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RESEARCH ARTICLE

# GEOLOGY AND WATER QUALITY OF AGBOGUGU AND ENVIRONS, ENUGU STATE, SOUTH EASTERN, NIGERIA

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ABSTRACT

*This study presents the geology and water quality of surface and groundwater within Agbogugu and environs, south eastern, Nigeria. The geology of the area was grouped into three lithological units; unit A comprises of planar, laminated shale, unit B comprises of bioturbated, planar, cross-bedded and sweley cross-stratified sandstone, while unit C comprises of planar laminated sandy shale and ironstone. Ten samples were collected and analysed for their physic-chemical proprieties. The minimum and maximum values of pH (4.4-5.7 on pH scale), TDS (009-112), Electrical conductivity (15-200). Ca+(10-35), Mg2+ (12-38), Na+ (0.01-0.05), and Cl+ (142-319.50); the trace element are relatively low except for Fe (0.01-0.16). piper and stiff diagram show that the water type is Mg2++Cl- which indicates a solution of precipitation with little variation in TDS due to the differences in temperature which causes dissolution, ion exchange capacity and adsorption.*

**Keywords:** *Groundwater; Hydrogeochemistry; Surface Water; Agbogugu; Water Quality*

## Introduction

Access and availability to fresh water is an irreplaceable need facing the civilization of the world. Water is one of the most important of all natural resources known on earth. It is important to all living organisms, mostly ecological systems, human health, food production and economic development (Postel *et al., 1996*). Currently, about 20% of the world population lacks access to safe drinking water, and more than 5 million people die annually from illness associated with safe drinking water or inadequate sanitation (Midhun *et al.,* 2016). Therefore, water quality control is a top priority policy agenda in many parts of the world (WHO, 2008). Water is processed to be safely consumed as drinking water and for other purposes. Water quality and suitability for use are determined by its taste, odour, colour and concentration of organic and inorganic matter. Impurities in the water can affect the water quality and therefore the human health. The inherent sources of water impurities are geological conditions, industrial and agricultural activities and water treatment plants (WHO, 2008). Groundwater occurrence within the study area is mainly along the fractured shale and the underlying sandstone. The quality of groundwater within Enugu metropolis, sub-urban and rural areas are largely affected by human activities and its geology. Different authors have worked relatively extensively on the quality of groundwater. Iyi *et al*. (2020) evaluated the quality assessment of surface and groundwater geochemistry within Isu Awaa. Ozoko *et al*. (2017) and Aniebonam (2015) evaluated the quality of surface and groundwater within the Enugu and Ugwueme areas. Their outcome shown that the water bodies are contaminated by facael contaminants. This paper presents the geology and water quality of the physio-chemical proprieties of sampled water within the study area and to evaluate its palatability for domestic functions.

## The Study Area

The study area, Agbogugu and environs lies between latitudes $06°13^{1}00^{11}$N and $06°18^{1}00^{11}$N and longitudes $007°26^{1}00^{11}$E and $007°31^{1}00^{11}$E. It is bounded to the south by Ihe, to the east by Amuri, to the north by Ozalla and the west by Isu-awaa, it covers an aerial extent of about 86.49$km^2$. It is accessible through Enugu-Portharcourt express way, also through Ozalla-old 4 corners road. There are also minor link roads and footpaths, connecting the various towns and villages.

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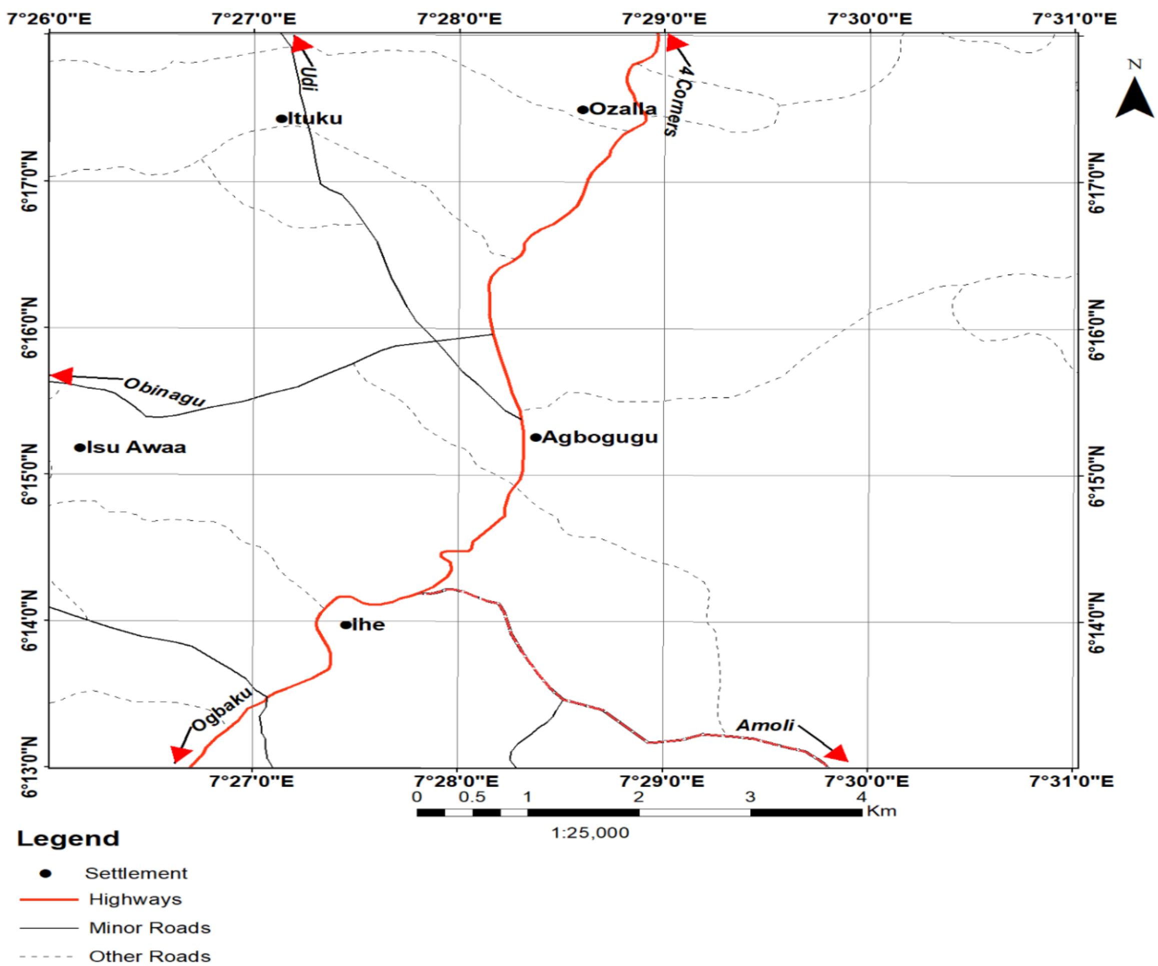


**Figure 1: Extend and accessibility map of the study area**

The study area is underlain by two geologic formations; the Enugu Shale and the Owelli Sandstone which are characterised under three lithological units namely; unit A, unit B and unit C. unit A comprises of planar laminated shale, unit B comprises of bioturbated planar cross-bedded and sweley, cross-stratified sandstone and unit C comprises of laminated sandy shale and ironstone (figure 2).

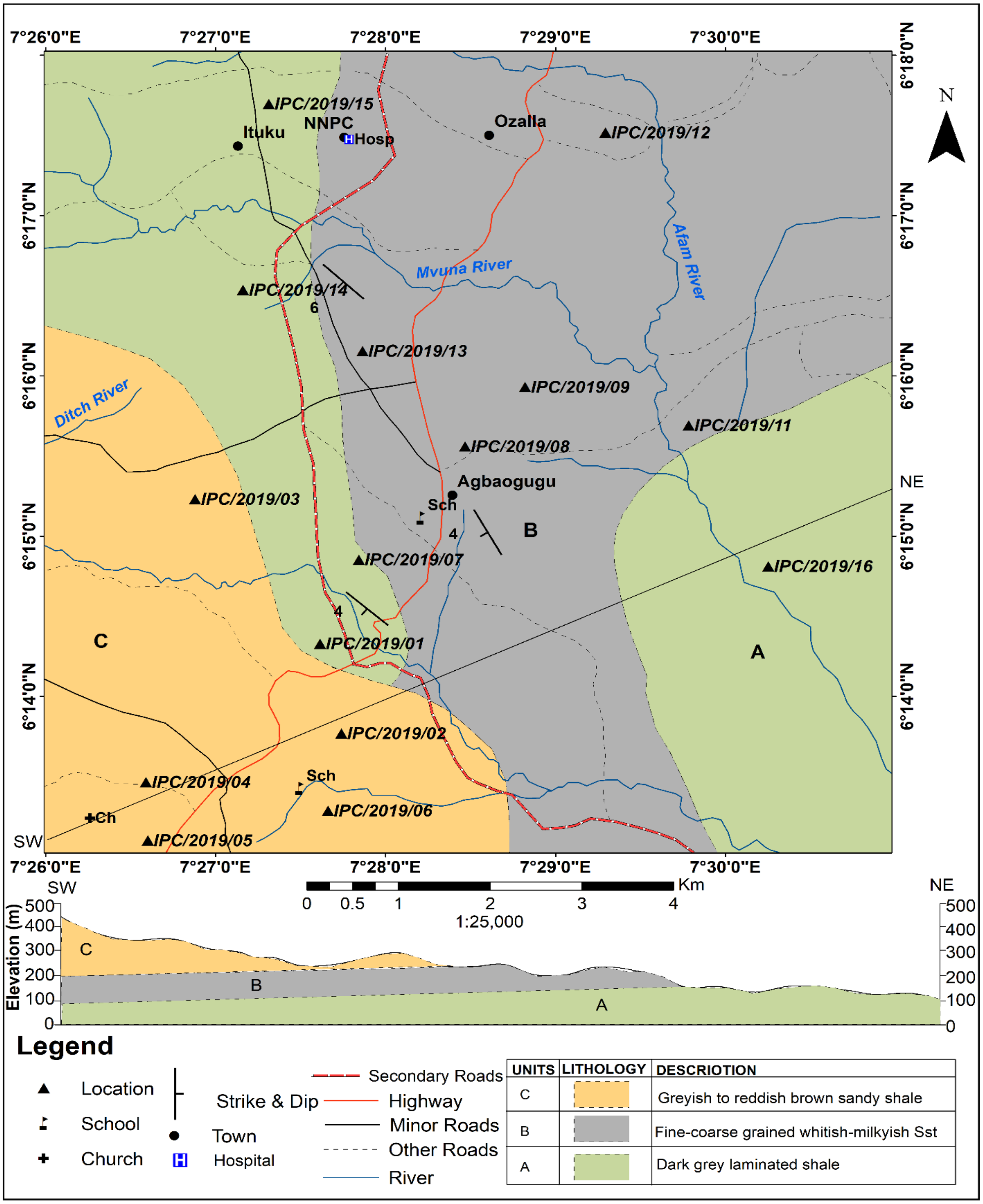


**Figure 2: Geologic map of the study area**

## Material and Methods

Groundwater samples were collected from five locations while surface water was collected from five seasonal stream within the study area. The samples were collected in September, during the rainy season to allow the dilution effect of precipitation during the rainy season and contaminating effects associated with storm water runoff. Sampling effectively covered the study area by taking samples from all the available streams, wells and boreholes.

The water samples were collected in pairs for every location in two (2) litre white plastic containers. The samples meant for cation determination were acidified with trioxonitrate (V) acid ($HN0_3$) to prevent the cations from adhering to the surface of the container thereby making them to remain in solution. The second pair of samples meant for anion determination was not acidified.

Parameters that change rapidly with time after water withdrawal were measured on the field as soon as samples were collected. The parameters are temperature, pH and electrical conductivity (EC). pH was measured using a portable pH meter. Temperature and electrical conductivity were also measured with a potable electrical conductivity meter. The geographical location and elevation of each sampling point above sea level was measured using a Global Positioning System (GPS). The water samples were analysed for the following cations, heavy metals and anions; TDS, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Na^+$, $Cl^-$, $SO_4^{2-}$, $HCO^{3-}$, $NO^{3-}$, $PO_4^-$, $Fe^{3+}$, Mn, Pb, As, Zn, Cd, Cr and Cu. Hardness was calculated. The digested samples were used for the cations and heavy metal analysis using the Atomic Absorption Spectrometer (ASS). The undigested samples were used for the anion analysis. Chloride (CT) ion was determined using the "mercury (11) nitrate method (Ademoroti, 1996). Sulphate ($SO_4^-$) ion was determined by the "turbidimetric method (Ademoroti, 1996). Nitrate ion concentration was determined by the Calorimetric method using a spectrophotometer used at 420nm.n during the rainy season and contaminating effects associated with storm water runoff (Thornson, 1996). Sampling effectively covered the study area by taking samples from all the available streams, wells and boreholes.

**Results and Discussion**

For ease of visual inspection, the chemical data are presented by the combined use of tables, and graphs. Each of the method presents the concentrations of the major ions in the water samples in milligrams per litre. Each graph or map for each sample represents a particular character of the groundwater under study.

**Table 1: Result of Physio-chemical analysis**

| *S/N* | *pH* | *EC* | *TDS* | *TSS* | *$Ca^{2+}$* | *$Mg^{2+}$* | *$Na^+$* | *$Cl^-$* | *$HCO_3^-$* | *$SO_4^{2-}$* | *$Fe^{3+}$* | *Mn* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *1* | 5.7 | 200 | 112 | 1.0 | 35.0 | 38.0 | 0.01 | 319.50 | 0.60 | 0.02 | 0.16 | 2.41 |
| *2* | 4.7 | 152 | 086 | 0.5 | 15.0 | 18.0 | 0.02 | 301.75 | 0.80 | 0.01 | 0.04 | 2.04 |
| *3* | 5.5 | 196 | 096 | 1.0 | 17.5 | 19.53 | 0.03 | 284.0 | 0.40 | 0.03 | 0.16 | 1.82 |
| *4* | 4.9 | 016 | 009 | 1.0 | 15.0 | 18.0 | 0.02 | 213.0 | 0.60 | 0.02 | 0.03 | 2.13 |
| *5* | 4.8 | 015 | 008 | 0.5 | 17.5 | 19.53 | 0.03 | 159.75 | 0.60 | 0.01 | 0.06 | 2.51 |
| *6* | 5.3 | 042 | 021 | 0.5 | 12.5 | 14.54 | 0.01 | 195.25 | 0.60 | 0.01 | 0.08 | 1.92 |
| *7* | 5.5 | 042 | 024 | 0.5 | 17.5 | 19.53 | 0.03 | 230.75 | 0.60 | 0.01 | 0.09 | 2.33 |
| *8* | 4.8 | 029 | 017 | 1.0 | 10.0 | 12.0 | 0.03 | 142.0 | 0.60 | 0.01 | 0.01 | 2.08 |
| *9* | 4.8 | 029 | 016 | 0.5 | 12.5 | 14.54 | 0.05 | 195.25 | 0.80 | 0.01 | 0.01 | 2.08 |
| *10* | 4.4 | 152 | 077 | 0.5 | 15.0 | 18.0 | 0.01 | 319.50 | 0.60 | 0.01 | 0.04 | 1.52 |
| ***11*** | **6.5-8.5** | **100** | **85** | **-** | **40** | **-** | **200** | **200** | **-** | **150** | **0.3** | **0.05** |

*1 (Hand Dug Well @ Amuowoh Ihe), 2 (Hand Dug Well @ Obodo-Akpu Agbogugu), 3(Hand Dug Well @ Ihueze Ihe), 4 (Spring Water @ Ihe), 5 (Spring Water @ Agbogugu), 6 (Nvana River Ihe), 7 (Ogbude River Ihe), 8 (Borehole @ Umuewo Ihe), 9 (Borehole @ Ihueze Ihe), 10 (Hand Dug Well @ Akwu Agbogugu), 11 (WHO 2008)*

From the table above, the value of pH ranges from 4.4 to 5.5 (figure 3) which fall within the WHO (2008) recommended standard.

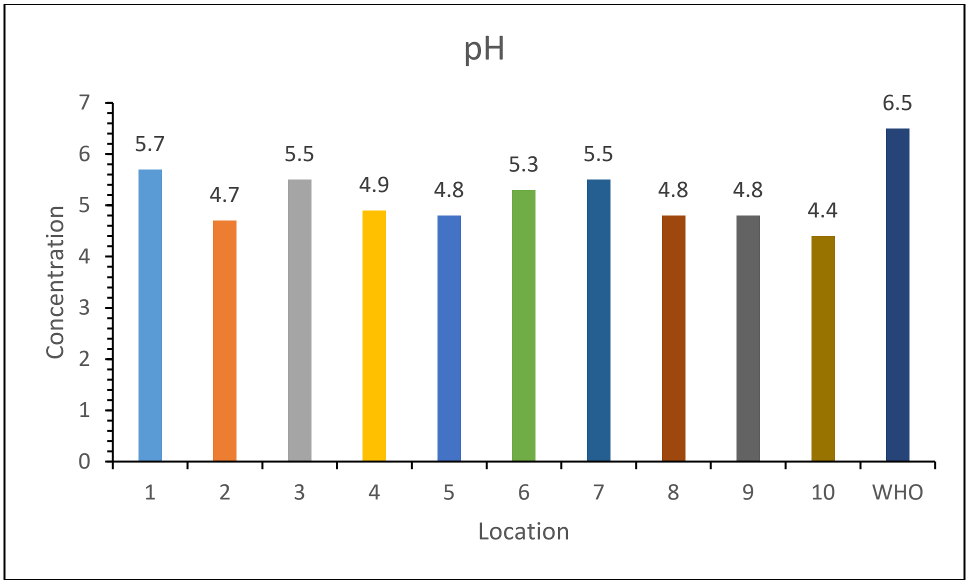


**Figure 3. Bar chart showing the distribution of pH in the study area**

Electrical conductivity is a measure of the ability of water to conduct electric current. It is sensitive to variations in dissolved solids, mostly mineral salts. The value of electrical conductivity measured on the field varied from 15 µS/cm to 200 µS/cm. These values are below WHO standard limit (Figure 4).

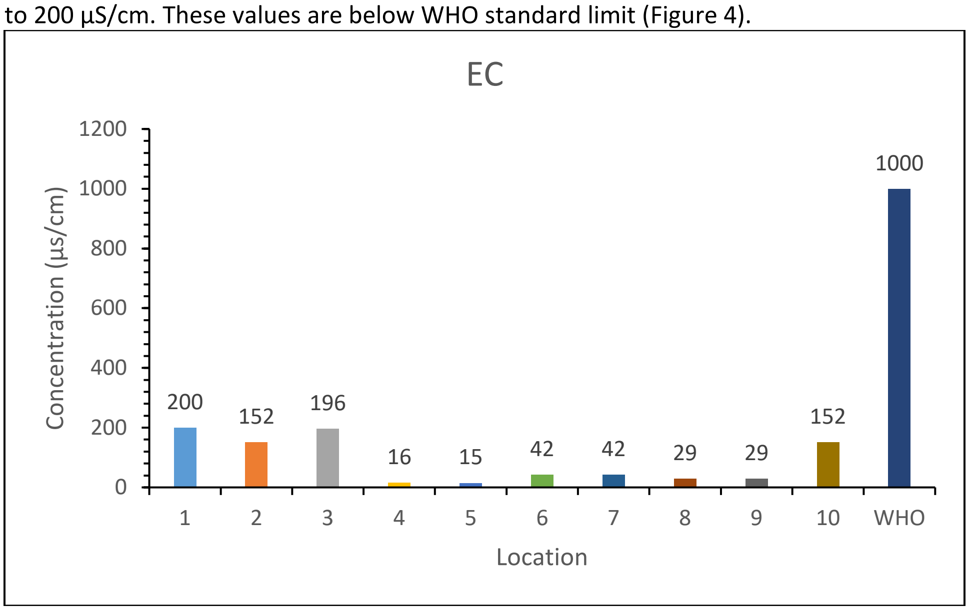


**Figure 4: Bar chart showing the distribution of EC in the study area**

An estimate of the TDS - values in mg/l was carried out by multiplying the conductance value by a factor of about 0.65 (Todd, 1980). The estimated values ranged from 9mg/l to 112mg/l (Figure 5). Using the Carroll (1962) groundwater classification based on TDS of the groundwater at Agbogugu can be classified as brackish water.

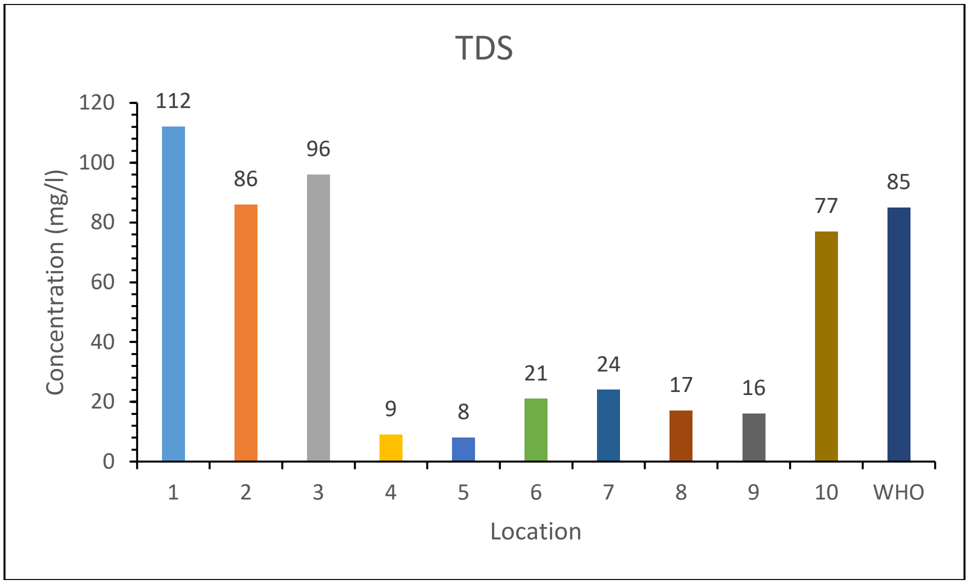


**Figure 5: Bar chart showing the distribution of TDS in the study area**

The measured TSS of the surface and groundwater samples ranged from 0.5mg/l to 1mg/l. The maximum recommended TSS limit set by WHO (2008) is 25 mg/L. The TSS values of all the water samples studied are shown in Figure 6. The low value of TSS implies that the surface and groundwater within the study area are pollution free.

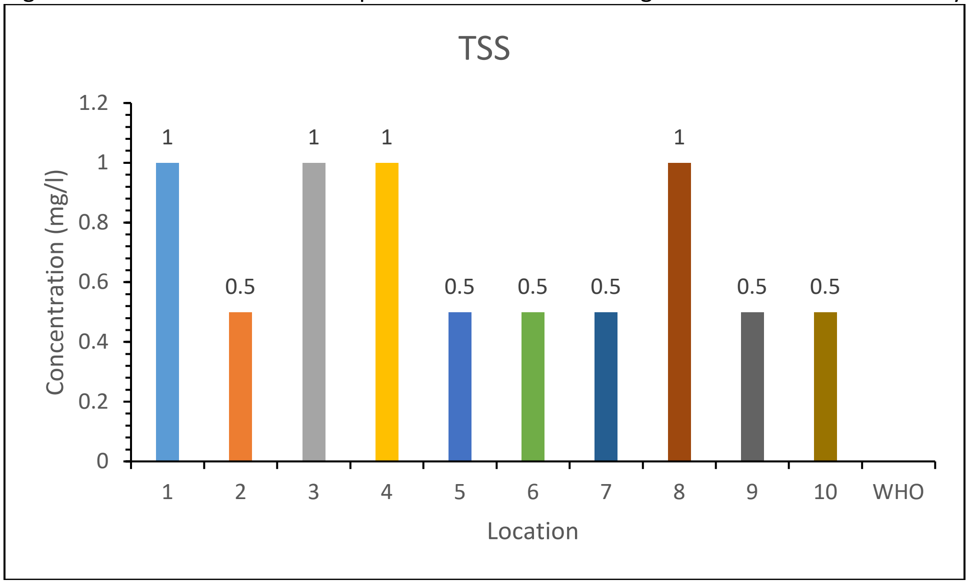


**Figure 6: Bar chart showing the distribution of TSS in the study area**

The measured calcium of the surface and groundwater samples ranged from 10mg/l to 35mg/l (Figure 7). The calcium concentration in the surface and groundwater in the study area is similar to that recorded by Utom *et al.*, (2013) within the Okpara and Ogbete fireclay mines. The calcium concentration is lower than the WHO, (2008) recommended guideline of 40mg/l for drinking water. Sources of calcium within the study area include amphiboles, feldspars clay minerals and pyroxene. Calcium exceeded magnesium in all the samples.

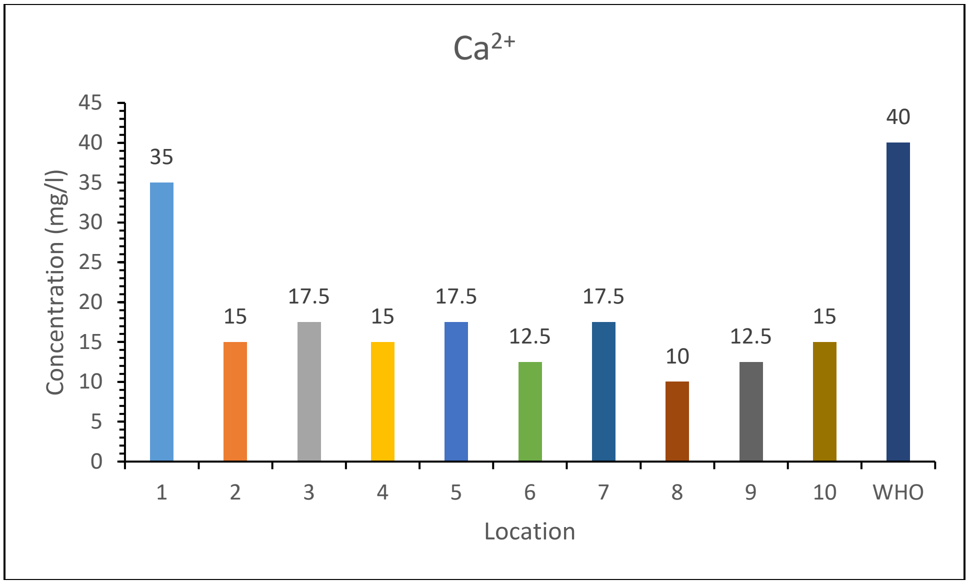


**Figure 7: Bar chart showing the distribution of calcium in the study area**

The concentration of magnesium within the study area was found to be similar to those from other parts of the Enugu area. The magnesium concentration is however lower than the value recorded in the work of Utom *et al.*, (2013) within the mine area. The value is also lower than the WHO (2008), recommended guidelines of 150mg/l (Figure 8). Common sources of magnesium at Agbogugu and environs include hornblende, ferruginous and chlorite which are common among gneisses around the study area.

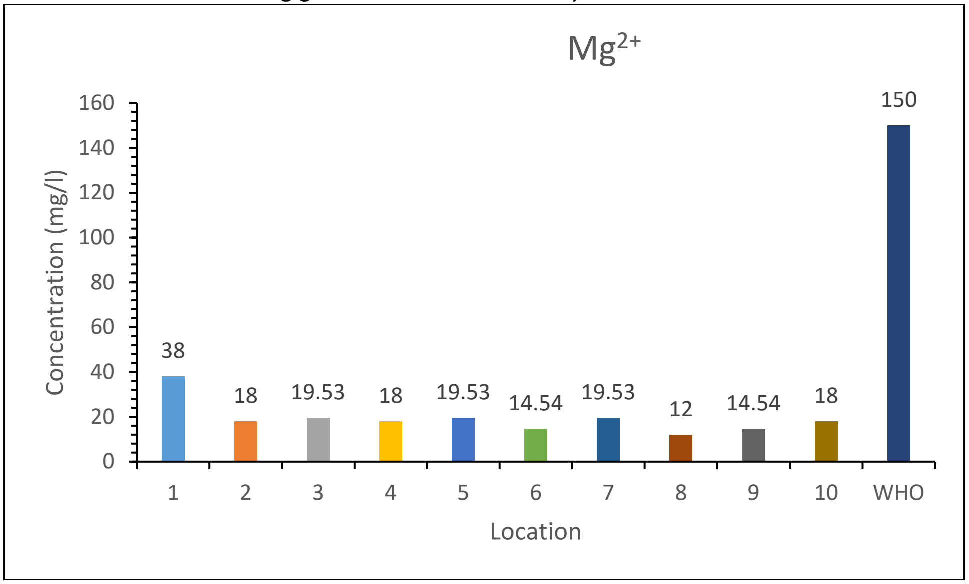


**Figure 8: Bar chart showing the distribution of magnesium in the study area**

The concentration of sodium ion in surface and groundwater within the study area compares well with concentration standard limit set by regulatory bodies. Sodium concentration exceeds potassium concentration in all the samples. Sources of sodium include plagioclase feldspars, evaporites such as halite (NaCl). The most common source of potassium in the groundwater is K-feldspar.

The measured chloride of the surface and groundwater samples ranged from 142mg/l to 319.5mg/l (Figure 9). The values are higher than those measured by Utom *et al*. (2013) from the Okpara coal and Ogbete fireclay mines near Enugu town. Some of the sources of chloride in area could be as result of low pH nature of the surface and groundwater found within the study area.

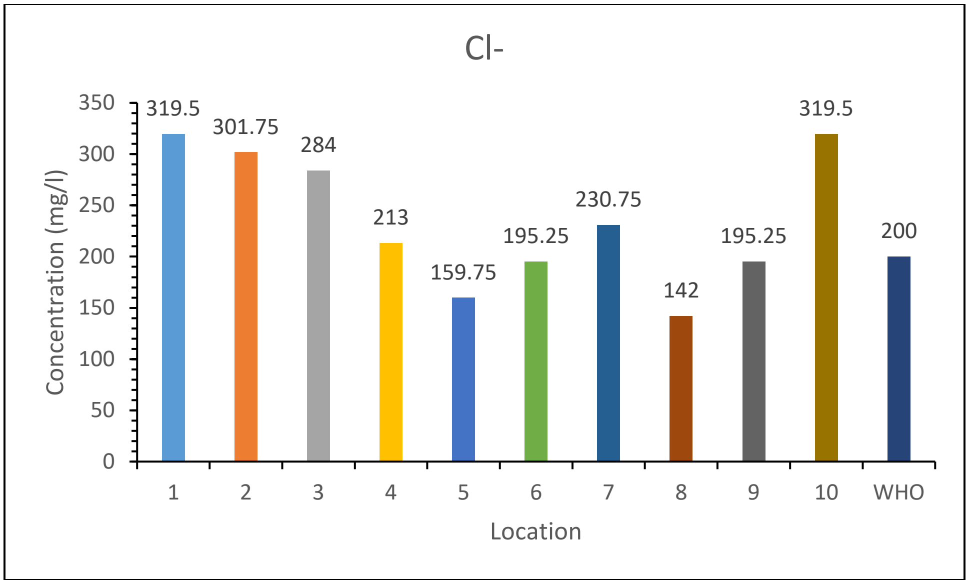


**Figure 9: Bar chart showing the distribution of chloride in the study area**

The values of bicarbonate concentration at Agbogugu and environs are generally of low or negligible concentrations in surface and groundwater. The source maybe from atmospheric precipitation. There is no standard limit recommended by WHO (2008) for bicarbonate.

The sources of sulphate in water may be anthropogenic, geological formation, and so on. Excess sulphate has a laxative effect, especially in combination with magnesium and/or sodium. Sulphates exist in nearly all-natural waters, the concentrations varying according to the nature of the terrain through which they flow. The values are however lower than the WHO (2008) recommended highest desirable level of 200mg/l. The concentrations of sulphate from the studied water samples ranged from 7.5 – 17.61 mg/l. These values are lower than the WHO (2008) standard limit recommended for drinking water.

The study area is an iron rich environment thus iron content of groundwater will naturally be expected to be high. The water analysis result shows that iron content in groundwater from the study area ranged from 0.01 mg/l to 0.16 mg/l which is lower than those analysed by Utom *et al.*, (2013) in coal mine environment. It however conforms with Egboka, (1986) concentration values of iron in the groundwater samples from surface and groundwater in non-existing mine area where iron content rarely exceeds 0.1mg/l. The iron content obtained from the study area lower than the WHO, (2008) recommended concentration limit of 0.3mg/l (Figure 10). The sources of iron in the area maybe from minerals rich in sulphide (FeS), ferric sulphide or pyrite ($FeS_2$) and hematite.

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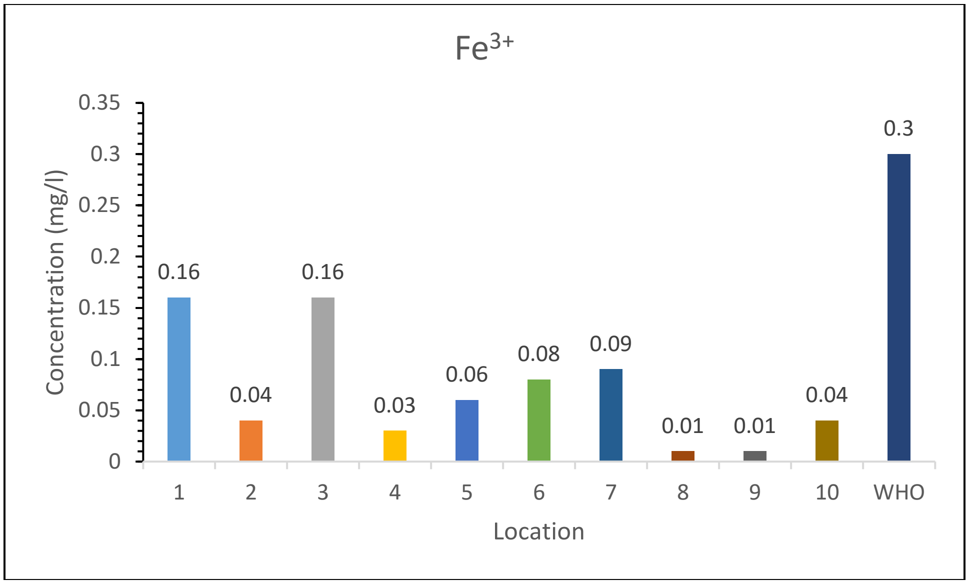


**Figure 10: Bar chart showing the distribution of iron in the study area**

All the water samples had manganese concentrations higher than the WHO (2008) maximum permissible level of 0.05mg/l for drinking water. In the study area manganese values obtained varied from 1.82 mg/l to 2.51mg/l (Figure 11). These values were also higher than those obtained by Utom *et a1.,* (2013). Water with higher concentrations of manganese may have unpleasant taste. The sources of manganese include mica, biotite and amphibole hornblende minerals which all contain large amounts of manganese.

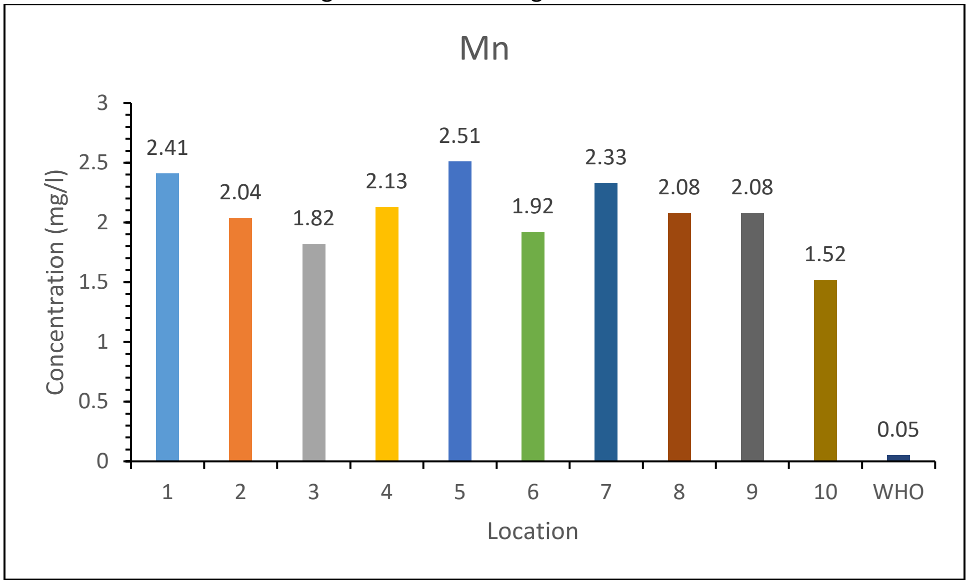


**Figure 11: Bar chart showing the distribution of Mn in the study area**

Surface and groundwater in the study area were also characterized using Piper trilinear diagram (Figure 12). The water types trend of the $Mg^{2+}$ + $Cl^-$ water type in a straight line on the Piper diagram which is an indication of a solution or precipitation.

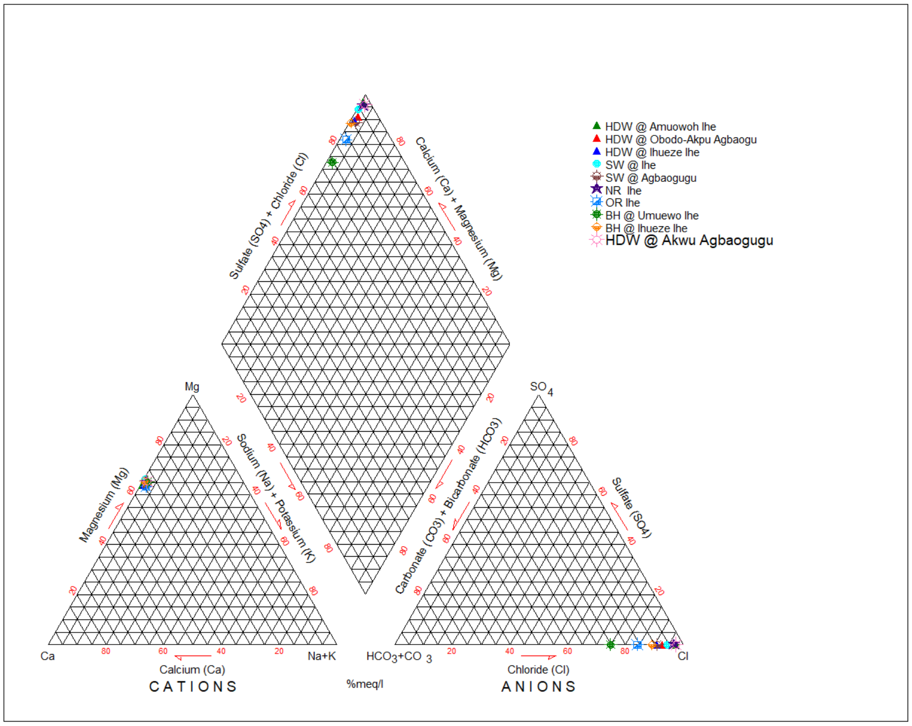


**Figure 12. Piper diagram showing water type in the study area**

The Stiff pattern diagrams showed similar patterns for all sample locations (Figures 13a, and 13b). Water with similar qualities tends to plot together as a group while the size of the pattern is approximately equal to the ionic content. The similarity in pattern is an indication that the water types are $Mg^{2+}$ + $Cl^{-}$ type of water with little variation in TDS due to the differences in temperatures which causes dissolution, ion exchange capacity and adsorption.

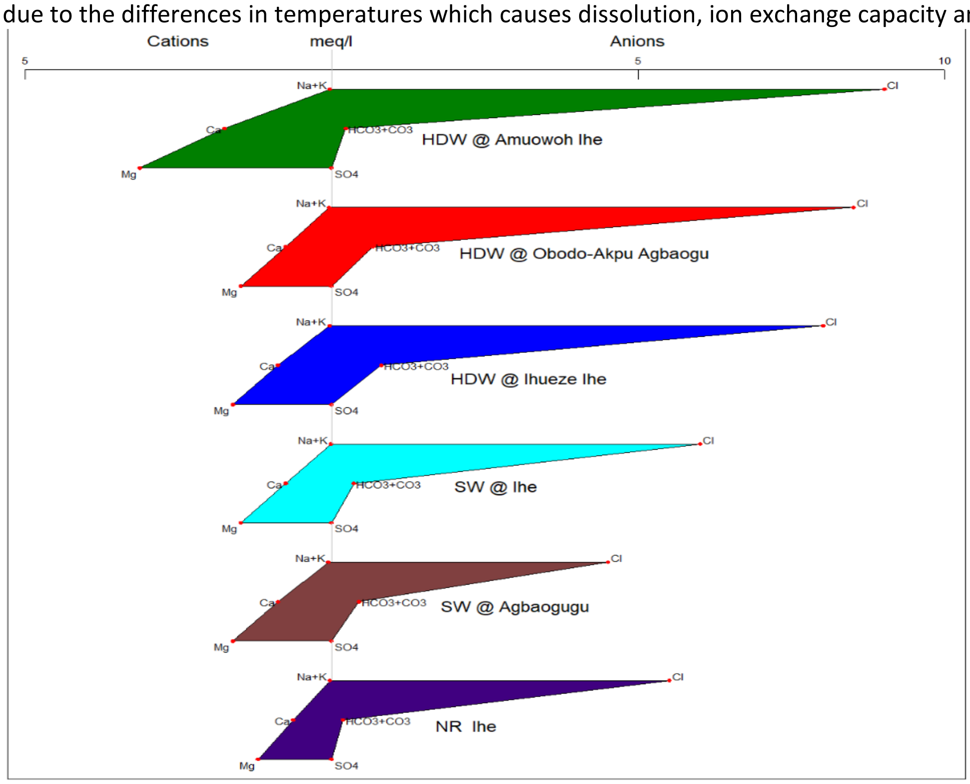


**Figure 13a. Stiff diagram showing water type of the area**

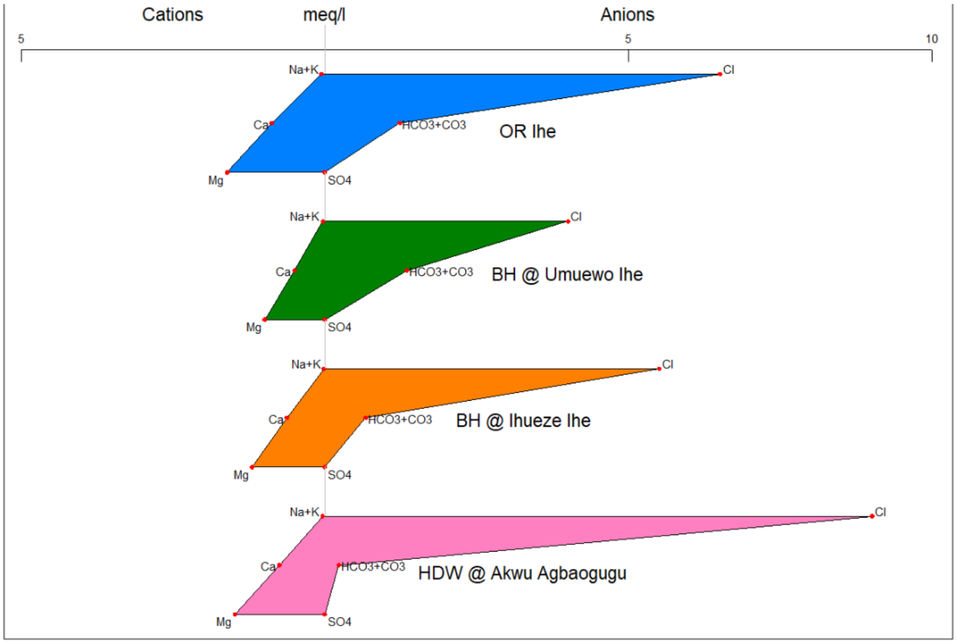


**Figure 13b. Stiff diagram showing water type of the area**

**Conclusion**

From the ongoing discussion of the hydrogeochemistry of Agbogugu and environs; which shows the analytical results of ten (10) water samples; with major cations and anions which were tested. The study area is an iron rich environment, although the sampled waters are within the WHO limits. It also has a high concentration of chlorine (except sampled water number 5, 6, 8 and 9) which alters its use for laundry activities, because chlorine is a good bleaching agent; thus, the need for the water to be treated before using it for laundry activities.

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