Hydrochemical Characteristics and Quality Assessment of Groundwater from Umuogadu Oshia, Ngbo, S.E, Nigeria

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Abstract
This study has evaluated the Hydrochemical characteristics of Umuogadu Oshia, Ngbo, Southeastern Nigeria. 12 representative groundwater samples in the study area were collected and analyzed using different analytical techniques. The pH range from 7.8 to 8.8, temperature from 27.00 to 29.00 ^{0}C, electrical conductivity (EC) from 10.0 to 1754.00 µS/cm, total dissolved solid (TDS) from 10.0 to 786.0 mg/l and total hardness (TH) from 14.0 to 271.0 mg/l. The analytical results present the abundance of the ions in the following order: Mg > Ca > Na > K and Cl > SO_4 > HCO3 > NO_3 > CO_3. This hydrochemical profile reflects a Na-Cl dominated water type suggesting impact of saline water on the groundwater system. The major ions concentrations are within recommended WHO (2011) standard for drinking water. Estimated major ionic ratios such as Mg/Ca (0.0286 to 8.619), HCO_3/Cl (0.033 to 0.125) confirmed the transformation of fresh water to saline water due to impact of saline water mixing. Piper trilinear diagram for the study area shows that there is only one types of water with Ca and Cl as the major dominant ions.
Keywords: Hydrochemical characters, Umuogadu Oshia and Quality assessment.

1. INTRODUCTION

In Umuogadu Oshia, Ngbo, Southeastern Nigeria, scarcity of potable water has been posing serious challenges to the people of the area for a long time and obtaining safe drinking water for domestic and other uses has been very difficult. The consequence of water scarcity in some villages in the area, especially during the peak of the dry season often manifests in the outbreaks of some water borne diseases like diarrhoea, cholera, guinea worm, typhoid, etc (Edet *et al.,* 2011). Even though the efforts of government agencies and international agencies like the Ebonyi State Rural Water Supply and Sanitation Agency, Abakaliki (EB-RWASSA), United Nations International Children Emergency Fund (UNICEF), the European Union (EU), have recorded significant success in making safe drinking water available to few villages and, therefore, curbing the menace of some of these diseases, a lot still needs to be done in many other communities. The assessment of groundwater quality status is important for socio-economic development of any region. It is therefore difficult to imagine any programme for human development that does not require a readily available supply of potable water. The physical, chemical and biological characteristics of water determine its usefulness for domestic, industrial and agricultural purposes (Ariyo *et al*., (2005). Many researchers have also shown that mineralogical composition of the underlying rock (s), secondary products and the nature of the surface run-offs are factors that affect quality of groundwater (Tijani, 1994, Edet and Ekpo, 2008; Amadi *et al*., 2010). It has also been established that geology has a role to play in the chemistry of subsurface water (Olatunji, *et al*., 2001; Abimbola, *et al*., 2002). The need to ascertain the quality of water used by humans has become very intense in the past decade (Olatunji, *et al*., 2005; Nwankwoala *et al*., 2007). The suitability of groundwater for drinking (domestic), industrial (manufacturing industry) and irrigation (agricultural) purposes depends on its hydrogeochemical composition (Singh and Singh, 2008; Khodapanah *et al*., 2009). No published data on the composition of the major ions of groundwater in Umuogadu Oshia area exist. This paper therefore examines the hydrochemical attributes, the quality of groundwater and finally factors affecting quality water in the area.

2. LOCATION OF THE STUDY AREA

Umuogadu Oshia is located within the Ngbo area of Southeastern Nigeria. It lies between latitudes $6^0 30^1$N and $6^0 50^1$N and longitudes $7^0 80^1$E and $8^0 00^1$E. The area is drained by River Ebenyi, River Iyizor and River Barabara. Two marked seasons in the study area exist: the dry and the wet seasons. The wet season begins in March and ends in October. The dry season begins in October and ends in February. These two seasons are dependent on two prevailing winds blowing over the country at different times of the year. The dry hammattan wind is the northeastern trade wind that blows from the Sahara Desert and prevails in the dry season, and the marine wind is the southwestern trade wind that blows from the Atlantic Ocean during the wet season. The temperature in the dry season ranges from 20 to 38°C and, during the rainy season, from 16 to 28°C. The average monthly rainfall ranges from 3.1 mm in January and 270 mm in July. The average annual rainfall ranges from 1750 to 2250 mm. Two distinctive vegetative regions in the study area exist. These are the Parkland, a savannah that occurs in the north of the study area, and the tropical rainforest, which occurs in the south. Stunted trees and pockets of derelict woodland or secondary forests consisting of few shrubs with dispersed large trees and climbers characterize the Parkland. The tropical rainforest is a luxuriant type of vegetation that comprises a multitude of evergreen trees. In addition, smaller palm trees, climbing plants, parasitic plants that live on other plants, and creepers are observed. The base map of Umuogadu Oshia showing the sample points is presented in Figure 1.

3. GEOLOGY AND HYDROGEOLOGY

The study area is underlain by the Abakaliki Shale Formation of the Albian Asu River Group (Reyment, 1965). It is the oldest marine sedimentation in the southeastern Nigeria which followed the deposition of Aptian Ogoja Sandstone. The Abakaliki shale Formation consists mainly of poorly bedded, dark grey shale, volcanoclastics, mudstone with subordinate lenses of sandstones, and sandy limestone. The sediments have been folded and fractured particularly following the series of tectonic episodes which have acted on them from the Albian times (Benkhelil, 1986). The geology of the study area is predominantly shale facies of the group otherwise known as the Abakaliki Shale (Agumanu, 1989). The lead – zinc mineralization in the Abakaliki – Benue Trough occur in the fractures. The evidence of igneous/volcanic activities in the Abakaliki area (Southern Benue Trough) is represented by various intrusive deposits and volcanoclastics in the study area. Umeji (2000) has argued that the fracture systems originated from movement resulting from the rising and cooling of magma, which intruded the sediments during the Santonian epirogeny which created uplifts in the Abakaliki and subsidence in both flanks of the Abakaliki Anticlinorium which resulted in the formation of Anambra and Afikpo Synclines. The high level of induration of the shales, which has made some people use them for construction works, have been interpreted as low grade metamorphism (Obiora and Charan, 2011). Sedimentary rock is folded and fractured, particularly in the country south of Abakaliki; the fold axes and dominant rock fractures are oriented northwest-southeast. Weathered rocks, alluvium, and fractured zones, some of which are isolated, form the aquifers in the study area.

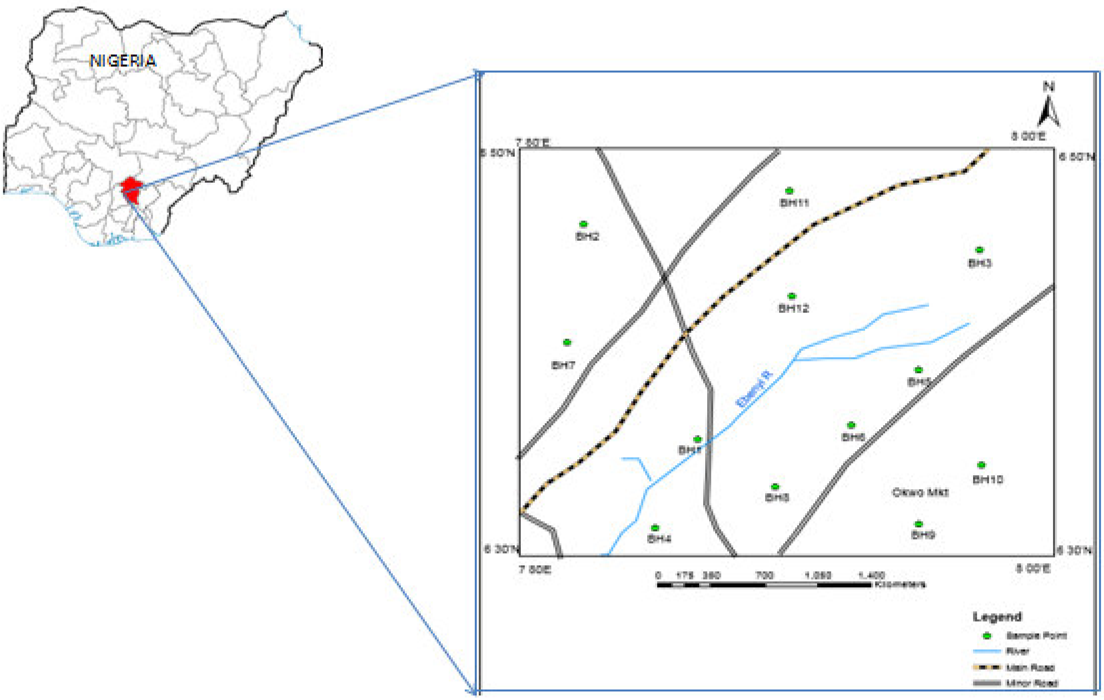

Fig. 1: Map of Umuogadu Oshia showing the Sample Points.

4. MATERIALS AND METHODS

Groundwater samples were collected from twelve (12) boreholes in the dry season (between November and February) from shallow borehole depth less than 40 m. These boreholes are the primary source of domestic water supply in the area. Samples were collected in plastic bottles that were precleaned with concentrated hydrochloric acid and distilled water (Hem, 1985). Parameters like Ph, temperature and electrical conductivity were determined in the field due to their transient nature. The pH of the water sample was measured with a pH-meter (ASTM D1293-12). The temperature was read using mercury in glass thermometer. The electrical conductivity was measured using a Mark electronic switchgear conductivity meter (APHA 2510B). The samples were then stored in an ice-packed cooler for analysis before taking them to the laboratory. All analyses were carried out at a standard laboratory using national and international regulatory methods. The evaluation of water quality was in accordance with regulatory standard. The approach ensures that the samples collected were tested in accordance with agreed requirements using competent personnel as well as appropriate equipment and materials. Cations (Na^+, k^+, Mg^{2+}, Ca^{2+}) were analysed using ASTM D511-09A. Anions (NO_3^-, SO_4^{2-}, Cl^- and HCO_3^-) were analyzed using different methods. Cl^- and SO_4^{2-} were determined by ASTM D4327-03, NO_3^- was determined by ASTM D3867-90A and HCO_3^- was analyzed by titration with sulphuric acid.

5. RESULTS AND DISCUSSION

The analytical results for groundwater samples from study area are presented in Tables 1 and 2. Groundwater temperature in the study area varied from 27.00 ^{0}C to 29.00 ^{0}C with an average of 28.50 ^{0}C. Electrical Conductivity value ranged from 10.0 µS/cm to 1754.00 µS/cm with an average value of 712.5 µS/cm in the water. Conductivity usually indicates the presence of dissolved ions. The groundwater has high conductivity and the values indicate that the borehole water is in contact with more dissolved inorganic constituents. The pH value ranged from 7.8 to 8.8 with an average of 8.33. This result revealed that the groundwater in the study area is moderately alkaline. Total dissolved solids (TDS) range in value from 10.0 to 786.0 mg/l with an average value of 341.0 mg/l. This is far below the stipulated value of 1200 mg/L for drinking water hence the water is not harmful in view of this parameter. Total hardness ranges from 14.0 to 271.0 mg/l with an average value of 125.6 mg/l in concentration indicating that the water is hard when compared with the classification of water based on hardness (Table 2). The analytical results present the abundance of the ions in the following order: Mg > Ca > Na > K and Cl > SO_4 > HCO3 > NO_3 > CO_3 (Table 3). Chloride is the dominant anion in the groundwater of the study area. Chloride values ranges from 42 to 167 mg/l, with mean value of 118.36 mg/l. Sulphate value ranges from 21.0 to 63.0 mg/l with mean of 40.25 mg/l, followed by Bicarbonate (2.5 - 20.8 mg/l), with the mean value of 7.29 mg/l, Nitrate values ranges from 0.47 to 0.76 mg/l, with mean value of 0.67 mg/l. These values are much below the WHO (2011) standard (50 mg/l) for NO_3^- in domestic/public water supply. Carbonate value ranged from 0.01 to 0.14 mg/l with a mean value of 0.07 mg/l. Magnesium dominate the cations with a mean value of 99.58 mg/l, followed by Calcium, with mean value of 30.92 mg/l. Next to calcium is sodium with a mean value of 7.47 mg/l followed by potassium with mean value of 1.28 mg/l.

5.1 Ionic Ratio and Cationic Exchange Value

The following ionic relationships were determined to infer the salinity and origin of the ions in groundwater of the study area. These includes: rMg/Ca, rHCO_3/Cl, r(Na + K)/Cl, rNa/K, rCa/Na, rSO_4/Cl and cationic exchange value (CEV = [Cl – (Na + K)]/Cl). Table 4 shows ratios of major chemical parameters of the study area compared with average values for seawater and Early Cretaceous brines in Israel. On the average, the chemical ratios of ions of the groundwater in the area deviate from the ocean/seawater ratio. However, there are some locations with similar ionic ratio with seawater. The salinity variation observed in different samples may be attributed to depth variation as well as subsequent modification of the initial seawater. Most of the boreholes tapping deep aquifer have ionic ratio close to the seawater. In general, freshwater is dominated by calcium and seawater by magnesium. The Mg^{2+}/Ca^{2+} ratio provided an indicator for delineating the sea-freshwater interface. Mondal et al. (2008) observed that extremely low $HCO3^-/Cl^-$ and variably high Mg^{2+}/Ca^{2+} (molar ratios) indicated the transformation of fresh groundwater to saline water in coastal aquifers. In this study the Mg^{2+}/Ca^{2+} ratio varies from 0.286 - 8.616 while HCO_3^-/Cl^- varies from 0.033 - 0.125 (Table 4) indicating the transformation of fresh groundwater to saline water in some portion of the study area. The highest Mg^{2+}/Ca^{2+} (8.616) was recorded at a borehole (BH4) with corresponding low $HCO3^-/Cl^-$ (0.033) ratio confirming transformation of fresh water to saline water due to impact of saltwater mixing. The critical r (Na+K)/Cl vary between 0.102 and 0.082 compared to a value of 0.88 for seawater while r$HCO3^-/Cl^-$ vary between 0.033 and 0.125 compared to a value of 0.004 for seawater. This trend clearly reflects the dominance of freshwater with mixing in places with salt water. In general, the CEV for seawater ranges from +1.2 to +1.3, where low salt inland waters give values close to zero, either positive or negative (Custodio, 1983). The plot of HCO_3/Cl versus TDS (Fig. 2) showed that the regression slope was negative in the high (>500 mg/l) TDS concentration range while the slope was positive in the low (<500 mg/l) TDS concentration range indicating that groundwater with high TDS concentration was enriched with chloride and groundwater with low TDS concentration was not. The CEV values for groundwater of the study area are generally below 1.0 (Table 4), ranging from 0.665 to 0.985, indicating that the groundwater is inland in some locations with respect to provenance. This result agrees with the findings of Bolaji (2009). The variations of Ca/Na and Mg/Ca ratios with TDS (Fig. 3 and 4) showed a similar trend and are subsequently subject to a similar interpretation opposite to plot of HCO_3/Cl versus TDS (Fig. 2). The shallow borehole of the study area is characterized by relatively low salinity and weak concentrations of chloride compared to the deep borehole water. This result agrees with the findings of Abel *et al*., (2012).

5.2 Classification of Groundwater Types

Groundwater of the study area can be classified based on the hydrogeochemical characteristics as shown in

Figure 5. Piper (1953) Trilinear diagram was used to classify groundwater types in the area. It permits the cation and anion compositions of many samples to be presented on a single graph in which major groupings in the data can be discerned visually (Freeze & Cherry, 1979; Hounslow, 1995). Piper trilinear diagram (Figure 5) for the study area showed just one type of water. The calcium chlorite water type with Ca and Cl as the major dominant ion. This $CaCl_2$ water type indicates result of mixing; mixing of the initial $CaHCO_3$ with saline water and it denotes water of paramount hardness.

Parameters	Sample Codes											
	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	BH9	BH10	BH11	BH12
Temp(^{0}C)	29.0	29.0	29.0	29.0	29.0	29.0	27.0	29.0	29.0	27.0	28.0	28.0
pH	8.5	8.2	8.0	8.2	8.5	8.3	8.3	8.4	8.3	8.7	7.8	8.3
TDS(mg/l)	786.0	188	10.0	388	415	213	654	397	282	338	35	386
EC(µS/cm)	1754	432	10.0	753	754	495	1240	857	644	922	42	647
TH(mg/l)	172.0	89.0	271	202	36	177	41	76	164	140	14	205
DO(mg/l)	9.5	8.6	9.0	9.2	9.5	9.4	8.5	9.5	9.5	9.5	4.0	9.1
TA(mg/l)	640.0	164	380	310	384	190	476	327	274	296	15	365
Ca^{2+}(mg/l)	31.0	35.0	50.0	21	8	31	25	25	56	30	35	24
Mg^{2+}(mg/l)	141.0	55.0	222	181	28	147	16	51	108	110	10	126
Na^+(mg/l)	6.0	27.0	6.4	11.6	6.2	4.0	8.4	3.6	9.0	2.0	2.4	3.0
K^+(mg/l)	0.6	0.51	1.8	1.5	0.4	1.5	5.0	0.7	0.9	0.2	0.8	1.5
HCO_3^-(mg/l)	20.8	6.5	7.5	7.5	5.6	5.6	8.5	5.5	5.2	7.3	2.5	5.0
SO_4^{2-}(mg/l)	48.0	27.0	26.0	21	54	42	36	63	50	63	21	32
Cl^-(mg/l)	167.0	82.0	105	112	131	150	136	70	160	147	42	124
NO_3^-(mg/l)	0.62	0.74	0.75	0.76	0.74	0.74	0.50	0.47	0.62	0.73	0.62	0.73
CO_3^{2-}(mg/l)	0.14	0.07	0.13	0.12	0.01	0.05	0.09	0.06	0.05	0.05	0.04	0.04

Table 1: Hydrochemical Analysis of Groundwater Samples.
TDS = total dissolved solids; EC = electrical conductivity; TH = total hardness; mg/L = milligram per litre.

Table 2: Classification of Water based on Hardness (Freeze and Cherry, 1977).

HARDNESS RANGE	**DESCRIPTION**
0 - 60	Soft
61 - 120	Moderately hard
121 - 180	Hard
More than 180	Very hard

Table 3: Descriptive Statistics of Analyzed Groundwater Samples Compared with Standards.

Parameters	**Number of samples**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**	**WHO (2011) Maximum Permissible Limit**
Temp(^{0}C)	12	27.0	29.0	28.50	0.83	-
pH	12	7.8	8.3	8.33	0.28	6.5-8.5
TDS(mg/l)	12	10.0	786.0	341.00	224.69	1200
EC(µS/cm)	12	10.0	1754.0	712.50	477.60	1250
TH(mg/l)	12	14.0	271.0	125.64	95.98	-
DO(mg/l)	12	4.0	9.5	8.78	1.55	4
TA(mg/l)	12	15.0	640.0	318.42	157.69	-
Ca^{2+}(mg/l)	12	8.0	56.0	30.92	12.68	75
Mg^{2+}(mg/l)	12	10.0	222.0	99.58	68.05	50
Na^+(mg/l)	12	2.0	27.0	7.47	6.80	200
K^+(mg/l)	12	0.2	5.0	1.28	1.28	55
HCO_3^-(mg/l)	12	2.5	20.8	7.29	4.53	-
SO_4^{2-}(mg/l)	12	21.0	63.0	40.25	15.34	500
Cl^-(mg/l)	12	42.0	167.0	118.83	38.30	250
NO_3^-(mg/l)	12	0.47	0.76	0.67	0.10	50
CO_3^{2-}(mg/l)	12	0.01	0.14	0.07	0.04	-

TDS = total dissolved solids; EC = electrical conductivity; TH = total hardness; mg/L = milligram per litre.

Table 4: Ionic Ratio compared to Seawater value

Parameters	Min.	Max.	Mean	Stdev	Seawater	E.Cret.
rMg/Ca	0.286	8.616	3.436	2.327	3.300	0.501
rNa/K	1.680	17.880	7.442	5.340	46.974	105.060
rCa/Na	1.290	15.000	6.571	4.608	0.044	0.105
r(Na+K)/Cl	0.102	0.082	0.087	0.089	0.871	0.882
$rHCO_3/Cl$	0.033	0.125	0.062	0.028	0.004	0.007
rSO_4/Cl	0.188	0.900	0.367	0.190	0.105	0.009
CEV	0.350	0.992	0.876	0.187	-	-

*Based on average values of data for seawater and early Cretaceous brines, from Collins, 1975.
**Based on data for Early Cretaceous brines in Israel, from Bentor, 1969.

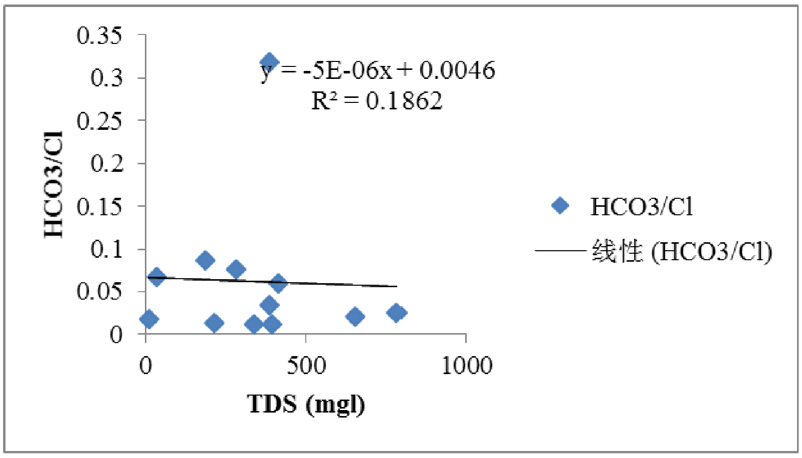

Figure 2: Ionic ratio of HCO_3/Cl Versus TDS

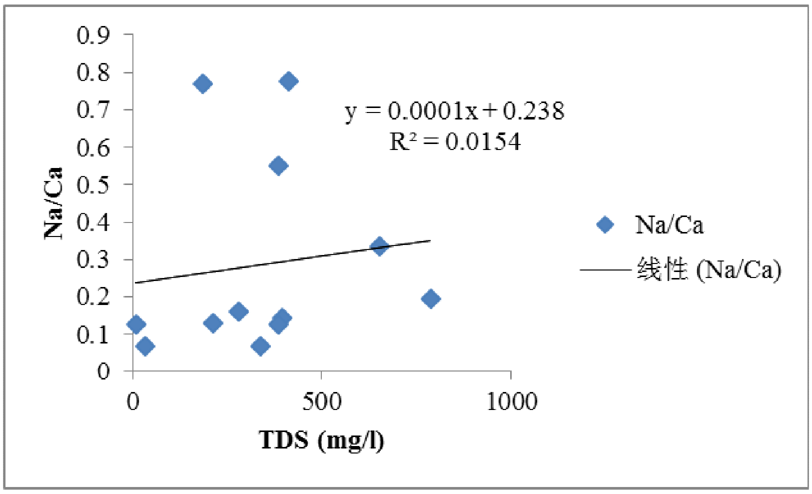

Figure 3: Ionic ratio of Na/Ca Versus TDS

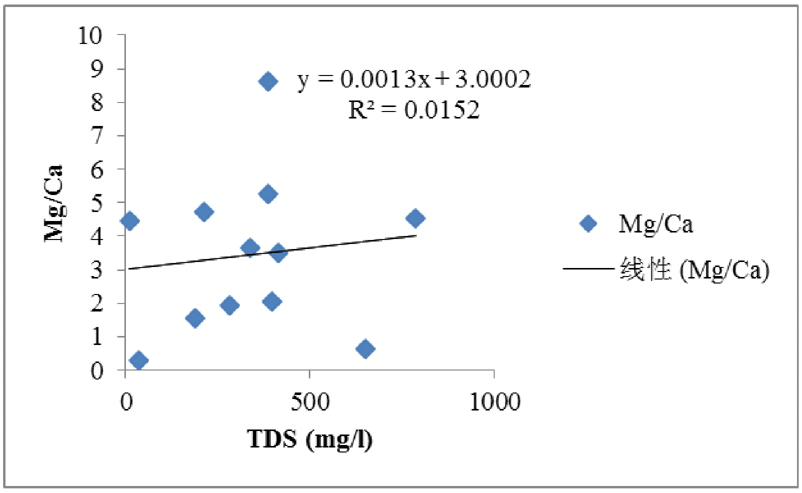

Figure 4: Ionic ratio of Mg/Ca Versus TDS

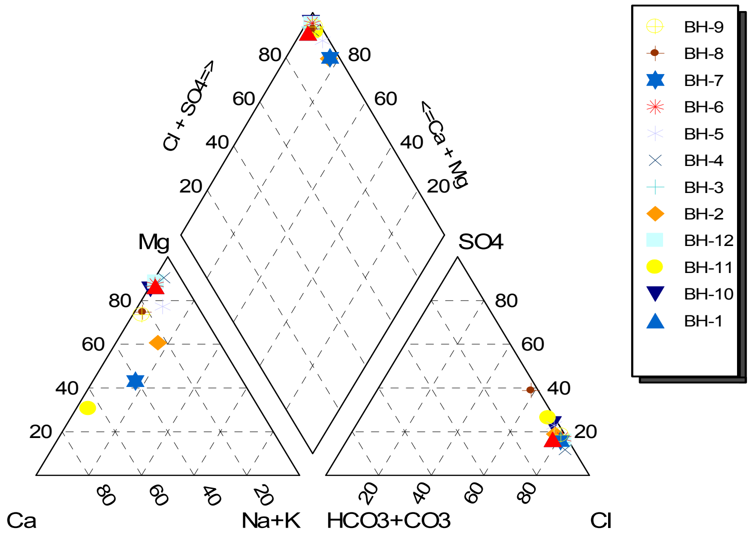

Fig. 5: Piper trilinear diagram for groundwater characterization in the area (Piper, 1953).

6. Conclusion

Hyrochemical analyses revealed that the groundwater within Umuogadu Oshia area is moderately alkaline and mostly hard in nature. The slightly high average electrical conductivity (712.50µS/cm) of the water samples implies that some of the groundwater samples are saline rather than fresh in nature. Majority of chemical constituents are well within the official WHO (2011) safe limits. Magnesium values were exceptionally high in some of the groundwater samples studied. Piper trilinear diagram for the study area revealed that there is just one type of water ($CaCl_2$) with Ca and Cl as the major ions. There is a need for regular hydrochemical studies in the study area in order to detect any future deterioration of groundwater quality.

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