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PHYSICO-CHEMICAL AND MICROBIAL ANALYSES OF GROUNDWATER FROM THE UPPER CRETACEOUS DEPOSITS UNDERLYING PARTS OF UDI AND EZIAGU AREAS OF SOUTHEAST, NIGERIA

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Abstract

Water is critical for socioeconomic development, human survival, terrestrial habitats and marine ecosystems. It is estimated that over 20 million Nigerians do not have access to 20 liters of safe drinking water. Groundwater quality is of utmost importance in water supply issues in any community in the developing regions of the world. The objective of this research work is to examine the status of water quality variables in the underlying aquifers of the Late Cretaceous deposits of Oji, Udi and Eziagu areas of southeastern Nigeria, and to establish if these variables conform to the WHO guidelines and SON-NSDWQ standards for drinking water and hence ensure a healthy citizenry and environmental sustainability. Thirteen water samples were collected from boreholes in the late Cretaceous deposits underlying Oji, Udi and Eziagu areas of southeast Nigeria. The aquiferous formations encountered are Nsukka, Ajali. Analytical data obtained were used to evaluate the physical, chemical and microbial parameters. The physical parameters analyzed include pH, temperature, turbidity, conductivity. Major chemical constituents analyzed are calcium, magnesium, potassium (cations) and bicarcarbonate, chloride and sulphate (anions). Microbial analyses were also carried out to indicate the amount of coliform counts. Water samples from Nsukka Formation gave mean values for pH to be 6.2 and turbidity 0.9mg/l. Calcium ion analyzed is 12.7, while bicarbonate ion gave 52.5mg/l. Results from Ajali Formation indicate mean value of pH is 6.13 while turbidity is 4.21mg/l. Mean values obtained for calcium is 25.0mg/l and bicarbonate ion gave 42.7mg/l. Results of microbial analysis gave zero count values for faecal coliform and total coliform. All the water samples analyzed fall within the recommended guidelines of WHO guidelines. Potable water is obtained from aquifer systems meeting the water needs of the local populace and thus improving the general health being of the people.

***Keywords**: anions, cations, environmental sustainability, microbial, physico-chemical*

INTRODUCTION

Water is critical for socioeconomic development, human survival, terrestrial habitats and marine ecosystems. A total of 748 million people do not have access to safe and improved drinking water source worldwide. It is estimated that over 20 million Nigerians do not have access to 20

liters of safe drinking water (UNHDR, 2007). Groundwater quality is of utmost importance in water supply issues in any community in the developing regions of the world.

Thirteen water samples were collected from boreholes in Oji, Udi and Eziagu areas of southeast Nigeria. The aquifers of the Late Cretaceous deposits lie within the Anambra River Basin of Nigeria (Offordile, 2009). The underlying geologic units are mainly Nsukka and Ajali Formations. (Nwajide, 2013; Reyment, 1965). On a national scale of study, the area is within the moderately populated zones of the country (NPC, 1996; Dada, Jibrin & Ijeoma, 2006).

Analyses of water samples were carried out and data obtained were used to evaluate the physical, chemical and microbial parameters. Because of the highly porous and permeability nature of the Ajali Formation, availability of surface water is not easy to come by. Both the semi urban and rural populace are largely dependent on groundwater systems in the area.

A study of the physical parameters made in this study includes temperature, turbidity, conductivity, color and appearance. Major chemical constituents were analyzed to determine the concentration of calcium, magnesium and potassium (cations) and bicarbonate, chloride and sulfate, nitrate, phosphate (anions). Microbial analysis was also made to determine faecal and total coliform counts in the groundwater and of their source and leakage in the water system.

Physiography and Drainage

The study area is made up of highlands and lowlands with the Enugu – Udi – Awgu escarpment trending in a north – south direction (Fig.1). It attains a height of 305-425m (1000-1400 ft) at Udi and Awgu areas. The topography slopes westwards with an elevation of 183-244m (600-800 ft) at Ezeagu and Aguobu Umumba. In Oji River and environ, the elevation is as low as 76m (250ft). Few rivers drain the area and are notably the Ajali River and the Oji River. Perennial springs flow out at the interface of sandstone and shale beds of Nsukka Formation, while 6th order streams drain the area. Hydraulic connectivity exists between surface water systems and groundwater systems. Infiltration from part of overland flow penetrate into the soil to recharge the groundwater system. (Fetter, 2001; Heath, 1983).

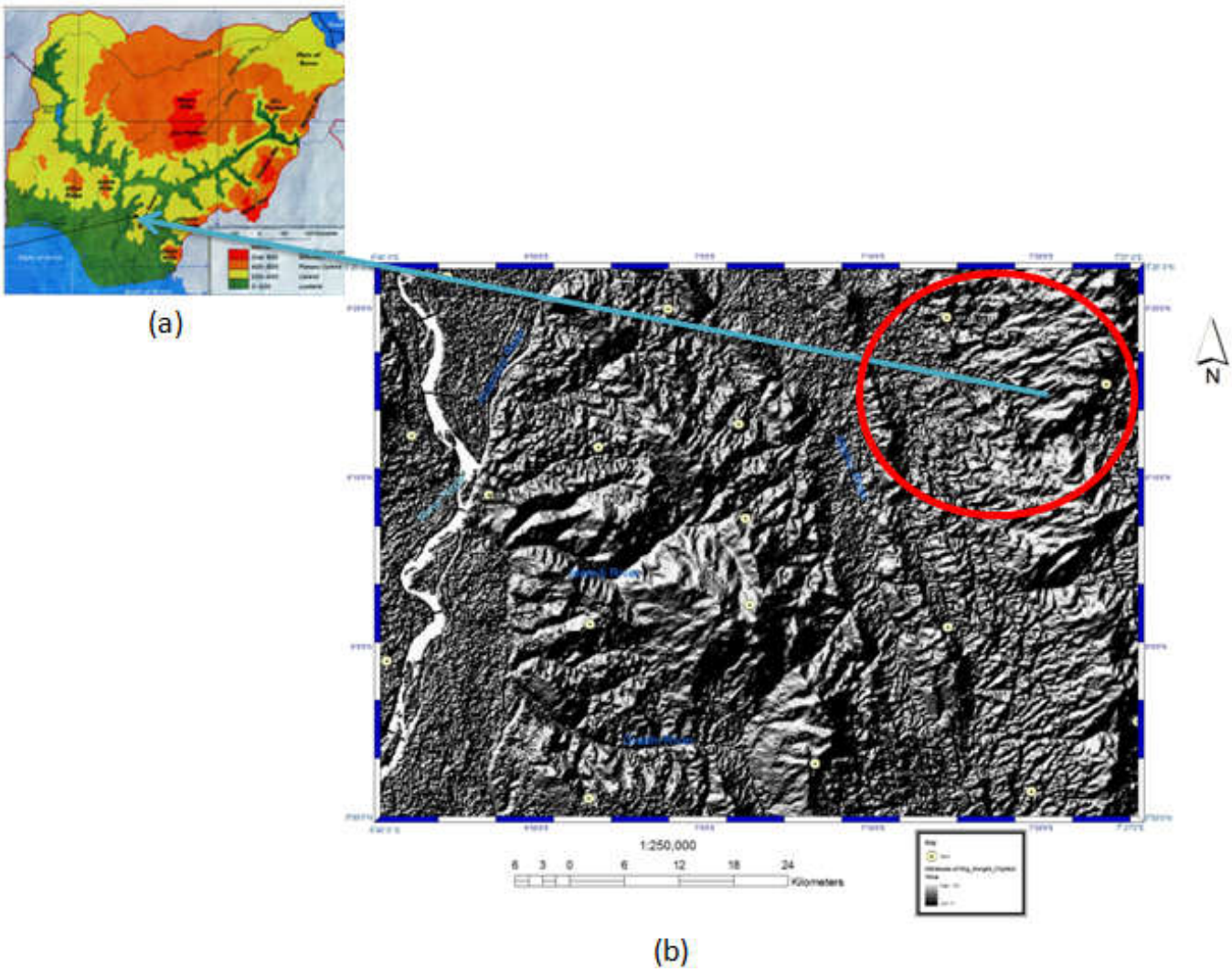

Figure 1: (a) Map of Nigeria showing study area (b) 3-D Physiographic map of part of southeast Nigeria showing study area encircled.

Climate and Vegetation

The climatic seasons experienced are characteristics of the Humid Tropical belt of the world. (Nagle, 2006; Waugh, 1995). Rainfall in the area is from March to October, while dry period lasts from the month of November to March. The rainy period is characterized by heavy downpour accompanied by thunderstorms, heavy flooding, soil leaching, extensive sheet outwash, groundwater infiltration and percolation. (Egboka and Okpoko, 1984). During the rainy season, the Northeast trade winds are pushed back out of the country by the moisture laden southwest monsoon winds that come from the Atlantic Ocean causing torrential downpour. In the dry spell of the year, the northeast trade winds blow from the Sahara and affect 80% of the

country. The weather is dry and dusty causing high evapotranspiration rates from ground surface and vegetation cover, and lowering of water levels. Mean monthly annual rainfall totals in the region range from 1500 mm to 2000mm. Average annual temperature ranges from 26^0C to 28^0C (Dada, Jibrin & Ijeoma, 2006; Balogun, 2009). Vegetation found in the area is the light forest and derived Savanna vegetation type. It is characterized by widely distributed tall trees and low shrubs. Trees found include a mixture of hardwood and softwood such as Mahogany, Obeche and Shea butter.

Geology and Hydrogeology

The study area is mainly underlain by the Nsukka Formation and Ajali Formation (Fig.2). A narrow strip occupied by Imo Shale is found in the western part. Nsukka Formation consists of an alternating succession of sandstone, dark shale with thin coal seams at different horizons. Average thickness of formation is about 233 meters. The Formation trends in a linear form in a north-south direction west of the outcrop of Ajali Formation and rests conformably on the later. The Formation is aquiferous and groundwater can be exploited from the upper and middle zone aquifers. Imo Formation is an aquitard with high porosity and poor permeability. Ajali Formation consists of thick friable, poorly sorted sandstones, whitish and sometimes iron stained. The lithology displays a large scale cross bedding of coarse to fine grained sands. The formation has high porosity and good permeability. (Nwajide, 2013; Offodile, 2009; Reyment, 1965).

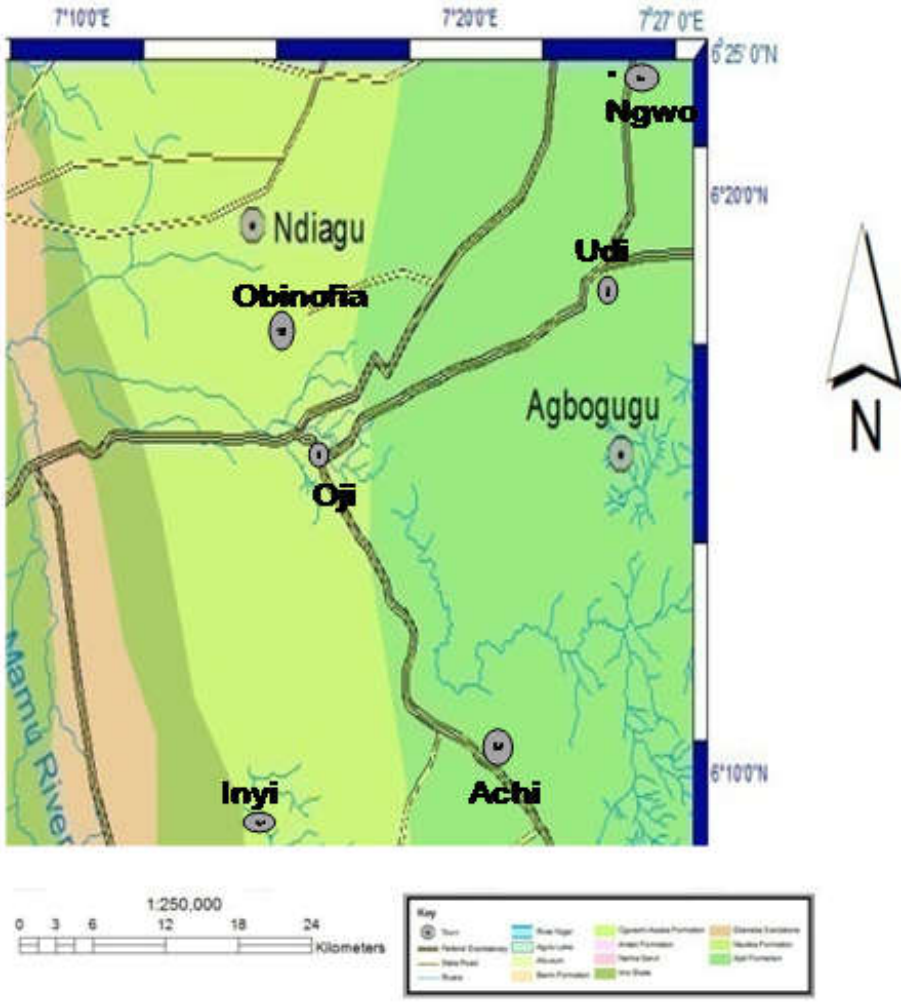

Figure 2: Geologic map of the study area.

MATERIALS AND METHODS

Materials and equipment used in the analysis of the water samples for physical, chemical and microbial parameters include one litre plastic containers, thermometer, concentrated nitric acid for acidification of samples, deionized /distilled water, chemical reagents, pH meter, conductivity meter, atomic absorption spectrophotometer, and filter papers.

All samples collected were preserved in a cool container plastic cover packed with ice blocks to keep temperature below 20^0C. They were later transported to the laboratory for analysis within 48 hours of collection. The reagents used were in standard form and prepared according to specified standard procedures.

The pH was measured using a pH meter (Jenway, 3051, Jenway Ltd London, UK). Temperature, total dissolved solids and conductivity were measured using a conductivity meter bridge type MC; Kent – EIL 5013, Kent Industrial Measurement Ltd, Chertsey, UK). Total Hardness was determined by the EDTA titration method. Ca and Mg ion concentrations were determined by the complex metric titration methods. K ion analyzed by the tetraphenylborate method. NO_3, by the cadmium reduction method, sulfate by the turbid metric method, phosphate by reactive ortho phosphate ascorbic acid method. Iron was analyzed using atomic absorption spectrophotometer Alpha 4 series no 4200 Chem. Tech. Analytical Ltd, UK.

Microbial analyses of faecal and total coliforms were determined using the Hatch Millipore bacteriological kit membrane (filtration method). All analytical methods and results obtained were within the operational standards of the Standards Organization of Nigeria (SON)-Nigeria Standards for Drinking Water Quality (NSDWQ) 2007, World Health Organization (WHO) Guidelines, 2006, and GEMS/Water Operational Guide, 2007.

RESULTS AND DISCUSSION

Results of hydro-geochemical data were subjected to statistical analysis. The statistical variables of mean, standard deviation, variance, range, maximum and minimum values were used in calculation and data obtained are also represented on graph forms. They are useful for comparing analysis and for indicating similarities and differences (Todd and Mays, 2005). Major constituents displayed include the following anions Ca, Mg, K, HCO_3, SO_4 and HCO_3.

Analysis of Data

Table.1 shows the statistical analysis of physico-chemical data of some water boreholes in Nsukka Formation. pH gave a mean value of 6.2 with a maximum value of 6.5 and minimum value of 5.8. Mean values for calcium, magnesium and potassium are 12.7 mg/l, 1.2 mg/l and 1.1 mg/l respectively. Maximum values obtained are 16 mg/L, 2.1 mg/L and 1.2 mg/L while minimum values recorded are 8.5 mg/l, 0.58 mg/l and 1.0 mg/l respectively.

For bicarbonate, sulfate and chloride ions, mean values obtained are 52.5 mg/l, 2.2 mg/l and 10.3 mg/l respectively. Maximum values are 60 mg/l, 2.3 mg/l and 10.8 mg/l and minimum values 49.6 mg/, 2.1 mg/l and 9.8 mg/l respectively. Mean values for total hardness and total dissolved solids recorded are 15.0 mg/l and 24.8 mg/l respectively.

Table 1: Statistical analysis of physico-chemical data of aquifers in Nsukka Formation

Parameters	Mean	Std Dev.	Var	Range	Max	Min
pH	6.2	0.37	0.14	0.7	6.5	5.8
Turbidity	0.9	0.04	0.002	0.1	0.9	0.8
Conductivity	49.4	2.31	5.34	5.5	52	46.5
Color	1.6	0.36	0.13	0.7	1.9	1.2
Calcium	12.7	3.4	11.9	7.5	16	8.5
Magnesium	1.2	0.7	0.49	1.52	2.1	0.58
Sodium	N/A	N/A	N/A	N/A	N/A	N/A
Potassium	1.1	0.1	0.01	0.2	1.2	1.0
Sulfate	2.2	0.08	0.007	0.2	2.3	2.1
Chloride	10.3	0.3	0.09	1	10.8	9.8
Bicarbonate	52.5	5	25.1	10.4	60	49.6
Carbonate	17.7	3.5	12.2	7.5	21	13.5
Nitrite	0	0	0	0	0	0
Nitrate	0	0	0	0	0	0
Phosphate	0	0	0	0	0	0
Iron	0.03	0.04	0.002	0.1	0.1	0.0
Total Hardness	15	4.1	17.1	8	18.6	10.6
Salinity	0	0	0	0	0	0
TDS	24.8	1.4	1.97	2.9	26.2	23.3

Nitrite, nitrate, phosphate and iron concentrations gave zero values. Statistical analysis for physico-chemical data obtained for Ajali Formation. (Table.2) indicated mean value for pH to be 6.13, maximum value is 6.90 mg/l and minimum value recorded is 5.4 mg/l. Mean values obtained for calcium, magnesium and potassium (cations) are 25.0 mg/l, 1.80 mg/l and 1.36 mg/l respectively. The maximum values obtained are 94 mg/l, 4 mg/l and 1.8 mg/l while minimum values obtained are 7.2 mg/l, 3.1 mg/l and 1.0 mg/l.

Bicarbonate, sulfate and chloride ions analyzed gave mean values of 42.7, 3.21, and 5.04 for pH, maximum values obtained are 91.0 mg/l, 6.8 mg/l and 9.8 mg/l respectively while minimum values recorded are 10.0 mg/l, 2.0 mg/l and 2.4 mg/l respectively.

Zero values were recorded for nitrite, nitrate, phosphate and iron respectively. Mean value for Total Hardness is 26.7 mg/l and Total dissolved solids is 16.42 mg/l.

Table 2: Statistical analysis of physico-chemical data of aquifers in Ajali Formation

Parameters	Mean	Std Dev.	Var.	Range	Max	Min
pH	6.13	0.15	0.02	1.5	6.9	5.4
Turbidity	4.21	5.1	26.2	13.2	15.2	2
Conductivity	31.02	16.5	272.1	43.4	50.4	7
Color	2.43	1.3	1.7	4.41	5.61	1.2
Calcium	25	14.37	206.5	86.8	94	7.2
Magnesium	1.80	1.13	1.28	0.9	4	3.1
Sodium	0	0	0	0	0	0
Potassium	1.36	0.26	0.07	0.8	1.8	1
Sulfate	3.21	1.75	3.06	4.8	6.8	2
Chloride	5.04	2.30	5.28	7.4	9.8	2.4
Bicarbonate	42.7	25.94	672.81	81	91	10
Carbonate	11.92	5.46	29.8	15	18.2	3.2
Nitrite	0.15	0.006	3.6×10^{-5}	0.15	0.15	0
Nitrate	0.15	0.006	3.6×10^{-5}	0.15	0.15	0
Phosphate	0	0	0	0	0	0
Iron	0.07	0.6	0.36	0.07	0.15	7.5
Total Hardness	26.7	14.82	219.6	89	98	9
Salinity	0	0	0	0	0	0
TDS	16.42	98.36	9675.2	23.6	27.5	3.9

The physico-chemical data for some cations (calcium, magnesium, potassium) and some anions (bicarbonate, carbonate, sulphate, nitrate, iron, chloride) which were analyzed and expressed in milligram per litre (mg/l) were converted to milliequivalent per litre (meq/l) and milliequivalent per litre in percentage (meq/l%) (Table.3). The units obtained were used for graphical illustrations of hydrogeochemical data analyzed.

Table 3: Mean physico-chemical data for major cations and anions in milligram per litre (mg/l), milliequivalent per litre (meq/l) and milliequivalent per litre in percentage (meq/l%) of groundwater study in Nsukka Formation and Ajalli Formation.

Parameter	Nsukka Fm			Ajali Ss		
	mg/l	meq/l	meq/l%	mg/l	meq/l	meq/l %
Calcium	12.70	0.63	86.30	24.9	1.24	88.1
Magnesium	1.23	0.09	12.33	1.78	0.15	10.6
Sodium	N/A	N/A	N/A	N/A	N/A	N/A
Potassium	1.13	0.01	1.37	1.36	0.02	1.4
Total	15	0.73	100	28.04	1.41	100
Sulphate	2.2	0.05	2.75	17.65	0.37	21.5
Bicarbonate	52.5	0.86	47.25	42.7	0.7	40.6
Carbonate	17.65	0.59	32.41	15.2	0.51	29.6
Nitrate	0.0	0.0	0.0	0.07	0.002	0.1
Iron	0.03	0.03	1.65	0.07	0.002	0.1
Chloride	10.28	0.29	15.9	5.0	0.14	8.1
Total	82.7	1.82	100	63.04	1.72	100

In areas underlain by Nsukka Formation, analysis of water samples from boreholes in Oji town ($SHAQ_1$ and $SHAQ_2$) have the pH values, 6.5, to be neutral. Nkwo Inyi ($SHAQ_3$) and Umuome Inyi ($SHAQ_{4)}$, the boreholes have pH values of 5.9 and 5.8 respectively and water is slightly acidic. Appearance of ground water collected is clear and colour values obtained fall below the maximum permissible level of WHO, 2007 guidelines, and NSDWQ, 2007. Turbidity which is dependent on suspended matter is very low. Calcium and magnesium which are major contributors to hardness in water have very low concentrations. By the NSDWQ standard, magnesium is slightly higher in concentration. Both are derived from their host rocks especially carbonate rocks. Potassium concentration is very low in the area as rock containing potassium is relatively generally resistant to weathering (UNESCO/WHO/UNEP, 1992). Sulphate is low and can be said to be free from industrial discharges. Chloride concentration is also below maximum permissible level by regulatory standards. Its low concentration is characteristic of freshwater source and non pollution from sewage and other waste outlets. Carbonates and bicarbonates in water influences hardness and alkalinity of water. They are formed from weathering of rocks. Nitrate was not detected and does indicate absence of high nitrogen fertilizer application. Iron was only detected in $SHAQ_2$ borehole in Oji town and still below the WHO, 2007, and NSDWQ standard of 0.3 mg/l. The occurrence of iron in aqueous dilution is commonly by oxidation and reduction. Total hardness values are far below recommended values and depend mainly on dissolved calcium and magnesium salts. The water in the area can be classified as soft. Total dissolved solids (TDS), the amount of concentrated salts in solution, is related to conductivity. Conductivity (specific conductance) is a measure of the ability of water to conduct an electric current. Zero values were obtained for faecal coliform and total coliform counts indicating groundwater to be free from sewage and municipal wastes, which include sewage effluents,

urban drainage and collected waste waters. Groundwater in the area is also free from agricultural activities that might involve animal rearing and heavy application of fertilizers and pesticides. Groundwater is not affected by leacheates from land disposal sites. These leacheates contain pathogens and metals that are injurious to health.

Analyses of borehole water samples from Ajali Formation indicate groundwater to be generally clear, and colour is within acceptable limits. Turbidity is within acceptable limits but with an unusual high value of 15.2 mg/ l at Abor Udi ($DPAQ_3$). Calcium, magnesium and potassium are all within recommended limits as well as the major anions bicarbonate, sulfate, chloride analyzed. Total hardness and Total dissolved solids are within recommended acceptable limits. Faecal coliform and Total coliform values recorded nil for all boreholes apart from Afor Oghe ($DPAQ_9$) where 1.0 cfu/100ml was recorded.

Water Quality analyses for both formation waters confirm groundwater to be potable, safe and useful for socio-economic development of the people. Potable water will help curb disease, improve the general wellbeing and elevate productivity of the inhabitants. One of the objectives of the Millennium Development Goals is to ensure environmental sustainability – Goal 7. Among its targets is to halve by 2015 the proportion of the population without sustainable access to drinking water and sanitation. Up to 1.5 hours a day on average is spent by the rural folks to collect water and fuel. Following professional guidelines boreholes drilled in Nsukka and Ajali Formations will yield adequate and potable water supply to both semi urban and the rural population, and help reduce the stress associated with long distances getting water for domestic and other needs.

Graphical illustrations of hydro chemical data.

Physico-chemical data obtained for geological formations in the study area are represented in graph forms. They are useful for comparing analysis and for indicating similarities and differences (Todd and Mays, 2005). For plotting the Schoeller semi logarithmic diagram, the principal ionic concentration expressed in miliequivalents per litre are plotted on equally spaced logarithmic scales and the points plotted are joined by straight lines. The graphs indicate the absolute value for each ion as well as the concentration differences among the various groundwater analyses. (Todd and Mays, 2005).

The stiff pattern diagram developed by H.A. Stiff in 1951 is widely used to display major ion composition of a water sample in a polygonal shape. The shape is formed from four parallel horizontal axes extending on either side of a vertical zero axis. Stiff diagrams require data converted to meq/l for plotting to visualize ionic related waters from which a flow path can be determined. Concentrations of cations are plotted to the left of a vertical zero axis and anions to the right. The resulting points when connected give an irregular polygonal shape pattern.

Piper (Trilinear) diagram indicate the relative concentrations of six to seven ions in solutions. The piper diagram includes two trilinear diagrams, anions on the lower right and cations on the lower left on the trilinear diagram, and both are projected up into the central quadrilateral. For the respective ions the concentrations in mg/l are converted to chemical equivalents meq/l.

The percentages of each ion relative to the total are calculated and plotted on the piper diagram (AECOM Environment Report, 2010). The trilinear diagram reveals similarities and differences among groundwater samples but those with similar qualities tend to plot together as groups. S.A. Durov (1948) proposed the use of a triangular diagram in the characterization of groundwater. The cations and anions are plotted in percentages in separate triangles. The intersection of lines at a rectangular field represents a type of water at a point. From that point lines drawn to adjacent rectangles give points indicating total concentration in mg/l.

Graph plots of Schoeller, stiff, piper and Durov for water boreholes in Nsukka Formation are illustrated in (Fig. 3, 4, 6).

The Schoeller and Stiff plots indicate type water to be calcium bicarbonate. The piper and Durov plots indicate type water to be calcium bicarbonate. Groundwater is soft and of freshwater origin. Graph plots of Schoeller and Stiff for groundwater in the Ajali Formation (Fig. 7, 8) indicate type water to be calcium bicarbonate. Piper and Durov plots also show that groundwater type water is calcium bicarbonate, soft and of freshwater origin.

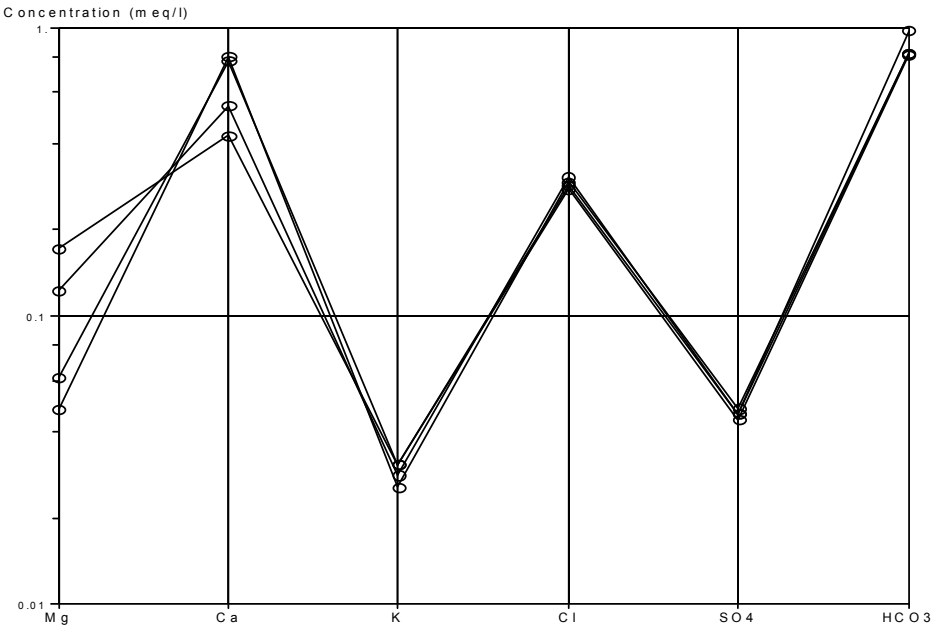

Figure 3: Schoeller plot for borehole water in Nsukka Formation.

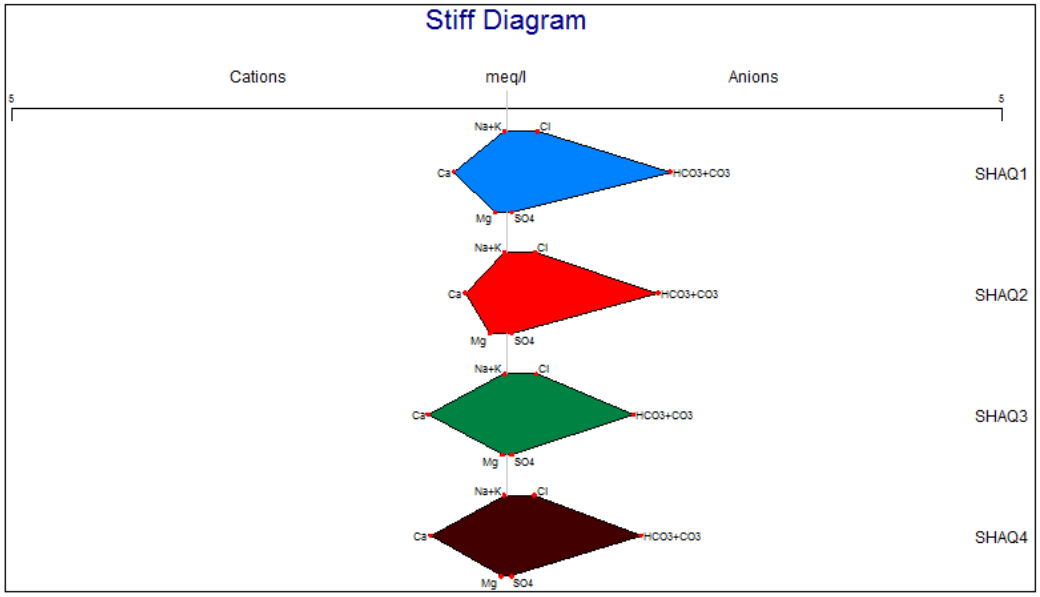

Figure 4: Stiff plot for borehole water in Nsukka Formation.

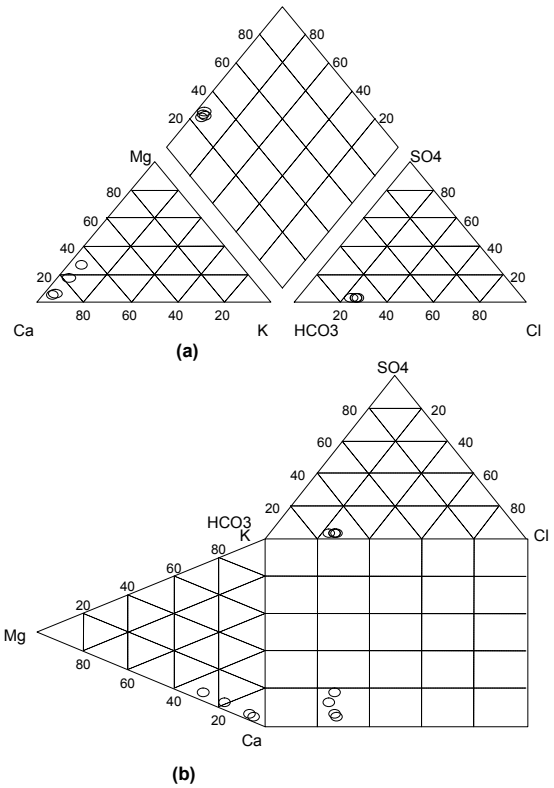

Figure 5: Piper (a) and Durov (b) plots for Nsukka Formation

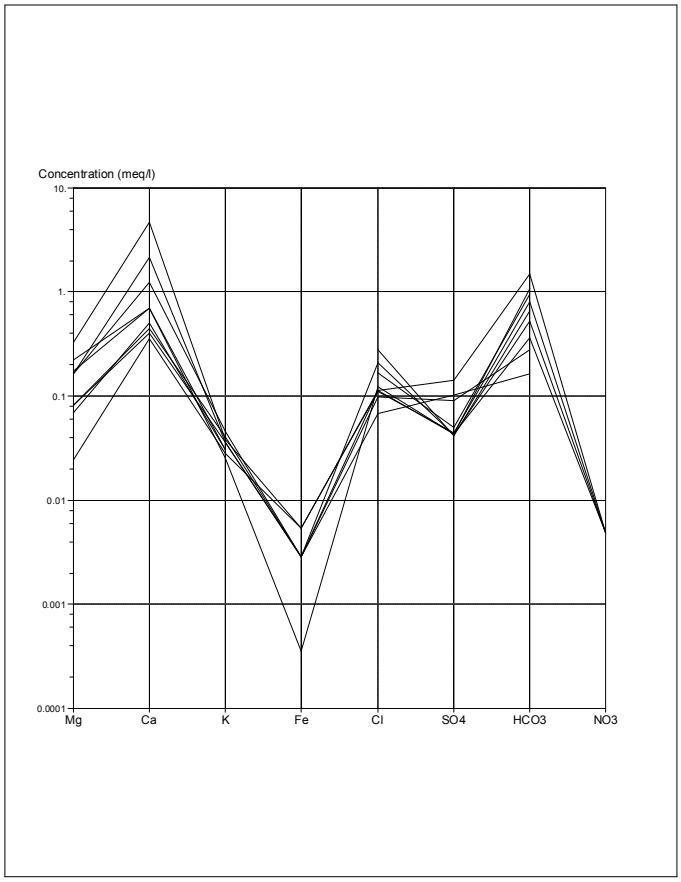

Figure 6: Schoeller plot for borehole water in Ajali Formation.

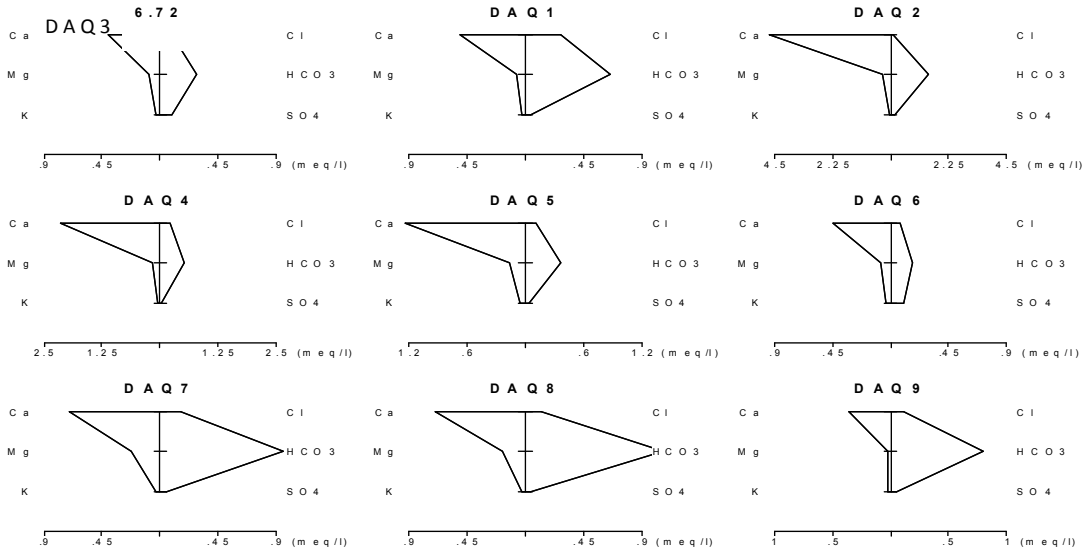

Figure 7: Stiff plot for borehole water in Ajali Formation.

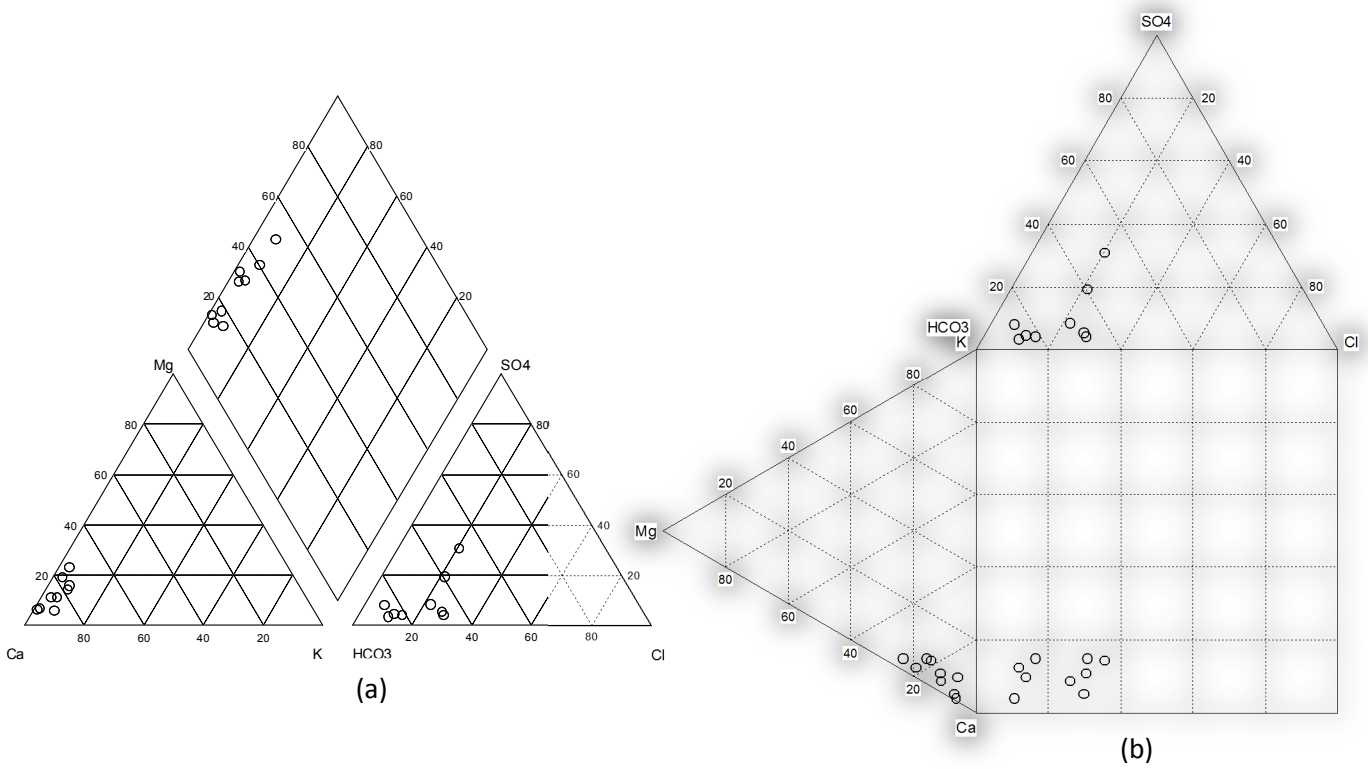

Figure 8: Piper (a) and Durov (b) plots for borehole water in Ajali formation.

CONCLUSION AND RECOMMENDATIONS

The Upper Cretaceous deposits of Nsukka and Ajali Formations are aquiferous and when exploited following professional guidelines can yield adequate and potable water for domestic, commercial, agriculture and industrial needs. Analyses of water samples indicate groundwater in the area to be potable, soft and of freshwater origin. Meeting the objectives of the MDG-Goal 7, Target 7C, can be improved and sustained upon by the relevant government agencies working in concert with the private sector. However there exits problems that might militate against set objectives. They include inadequate funding of projects, lack of effective maintenance culture, poor/complete absence of community participation in projects, absence of strong institutional strengthening mechanisms, erratic electric power supply, non enforcement of environmental protection and regulatory laws, diversion and embezzlement of funds for projects beneficial to

the people. If these lapses can be addressed and their recommendations and implementations put in place, the water needs of the people will be fully met.

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