Investigation of Groundwater quality for Domestic and Irrigation purposes around Gubrunde and Environs, northeastern Nigeria

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Abstract: Fourteen groundwater samples were collected from boreholes, springs and hand dug wells in and around Gubrunde in Borno State north-eastern Nigeria to investigate its quality for domestic and irrigation uses. The area investigated falls within longitude 11° 35' - 12° 05' and latitude 10° 10' - 10° 31'. The samples were analyzed using Atomic Absorption Spectrometer (AAS), multi-analyte photometer and Flame photometer while interpretation of the results was carried out with RockWare Aq•QA software, a spreadsheet for water analysis. Six of the samples investigated are of NaCl water type while fourteen were CaCl water types. Sodium Adsorption Ratio (SAR) values recorded ranges from 0.80 – 2.84, Exchangeable Sodium Ratio (ESR) 0.33 – 1.78, Magnesium hazard (MH) 5.19 – 47.9, Residual Sodium Carbonate (RSC) 0.00, Hardness 0.65 – 221.48 and Total Dissolved Solid (TDS) ranges from 130 – 407308mg/l. Twelve of the samples analyzed had medium Salinity Hazard (SH), and one each for high and low Salinity Hazard (SH), respectively. The variation in chemical composition of groundwater in the study area may be due to leaching of terrestrial salts, extensive use of chemical fertilizers and ion exchange between water and the host rock. The result of samples analyzed indicates that all the samples are undersaturated in calcite and aragonite, while most of the major anion and cations falls within World Health Organization and Nigeria Industrial Standard for Drinking water Values. Nine samples had NO_3 values ranging from 53 – 106mg/l exceeding the 50mg/l standards. NO_3 values exceeding 50mg/l has the tendency of causing asphyxia to infants less than three months old. A plot of SO_4, HCO_3 and Cl indicates that the groundwater samples are from intermediate water category (neither fresh nor old). Generally, the groundwater quality is fairly suitable for agricultural uses and suitable for domestic utilization.[Arabi, Suleiman Abdullahi; Funtua, Idris Isa; Alagbe, Solomon Ayodele; Zabosrki, Peter; and Dewu, Bala Bello Muhammad. Investigation of Groundwater quality for Domestic and Irrigation purposes around Gubrunde and Environs, northeastern Nigeria, Journal of American Science 2010; 6(12):664-672]. (ISSN: 1545-1003).

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1. Introduction

Urbanization, population increase, dewatering of aquifers for irrigation and extensive use of chemical fertilizers are some of the factors that have direct effects on quantity and quality of groundwater resources especially in arid and semi arid region of northern Nigeria. Hydrochemical data has the potential uses for tracing the origin and history of water. Globally, the quantity and quality of groundwater reserves is diminishing day by day. Therefore, any study that can aid in identifying new sources or threats to groundwater is desirous not only around the study area but anywhere. There is no life without water, therefore, it is essential to safeguard the future of our water resources by studying its past and present both quantitatively and qualitatively. This Study of hydrochemistry of groundwater from Gubrunde and environs utilizes the results of the chemical analysis of water samples from different sources around the study area. The locations sampled falls between longitude 11° 35' - 12° 05' and latitude 10° 10' - 10° 31' in Borno State, north-eastern Nigeria, covering an area of about 2250km^2 (Fig. 1). Gubrunde village is central in the Geology of Nigeria because it is one of the three Uranium mineralization areas in north-eastern Nigeria. It can be accessed through Dadin-kowa from Gombe State and/or through Biu or Guyuk from Adamawa State. he Geology of the area (Fig. 2) is made of the tertiary basalt of the Biu plateau on the north, sedimentary sequence of Bryel and Zange grabens on the north-west and south-east, respectively. The area is underlain by the crystalline basement of north-eastern Nigeria.

Groundwater in the crystalline basement rock is confined to pockets and patches of weathered rock and to fractures. Wells usually encounter water at shallow depths but yields are often low and subject to seasonal fluctuations. Boreholes are usually sited on basement along drainage lines where overburden is often thickest. On the basalt capped plateau, the weathered zone near some of the larger streams is up to 9m thick and yields moderate amounts of water, usually 2 to 3 liter per second (Nur, et al.).

The composition of water changes through reactions with the environment and the natural chemistry can have an important bearing on anything living that utilizes this resources including human beings, livestock and even plants, so a detailed analysis of major, minor and trace constituents of groundwater is very important. Fourteen groundwater samples were collected from boreholes, springs and hand dug wells from the study area (Fig. 1) using standard sample collection procedures and analyzed for major, minor and trace constituents at the Center for Energy Research and Training, Ahmadu Bello University, Zaria and The Regional Groundwater Laboratory, Gombe using an Atomic Absorption Spectrophotometer, multi-analyte photometer and Flame Photometer and the data was interpreted with the help of RockWare Aq•QA software, a spreadsheet for water analysis to determine its suitability for use in culinary and agricultural purposes.

Six of the samples investigated are of NaCl water type while fourteen were CaCl water types. Sodium Adsorption Ratio (SAR) recorded values ranges from 0.80 – 2.84, Exchangeable Sodium Ratio (ESR) 0.33 – 1.78, Magnesium hazard (MH) 5.19 – 47.9, Residual Sodium Carbonate (RSC) 0.00, Hardness 0.65 – 221.48 and Total Dissolved Solid (TDS) ranges from 130 – 407308mg/l. Twelve of the samples analyzed had medium Salinity Hazard (SH), and one each for high and low Salinity Hazard (SH), respectively. For water with high salinity hazard, adverse effect is expected on crops, medium salinity hazard has detrimental effects only on crop that are sensitive to salinity while low salinity is suitable for all crops. The variation in chemical composition of groundwater in the study area may be due to leaching of terrestrial salts, extensive use of chemical fertilizers and ion exchange between water and the host rock.

The investigation will serve as an avenue to update groundwater data bank of the study area for those whose responsibility is the provision of safe drinking water to the entire populace around the area. It will also help in planning agricultural practices in advising the farmers on choosing the appropriate crops to be cultivated around the study area.

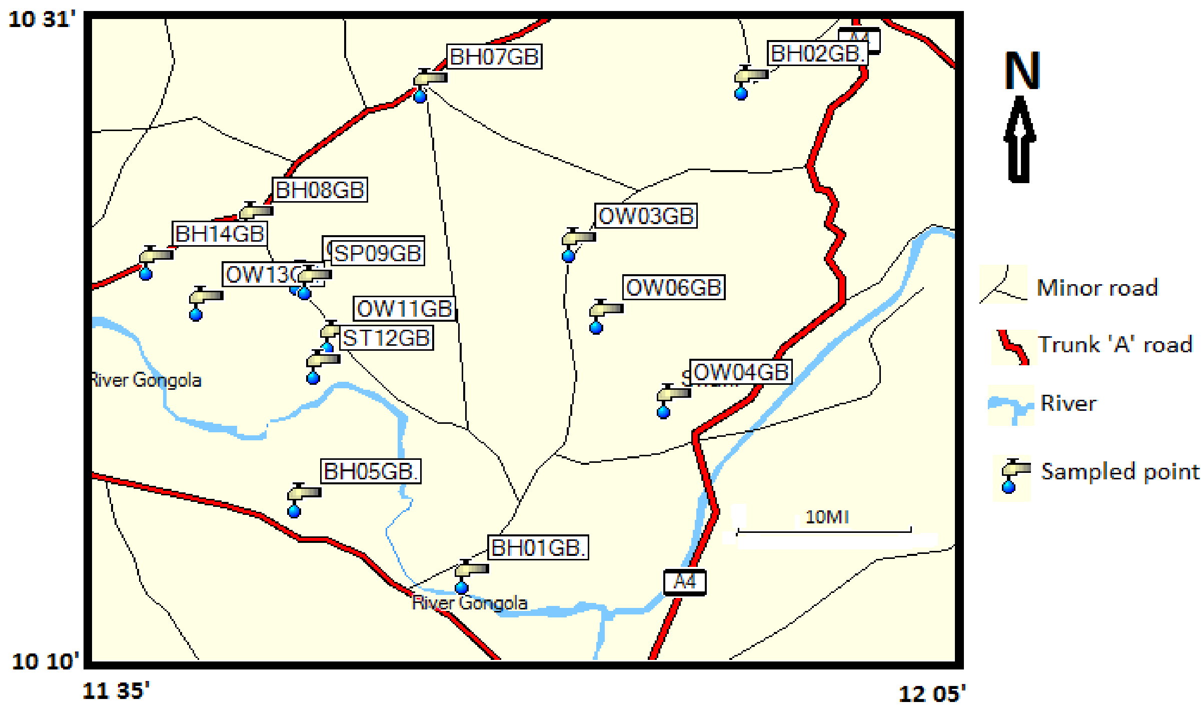

Figure 1: Location map of the study area showing sampled points (MapSource, 2006)

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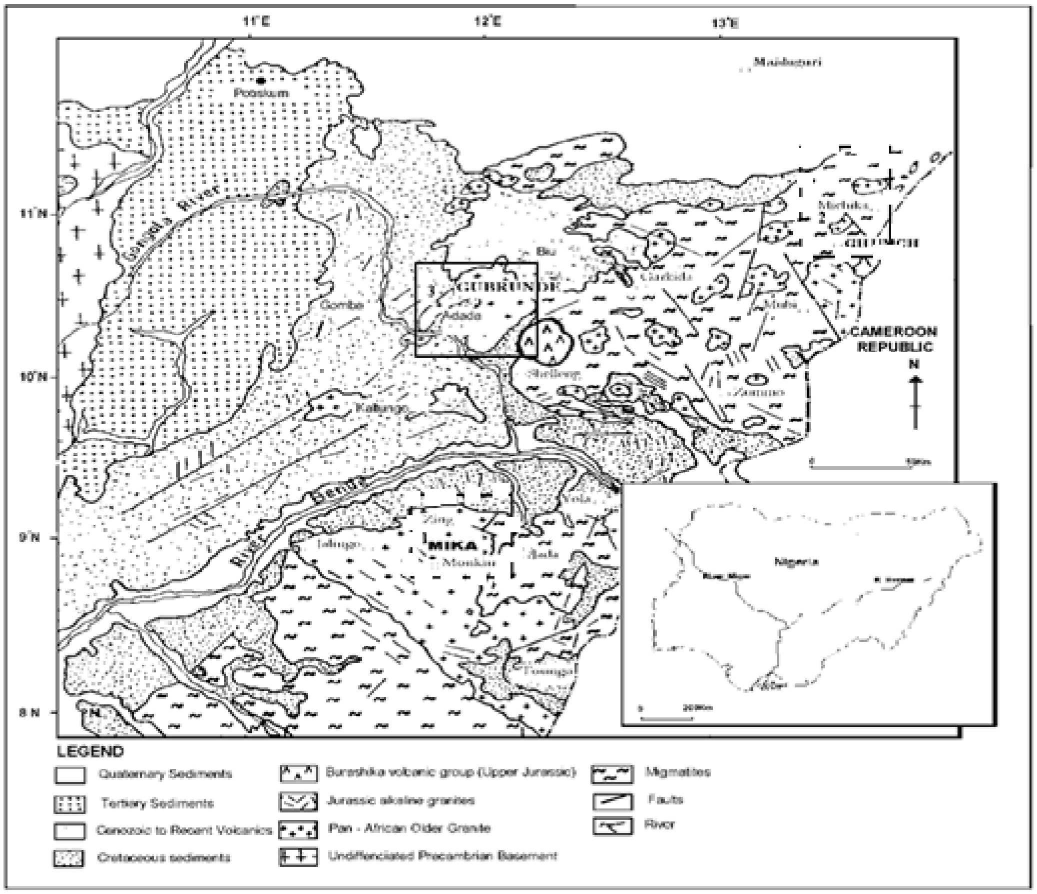

Fig.2: Geologic map of northeastern Nigeria showing the study area (Funtua, 1992)

2. Materials and Method

The water samples were collected in April, 2009 from boreholes, springs and hand dug wells with the aid of environmental sampler in order to have representative sample free from contamination from sampling tools. After each sample is collected, an in-situ measurement was made for conductivity, pH, TDS and temperature using Sension Platinum Series portable pH and Conductivity meter (HACH made). Also measured at the field are coordinates, elevation and static water level of each of the locations sampled (Table 1) using GPS and a deep meter. Samples were then stored in a plastic container after acidification with nitric acid before transporting them to the laboratory. The analysis of Si, K, O_2 and P were carried out using V2000 multi-analyte photometer, Na and K were carried out with a CORNING FLAME PHOTOMETER 410 after calibrating it with the analyte standard while the remaining analyte were carried out with BUCK SCIENTIFIC 210 VGP ATOMIC ABSORPTION SPECTROPHOTOMETER. The results obtained were then interpreted using RockWare (2006) Aq•QA spreadsheet for water analysis.

3. Results

The results of measurements obtained in-situ is presented in Table1, these include pH, conductivity, TDS, static water levels, coordinates of sampled locations, temperature and elevation of each point. Results of analysis of major and minor elements, determined water types, Sodium Adsorption Ratio (SAR), Exchangeable Sodium Ratio (ESR), Magnesium hazard (MH), Residual Sodium Carbonate (RSC), and Total Dissolved Solid (TDS) is presented in Table 2.

A graph of SO_4, HCO_3 and Cl distribution in groundwater samples is also presented in Figure 3

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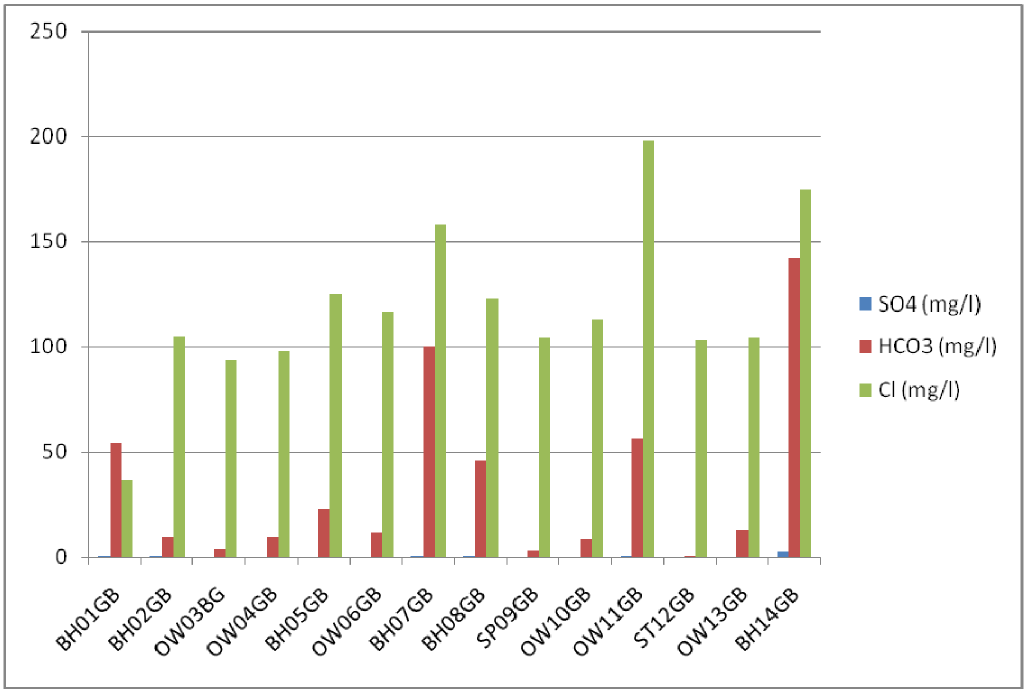

Figure 3: A graph of SO_4, HCO_3 and Cl in groundwater samples from Gubrunde and environs

Table 1: Parameters measured in-situ during field work

S/N	SAMPLE ID	COORDINATES LATITUDE	LONGITUDE	ELEV (m)	S.W.L (m)	H-HEAD (m)	PH	COND. (μs/cm)	TEMPT. (˚C)	TDS (mg/L)
1	BH01GB	09°44.176´	11°59.862´	169.47	5.00	164.47	6.55	384.00	31.20	185.30
2	BH02GB	10°36.750´	12°11.475´	757.73	10.79	746.94	6.92	1,271.00	28.20	628.00
3	OW03BG	10°21.645´	11°58.216´	312.12	2.38	309.74	5.68	71.80	28.50	33.80
4	OW04GB	10°13.370´	12°03.141´	259.69	3.54	256.15	6.59	197.10	30.00	94.30
5	BH05GB	09°33.746´	12°00.463´	188.37	6.25	182.12	7.24	779.00	32.40	380.00
6	OW06GB	10°17.853´	11°59.704´	368.81	5.33	363.47	7.45	281.00	31.20	135.00
7	BH07GB	10°30.167´	11°50.628´	350.83	11.89	338.94	6.81	1,155.00	31.30	569.00
8	BH08GB	10°23.045´	11°41.760´	306.02	25.91	280.11	6.85	699.00	31.00	340.00
9	SP09GB	10°19.688´	11°44.793´	294.13	0	294.13	6.87	142.10	28.50	67.70
10	OW10GB	10°19.934´	11°44.315´	295.96	2.50	293.46	6.39	684.00	29.10	333.00
11	OW11GB	10°16.679´	11°45.933´	254.81	11.03	243.78	6.59	1,206.00	29.50	595.00
12	ST12GB	10°15.199´	11°42.219´	261.21	0	261.21	6.15	101.70	29.40	48.20
13	OW13GB	10°18.571´	11°39.2025´	299.92	6.89	293.04	6.54	220.00	29.80	105.30
14	BH14GB	10°20.710´	11°36.656´	241.10	10.67	230.43	6.58	3,250.00	30.70	1,667.00

ELEV = elevation, S.W.L =static water level, H-HEAD = hydraulic head, COND = conductivity, TEMP = temperature and TDS = total dissolved solid

Table 2: List of major, minor elements and some fluid property parameters as determined in water samples from Gubrunde and environs

S/N	SAMPLE ID	Na (mg/l)	K (mg/l)	O_2 (mg/l)	Fe (mg/l)	NO_3 (mg/l)	Mg (mg/l)	P (mg/l)	Si (mg/l)	Ca (mg/l)	SO_4 (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	Water type	SAR	ESR	Salinity
1	BH01GB	16.3±0.02	10.6±0.51	6.24±0.80	0.14±0.02	27.2±2.01	3.74±0.21	0.02±0.001	28±0.20	6.70±0.05	0.54±0.01	54±0.21	37±0.21	Na-Cl	1.25	1.10	low
2	BH02GB	36.4±0.12	16.8±0.12	6.0±0.01	0.23±0.21	53±1.3	5.26±0.62	0.05±0.004	29.4±0.13	10.70±0.03	0.50±0.01	9.8±0.05	104.7±0.71	Na-Cl	2.27	1.64	Medium
3	OW03BG	29.7±0.022	12.5±0.33	7.73±0.62	0.74±0.12	25±0.2	4.57±0.51	0.05±0.001	33.6±0.25	10.7±0.27	0.01±0.001	3.60±0.01	93.4±0.25	Na-Cl	1.91	1.42	Medium
4	OW04GB	17.7±0.14	3.4±0.23	6.77±0.62	0.81±0.15	34±3.5	3.05±0.17	0.15±0.011	31.7±0.65	32±0.32	0.12±0.001	9.8±0.21	98. ±0.51	Ca-Cl	0.80	0.42	Medium
5	BH05GB	52±0.11	16.2±0.71	6.03±0.32	0.13±0.12	65±0.95	3.79±0.21	0.02±0.01	28.9±0.32	19.16±0.04	0.26±0.01	22.96±0.31	125±0.32	Na-Cl	2.84	1.78	Medium
6	OW06GB	36.4±0.25	2.9±0.52	6.55±0.53	0.59±0.23	76±1.9	3.49±0.51	0.04±0.001	29.4±0.52	29.8±0.06	0.14±0.001	11.84±0.18	117±0.66	Na-Cl	1.68	0.90	Medium
7	BH07GB	32.9±0.21	6.4±0.25	6.14±0.53.	0.04±0.25	47±2.1	4.06±0.90	0.01±0.002	33.1±0.51	79.6±0.21	0.8±0.002	99.68±0.54	158±0.85	Ca-Cl	0.97	0.33	Medium
8	BH08GB	36.4±0.32	2.0±0.11	5.84±0.32	0.41±0.32	21.2±0.52	3.84±0.55	0.01±0.003	20.9±0.54	41.71±0.62	0.31±0.01	45.55±0.31	123±0.32	Ca-Cl	1.44	0.66	Medium
9	SP09GB	28.3±0.57	1.3±0.23	6.03±0.52	3.01±0.25	63.8±0.25	2.64±0.01	0.04±0.002	40.6±0.61	27±0.51	0.01±0.001	2.86±0.62	104.3±0.61	Ca-Cl	1.39	0.79	Medium
10	OW10GB	33.5±0.52	26.1±0.08	6.47±0.51	0.06±0.51	72.01±2.1	3.76±0.54	0.08±0.002	27.9±0.51	14.7±0.08	0.09±0.01	8.72±0.21	113.2±0.34	Na-Cl	2.02	1.40	Medium
11	OW11GB	35.2±0.21	23.6±0.21	6.44±0.11	0.13±0.31	56.3±1.3	4.1±0.23	0.12±0.005	24.7±0.41	75±0.21	0.82±0.001	56.28±0.51	197.6±0.61	Ca-Cl	1.07	0.38	Medium
12	ST12GB	16.7±0.21	1.1±0.62	6.19±0.61	2.28±0.63	76.3±1.2	2.04±0.001	0.05±0.001	25.7±0.25	36.4±0.61	0.01±0.001	0.40±0.01	103.2±0.21	Ca-Cl	0.73	0.37	Medium
13	OW13GB	21.9±0.32	13.2±0.28	6.05±0.22	4.1±0.11	62±.23	2.5±0.11	0.17±0.01	34.5±0.31	27.6±0.05	0.21±0.01	13.16±0.31	104.5±0.61	Ca-Cl	1.07	0.60	Medium
14	BH14GB	93.8±0.02	46.4±0.01	5.9±0.32	0.18±0.01	106.5±1.2	2.8±0.21	0.21±0.001	48.9±0.61	84.3±0.11	2.75±0.03	142.6±0.71	174.4±0.61	Ca-Cl	2.14	0.72	High

SAR = sodium Adsorption Ratio,
ESR = Exchangeable Sodium Ratio

4. Discussion

The results of chemical analysis of groundwater in the study area are discussed in the following order:

a) Water types and major and minor constituents
b) Sodium Adsorption Ratio (SAR)
c) Mineral Saturation (MS)
d) Hardness
e) Residual Sodium Carbonate (RSC)
f) Total Dissolved Solid (TDS)
g) Hydrochemical data
   - Piper diagram
   - Schoeller diagram.

a. Water type

The analysis of water samples allowed the categorization of water from the study area in to two water types with formulae Ca-Cl and Na-Cl indicating Calcium and Sodium water types.

Calcium is the most abundant of alkaline earth metal and a major constituent of vast common rock minerals. Sources of calcium (Ca^{2+}) in water include calcite, aragonite, dolomite, gypsum, anhydrite, fluorite, plagioclase, pyroxene and amphibole (Brian, et al. 1980). From health point of view, the content of calcium in groundwater is unimportant. Its concentration in natural waters is typically <15mg/l. concentration of calcium in water samples analyzed ranges from 6.7 – 84.33mg/l.

Sources of sodium are halite, sea spray, some silicate and rare minerals such as plagioclase, plagioclase variety of albite and nepheline. Most sodium results from natural ion exchange. Sodium and potassium are common constituents of natural waters with sodium being more prevalent than potassium. From health point of view, potassium is unimportant but sodium can have negative effects on people with heart disease. Sodium hydrogen carbonate mineral waters are important for treatment of gastric and biliary tract diseases. WHO(2008) and the NIS(2007) Nigeria Standard for Drinking water Quality has set limit for sodium in drinking water at 200mg/l. The highest value recorded for sodium in the samples analyzed is 93.8mg/l. Except for nitrate which exceeded the limited of 50mg/l in nine of the samples analyzed all the other parameters measured (Table 2) complied with the set standard. Nitrate levels exceeded 50mg/l in drinking water having the potential of causing cyanosis, and asphyxia (blue baby syndrome) in infants less than 3 months.

Based on the HCO_3, SO_4 and Cl recorded in the samples and plotted on bar graph (Fig. 3), the water samples analyzed belong to the intermediate water category (not fresh nor old) because Cl > HCO_3 > SO_4 .

b) Sodium Adsorption Ratio (SAR)

Sodium Adsorption Ratio (SAR) is an estimate of the degree to which sodium will be adsorbed by the soil. It is used to evaluate the suitability of water for irrigation. High value of SAR means that sodium in the water may replace calcium and magnesium ions in the soil, potentially causing damage to the soil structure (Lloyd, 1985). SAR is calculated from the formula;

$$SAR = \frac{[Na^+]}{\sqrt{\frac{[Ca^{2+}] + [Mg^{2+}]}{2}}}$$

Most of the analyzed groundwater samples are medium sodium waters meaning that the water is most suitable when used on coarse-textured or organic soil with good permeability and plants with good salt tolerance. The sodium hazard is a function of both SAR and Salinity. Salinity hazard dividing points are 250, 750 and 2250µohms, resulting in four categories as given in Table 3 with corresponding µohms values.

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Table 3: Sodium and Salinity control values (Wilcox, 1955)

	Salinity status	**Sodium status**
<250 µohms	Low salinity water	Low sodium water
250 -750 µohms	Medium salinity water	Medium sodium water
750 -2250 µohms	High salinity water	High sodium water
>2250 µohms	Very high salinity water	Very high sodium water

c) Mineral Saturation (MS)

The minerals calcite and aragonite have the same chemical composition ($CaCO_3$), but different chemical structures. The saturation index of these minerals is given as;

$SI = \log Q/K = \log Q - \log K$,

where Q is the ion activity product and K the equilibrium constant and this tells whether they are;

1. supersaturated (Saturation Index > 1)
2. saturated (Saturation Index $= 0$) or
3. under-saturated (Saturation Index < 0)

All the samples analyzed are under-saturated in both calcite and aragonite with saturation values ranging from -4.34 to -0.71 for calcite and -4.89 to 0.88 for aragonite.

d) Hardness

Hardness is the sum of Ca^{2+} and Mg^{2+} concentrations expressed in terms of mg/l of calcium carbonate:

Hardness = 2.5 Ca (mg/l) + 4.1 Mg(mg/l) (Fournier,1981)

Calcium and magnesium form an insoluble residue with soap. The degree of hardness in water is commonly based on the classification listed in Table 5(Sawyer and McCarty, 1967).

Table 5: Classification of water hardness (Sawyer and Mc Carty, 1967)

Hardness range (mg/l of $CaCO_3$)	**Water classification**
0 – 75	Soft
75 – 150	Moderately hard
150 – 300	Hard
>300	Very hard

Most of the groundwater samples analyzed had hardness value ranging from 0.65 – 74.5mg/l except sample BH07GB and BH14GB which have hardness value of 163.07 and 221.48, respectively. Hardness value below 75mg/l indicate that the samples analyzed are soft water indicating that twelve of the fourteen water samples analyzed are soft water while the remaining two are hard water. These samples also recorded the highest conductivity values of 664 and 962µs/cm, respectively. So, most of the samples analyzed passed the hardness limit set by WHO, 2008 and NIS, 2007 Nigeria Standard for Drinking Water Quality except samples BH07GB and BH14GB.

e) Residual Sodium Carbonate (RSC)

Residual Sodium Carbonate (RSC) value considers the bicarbonate content of the water. High concentration of bicarbonate leads to an increases in pH value of water that causes dissolution of organic matter. An increase in RSC value leads also to precipitate calcium and magnesium that can cause an increase in sodium content in the soil. The high concentration of bicarbonate ion in irrigation water leads to its toxicity and affects the mineral nutrition of plants.

According to Eaton's classification, water with RSC greater than +2.5epm is considered unsuitable for irrigation. The water with RSC of +1.25 to +2.5 is considered as marginal and those with a value less than +1.25 are safe for irrigation purpose. All the water samples analyzed had RSC values of less than 1.25 suggesting that the water can be used for irrigation purpose.

f) Total Dissolved Solid (TDS)

Increase in dissolved solids in irrigation water affects soil efficiency and growth and yield of plants. For long term irrigation under average conditions, the total dissolved solids should not exceed 2000mg/l. High increase in water salinity increases salts amount in soil and leads to salinization problem. Classification of water according to TDS values (Wilcox, 1955) is given in Table 4.

Table 4: Classification of irrigation water based on TDS value (Wilcox, 1955)

TDS (mg/l)	Status
200–500	Best quality water
1000–2000	Water involving Hazard
3000-7000	Used for irrigation only with leaching and perfect drainage

The highest TDS value recorded in the examined groundwater samples is 670mg/l and the lowest is 130mg/l which indicates that base on TDS categorization, the water in the area studied is good for irrigation purpose.

g) Graphical presentation of data

Piper diagram is a combination of anions and cations triangle that lies on a common baseline. It divides waters into basic types according to their placement near the four corners of the diamond. Water that plots at the top of the diamond is high in Ca^{2+} + Mg^{2+} and HCO_3^- and is the region of waters with temporary hardness. Waters plotted at the lower corner of the diamond is composed primarily of Na^+ + K^+ and HCO_3^- + CO_3^{2-}. The plot according to this arrangement is presented in Figure 4 where three classes of combinations were obtained. The Schoeller diagram represents the combination of major and minor constituents of groundwater in the study area in a diagram (Fig. 5) and the result obtained indicates that Cl is dominant and SO_4 as the least in the following order: Cl, Na + K, Ca, Mg, HCO_3,+ Co_2 then SO_4.

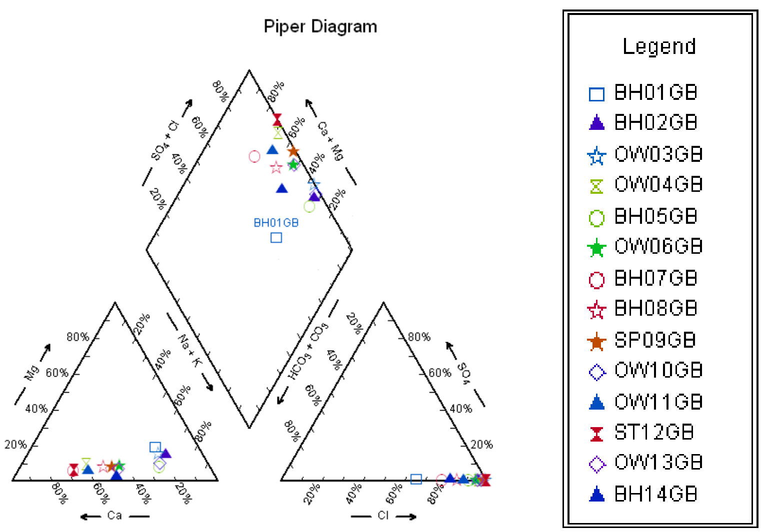

Figure 4: Piper diagram for water samples from Gubrunde and environs

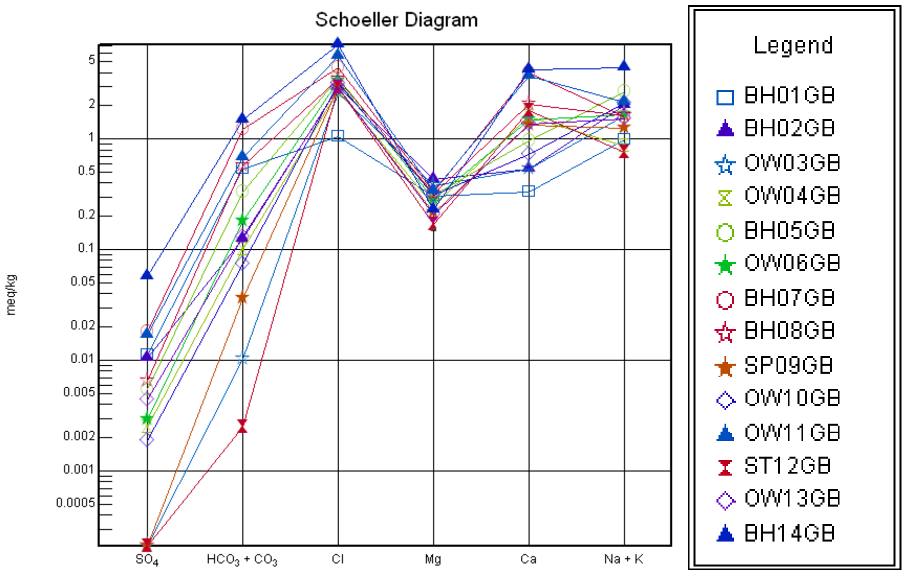

Figure 5: Schoeller diagram for water samples from Gubrunde and environs

5. Conclusions

The results of analysis and interpretation of groundwater from Gubrunde and environs for domestic and irrigation purpose indicates that samples BH14GB is not suitable for irrigation while sample BH01GB being most suitable, the remaining twelve samples is most suitable on coarse-textured or organic soil with good permeability and plants with good salt tolerance. For domestic uses and based on WHO, 2008 and NIS, 2007 Nigeria Standards, the water is good for drinking and other culinary purposes except the high concentration recorded for nitrate which can cause asphyxia in infants less than three months. Based on the findings, the groundwater in the area studied is fairly suitable for agricultural purpose and suitable for use in homes.

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