ISSN: 2634-9221
European Journal of Applied Sciences; Vol. 14 No. 03 (2026) (233-243)
https://doi.org/10.14738/aivp.1403.10817

Hydrogeochemistry of Water Sources in Obimo and its Environs, Nsukka LGA, Enugu State, Southeastern Nigeria

Austin C. Okonkwo*[1], Emmanuel C. Iyi[1] Nnaeto R. A. Nwatarali[1], Ozoemena C. Ike[2], Okechukwu P. Nsude[2], Onyinye L. Eze[1], Chigozie I. Aganigbo[1], Ejiofor C. Ezike[1], Aniebonam I. Amoke[3] and Benjamin A. Utazi[1].

1. Department of Geology and Mining, Enugu State University of Science and Technology, Enugu, Enugu State
2. Department of Industrial Chemistry, Enugu State University of Science and Technology, Enugu, Enugu State
3. Department of Geology, Alex Ekwueme Federal University, Ndufu-Alike, Ebonyi State

Abstract: The hydrochemistry of water sources in Obimo and its environs has been carried out. The study area lies within latitudes 06^0 46^I 00^{II}N and 06^0 50^I 00^{II}N and longitudes 007^0 18^I 00^{II}E and 007^0 22^I 00^{II}E, with an area extent of 54.76Sqkm. It is underlain by the Ajalli Formation and Nsukka Formation. A total of five (5) water sources were sampled. Four (4) springs sources and one (1) hand dug well source. The spring sources are Adagboro, Omorimo, Ukpata and Ugolo. The physical parameters were tested insitu using integrated geochemical equipment while the chemical parameters was analyzed in the laboratory using Atomic Adsorption Spectrophotometer (AAS). The average values of temperature, pH and electrical conductivity are 25.2 ^oC, 8.91 and 73.0µS/cm respectively. The pH value implies slightly alkaline water. Color, taste and odour are less significant in observation. The average elemental ion concentration for the cations and anions analyzed are in the following order: Ca^{2+} > K^+ > Na^+ > Mg^{2+} and NO_3^{2-} > CL^- > SO_4^{2-} > HCO_3^- > CO_3^{2-} respectively. The elemental ion concentration for all cations and anions are far below the WHO drinking water standard. Hence, Obimo water sources are safe for drinking water with respect to the cations and anions. Fe^{2+} average concentration is 1.63mg/l which largely exceeds the WHO drinking water standard. Possible source is geogenic. TH of Obimo water sources are classified as moderately hard to hard water. The average TDS is 49.1mg/l. this very low TDS implies low concentration of dissolved mineral and salts in Obimo water sources. ORP varies from -174mV to 156mV with an average of -44.4mV. A reducing environment is suggested. SAR classified the water sources as excellent for irrigation purposes. MAR also classified the Obimo water sources as low magnesium, implying calcium – type water. Analysis of Piper trilinear diagram classified the natural water sources as Ca^{2+} $Mg^{2+}HCO_3^-$ type. The study has shown the water sources in Obimo suitable has shown the water sources in Obimo suitable for as drinking water and other purposes.

Keyword: Hydrogeochemistry, water sources, Obimo, Nigeria.

INTRODUCTION

Obimo town is located in Nsukka local government area Enugu State, Southeastern, Nigeria (Figure 1). It is situated on the outskirts of Nsukka town. The study area lies within latitudes 06^0 46^I 00^{II}N and 06^0 50^I 00^{II}N and longitudes 007^0 18^I 00^{II}E and 007^0 22^I 00^{II}E, with an area extent of 54.76Sqkm. The hydrogeological studies of the southeastern Nigeria have been undertaken (BRGN Report, 1979). Studies in this region relied strongly on the different aspect of hydrogeology (Egboka, 1983; Uma and Egboka, 1986; Ahiarakwem, 2004; Okonny, 1991). However, Ahiarakwem, (2004) maintained that these investigations covered both surface water and groundwater resources of the region, with data sources for groundwater resources from borehole records. Nwankwo (1995) and Ahueke (1999) researched on the natural spring sources of Umuosinta and the Ubaha spring waters respectively. Obimo community consists of four (4) number natural spring sources and one (1) number groundwater source. The community relies heavily on these water sources for drinking, domestic and agricultural purposes. However, the hydrogeochemical characteristics of these water sources remain poorly understood, posing potential health risks and water resource management challenges. The current study hopes to evaluate the physico-chemical characteristics of these water sources in Obimo and its environs with a view of determining its portability for drinking and other purposes which should be in conformity with the World Health Organization (WHO, 1993) drinking water standard.

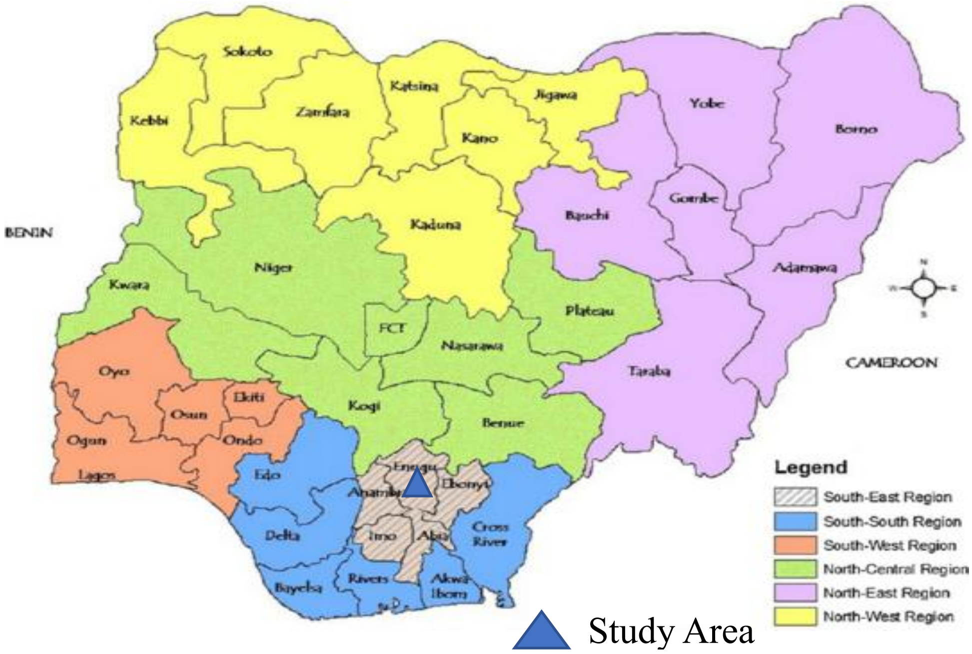


Figure 1: Map of Nigeria showing the study area (World Gazatte, 2011).

Physiography

Obimo and environs are characterized by residual hills, lowlands and broad dry valley that bear vegetation (Figure 2). The residual hills are remnants of the Nsukka Formation and they form prominent physiographic features of the area. They form characteristic elongate ridges that trends in a NW-SE direction. These residual hills are recapped by laterites which are resistant to erosion, thus giving the present geomorphic features (ridges and dome shaped outliers) of the area. The topography of the study area is essentially undulating with elevation ranging from 1300ft and 1600ft. Most of the highest peak in the region are lateralized and the remnant of Nsukka Formation that occur as residual hills completely surrounded by dry valleys, forming part of the extensive Nsukka-Okigwe cuesta. The most prominent topographic features in the study area are N-S escarpment which is part of Enugu escarpment, the cone-shaped hills and the broad dry valleys. These prominent hills and ridges are frequently capped by laterite. The escarpment is part of the N-S trending cuesta of the Ajalli Formation described by Umeji (1980). The dip slope of the cuesta is generally Southwest ward which is thought to have formed by weathering processes, Umeji (1980).

These hills are outliers of the Nsukka Formation and they overlie the Ajalli Formation. Along the slopes of some of these outliers are numerous seasonal springs and disappearing upon descent to the valleys. The uppermost layers of the Nsukka Formation are greatly lateralized, consisting of soft and hard types and are resistant to erosion unlike the friable Ajalli Formation, which depicts the undulating geomorphic features.

Geology

The study area falls within the Anambra Basin (Figure 3). The basin is Campano-Maastrichtian in age. It developed after the Santonian deformational era, when sedimentation was displaced to the western arm. Lithologically, the basin consists of the following geological formations, from the oldest – Enugu Formation, Mamu Formation, Ajalli Formation and Nsukka Formation. Field studies in Obimo and environs shows that the area is locally underlain by Ajalli and Nsukka Formations, based on the surface outcrops and exposures visited. Two units were delineated and was correletable to these formations, hence the local geologic map (Figure 4).

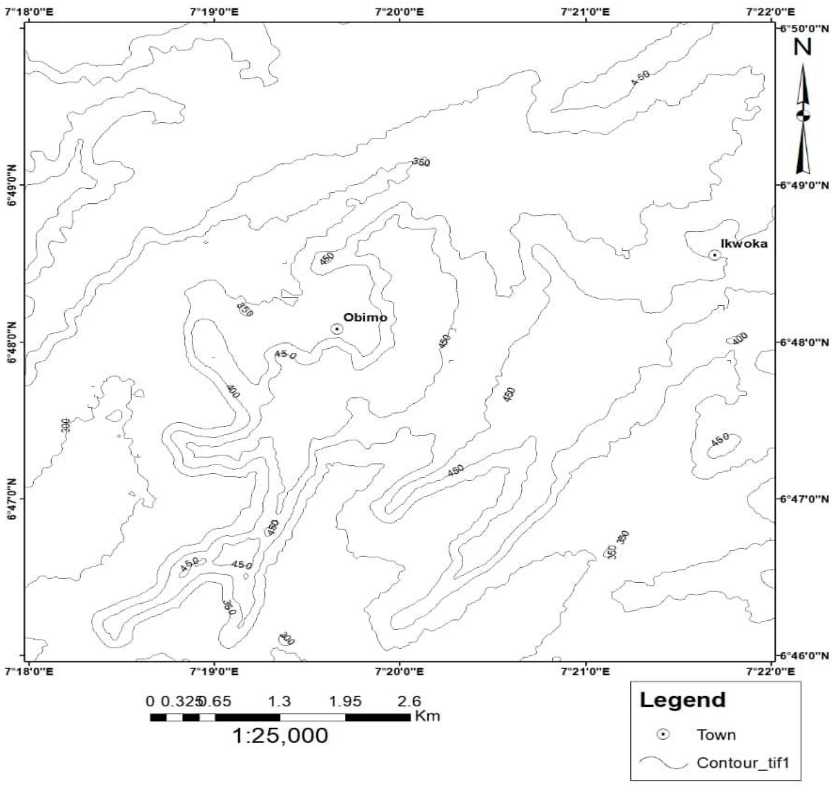
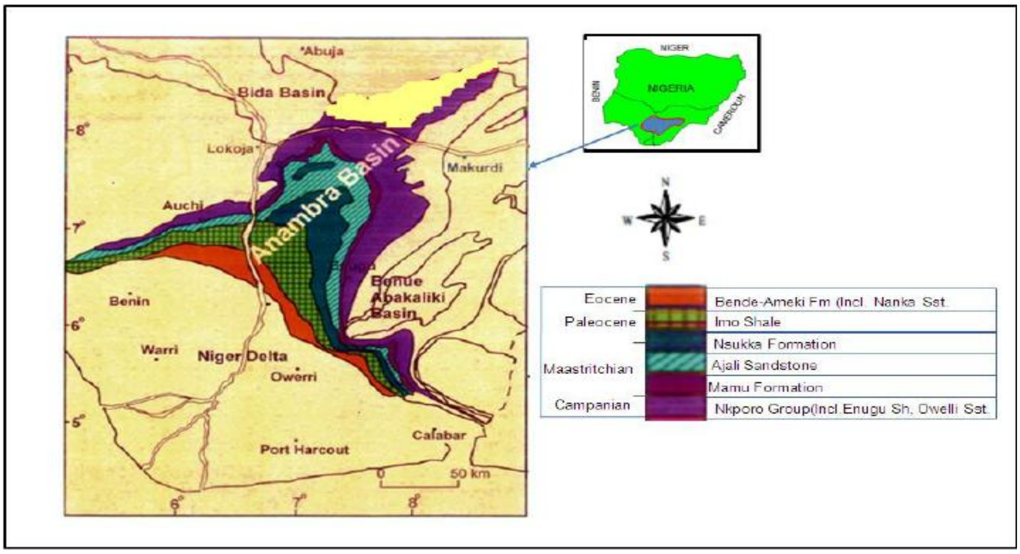
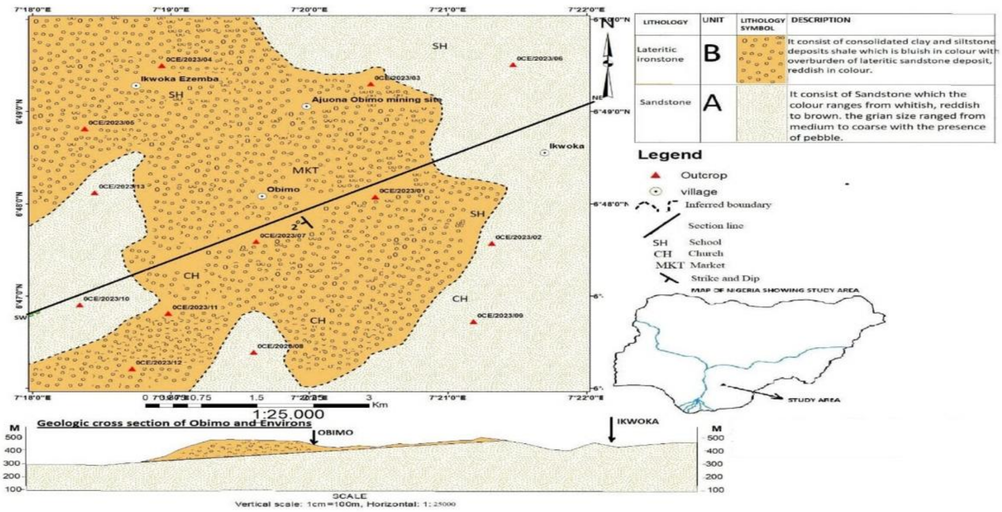


Figure 2: Elevation map of the study area.

The Ajalli Formation has been variously named False Bedded Sandstone and White Bedded Sandstone (Grove 1951), (Simpson 1954). The name Ajalli Sandstone was proposed by Reyment (1965) with its type locality at Ajalli River near Enugu. Other workers who studied this formation include (Hoque 1976, 1977) Hoque and Ezepue (1977) Amajor (1984) and Ladipo (1985). It consists of thick friable, poorly sorted cross-bedded sandstone, typically white and may contain iron-stains. A marked bedding of the course to medium grained layer is displaced. The medium sand grained layer is displaced. The medium sand grains and the larger fragments are sub-angular to sub-round with a sparse cement of white clay. The Ajalli Formation may be regarded as the major classic formation of the southern Nigeria sedimentary basin (Hoque and Ezepue 1977). The thickness of the sandstone is about 450m and is often overlain by a thick layer of red earth as a result of weathering and ferroginization.



<u>Figure 3</u>: Synoptic map of Anambra Basin. *Inset, map of Nigeria*. (Uma and Onuoha, 1988).



<u>Figure 4</u>: Geologic map and Cross-section of the study area.

The Nsukka Formation conformably overlies the Ajali Formation and its lithology is similar to Mamu Formation. In Nsukka area, the sequence started with a basal sandstone of blue, grey and clayey sandstone and carbonaceous shales with thin beds of impure coals. In Okigwe area, coal does not occur towards the top of the Formarion. It is named "upper coal measures", geological survey of Nigeria (1974), while Reyment (1965) formalized Nsukka Formation with type locality at Nadu River north of Nsukka.

MATERIALS AND METHOD

The study commenced with detailed geological field mapping. The field mapping in addition to locating exposed rock units, also took notice of the water sources in the study area. A total of five (5) water samples were collected from two different water sources (spring and groundwater). The spring water source is contact in nature (contact spring), possibly the contact between the top bed of Ajalli Formation and the base bed of the Nsukka Formation. The spring sources are Adagboro, Omorimo, Ukpata and Ugolo. While the groundwater source is an existing Hand Dug Well (HDW) in the study area. Physical parameters like colour, turbidity, taste, odour, temperature and conductivity were measured insitu, using hand held standard integrated geochemical equipment. Plastic containers were used to collect the water samples. At each location of the water source to be collected, the water source to be collected was used to rinse the plastic containers before collection. This was to prevent dilution from the existing content of the plastic container. Water samples collected into the plastic containers were properly corked to prevent any interaction between the content and the environment. After the collection, the water samples were stored in a cool box and later taken to the laboratory for analysis. The water samples were taken to the laboratory and thoroughly filtered, in order to prevent suspended particles from blocking nebulizer of the Atomic Absorption Spectrophotometer (AAS) machine and other equipment. The concentration in milligram per liter (mg/L) of the following elemental ions were tested; Na^{+}, K^{+}, Ca^{2+}, Mg^{2+} (as Cations); Fe^{2+} (as trace); NO_3^{2-}, HCO_3^{-}, CL^{-}, SO_4^{2-}, CO_3^{2-} (as Anions) and Salinity, Total Dissolved Solids (TDS), Oxygen Reduction Potential (ORP). Total Hardness (TH), Sodium Adsorption Ratio (SAR) and Magnesium Adsorption Ratio (MAR) were computed deploying empirical formulae. Total Hardness (TH) based on $CaCO_3$ was computed using the formula below

$$TH = 2.5Ca^{2+} + 4.1Mg^{2+} \quad \text{(Equation 1)}$$

Sodium Adsorption Ratio (SAR)

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{2+}+Mg^{2+})/2}} \quad \text{(Equation 2)}$$

Magnesium Adsorption Ratio (MAR)

$$MAR = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \quad \text{(Equation 3)}$$

Equipment deployed for the analyses are spectrophotometer, flame photometer and AAS and other different indicators. Elemental ion concentration for SAR and MAR were converted from mg/l to meq/l (Table 3) while TH remains in mg/l.

RESULTS AND DISCUSSION

The results of the physical and chemical analysis of the water sources in Obimo and its environs are as shown in Table 1, Table 2a and 2b respectively. From the results, the followings were observed.

Physical Parameters

Temperature ^{O}C

The measured temperature (table 1) of the different water sources varied between 24.2 ^{O}C and 26.2 ^{O}C with an average of 25.2 ^{O}C. This is far below the WHO (1993) drinking water standard of 40 ^{O}C.

pH

The measured pH value (Table 1) varied between 8.32 and 9.18 with an average of 8.91. The pH is slightly alkaline when compared with the WHO (1993) drinking water standard. pH values at Ukpata and Ugolo spring and Obimo hand dug well (HDW) show moderate alkalinity. This could be attributed to geogenic processes such as high levels of bicarbonates, carbonates and hydroxides dissolution.

Colour, Odour and Taste

In all the water sources sampled, the colour, odour and taste are less significant in observation (Table 1). That is, the water sources are colourless, odourless and tasteless.

Table 1: Summary of Physical Characteristics of Water Sources in Obimo and Environs.

					Physical Parameters					
S/N	**Location**	**Latitude (N)**	**Longitude (E)**	**Water Source**	**Temp °C**	**Ph**	**Colour**	**Odour**	**Taste**	**Electrical Conductivity µS/cm**
1	Adagboro	06^{0} 47^{I} 21.3^{II}	007^{0} 19^{I} 30.3^{II}	Spring	25.3	8.84	less	less	Less	91.9
2	Omorimo	06^{0} 47^{I} 39.6^{II}	007^{0} 19^{I} 15.1^{II}	Spring	25.2	8.32	less	less	Less	37.6
3	Ukpata	06^{0} 47^{I} 51.0^{II}	007^{0} 19^{I} 28.5^{II}	Spring	24.2	9.07	less	less	Less	159.7
4	Ugolo	06^{0} 47^{I} 17.8^{II}	007^{0} 19^{I} 20.2^{II}	Spring	25.2	9.15	less	less	Less	38.0
5	Obimo HDW	06^{0} 47^{I} 43.4^{II}	007^{0} 19^{I} 28.5^{II}	HDW	26.2	9.18	Less	Less	Less	38.0
Average					**25.2**	**8.91**				**73.0**
WHO limit (1993)					40	6.5-8.5				500

Electrical Conductivity (EC)

The measured EC values (Table 1) varied from 37.6µS/cm and 159.7µS/cm with an average of 73.0µS/cm. The EC values are quite below the WHO (1993) drinking water standard of 500µS/cm. EC indicates the presence of dissolved ions, salts and minerals in water.

Chemical Parameters

Cations

The average elemental ion concentrations for the cations (Table 2a) analyzed are in the following order: Ca^{2+} > K^{+} > Na^{+} > Mg^{2+}. The elemental ion concentration are far below the recommended WHO (1993) drinking water standard. Hence, Obimo water sources are safe for drinking with respect to the anions.

Anions

In the case of the anions (Table 2a and 2b) the average elemental ion concentration in all water sources range in the order: NO_3^{2-} > CL^- > SO_4^{2-} > HCO_3^- > CO_3^{2-}. The elemental ion concentration for all anions are far below the WHO (1993) drinking water standard. Hence, the water sources are safe for drinking water with respect to the anions.

Iron (Fe)

The measured Fe (Table 2b) in the water sources varied between 0.05mg/l and 2.80mg/l with an average of 1.63mg/l. The concentration of Fe largely exceeds the WHO (1993) drinking water standard for the spring sources except the Obimo HDW having 0.05mg/l. The source of the Fe may be geogenic that is, weathering of siderite ($FeCO_3$) rock layers. A dominant bedrock unit within the Nsukka Formation.

Table 2a: Summary of Chemical Characteristics of Water Sources in Obimo and Environs.

					Chemical Parameters (Mg/L)							
S/N	**Location**	**Latitude (N)**	**Longitude (E)**	**Water Source**	**Na^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**	**HCO_3^-**	**CL^-**	**CO_3^{2-}**	**SO_4^{2-}**
1	Adagboro	06^0 47^I 21.3^{II}	007^0 19^I 30.3^{II}	Spring	44.0	34.0	30.0	12.0	0.60	43.0	0.09	4.7
2	Omorimo	06^0 47^I 39.6^{II}	007^0 19^I 15.1^{II}	Spring	56.5	39.0	40.0	15.0	0.60	12.0	0.05	2.6
3	Ukpata	06^0 47^I 51.0^{II}	007^0 19^I 28.5^{II}	Spring	17.5	12.9	14.0	18.0	0.60	32.0	0.08	5.8
4	Ugolo	06^0 47^I 17.8^{II}	007^0 19^I 20.2^{II}	Spring	12.8	64.7	35.0	0.50	0.40	19.0	0.01	5.2
5	Obimo HDW	06^0 47^I 43.4^{II}	007^0 19^I 28.5^{II}	HDW	0.90	2.34	100.0	87.0	6.60	78.0	2.67	99.0
Average					**26.3**	**30.6**	**43.8**	**26.5**	**1.76**	**36.8**	**0.58**	**23.4**
WHO limit (1993)					500	50	200	150	500	200	500	400

Table 2b: Summary of Chemical Characteristics of Water Sources in Obimo and Environs. Cont'd

					Chemical Parameters (Mg/L)							
S/N	**Location**	**Latitude (N)**	**Longitude (E)**	**Water Source**	**Fe^{2+}**	**NO_3^{2-}**	**Salinity**	**TH**	**TDS**	**ORP (mV)**	**SAR (Meq/L)**	**MAR (Meq/L)**
1	Adagboro	06^0 47^I 21.3^{II}	007^0 19^I 30.3^{II}	Spring	2.50	12.0	46.10	124.2	61.9	-135	1.715	0.40
2	Omorimo	06^0 47^I 39.6^{II}	007^0 19^I 15.1^{II}	Spring	1.60	10.0	18.8	161.5	25.3	103	1.928	0.38
3	Ukpata	06^0 47^I 51.0^{II}	007^0 19^I 28.5^{II}	Spring	2.80	11.0	80.0	108.0	107.1	156	0.730	0.68
4	Ugolo	06^0 47^I 17.8^{II}	007^0 19^I 20.2^{II}	Spring	1.20	8.0	19.1	89.0	25.6	-174	0.588	0.02
5	Obimo HDW	06^0 47^I 43.4^{II}	007^0 19^I 28.5^{II}	HDW	0.05	160.0	19.1	606.7	25.6	-172	0.015	0.58
Average					**1.63**	**40.2**	**36.62**	**217.9**	**49.1**	**-44.4**	**0.995**	**0.41**

WHO limit (1993)	0.3-1.0	45-70	2000	500	100-300			

Table 3: Summary of Chemical Characteristics of Water Sources in Obimo and Environs in Miliequivalent per liter (Meq/L)

					Chemical Parameters (Meq/L)							
S/N	**Location**	**Latitude (N)**	**Longitude (E)**	**Water Source**	**Na^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**	**HCO_3^-**	**CL^-**	**CO_3^{2-}**	**SO_4^{2-}**
1	Adagboro	06^0 47^I 21.3^{II}	007^0 19^I 30.3^{II}	Spring	1.91	0.87	1.50	0.98	0.60	1.21	0.003	0.09
2	Omorimo	06^0 47^I 39.6^{II}	007^0 19^I 15.1^{II}	Spring	2.45	0.99	2.00	1.23	0.60	0.33	0.002	0.05
3	Ukpata	06^0 47^I 51.0^{II}	007^0 19^I 28.5^{II}	Spring	0.76	0.33	0.68	1.48	0.40	0.90	0.003	0.12
4	Ugolo	06^0 47^I 17.8^{II}	007^0 19^I 20.2^{II}	Spring	0.55	1.66	1.73	0.04	6.60	0.54	0.000	0.11
5	Obimo HDW	06^0 47^I 43.4^{II}	007^0 19^I 28.5^{II}	HDW	0.04	0.06	5.00	7.16	1.76	2.20	0.089	2.06

Total Hardness (TH)

Total hardness of all the water sources analyzed as $CaCO_3$ were determined in order to classify all the analyzed water sources (Hem, 1970). TH was analytical computed using Equation 1. Table 2b show the TH values. It varied from 89.0mg/l to 606.7mg/l with an average of 217.9mg/l. Based on the water classification (Table 4), all water sources are classified as moderately hard to hard water.

Table 4: Water Classification based on Total Hardness as $CaCO_3$ (Hem, 1970).

S/N	**Hardness, Mg/L as $CaCO_3$**	**Water Classification**
1	0-60	Soft
2	61-120	Moderately hard
3	121-180	Hard
4	>180	Very Hard

Total Dissolved Solids (TDS)

TDS measures the concentration of dissolved substances (minerals salts and other inorganic compounds) in water. The measured TDS values (Table 2b) varied between 25.3mg/l and 107.1mg/l with an average of 49.1mg/l. The average concentration does not fall within the WHO (1993) drinking water standard range of 100 – 300mg/l. However, the TDS values in all water sources sampled do not fall within the WHO (1993) acceptable range except for the Ukpata spring water source with value of 107.1mg/l. the very low TDS in water sources in Obimo implies low concentration of dissolved minerals and salts and corrosion potential.

Oxygen Reduction Potential (ORP)

ORP measures the ability of a solution to oxidize or reduce substances. It's a key indicator in water quality. The measured ORP values (Table 2b) varied from – 174mV to 156mV with an average of – 44mV. Based on the average ORP value, a reducing environment is suggested.

Sodium Adsorption Ratio (SAR)

SAR assess the suitability of water for irrigation purposes (Etu-Efeotor, 1981) particularly in relation to soil properties. The cations Na^{+}, Ca^{2+} and Mg^{2+} from the analyzed water sources (Table 3) in miliequivalent/liter (meq/l) have been used to compute for SAR using Equation 2. SAR values (Tables 2b) range from 0.015meq/l to 1.928meq/l with an average of 0.995meq/l. Based on the average SAR value, these water sources are classified as excellent (Table 5) for irrigation purposes.

Table 5: Water Classification based on Sodium Adsorption Ratio (SAR) (Etu-Efeotor, 1981).

S/N	SAR	Water Classification
1	0-10	Excellent
2	10-18	Good
3	18-26	Fair
4	>26	Poor

Magnesium Adsorption Ratio (MAR)

MAR assessed the relative abundance of magnesium and calcium ion in water, which can be important in understanding water quality. The measured MAR values (Table 2b) varied between 0.02meq/l and 0.68meq/l with an average of 0.41meq/l. MAR as computed using equation 3. Based on the average MAR of the water sources in the study area, it is classified as low magnesium (Table 6) indicating calcium-type water.

Table 6: Water Classification based on Magnesium Adsorption Ratio (MAR)

S/N	MAR value	Classification	Water Classification
1	<0.50	Low Magnesium	Calcium-type water
2	0.50-1.00	Medium Magnesium	Calcium-Magnesium type water
3	>1.00	High Magnesium	Magnesium-type water

Piper – Trilinear Diagram

This is a trilinear plot (Piper, 1944). It investigates the hydrochemical facies, which is helpful in understanding the possible water-rock interaction (Tijani, 2004). Based on the Piper diagram (Figure 5), the natural water sources in Obimo belong to the $Ca^{2+}Mg^{2+}HCO_3^-$ type, indicating slight hardness. The quality of any groundwater is due to the mineralogical composition of the aquifer (Ozoko, 2004).

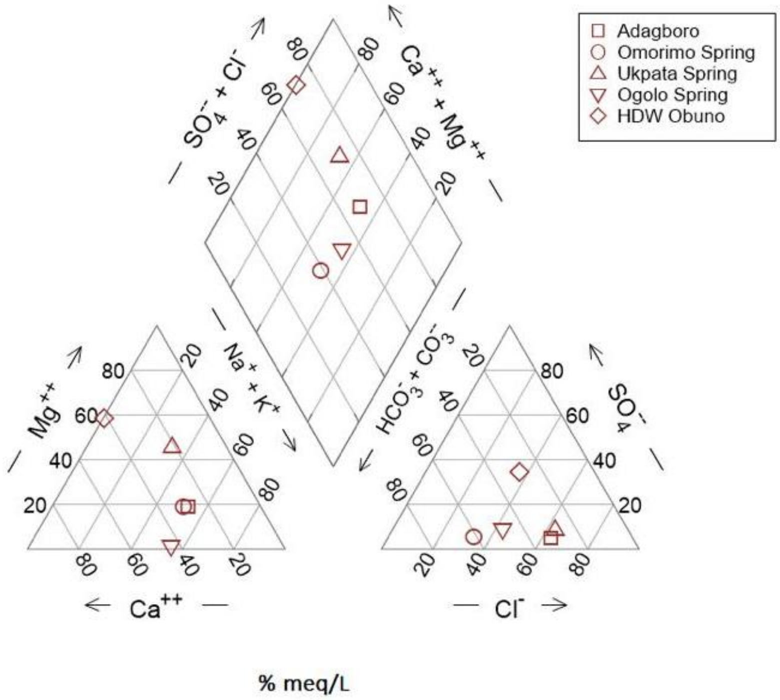


Figure 5: Piper Trilinear Diagram for natural water sources in Obimo and its environs.

CONCLUSION

This study has evaluated the physic-chemical characteristics of water sources (springs and groundwater) in Obimo and its environs, in terms of its portability for drinking and other purposes. Ozoko, 2004 noted that rock-water reaction helps to define the geochemical environment within an aquifer. As the water moves slowly through the aquifer, its chemical composition gradually changes as the saturation of chemical species or ions in the water increases. Such increases might lead to end-products of rock-water reactions due to precipitation or dissolution. Based on the above fact, the general physical and chemical characteristics of water sources in Obimo that are above the (WHO, 1993) drinking water standard are geogenic attributed and not anthropogenic.

REFERENCES

Ahiarakwem C.A, 2004. Physical and Chemical properties of the Ubaha spring water, southeastern, Nigeria. Water resources Journal of the Nigerian association of Hydrogeologists. Vol. 15, No. 2. p6-10.

Ahueke L, 1999. Discharge rate flow type and microbial charateristics of the Ubaha Spring Southeastern Nigeria. Unpl. Technical Report. 15p.

Amajor, L.C., 1984. Sedimentary Facies analysis of the Ajali Sandstone (Upper Cretaceous), Mining and Geol., Vol. 21 no. 4, p. 171-176.

Egboka B.C.E, 1983. Analysis of the Groundwater Resources of Nsukka Area and environs, Anambra State, Nigeria Jour. Of Min. Geol. No. 1. Vol. 20 (1&2). pp1-16.

Etu – Efeotor J.O, 1981. Preliminary hydrogeochemical investigations of the subsurface water in parts of the Niger Delta Jour. Min. Geol. 18(1). Pp103-105.

Hem, J.D, 1970. Study and Interpretation of chemical characteristics of natural water. Water supply papers. Publication of US geological survey, Washington DC. No. 1473. Pp254-255.

Hoque, M, 1976. Significance of textural and petrographic attributes of several Cretaceous sandstones southern, Nigeria. GeoLSoe.India. Vol. 17, p. 514-521.

Hoque, M. 1977. Petrographic differentiation of tectonically controlled Cretaceous sedimentary cycles, south eastern Nigeria Sedimentary Geology. 17, p. 235-245.

Hoque, M. and Ezepue,M.C.,1977. Petrology and paleo-geography of the Ajali Sandstone. Jour. Min.Geol. Vol. 14, No. 1, p. 16-22.

Ladipo, K.O., 1985. Tidal Shelf Depositional Model for Ajali Sandstone, Anambra Basin, Southern Nigeria. J. Afr. Earth Science, Vol. 5 no. 7, p. 177-185.

Nwankwo, G.I, 1995. Aspects of the hydrogeology of the Umuosinta spring Area of Imo State, Nigeria. Unpubl. Technical Report for Uzzi spring water supply. 17p.

Okonny, I.P, 1991. Imo Tectonic River. Journal of Min and Geology. Vol. 27, No. 2. Pp41-43.

Ozoko D.C, 2004. Geochemical and Microbial studies of the Natural water systems in agila, Benue State, Nigeria. Water resources Journal of the Nigerian association of Hydrogeologists. Vol. 15, No. 2. p60-65.

Piper A.M, 1944. A graphical procedure in the Geochemical interpretation of water analysis. Trans. Am. Geophys. Union. Vol. 24. p914-928.

Reyment, R..A.,1965. Aspects of the Geology of Nigeria. Ibadan University press, 145pp.

Tijani M.N, 2004. Bacteriological, chemical and lithologic controls on the water quality in Sagamu area, south-western Nigeria. Water resources Journal of the Nigerian association of Hydrogeologists. Vol. 14, No. 2. p66-76.

Uma, K.O and Egboka, B.C.E, 1986. Water Resources of Owerri and it's Environs, Imo state, Nigeria. Jour. of Min and Geol. Vol.22 (1&2). Pp57-64.

Uma, K.O., and Onuoha, K.M., 1988. Ground Water Fluxes and Gully Development in Southern Nigeria. Geological Magazine, Vol. 30 no. 4, p. 39 –59.

Umeji, O. 1980. The geomorphology and geological history of south eastern Nigeria. Nigeria Geological Journal, Vol. 3, p. 51-55.

World Gazette. 2011. Colourful map of Nigeria with 36 states. www. World-gazette.com.

World Health Organization, 1993. International standard for drinking water and guidelines for water quality. Geneva.