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RESEARCH ARTICLE

Study of Suitability of Groundwater for Household and Irrigation Purposes in Parts of Adamawa State, Northeastern Nigeria

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ABSTRACT

Groundwater samples were collected from boreholes, streams, springs and hand dug wells during the peak of dry season from twelve different locations covering an area of about 159km^2 in and around Ghumchi in Adamawa State north-eastern Nigeria to evaluate its quality for household and irrigation purposes. The area covered falls within longitude 13° 17' - 13° 33' and latitude 10° 34' - 10° 48'. The samples collected were analyzed using Atomic Absorption Spectrometer (AAS), multi-analyte photometer and Flame photometer while the results were interpreted with a software, RockWare Aq•QA spreadsheet for water analysis. Two of the water samples analyzed were NaCl type while the remaining ten samples were CaCl type. The recorded average values for Sodium Adsorption Ratio (SAR), Exchangeable Sodium Ratio (ESR), Magnesium Hazard (MH), Residual Sodium Carbonate (RSC), hardness and Total Dissolved Solid (TDS) 1.24, 0.67, 15.06, 0.0, 24.61 and 180.82mg/l respectively. All the samples analyzed had medium salinity. The variation in chemical composition of groundwater in the study area may be due to extensive use of chemical fertilizers, ion exchange between water and the host rock and leaching of terrestrial salts,. The result also indicates that the water samples analyzed are undersaturated in calcite and aragonite. Only four of the samples analyzed had nitrate value slightly exceeding the Nigeria Standard for drinking water quality of 50mg/l, while major anion and cations falls within the Standard Values. Most of the groundwater samples analyzed are suitable for domestic uses except four samples which had nitrate values exceeding the set standard and so have the tendency of causing cyanosis, and asphyxia in babies less than three months old while for irrigation purposes the water is good for coarse-textured or organic soil with good permeability and plants with good salt tolerance.

***KEY WORDS**: Asphyxia; Detrimental effect: Sodium Adsorption Ratio: Exchangeable Sodium Ratio*

INTRODUCTION

Water is life and its quality has direct implication on the health of animals, human beings, yield of crops and even the quality of product whose production in industries utilizes water. Safe drinking water most satisfies all conditions sets as standard either by the World Health Organization or by individual national bodies that regulates the use of water resources. Hydrochemical data is used in this study of quality of groundwater and in tracing the origin and history of water. This Study of hydrochemistry of groundwater from north-eastern Nigeria is based on the results of the chemical analysis of water samples from the study area. The area sampled area covered about 159km^2 and falls within longitude 13° 17' - 13° 33' and latitude 10° 34' - 10° 48' in Michika and parts of Madagali local government areas of Adamawa State, north-eastern Nigeria.. Geologically, the area is covered by the Basement complex rocks which consist of Gneiss-migmatite, Quartzite and other Granitoids rock of Precambrian age. The Gneiss-migmatite rocks have undergone a weathering process that leads to the formation of laterite, gravels, sand, clays and silt materials. The Granitoids mainly contain feldspars, biotites, and occasionally microcline (Figure 1). The granitoids, also called older granites, are products of the Pan African Orogeny (about 1500 my ago). Water supply in the study area is mainly from a few hand-dug wells and an inadequate number of boreholes. The aquifer unit in the study area is mainly in the weathered/fractured basement, and poor infiltration of the surface water during the rainy season results in shallow water table conditions because of the low permeability characteristics of these rocks [1].

The composition of water changes right from the time it falls from space, during infiltration into the subsurface through different geologic materials and in the saturation zones. The reactions of water with the environment and the natural chemistry can have an important bearing on human beings, livestock and even plants, therefore, a detailed analysis of major, minor and trace constituents of groundwater is an important step in reducing the risks that is associated with water.

A total of twelve groundwater samples were collected from different sources(boreholes, hand dug wells, springs and streams) from the study area using a 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 while the data was interpreted using RockWare Aq•QA spreadsheet software for water analysis to determine its suitability for domestic and irrigation purposes.

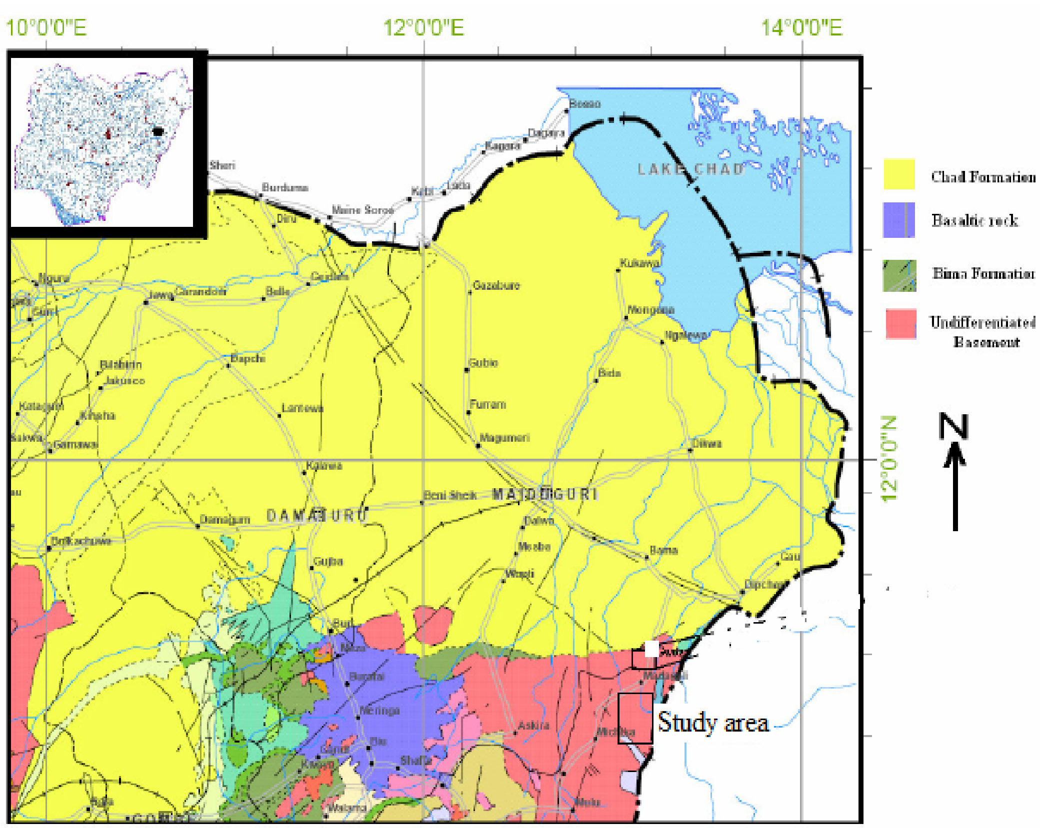

Fig.1: Geologic map of northeastern Nigeria showing the study area (GSNA, 2008)

The results of the interpretation categorized the water samples into two water types; these are CaCl and NaCl. The recorded average values for Sodium Adsorption Ratio (SAR), Exchangeable Sodium Ratio (ESR), Magnesium Hazard (MH), Residual Sodium Carbonate (RSC), hardness and Total Dissolved Solid (TDS) 1.24, 0.67, 15.06, 0.0, 24.61 and 180.82mg/l respectively. All the samples analyzed had medium salinity hazard which is an indication that for irrigation purposes, the water has detrimental effects on crops that are sensitive to salinity. The variation in chemical composition of groundwater in the study area is due to ion exchange between water and the different geologic materials that constitute the host rock and extensive use of chemical fertilizers.

This study will be of importance in planning the appropriate that is most suitable for the study area, it has updated the knowledge of groundwater in the area and has enriched groundwater data bank of the area. It is also important to those charged with responsibility of planning and providing safe drinking water to the entire populace around the area.

MATERIALS AND METHOD

The water samples were collected in April, 2009 from boreholes, springs and hand dug wells using an environmental sampler supplied to the Centre for Energy Research and Training by the International Atomic Energy Agency (IAEA). The use of environmental sampler was to have a representative sample that is free from contamination from sampling tool. 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 it to the laboratory. The analysis of Si, 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 a BUCK SCIENTIFIC 210 VGP ATOMIC ABSORPTION SPECTROPHOTOMETER. The results obtained was then interpreted using RockWare [2] Aq•QA spreadsheet for water analysis.

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 tables 1and 2. A graph showing the distribution of SO_4, HCO_3 and Cl is presented in figure 2.

Table 1: Parameters measured in-situ during field work in Ghumchi and environs

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	BH01GM	10°38.835´	13°26.722´	548.34	18.32	530.02	6.91	424.00	32.70	246.00
2	SP02GM	10°38.811´	13°27.438´	549.86	-	549.86	6.10	394.40	27.00	196.50
3	BH03GM	10°38.896´	13°28.385´	561.14	20.42	540.72	6.69	347.00	31.20	199.00
4	BH04GM	10°37.347´	13°29.250´	600.76	16.46	584.30	7.16	312.00	30.50	172.00
5	ST05GM	10°34.639´	13°31.336´	649.83	-	649.83	6.11	419.60	31.00	211.30
6	BH06GM	10°38.757´	13°32.902´	642.52	17.98	624.54	6.46	375.00	30.00	179.10
7	BH07GM	10°44.875´	13°25.090´	461.47	3.38	458.08	6.62	310.00	28.60	137.40
8	OW08GM	10°34.909´	13°20.417´	510.24	1.89	508.35	6.25	263.60	26.00	133.60
9	OW09GM	10°47.285´	13°26.248´	456.29	9.33	446.96	6.38	319.00	29.60	164.50
10	OW10GM	10°44.240´	13°29.003´	510.54	13.35	497.19	6.06	342.00	30.00	164.80
11	BH11GM	10°43.024´	13°29.616´	534.01	11.55	522.46	7.05	372.00	30.00	198.00
12	OW12GM	10°42.060´	13°30.823´	544.37	1.86	542.51	6.44	309.40	30.60	155.90

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

DISCUSSION

The results of chemical properties 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) Piper diagram and Schoeller diagram.

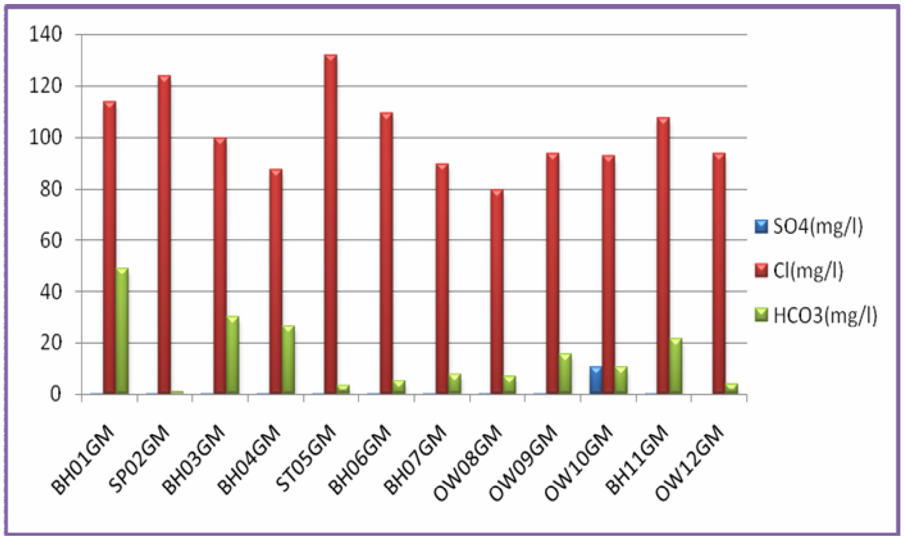

Figure 2: A graph of SO_4, HCO_3 and Cl from studied samples

a. Water type

The results of analysis made revealed that water samples from the study are of two types; the CaCl type and NaCl type, only two of the twelve samples analysis constitute the NaCl type while the remaining are the CaCl type.

Calcium is the most abundant of alkaline earth metal and a major constituent of vast common rock minerals. Sources of calcium (Ca^{++}) are calcite, aragonite, dolomite, gypsum, anhydrite, fluorite, plagioclase, pyroxene and amphibole [3]. 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 21.7 – 45.01mg/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[4] and the NIS, 2007 [5]Nigeria Standard for Drinking water Quality has set limit for sodium in drinking water as 200mg/l.

The highest value recorded for sodium in the samples analyzed is 33.6mg/l. Except for nitrate which exceeded the limited of 50mg/l in five of the twelve samples analyzed (Table 2) while the remaining samples complied with the set standard. Nitrate levels exceeded 50mg/l in drinking water have the potential of causing cyanosis, and asphyxia (blue baby syndrome) in infants less than 3 months. Six of the samples had Fe values greater than the 0.3mg/l set standard, and for magnesium, all the samples had Mg values slightly exceeding a set standard of 0.2mg/l with highest record of 3.95mg/l.

b) Sodium Adsorption Ratio (SAR)

Sodium Adsorption Ratio (SAR) is used to evaluate the suitability of water for irrigation. It estimates the degree to which sodium will be adsorbed by the soil. 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 [8]. SAR is calculated from the formula;

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

Table 2: List of major, minor elements and some fluid property parameters as determined in water samples from the study area (SAR= sodium Adsorption Ratio, ESR= Exchangeable Sodium Ratio and MH= Magnesium Hazard)

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	MH
1	BH01GM	30.7±0.02	2.10±0.09	6.23±0.21	0.15±0.01	35.2±0.21	3.95±0.12	0.008±0.001	36.4±0.31	45.01±.021	0.25±0.01	48.96±0.21	113.60±0.08	Ca-Cl	1.18	0.52	12.6
2	SP02GM	27.3±0.12	2.80±0.12	6.65±0.32	5.64±0.12	65.01±0.28	2.49±0.012	0.05±0.0012	33.1±0.48	38.70±0.02	0.02±0.00	0.80±0.01	123.5±0.51	Ca-Cl	1.15	1.56	9.60
3	BH03GM	24.6±0.022	1.40±0.01	7.64±0.31	8.06±2.51	167±0.51	3.62±0.17	0.003±0.001	33.6±0.22	32.6±0.23	0.10±0.01	30.16±0.62	99.4±0.61	Ca-Cl	1.09	0.56	15.50
4	BH04GM	28.3±0.14	2.30±0.01	5.98±0.31	0.28±0.21	173±2.5	3.7±0.054	0.0056±0.001	34.5±0.61	23.00±0.021	0.12±0.01	26.70±0.52	87.21±0.32	Na-Cl	1.44	0.85	21.00
5	ST05GM	33.6±0.11	2.70±0.03	7.29±0.14	5.79±0.12	24.03±0.61	2.45±0.01	0.05±0.002	29.4±0.54	37.4±0.001	0.12±0.001	3.28±0.03	132±0.91	Ca-Cl	1.44	0.71	9.75
6	BH06GM	31.0±0.25	1.30±0.02	5.85±0.051	0.32±0.021	54.01±0.09	2.45±0.14	0.005±0.001	35.5±1.02	29.3±0.21	0.19±0.02	5.10±006	109±0.80	Ca-Cl	1.48	1.81	12.10
7	BH07GM	27.3±0.21	4.30±0.02	6.49±0.36	3.60±0.012	13.7±0.13	3.44±0.012	0.03±0.001	11.3±0.91	24.7±0.32	0.07±0.001	7.60±0.21	89.62±0.51	Ca-Cl	1.36	0.78	18.70
8	OW08GM	16.0±0.32	1.00±0.01	5.92±0.21	7.03±0.21	40.0±0.66	2.81±0.03	-	14.6±0.70	24.00±0.52	0.09±0.01	6.80±0.07	79.4±0.32	Ca-Cl	0.82	0.49	16.20
9	OW09GM	27.3±0.57	1.60±0.01	6.41±0.41	0.14±0.01	39.02±0.32	3.49±0.021	0.01±0.007	12.7±0.11	21.7±0.61	0.25±0.003	15.36±0.09	93.4±0.21	Na-Cl	1.43	0.87	21.00
10	OW10GM	23.1±0.52	1.70±0.12	6.16±0.08	0.25±0.01	46.33±0.65	3.36±0.011	0.02±0.002	45.12±0.84	28.6±0.52	10.60±0.05	10.72±0.12	92.740±0.11	Ca-Cl	1.09	0.59	16.20
11	BH11GM	27.0±0.21	3.50±0.17	6.86±0.012	4.23±0.21	74.31±0.07	3.83±0.14	0.0054±0.001	32.17±0.27	34.32±0.21	0.27±0.01	21.3±0.05	107±0.51	Ca-Cl	1.16	0.58	15.50
12	OW12GM	24.4±0.21	2.70±0.021	6.46±0.04	0.98±0.01	37.01±0.62	2.3±0.051	0.02±0.004	17.9±0.46	26.4±0.51	0.00	3.76±0.03	93.6±0.91	Ca-Cl	1.22	0.70	12.60

Table 3: Nigeria Standard for Drinking water Quality (NIS, 2007)

Parameter	Unit	Maximum Permitted	Health Impact	Notes
Aluminum (Al)	mg/L	0.2	Potential Neuro-degenerative disorders	Note 1
Arsenic (As)	mg/L	0.01	Cancer,	
Barium	mg/L	0.7	Hypertension	
Cadmium (Cd)	mg/L	0.003	Toxic to the kidney	
Chloride (Cl)	mg/L	250	None	
Chromium (Cr^{6+})	mg/L	0.05	Cancer	
Conductivity	µS/cm	1000	None	
Copper (Cu^{+2})	mg/L	1	Gastrointestinal disorder,	
Cyanide (CN^-)	mg/L	0.01	Very toxic to the thyroid and the nervous system	
Fluoride (F^-)	mg/L	1.5	Fluorosis, Skeletal tissue (bones and teeth) morbidity	
Hardness (as $CaCO_3$)	mg/L	150	None	
Hydrogen Sulphide (H_2S)	mg/L	0.05	None	
Iron (Fe^{+2})	mg/L	0.3	None	
Lead (Pb)	mg/L	0.01	Cancer, interference with Vitamin D metabolism, affect mental development in infants, toxic to the central and peripheral nervous systems	
Magnesium (Mg^{+2})	mg/L	0.20	Consumer acceptability	
Manganese (Mn^{+2})	mg/L	0.2	Neurological disorder	
Mercury (Hg)	mg/L	0.001	Affects the kidney and central nervous system	
Nickel (Ni)	mg/L	0.02	Possible carcinogenic	
Nitrate (NO_3)	mg/L	50	Cyanosis, and asphyxia ("blue-baby syndrome") in infants under 3 months syndrome") in infants under 3 months	
Nitrite (NO_2)	mg/L	0.2	Cyanosis, and asphyxia ("blue-baby syndrome") in infants under 3 months	
pH	-	6.5-8.5	None	
Sodium (Na)	mg/L	200	None	
Sulphate (SO_4)	mg/L	100	None	
Total Dissolved Solids	mg/L	500	None	
Zinc (Zn)	mg/L	3	None	

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. SAR recorded ranges from 0.822 – 1.48 and had an average value of 1.24.

Table 4: 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 of the samples analyzed are under-saturated in both calcite and 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) [6].

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 Mc Carty, 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

All groundwater sample analyzed had hardness value ranging from 91.31 – 80.09mg/l with average value of 24.61mg/l. From these values, only one had hardness value greater than the set standard of 75mg/l, this is recorded in sample BH01GM and the recorded value is 80.09mg/l. Most of the samples are soft water and has satisfied the limit set by WHO, 2008 and NIS, 2007 Nigeria Standard for Drinking Water Quality.

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 the organic matter. The 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 analysis has RSC values of 0.0 which is less than 1.25 meaning that the water is suitable for irrigation purpose.

f) Total Dissolved Solid (TDS)

The 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 [7] is given in table 6.

Table 6: Classification of irrigation water base on TDS value [7]

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

The TDS recorded ranges from 132.62 – 245.3mg/l with average value of 180.82mg/l. The highest TDS value recorded in the examined groundwater samples is 245.3mg/l, this indicates that base on TDS categorization, and the water samples analyzed is good for irrigation purpose.

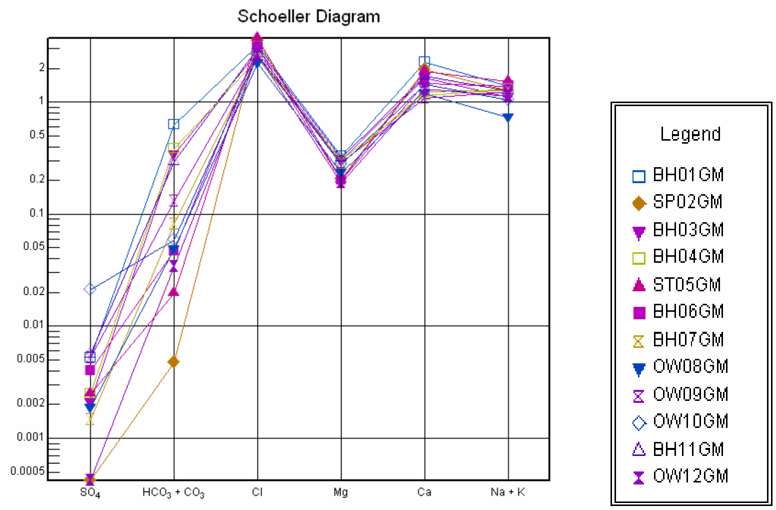

Figure 3: Schoeller diagram for water samples from Ghumchi and environs

g) Schoeller diagram and Piper

Piper diagram is a combination 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 is 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. 3) and the result obtained indicates that Cl is dominant and SO_4 as the least in the following order: Cl, Ca, Na + K, Mg, HCO_3,+ CO_2 then SO_4.

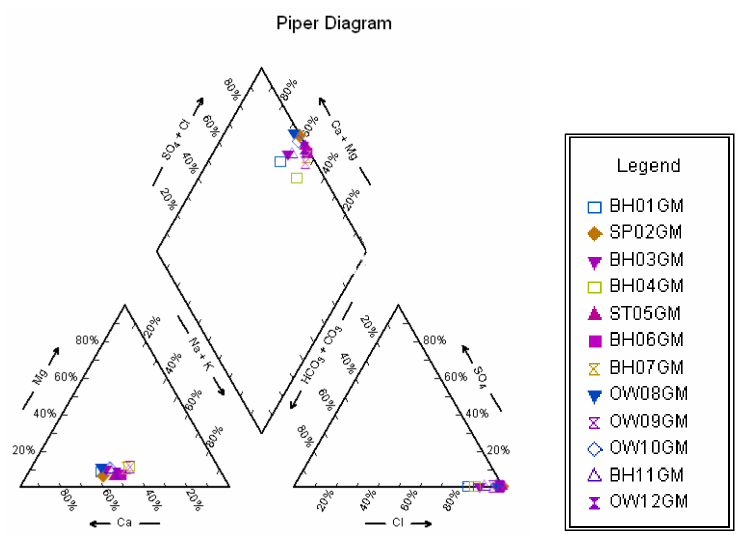

Figure 4: Piper diagram for water samples from Ghumchi and environs

CONCLUSIONS

The results of analysis and evaluation of groundwater from twelve locations in Adamawa State for domestic and irrigation purpose revealed that the water is suitable for domestic uses. And for irrigation purposes, the water is good for irrigation base on results of RSC, TDS, MH and hardness, while SAR and salinity hazard indicates that the water is best for coarse-textured or organic soil with good permeability and suggest that plants with good salt tolerance be cultivated using this water. And based on WHO, 2008 and NIS, 2007 Nigeria Standard for Drinking Water Quality, the water is good for drinking and other culinary purposes except the higher concentration recorded for nitrate which can cause blue baby syndrome in infants less than three months. Base on these findings, the groundwater samples analyzed is generally suitable for use in homes and for agricultural purpose if used on the appropriate type of land.

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References

[1] Nur, A and Kujir, A. S. (2006).Hydro-Geoelectrical study in the northeastern part of Adamawa State, Nigeria. *Journal of environmental Hydrology*. Vol 14(**19**). 20-26.

[2] RockWare. Spreadsheet software for water analysis. Prairie city computing, inc. Aq•QA Application 1.1.1 [1.1.5.1] (Unicode Release) 07/22/2006

[3] Brian, J. S and Stephen C. P, Physical Geology. Fourth edition, Wiley. 2006.

[4] World Health Organization. Guidelines for Drinking Water Quality. 2008. Third edition incorporating the first and second addenda, Vol.1.Recommendation, NCW classifications WA675.

[5] Nigeria industrial Standard,NIS:554, Nigeria Drinking Water Quality Standard: 2007. ICS 13.060.20. Approved by the Standard Organization of Nigeria. 2007. Pp30.

[6] Fournier, R.O. Application of water Geochemistry to Geothermal exploration and reservoir engineering in L. Rybach and L.J.P. Muffler, eds., Geothermal Systems, Principles and Case Histories, Wiley, New York, .1981. 109-143.

[7] Wilcox, L. V. Classification and Use of irrigation Waters, U.S.A. Salinity lab. Circulation. No. 969. 1955.

[8] Lloyd, J.W. and Heathcote, J.A. Natural Inorganic Hydrochemistry in Relation to Groundwater. Oxford Press Oxford 1985. 296 pp.

[9] Funtua, I.I. Geology and Geochemistry of Uranium Mineralization in Mika, north-eastern Nigeria, PhD thesis Department of Geology, Ahmadu Bello University, Zaria Nigeria. 1992..

[10] MapSource. Trip waypoint manager V4.4.00, Garmin limited. Version 6.11.6. 2006..