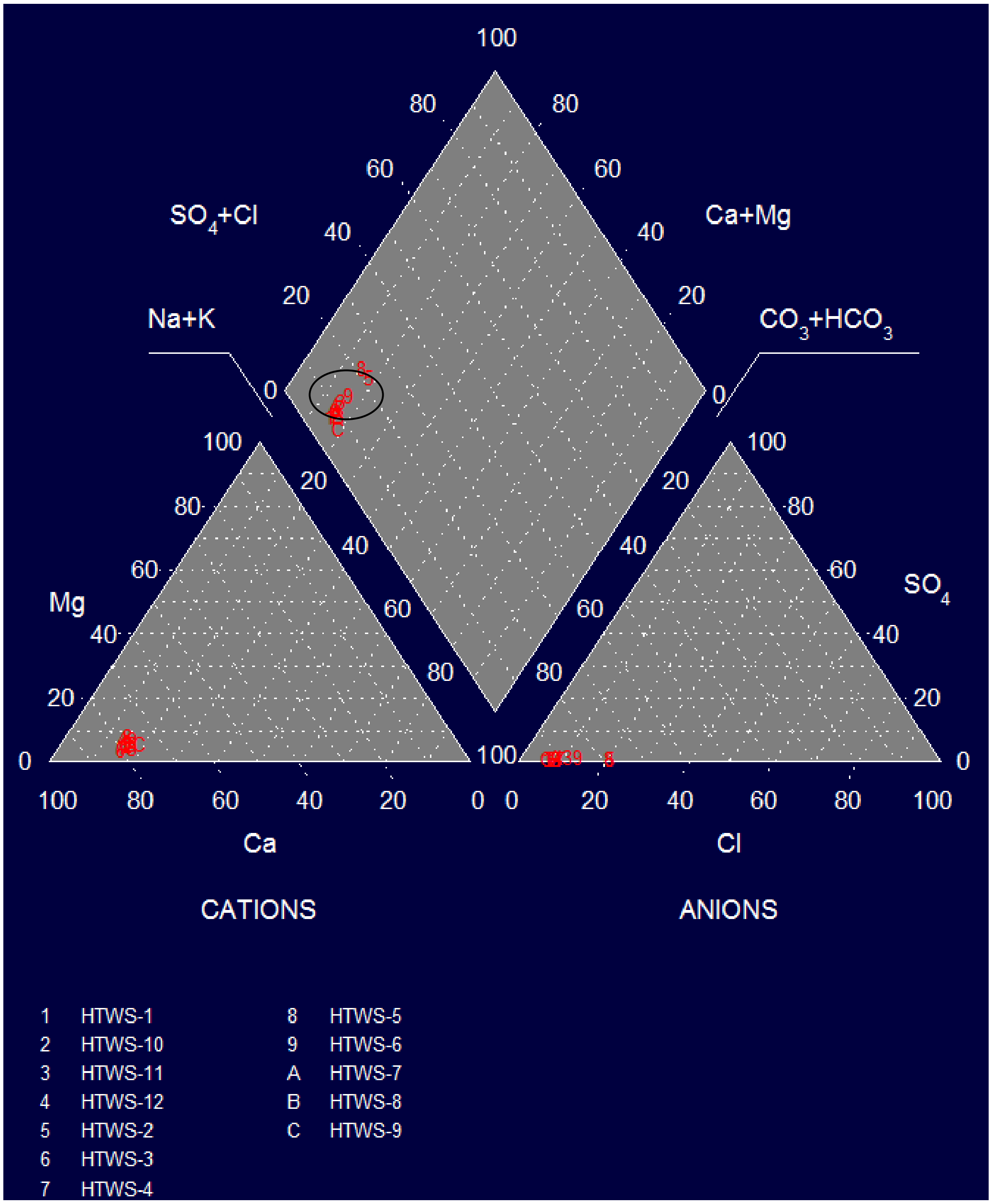

Figure 9. Piper's Trilinear Diagram representing groundwater parameters of the study area.

earth (Ca^{++} and Mg^{++}) and weak acids.

Calculated saturation indices of mineral in aquifer using FREEQUE Software

From the calculated saturation indices of mineral in aquifer using FREEQUE Software, the common rock forming minerals such as Anhydrite, Aragonite, Calcite, Dolomite, $Fe(OH)_2$, Fluorite, Gypsum, Halite, Hematite, Magnesite, Magnetite and Siderite were obtained. Most of the minerals were dissolved and the others were precipitated (Table 2).

Classification of hand tubewell water

Genetic classifications

Schoeller (1965) classified water from several points of view such as Cl^-, SO_4^{2-}, HCO_3^- and CO_3^- concentration, etc. In the study area, the concentrations of Cl^- in groundwater ranged from 0.24 to 1.14 meq/l. According to Schoeller (1965) classification, the groundwater is normal chloride water. In the study area, the concentrations of SO_4^{2-} in groundwater ranged from 0.02 to 0.03 meq/l. According to Schoeller (1965)

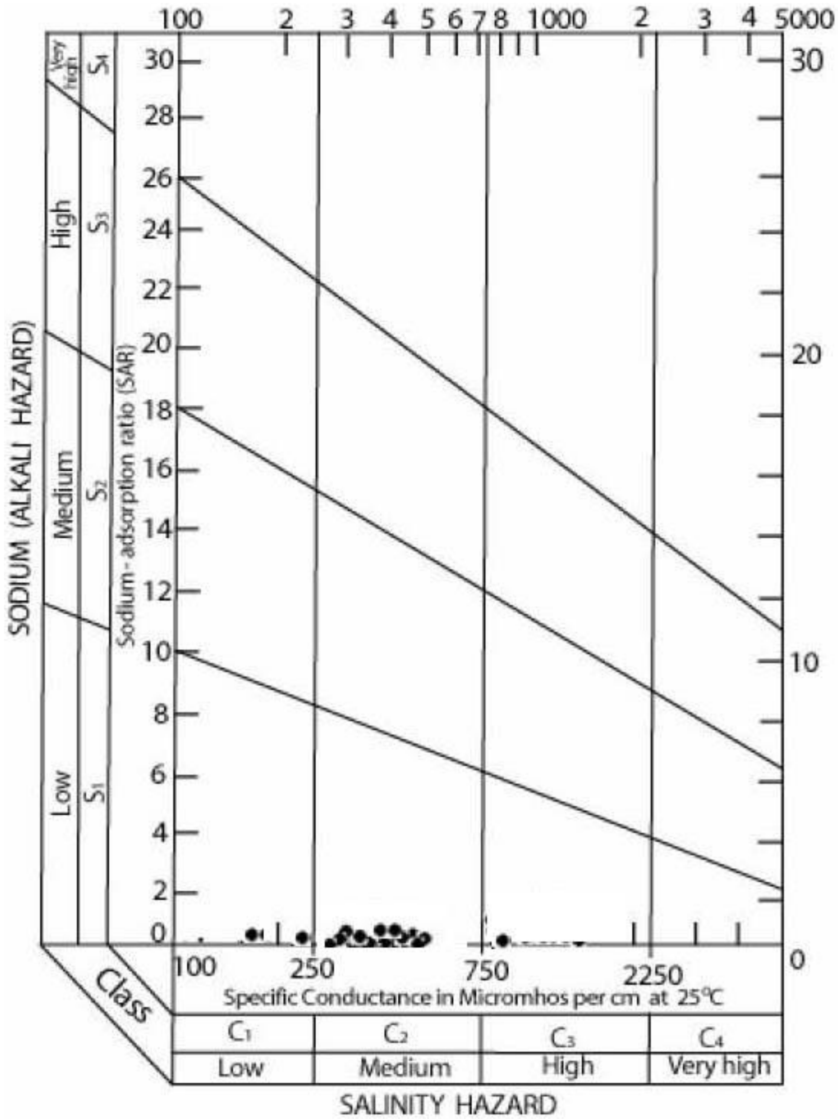

Figure 10. Classification of ground water depending upon EC and SAR values.

Table 3. Comparison of the hand tubewell water quality in the study area with WHO, USEPA and DOE standards.

Sl/N	Water quality parameters	Unit	WHO standards (1983)	USEPA standards (1975)	DOE standards (1997)	Concentration in study area	
						Max	Min
1	Calcium	mg/1	200	-	75	58.27	52.61
2	Magnesium	mg/1	150	-	30-35	5.37	2.58
3	Sodium	mg/1	200	-	200	13.39	9.78
4	Potassium	mg/1	-	-	12	0.39	0.20
5	Iron	mg/1	0.3-1.0	0.3	0.3-0.1	1.97	0.20
6	Bicarbonate	mg/1	-	-	600	163.78	105.1
7	Chloride	mg/1	600	250	150-600	40.63	8.47
8	Sulfate	mg/1	400	250	400	1.77	1.12
9	Fluoride	mg/1	1.5	-	1.0	0.1	0.03
10	TDS	mg/1	1500	-	1000	553.6	104.32
11	Total hardness	mg/1	500	200-500	200-500	166.82	147.66
12	Iodine	mg/1	0.005	-	0.005	0.005	0.001

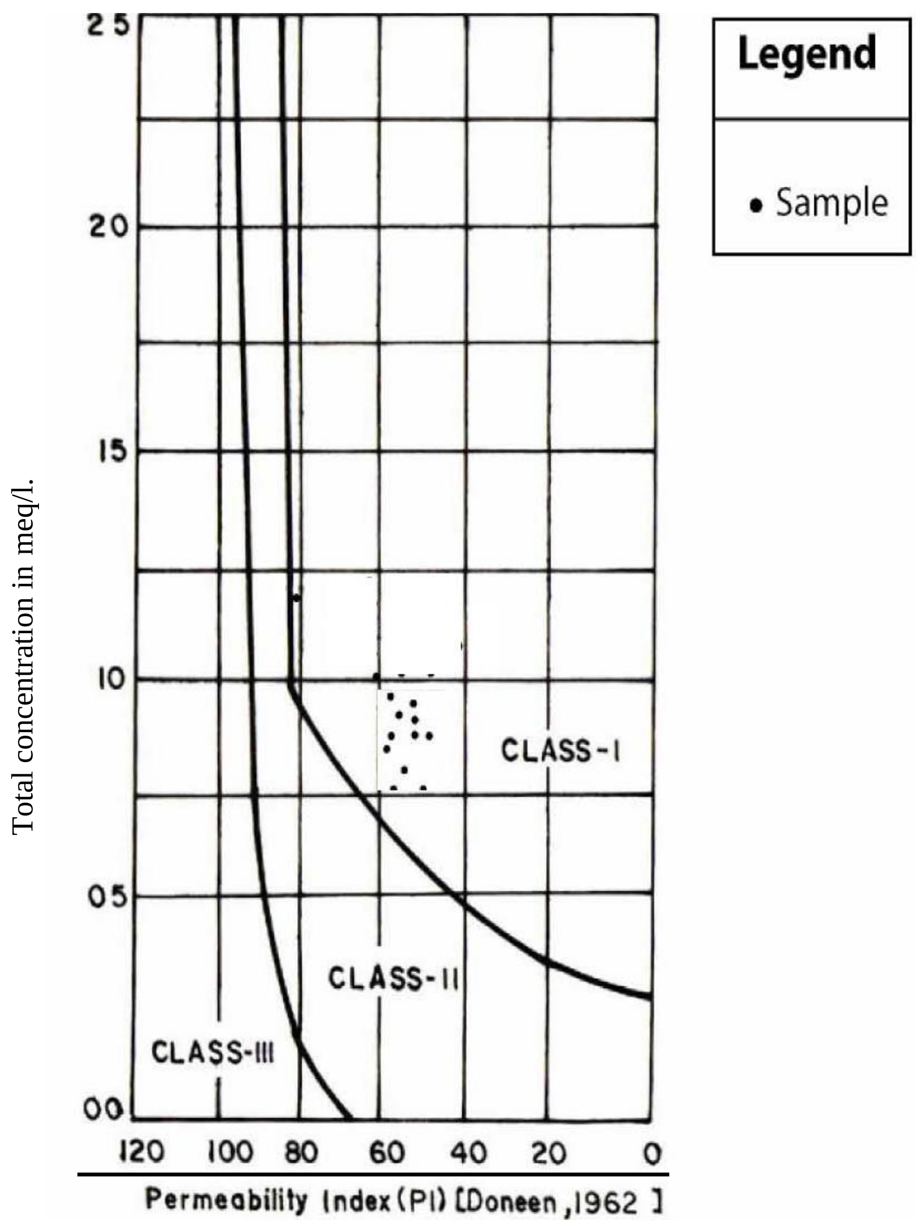

Figure 11. Classification of ground water depending on permeability.

classification, the groundwater is normal sulfate water. In the study area, the concentrations of (HCO_3^- +CO_3^{2-}) in groundwater ranged from 1.82 to 2.84 meq/l. According to Schoeller (1965) classification, the groundwater is under carbonate to normal carbonate water.

From the foregoing discussion, it may be concluded that genetically the groundwater of the studied area is "normal chloride", "normal sulfate" "under to normal carbonate" water.

Classification based on hardness

Water is classified according to its hardness (meq/l) (hardness as $CaCO_3$) by USGS (1984). The total hardness of ground water of the study area ranges from 147.66 to 166.82 meq/l which implies that the groundwater of the studied area is moderately hard. Therefore, it can be concluded that the groundwater is not suitable for some industrial purposes especially for food making industries.

Classification based on Total Dissolved Solids (TDS)

The relationship between conductance and TDS depends on the particular ions in solution. Hand tubewell water is classified according to its TDS content (Hem, 1970). TDS in the study area ranges from 104.32 to 553.6 mg/l. According to the classification of HEM, WHO standards, the water type is fresh.

Classification based on water use criteria

Drinking water quality standards

Water quality is an important factor for drinking purposes. Domestic water quality generally conforms to universally accepted standards. The drinking water quality standards are those which satisfy all of the limitation of water use criteria recommended by public health organization. The hand tubewell water of the study area is compared and correlated with WHO and Bangladesh Standards for drinking purposes are given in Table 3.

From the chart, it can be concluded that all the parameters as determined show suitability for drinking and health purposes. Here the groundwater of the study area is suitable for use as drinking water.

Quality of water requirement for livestock

Most of the animals can drink water with moderately high dissolved solid (10 g/l) when NaCl is the chief constituent. Like human beings, livestock heeds some guideline values of chemical constructions for its water use. The department of Agriculture of Western Australia in 1850 has suggested the upper limits of total dissolved solids (TDS) concentration in water for livestock consumption. It has been found that the groundwater of the study area is suitable for livestock consumption.

Irrigation water quality standards

The groundwater contains some dissolved mineral constituents and salts in it. Effects of salts like Na^+ on soil tend to reduce its permeability and change its structure (Todd, 1980). The most important characteristics properties of irrigation water which are used to determine its quality are described as follows:

Electrical conductance (EC): If the TDS of water increases, it is difficult for plants to extract water. The electrical conductance is a function of TDS (TDS in mg/l = 0.64×EC in μS/cm). Wilcox (1955) classified water for irrigation bases on EC. The EC values of groundwater in the study area ranges from 163 to 865 μS/cm. This concluded that the hand tube well water of the study area is good quality for irrigation.

Sodium absorption ratio (SAR): SAR is important for determination of irrigation water quality as it is responsible for the sodium hazard. SAR is defined by:

$$SAR = \frac{Na}{\sqrt{\frac{ca^{+2} + Mg^{+2}}{2}}}$$

Where, the concentrations of ions are expressed in meq/L.

Raghunath (1987) classified water for irrigation based on SAR values. The SAR values of groundwater of the study area ranges from 0.34 to 0.47 meq/L which implies that no alkali hard is anticipated in the studied area and the water is of excellent quality for irrigation. Figure 10 shows that the samples of the studied area fall into the C_2–S_1 quality category, which suggests that the ground water is medium salinity and low alkali, hazard for irrigation purpose.

Sodium percentage (Na%): The sodium percentage is calculated by the formula:

$$Na\% = \frac{Na + k}{Ca + Mg + Na + k} \times 100$$

Where, the concentration is measured in meq/L.

Wilcox (1967) classified water for irrigation based on Na% values. The Na% in the studied area ranges from 11.94 to 16.21%. According to Wilcox (1967) classification, the groundwater of the study area is excellent in quality for irrigation purpose.

Permeability index (PI): The permeability index (PI) is defined by:

$$PI = \left\{ \frac{Na^+ + \sqrt{HCO_3}}{Ca^{2+} Mg^{2+} + Na^+} \times 100 \right.$$

Where, the concentration is measured in meq/L.

Doneen (1964) proposed a chart for classification of irrigation water based on permeability index (PI) (Figure 11) which shows that the samples of the studied area fall in the classes of I which suggest that the ground water is very good in quality for irrigation purposes.

From the overall correlation from different schemes of classification (EC, SAR, SSP, PI) it can be concluded that the groundwater of the study area is good to excellent in quality for use in irrigation purposes.

Conclusion

This study reveals that environment sensitive index parameters like pH, EC Eh, which are temperature values of groundwater samples in the study area, are within permissible limit. It changes season to season. Total concentration of dissolved ions is within permissible limit. The concentration of calcium is the highest among all of the cations of the allowable limit of WHO, but some samples exceed the all allowable limit of DOE.

The groundwater of the studied area contains "normal chloride", "normal sulfate" and "under to normal carbonate water" types. Based on hardness, the ground water of this area is moderately hard. Concentration of Magnesium, Sodium, Potassium and Calcium of all the samples are within permissible limit. Some samples of the study area exceed the permissible limit of iron concentration but not to a greater extent. All the values of trace elements (Mn, Pb, Cr and Cd) concentration are below the allowable limit of WHO standards. The fluoride concentration of all samples in the study area ranges from 0.03 to 0.1 mg/l. All these values are relatively low. Indeed many are in the range where fluoride deficiency and development of dental caries may become a problem. The iodide concentration of all samples ranges from 0.001 to 0.005 mg/l. In the study area, iodine is not sufficient in water, studies else where suggest that concentrations at the lower end of the observed range can be insufficient for dietary requirements without other sources of dietary iodine. Some parts of the study area may be prone to iodine deficiency disorders as a result. Correlating with WHO, DOE guideline values for drinking water and public health, it may be concluded that the groundwater of the studied area except iodide and fluoride is suitable for all domestic and drinking purposes. Based on Sodium Absorption Ratio (SAR), Sodium percentage (Na%) and Permeability Index (PI) of the groundwater in the studied area have excellent quality for irrigation purpose.

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