A STATISTICAL ASSESSMENT OF GROUNDWATER QUALITY IN NILPHAMARI POURASHAVA, NILPHAMARI DISTRICT, BANGLADESH

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ABSTRACT
Groundwater quality is the vital issue in Bangladesh due to extreme value of some parameters. Though the abundance of groundwater is not the problem but concern is in the quality. The present research work deals with the assessment of quality of 15 groundwater samples from Nilphamari Pourashava. In situ measured physical parameters include temperature, pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS). Quality assessment was made through the estimation of major cations(Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} Fe^{total}), and the major anions (HCO_3^-, CO_3^-, SO_4^{2-}, NO_3^-, Cl^-). According to the overall assessment of the basin, all the parameters analysed are below the desirable limits of WHO Facies mapping approach of the groundwater indicate Sodium-Calcium cation facies and Bicarbonate-Chloride-Sulphate anion facies. According to the drinking water quality standards the groundwater of the study area is suitable for public health. The groundwater of the study area is of good quality for irrigation.

Keywords: Groundwater chemistry; inverse distance weight; bar diagram; box and whisker plots, facies mapping.

INTRODUCTION

Water is one of the earth's most important resources for human life. Groundwater has been used to supply living, agricultural and industrial water for a long time in many countries. The water quality depends upon the geological environment, natural movement, recovery and utilization (Senthikumer et al., 2008). Groundwater is a important water supply source in Bangladesh. It is a major source of drinking water in urban Nilphamari area. In this paper an attempt has been made to evaluate the chemistry of groundwater in the Nilphamari pourashava of Nilphamari District. Nilphamari Pourashava is located in the south-western part of Nilphamari District in north-western Bangladesh [Fig. 1]. It is located within the geographical co-ordinates between 25°54′ to 25°58′N latitudes and 88°49′ to 88°53′E longitudes. Physio graphically the study area falls within the Tista river flood plain in the overall physiographic units of Bangladesh. The study area lies on the Northern flood plain of the Tista River. The southern part of this flood plain is a levee. The northern part of the area is influenced by the flow of the Jamuneshwari River. The study area is characterized by moderate rainfall with regional and seasonal variations. The average annual rainfall of the study area of period 1993 to 2008 is about 2095.14 mm. There is excess of rainfall during the rainy season (June to October), which is due to the occasional incursion of cyclonic storms, when heavy rain may fall for several days. The temperature data of the study area of 15 years shows that the temperature varies distinctly both diurnally and seasonally. Maximum temperature recorded in the study area is about 22.4°C to 33.2°C and average minimum temperature varies from 9.8°C to 25°C. In the study area, the highest monthly average humidity was 86.46% in the month of July and the lowest was 71.13 in the month of April during the period of 1993 to 2008.Objectives of the Research Work is to

- To carry out necessary field visits to collect groundwater samples from the study area.
- To carry out detail hydro chemical analysis of groundwater samples.

- Classification on the basis of water chemistry.
- To compare the analytical results with national and international standards for water use in domestic, irrigation and industrial purposes.

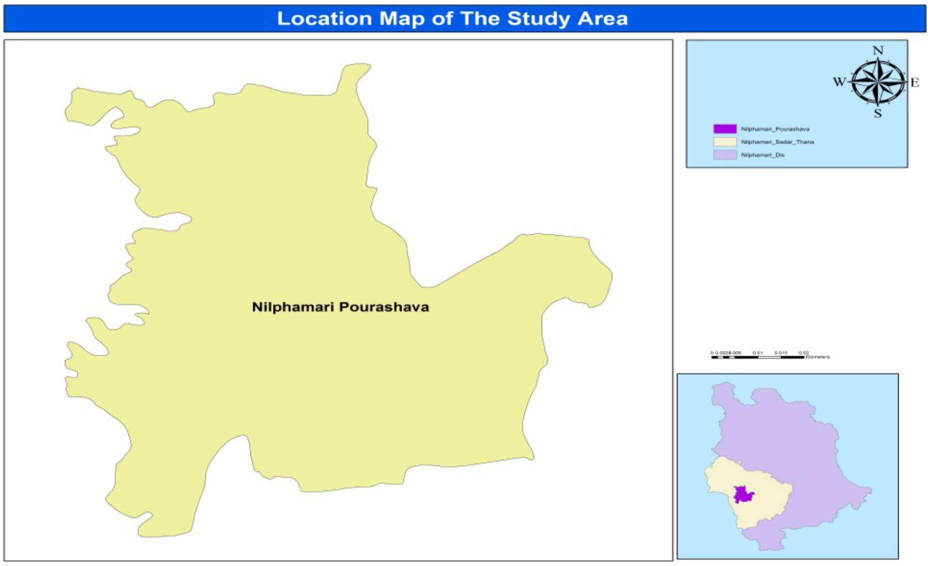

Fig 1: Location Map of the Study Area.

Methodology

Available geologic, climatic, topographic and hydrologic data provided by different organizations related to surface and subsurface water works are used to ascertain the groundwater condition of the studied area. Among the organizations Bangladesh Agricultural Development Corporation (BADC) is one of the most important sources for obtaining this information. Besides, Department of Meteorology, Department of Public Health Engineering (DPHE), Bangladesh water Development Board (BWDB) of Nilphamari district and various published reference reports also served as sources of information and data. In the dry season (2010) the studied area was investigated for several times to know the geological, hydrological and environmental condition prevailing at the surface.Data processing and chemical analysis include data verification and quality control, data entry, data processing and finally the analysis to facilitate the required output generation. The field and laboratory measured parameters has been used to delineate spatial trend. Hydrogeological and hydro-chemical interpretation has been made using necessary hydrogeological and hydro-chemical diagram to decipher the hydro-chemical process taking place in the aquifer. Findings of the total analysis output has compared with national and international water standards for drinking and irrigation purposes to determine their sustainability to use in particular purposes. For the field measurement of pH a portable pH meter (Hanna, HI 7039P) was used and pH of each sample was recorded. The conductivity of a body or mass of fluid of unit length and cross-section at a specific temperature is defined as EC. Measurement of EC was carried out by immersing a conductance cell in water samples and then the EC was recorded from the digital display of the EC meter (Whatman micrometer). Temperature of groundwater samples of the study area was measured by the help of laboratory thermometer. A rapid determination of Total Dissolved Solids (TDS) is made simply by multiplying the measured EC values (in µs/cm) by the constant 0.64 (Todd, 1980). The concentration of some cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Fe^{total}) and anions (HCO_3^{-}, CO_3^{-}, SO_4^{2-}, NO_3^{-}, Cl^{-},) were determined in the Soil Resources Development Institute (SRDI) of Rajshahi and the Hydrogeology Laboratory of the Department of Geology and Mining, Rajshahi University.

RESULTS AND DISCUSSIONS

The guideline of quality standard values recommended by World Health Organization (WHO, 1984) and Bangladesh Water Pollution control Board (BWPCB, 1976) for drinking water are given in the [Table 1]. From this chart it can be concluded that the parameters as determined show suitability for drinking and health purposes. Hence the groundwater of the study area is suitable for use as drinking water. From the analysis of the calculated values of EC and SAR of the studied groundwater samples it may be concluded that the groundwater of the study area is of good to medium quality for uses in irrigation purposes.

Table 1: Correlation of groundwater quality in the study area with WHO (1984) and Bangladesh (BWPCB, 1976) standards for drinking purpose

Water quality parameters	**WHO standard (1983)**		**Bangladesh standard (BWPCB, 1976)**		**Concentration in the study area**	
	Max. accept. limit	**Max. allow. limit**	**Max. recom. limit**	**Max. allow. limit**	**Min.**	**Max.**
pH	6.5	8.5	6.5	8.5	6.1	7.2
TDS	500	1500	-	1500	32.0	268.8
Total Hardness	100	500	200	500	61.28	197.06
Calcium	75	200	-	-	2.00	44.00
Magnesium	50	150	-	-	10.12	26.08
Sodium	-	200	200	-	0.11	0.56
Potassium	-	-	12	-	0.002	0.022
Bicarbonate	-	-	-	-	3.05	61.00
Chloride	200	600	600	1000	27.28	197.78
Sulfate	200	400	-	400	1.20	2.55

From the analysis of the calculated values of EC and SAR [Table 2] of the studied samples, it may be concluded that the groundwater is good to medium quality for uses in irrigation purposes.

Table 2*:* Values of various hydro-chemical parameters calculated from sample.

Sample No.	**PI (meq/l)**	**SAR (meq/l)**	**Na%**	**TH (mg/l)**	**RSC (meq/l)**
HTW-1	1.19	0.05	0.205	161.22	5.80
HTW-2	1.33	**0.14**	1.098	**61.28**	4.26
HTW-3	1.21	**0.03**	**0.194**	125.18	6.98
HTW-4	1.17	0.06	0.483	119.40	**7.25**
HTW-5	1.35	0.04	0.281	195.25	4.97
HTW-6	**0.89**	0.08	0.498	109.15	6.16
HTW-7	1.09	0.11	0.716	103.23	5.32
HTW-8	0.96	0.12	**1.154**	77.72	**4.13**
HTW-9	1.22	0.09	0.700	106.86	4.56
HTW-10	1.02	0.06	0.463	132.55	5.15
HTW-11	1.32	0.06	0.412	184.66	9.56
HTW-12	0.98	0.12	0.873	138.66	6.25
HTW-13	**1.34**	0.05	0.311	**197.06**	5.42
HTW-14	1.06	0.13	0.921	110.58	5.01
HTW-15	0.99	0.06	0.404	166.94	4.98

The Piper Trilinear Diagram (Piper, 1953) is an effective tool in separating hydro chemical analysis data for critical studies with respect to the sources of the dissolved constituents in water (major cations; Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Fe^{total} and major anions; HCO_3^{-}, CO_3^{2-}, Cl^{-}, NO_3^{-}, SO_4^{2-}) in waters, modifications in the character of water as it passes through an area, and geochemical problems. The Pipers diagram provides rapid classification of water in to fields according to the combination of dominant cations and anions. The central plotting field (diamond shape) of the trilinear diagram is divided in lo nine areas and water is classified into nine types depending upon the area in which analysis results fall and the alkali cations (Na^+ and K^+) are called primary constituents and the alkaline earth cations (Ca^{2+} and Mg^{2+}) are called secondary constituents. The strong acid cations ($S0_4^{2-}$, Cl^-) are treated as saline constituents and CO_3^{2-} and HCO_3^- are treated as weak acid. Approximate balancing of these cations and anions determine the chemical character of water [Fig. 5.1].

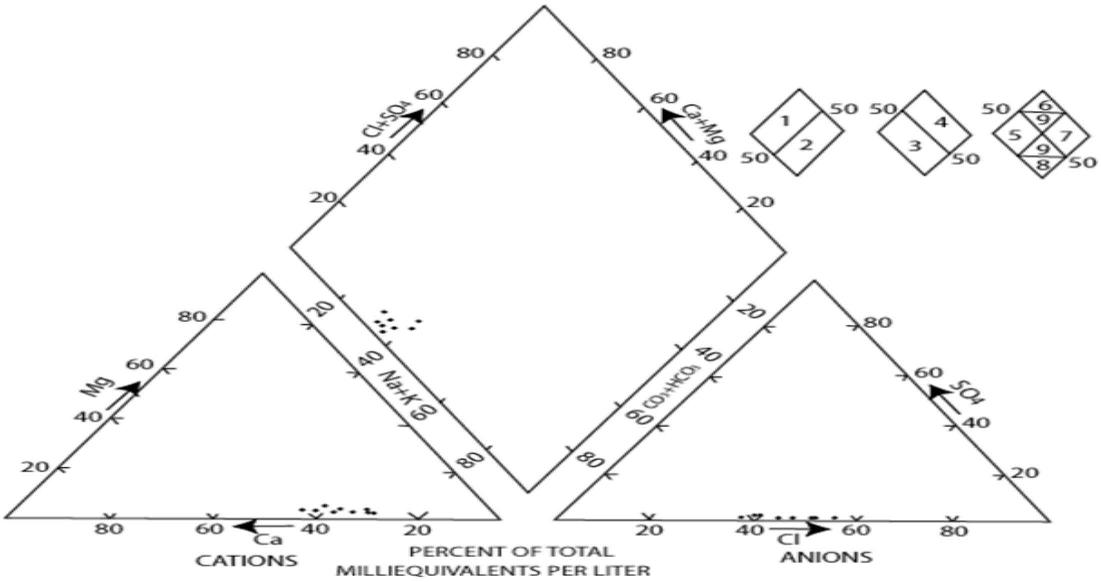

Figure 5.1. Trilinear diagram for groundwater samples from the study area

It is observed that all the groundwater samples collected from the study area show Sodium-Calcium cation facies and Bicarbonate-Chloride-Sulphate anion facies. PH value of the groundwater samples from the study area ranges from 6.1 to 7.2 indicating almost neutral water and suitable for drinking and irrigation purposes. The temperature of groundwater determined in the dry season ranges from 25°C to 27°C. The total dissolved solids (TDS) content of wells ranges from 32.0 mg/l to 268.8 mg/l. The relationship between conductance and TDS depends on the particular ions in solution. Groundwater is classified according to its TDS content (Hem, 1970) [Table. 3]

Table 3: Groundwater classification according to TDS (WHO, 1984)

Water type	**TDS (mg/l)**
Fresh	<1000
Moderately saline	3000-10000
Very saline	10000-35000
Briny	>35000

Concentration of TDS in groundwater of the study area ranges within 1000 mg/l. According to the classification of Hem, WHO standards for TDS (WHO, 1984) (Maximum allowable 500 mg/l and maximum acceptable 1500 mg/l) it could be said that the groundwater of the study area is safe for drinking and irrigation purposes. Water samples have been taken from different shallow and deep tube-wells of the study area are analysed for detailed description of the hydro-chemical changes in groundwater chemistry. Subsurface waters in contacts with sedimentary rocks of marine origin derive most of their calcium from the solution of calcite, aragonite, dolomite, anhydrite, and gypsum. Concentration of calcium in normal portable groundwater generally ranges between 10 mg/l to 100 mg/l. Calcium in health of humans or other animals are needed as much as 1000 mg/l. The calcium concentration in groundwater of the study area ranges from 2.00 mg/l to 44.00 mg/l. Common concentration of magnesium ranges from 1.0 to 40.0 mg/l in drinking water. The Magnesium concentration in groundwater of the study area ranges from 10.12 to 26.08 mg/l, suggesting that the water of the study area is suitable for drinking and irrigation purposes. Sodium unlike the Calcium, Magnesium and Silica is not found as essential constituents of many of common rock-forming minerals. The primary source of most Sodium in natural water is form the release of soluble product during the weathering of plagioclase feldspars Sodium concentration in fresh water is 10 mg/l. More than 50 mg/l Sodium and Potassium in the presence of suspended matter causes framing. More concentration makes the water brine. Concentration of sodium in groundwater of the study area ranges from 0.11 to 0.56 mg/l. Hence the groundwater of the study area is suitable for drinking and irrigation purposes. Water percolating through evaporate deposits may contain very large quantities derived from the dissolution of sylvite and niter. Its concentration in most drinking water is less than 10 mg/l. In the study area, concentration of potassium ranges from 0.002 to 0.022 mg/l, suggesting that the groundwater of the study area is suitable for drinking and irrigation purposes. Abundant sources of iron exist in the earth's crust. Some of the important minerals and mineral group, which may contain large amounts of iron are pyroxenes, amphiboles, magnetite, pyrite, biotite and garnets. The weathering of these minerals release large quantities of iron in groundwater. The iron (Fe^{total}) concentration in groundwater of the study area ranges from 0.15 to 0.65 mg/l. From the above stated it may be concluded that the groundwater of the study area is suitable for drinking and irrigation purposes.

The properties of alkalinity and acidity are important characteristics of groundwater. The measurement of pH provides values of concentration of H^+ and OH^- in solution. These species contribute to acidity or alkalinity. In almost all natural waters the alkalinity is produced by the dissolved carbon-dioxide (CO_2) species, bicarbonate (HCO_3) and carbonate (CO_3). The principal source of carbon-dioxide species that produce alkalinity in groundwater is the CO_2 gas fraction present in the soil or in the unsaturated zone lying between the surface of the land and the water table. The soil minerals may absorb H^+, which could be released from time to time by addition of soil amendment or by other changes in chemical environment to reinforce the hydrogen ion content of groundwater recharge. It is assumed the pH of the water is controlled by CO_2 equilibria. The bicarbonate concentration of natural water generally held within a moderate range by the effects of carbonate equilibria. Concentrations of bicarbonate more than 200 mg/l are not uncommon in groundwater and higher concentrations can result where carbon dioxide is produced within the aquifer mixed with organic matters (Matthess, 1982). In the present study acidity and alkalinity in groundwater from water sample was measured as bicarbonate (HCO_3). The concentration of HCO_3 in the study area ranges from 3.05 mg/l to 61.00 mg/l, suggesting that the water of the study area is suitable for drinking or irrigation purposes. Most Chloride in groundwater comes from ancient sea water entrapped in sediments; second, solution of halite and related minerals in evaporate deposits; third concentration by evaporation of chloride contributed by rain or snow; fourth, solution of dry fallout from the atmosphere, particularly in arid regions. Chloride is one of the major constituents found in all natural waters in different concentrations, commonly less than10 mg/l in humid region but up to 10000 mg/l in more arid regions. Concentrations greatly in excess of 100 mg/l may cause psychological damage. For public health chloride up to 250 mg/l are not harmful but values greater than this are indication of organic pollution. Chloride concentration in groundwater in the study area ranges from 27.28 mg/l to 197.78 mg/l. Hence the water of the study area is suitable for drinking and irrigation purposes. The occurrence of sulphate (SO_4^{2-}) in groundwater results from the oxidation of sulfur in igneous rocks, the solution of other sulfur bearing minerals and the oxidation of mercasite 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. Concentration of sulfate in groundwater of the study area ranges from 1.20 to 2.55 mg/l. The concentrations of sulfate ions obtained in the waters are by all standards, very much within the range recommended for drinking and household purposes. Nitrogen occurs in water as nitrate or nitrite anions (NO_2 and NO_3) in cationic form as ammonium (NH_4^+) at intermediate oxidation states as a part of organic solute. The nitrate and organic species are unstable in aerated water and are generally considered to be indicators of pollution through disposal of sewage organic waste. The presence of nitrate or ammonium might be indicative of such pollution also. Concentration in excess of 10 mg/l as N, equivalent to 44 mg/l of NO_3^- evidently present this hazard (NAS-NAF, 1972). The concentration of nitrate in groundwater from the study area ranges from <0.1 to 0.66 mg/l. The facies mapping approach (Back, l96l) is one of the most significant ways to determine the hydro chemical facies from chemical data. In this case samples are classified according to facies with two templates for the Piper's Trilinear diagram. In the present study the chemical data were plotted on the facies mapping approach (Back, 1961) and the variations and distributions of hydro chemical facies of groundwater throughout the study area are interpreted. It is observed that all the groundwater samples collected from the study area show Sodium-Calcium cation facies. All the groundwater samples of the study area indicate Bicarbonate-Chloride-Sulfate anion facies.

CONCLUSIONS

Correlation with different guideline values for drinking water and public health it is be concluded that the groundwater of the study area is suitable for drinking purposes. The pH value of groundwater ranges from 6.1 to 7.2 indicating almost neutral groundwater. Average temperature ranges from 25.0°C to 27.0°C. The electrical conductance (EC) of groundwater ranges from 50.0 to 420.0 µs/cm, which is of good to medium quality for irrigation purposes. The TDS value ranges from 32.0 to 268.8 mg/l, which is within allowable limit. The hardness of groundwater ranges from 61.28 to 197.06 mg/l, which is implies very hard, so it requires little softening. Concentration of cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} Fe^{total}) ranges from 2.0 to 44.0 mg/l, 10.12 to 26.08 mg/l, 0.11 to 0.56 mg/l, 0.002 to 0.022 mg/l and 0.15 to 0.65 mg/l respectively. The concentration of calcium is the highest among all of the cations but within the permissible limit. Concentration of Sodium, Potassium, Magnesium and $Iron^{total}$ in all of the studied samples are also within the permissible limit. Concentration of anions (HCO_3^-, CO_3^-, SO_4^{2-}, NO_3^-, and Cl^-) range from 3.05 to 61.00 mg/l, 5.2 to 17.0 mg/l, 1.20 to 2.55 mg/l, <0.1 to 0.66 mg/l and 27.28 to 197.78 mg/l respectively. All of the anions in the groundwater are within allowable limit. Distribution of water samples in the Piper Trillinear Diagram shows that all the samples fall in the field-1, which indicates that the alkaline earth exceeds alkalies. Six samples fall in field-3, indicating week acids exceed strong acids, finally all the samples fall in field-5, indicating that the groundwater has an excess of 50% carbonate hardness (secondary alkalinity). This confirms that alkaline earths and weak acids dominate the chemical properties of groundwater of the study area. From the facies mapping approach of water quality data it is revealed that the groundwater of the region could be classified as Sodium-Calcium cation facies and as Bicarbonate-Chloride-Sulfate anion facies. Correlation with different guideline values for drinking water and public health it is be concluded that the groundwater of the study area is suitable for drinking purposes. Genetically the groundwater of the study area belongs to “Strong Chloride”, “Normal Sulfate”, and “Normal Carbonate” group. Based on EC, PI and SAR groundwater of the study area is of good to permissible quality for irrigation purposes. As far as the quality for irrigation is concerned the groundwater falls under quality category of low alkali hazard and low to medium salinity hazard.

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