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Assessment of Water Quality for Sustainability and Health Management in Parts of Aguata, Anambra State, Southeastern Nigeria, Using Physiochemical Analysis

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Abstract
The chemical analysis carried out on the water samples show varying chemical concentrations across the study area. Bicarbonate has value range of 9 – 35 mg/l across the study area with its WHO permissible limit (006) being 300 mg/l, Sulfate has a value range of 1 – 7 mg/l with its WHO standard (2006) for drinking water quality being 250 mg/l, nitrite has a value range of 0.01 to 0.07 mg/l with its WHO standard being 10 mg/l, nitrate has a value range of 1.5 mg/l – 12 mg/l with its WHO standard (2006) being 45 mg/l. Magnesium has a value range of 4 to 22 mg/l with the WHO standard (2006) being 30 mg/l. Calcium has a value range of 6 – 19 mg/l with its WHO standard (2006) being 75 mg/l. Manganese are Iron are heavy metals which may be sourced from industrial, mine, landfills, etc. The Iron content across the study area ranges from 0.01mg/l to 0.04 mg/l against the WHO (2006) permissible limit of 0.3. The Manganese content across the study area ranges from 0.01 to 0.04mg/l as well which falls below the 0.5 mg/l WHO standard (2006). the piper plot of the study area revealed that the water samples fall within the bicarbonate type in the anion triangle while the cation triangle has Magnesium as the dominant type showing magnesium-calcium-bicarbonate water type. The traces of magnesium-calcium-bicarbonate is also proven in scholar diagram. The stiff plot resulted that bicarbonate concentration is most dominant in all seven locations with Achina having a concentration greater than 0.5Meq/L. From pH level result, the study area resulted below 7, with the lowest being 5.4 at Isuofia and the highest being 6.4 at Achina, which revealed pH level of an acidic water type.

Keywords: Chemical Concentrations, Magnesium-Calcium-Bicarbonate, Schollar Diagram, Cation Triangle, Anion Triangle, pH level

1. Introduction

Suitability of water for various uses depends on type and concentration of dissolved minerals. Groundwater has more minerals concentration in comparison with surface water. All groundwater contains minerals carried from the ground earth. Type and concentration of minerals depend on the environment, movement and source of the groundwater. The degree and type of mineralization of ground and surface water determines its suitability for municipal, industrial, irrigation and other uses. In general, standards of water quality have been established for almost every water use using diverse criteria. The criteria used are based on the Chemical, physical and biological constituents of water.

1.1 Properties of Water

i. Physical properties
ii. Chemical properties
iii. Biological properties

1.1.1 The Physical Properties

They include color, pH, temperature, turbidity, T.D.S (Total Dissolved Solids), turbidity and E.C (Electrical Conductivity).

1.1.2 The Chemical Properties

They encompass all chemical elements and compounds present in water. Their distribution in water depends on the water source, i.e. groundwater or atmospheric water. While rock formations majorly account for the chemistry of groundwater, anthropogenic activities remain active players when it comes to the chemistry of both ground and surface water chemistry. Elements and compounds occur in variable amounts due to the nature of their individual reaction with hydrogen and oxygen atoms. Some are readily soluble in water while others are not. The chemical components of water are divided into two major ion types.

a. Cation

b. Anion

The cations are divided into major and minor cations, likewise the anions. The major cations are Sodium (Na^+), Potassium (k^+), Magnesium (Mg^{2+}) and Calcium (Ca^{2+}) while the major anions are Bicarbonate (HCO_3-), Nitrate (NO_3-), Carbonate (CO_3-) and Chloride (Cl-). Other elements and compounds occur in minute concentration known as trace elements

1.1.3 Biological Properties

They encompass all micro-organisms present in water. Examples are E.coli and coliform. The chemical and physical properties of water have a threshold beyond which they may be considered unsafe for use. It is in this regard that water quality assessment becomes necessary.

2. Location and Geological Setting of the Study Area

The study area lies within the southeast of Anambra State on Latitude: 6° 55' N and 6° 58' N and Longitude: 6° 58' E and 7° 10' E. Awka-Orlu upland and the flood plain of Mamu river which is an area of moderate relief characterized the drainage of Aguata. Geologically, the study area is overlaid by Agulu Nanka formation, made up of highly sediments of friable sandstones, shales and limestone. Agulu-Nanka gully sites contributes to the vulnerability of the study area to erosion and environmental hazard which has been unfair to resources. The drainage system of the study area formed the tributaries of Mamu and Anambra rivers which empty into the River Niger and there is much surface drainage systems where much water is washed away from the land. The study covered Ekwulobia, Achina, Uga, Isuofia, Umuchu, Ezinifite and Nkpologwu (Figure. 1).

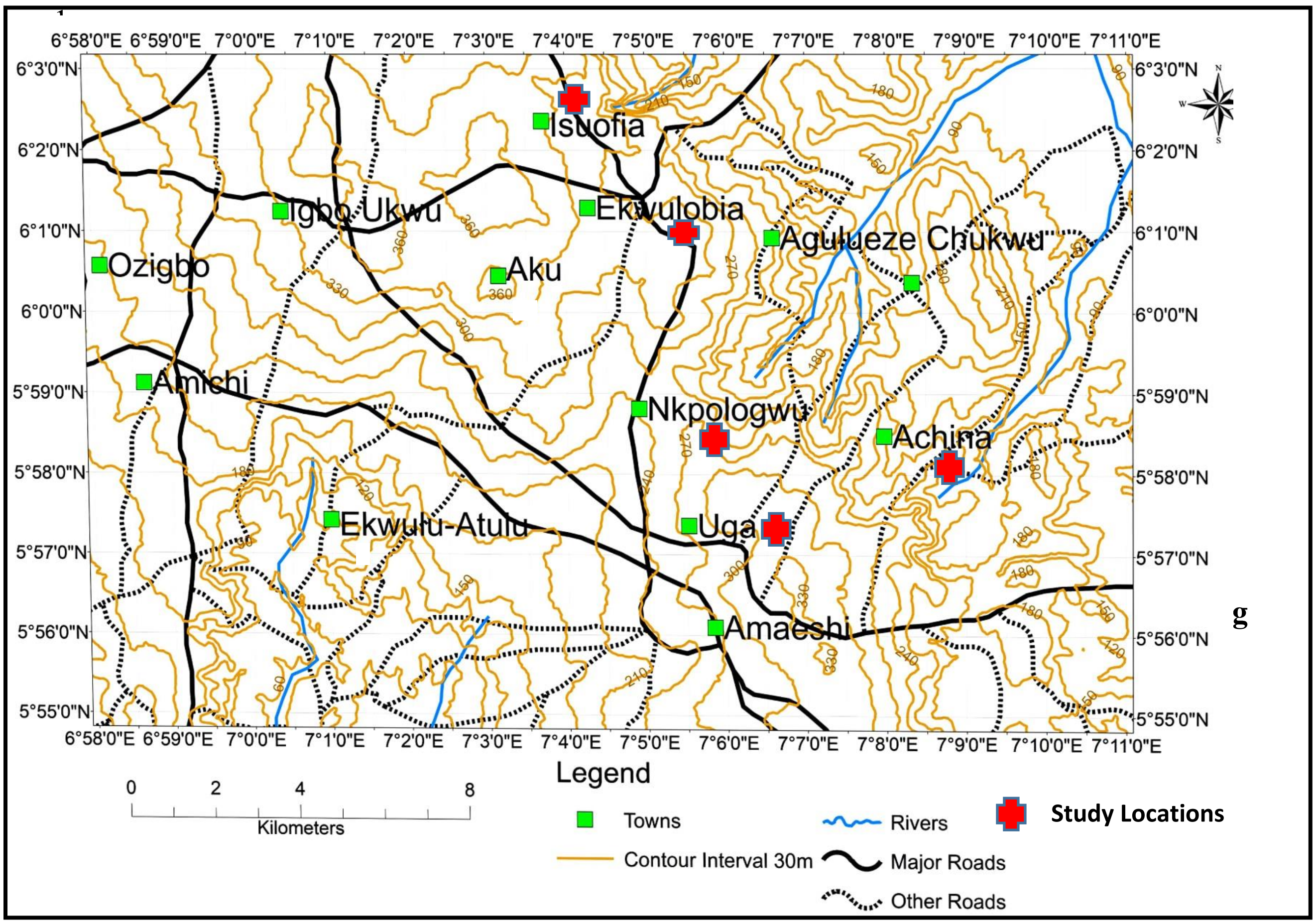

Figure 1: Drainage Map of the Study Area Modified by the Authors using ArcGIS Software

3. Methodology

Water quality assessment refers to the methods/techniques used to determine the suitability of water for different uses according to its physical, chemical and organoleptic (e.g., taste) properties (www.svalbardi.com/blogs/water/quality). Water quality is determined by physical, chemical and microbiological properties of water. These water quality characteristics are characterized with wide variability. The suitability of water based on its properties depends on its intended application. The suitability of water for domestic application differs from its suitability for industrial/ agricultural application. Hydro-chemical plots are used to classify water into their respective hydro-chemical facies for easy classification. The results from the laboratory analysis carried out on the water sample are displayed in the table 1 below:

SAMPLE	Ph	EC	TDS	SALINIT	TOTAL HARDNESSS	Cl	HCO3	Ca	Mg	SO4	NO2	NO3	Fe	Mn
Umuchu	6.1	18.4	9.2		12		23	8	4	5		4		0.01
Ekwulobia	6.2	58.8	29.4		11		18	6	5	4	0.01	3.5	0.02	0.04
Isuofia	5.4	25.1	12.5	1.7	20	1	16	12	8		0.01	1.8	0.01	
Ezinhifite	6.2	27.6	13.8		15		9	7	8	7	0.07	6.2	0.04	0.04
Uga	6.28	16.8	8.4		30		9	8	22		0.01	1.48	0.01	
Achina	6.35	58.7	29.3		32		35	19	13	1	0.01	12	0.02	
Nkpologwu	6.1	18.4	9.2		12		23	8	4	5		3		0.01

Table 1: Physiochemical analysis of water quality of the study area.

4. Results and Discussion

In order to establish the hydro-geological characteristics of the water, the laboratory results were subjected to different hydro-geological interpretation models. Piper, stiff and Scholler diagrams were created for each water samples. The results are displayed below;

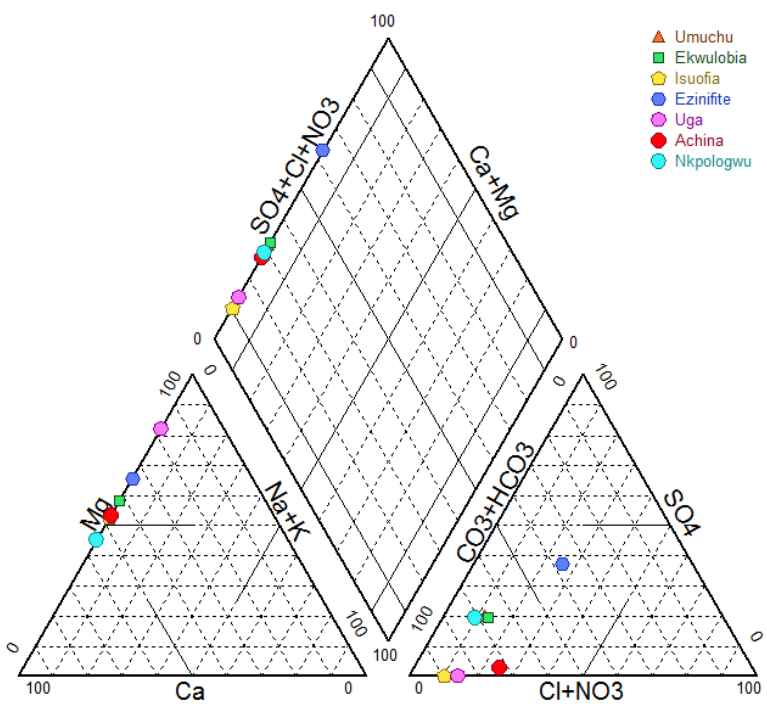

Figure 2: Piper Diagram Showing the Distribution of Ionic Types and Hydro-Chemical Facies of Water in the Study Area.

The trilinear Piper diagram is widely used for determining the relationships between the various dissolved constituents in water and for identification of ionic types and hydro-chemical facies of water. Hydro-geochemical facies are used to denote the diagnostic chemical character of water solutions in hydro-geologic systems whereby the facies reflect the effect of chemical processes occurring between the minerals of the lithologic framework and groundwater. In the anion triangle, the water samples fall within the bicarbonate type while the cation triangle has Magnesium as the dominant type. The piper plot shows that the water belongs to the Magnesium-calcium-bicarbonate type water (Fig. 1).

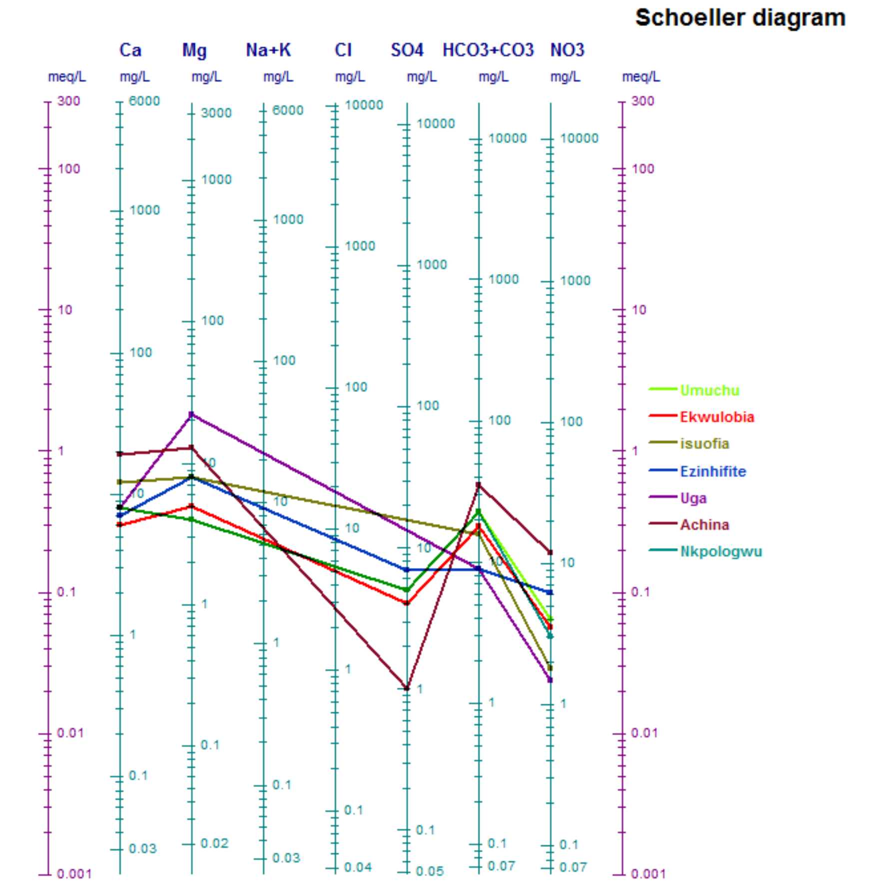

Figure 3: Scholler Diagram representing the Relative Concentrations of Anions and Cations in the Groundwater System of the Study Area

Figure. 3 above is the Scholler diagrams used to show the relative concentrations of anions and cations typically expressed in milli-equivalents per liter. Multiple samples from locations may be plotted on a single diagram to distinguish similar patterns in the ratios of particular anions and cations. The schoeller diagram shows that the dominant ionic concentration at Uga is the cations with Magnesium having the highest concentration. At Achina, Magnesium has the highest concentration while sulfate has the lowest. There is a general Magnesium-Calcium-bicarbonate trend displayed by the schoeller diagram. The ionic concentration as shown by the Schoeller diagram agrees with the facies type has displayed by the piper diagram.

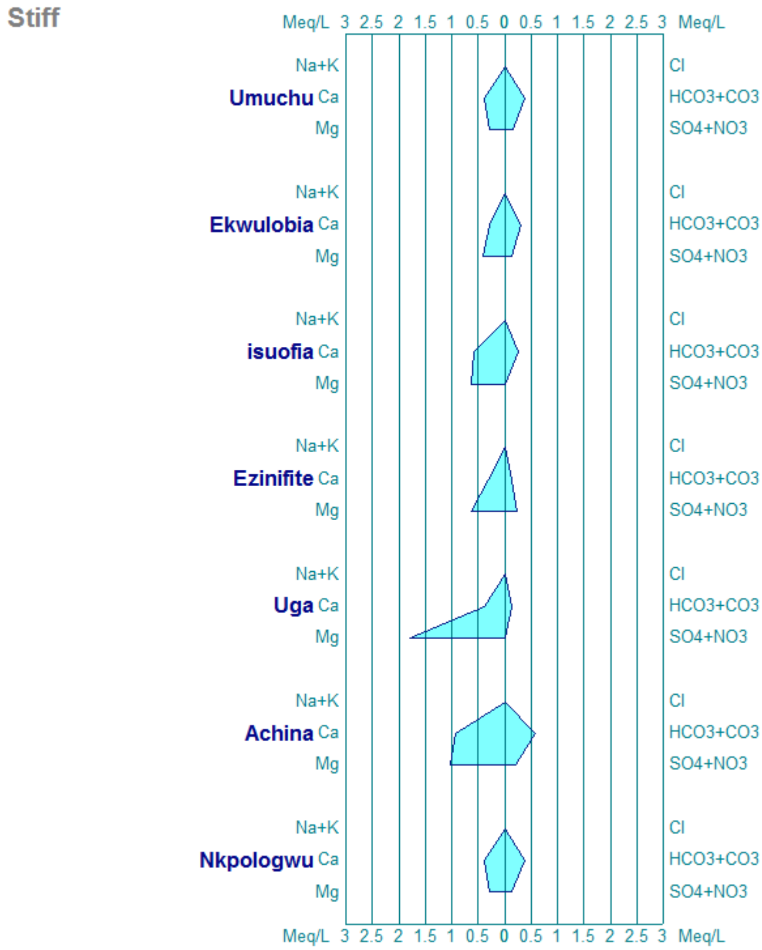

Figure 4: Stiff Diagram of the Study Area

The stiff diagram is used to determine the ionic class of water. Stiff diagrams are useful in creating a visual comparison between water from different sources.Result from the stiff diagram shows very low concentration of Chloride and Sodium-Potassium ions from all the locations. Umuofia, Ezinifite, Uga and Achina all have a magnesium concentration>1 Meq/L with Uga having about 1.8Meq/L, while Isuofia and Achina have a Calcium concentration >1Meq/L. On the anion side, Isuofia and Uga have the lowest Sulfate-Nitrate ionic concentrations. The bicarbonate concentration is most dominant in all seven locations with Achina having a concentration greater than 0.5Meq/L (Fig.4).

4.1 Physical Properties

4.1.1 Total Hardness

Water hardness is the total calcium and magnesium ion concentration in a water sample and is expressed as the concentration of calcium carbonate. The hardness of water has its industrial and domestic implications. Hard water can result in calcification which may reduce the quality of pipes and boilers in both domestic and industrial applications. The water hardness chart from the study area is presented below (Figure. 5 and Table 2).

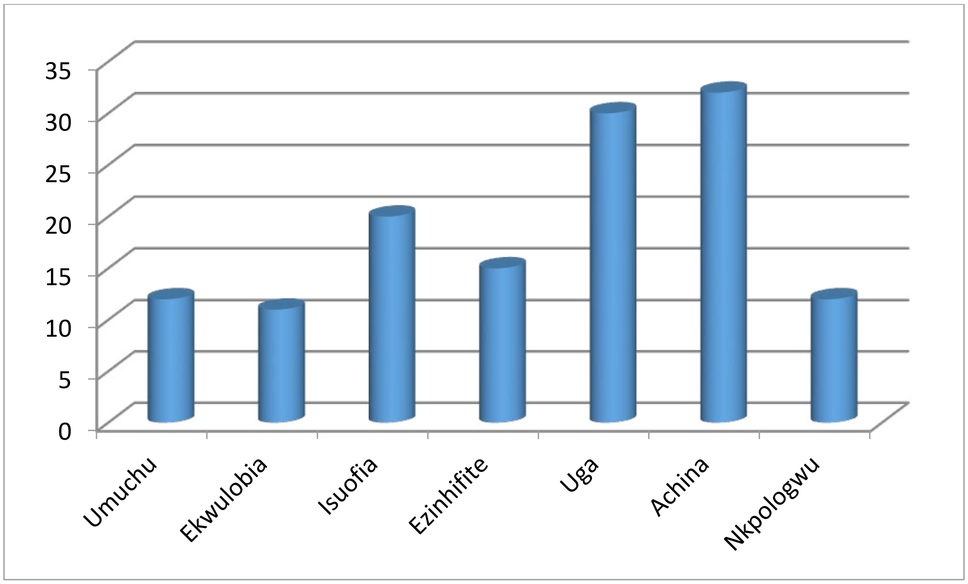

Figure 5: The Chart shows that Achina, Uga and Isuofia have the Highest Degree of Hardness in the Study Area while Ekwulobia have the Lowest.

DESCRIPTION	HARDNESS (mg/L)
Extremely soft	0-45
Soft	46-90
Moderately Hard	91-130
Hard	131-170
Very Hard	171-250
Excessively Hard	>250

N/B: The Index Shows that the Water Samples from all the Locations are Extremely Soft from the results of Laboratory Analysis of the Study Area.

Table 2: The Index for Water Hardness is Presented Below

4.2 Electrical Conductivity and Total Dissolved Solids. EC & TDS the Physical Properties of the Water Samples are Presented in a Chart Below:

The conductivity of water heavily depends on its temperature and Total dissolved solids. The higher the dissolved salts in the water the higher its electrical conductivity. Also, temperature is directly proportional to the electrical conductivity such that high temperature leads to increase in the free motion of ions while reverse is the case when the temperature is lowered. This leads to increase or decrease in the Electrical Conductivity as the case may be. The pH level across the study area fell below 7, with the lowest being 5.4 at Isuofia and the highest being 6.4 at Achina. This pH level shows an acidic water type. Fig. 6 show that the EC and TDS indicates the presence of inorganic salts and organic matter and the ability of the water to conduct electrical current (Anna, 2018). The low TDS values obtained indicates low mineralization/scarce presence of organic salts. The EC values correspond with the TDS values such that the low mineralization accounts for the low EC values obtained. This, however, may not always be the change as water temperature also affects its ability to conduct electrical current. The EC and TDS values fall below the WHO standard (2006) for drinking water.

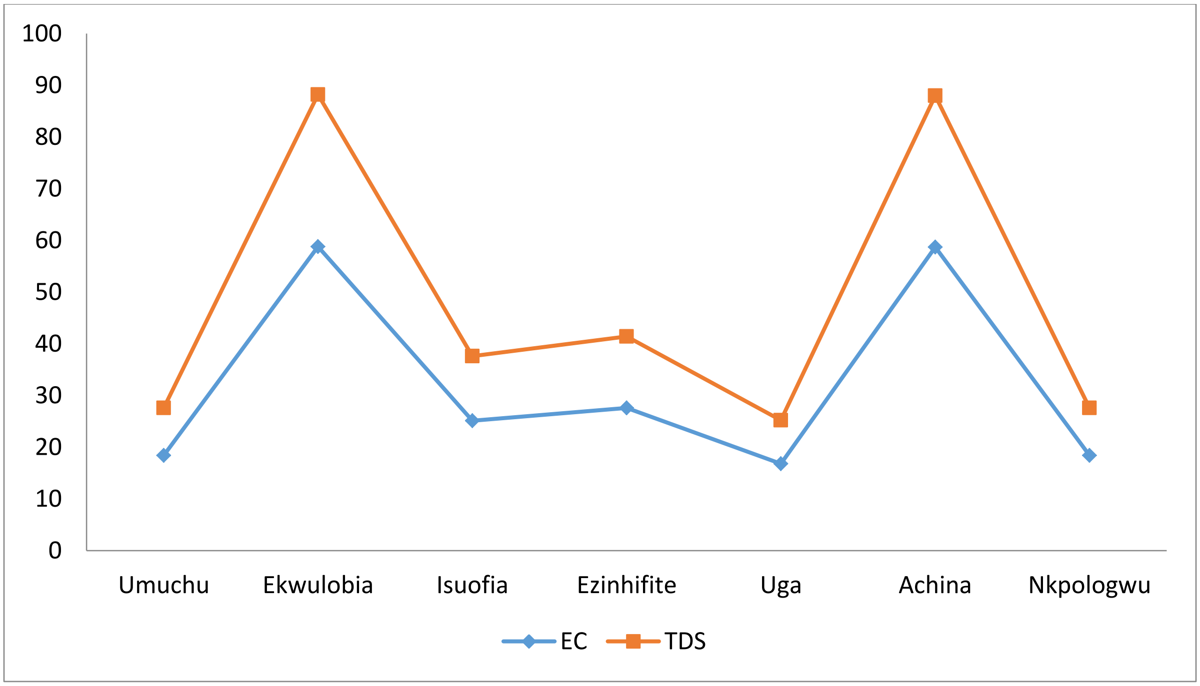

Figure 6: Chart of EC and TDS Distribution in the Groundwater System of the Study Area.

5. Conclusion

The physio-chemical results as shown in piper diagram revealed composure of magnesium – calcium – bicarbonate in the groundwater resources of the study area. The bicarbonate values ranged from 9 mg/l – 35 mg/l, sulfate range of 1 mg/l – 7 mg/l, nitrite ranged from 0.01 – 0.07 mg/l and nitrate of 1.5 – 12 mg/l range in the study area. Result of magnesium and calcium in the study area showed 4 mg/l – 22 mg/l and 6 mg/l – 19 mg/l range respectively. However, the water falls below the WHO standard (2006) for drinking water quality. The low mineralization is indicative of a soft water. This may not be advised for primary domestic consumption due to its lack of essential elements found in water. From the piper plot of the study area the result revealed that in the anion triangle, the water samples fall within the bicarbonate type while the cation triangle has Magnesium as the dominant type. The result show that the water belongs to the Magnesium-calcium-bicarbonate type water. The schoeller diagram revealed a general Magnesium-Calcium-bicarbonate trend displayed in the study area. From the stiff plot the result proved that bicarbonate concentration is most dominant in all seven locations with Achina having a concentration greater than 0.5Meq/L. The physical property test carried showed that Achina, Uga and Isuofia have the highest degree of hardness in the study area while Ekwulobia have the lowest, generally according to the rating of degree of hardness the water in the locations of the study area fall within the range of 0-45 mg/L, which is termed extremely soft. The pH level across the study area resulted below 7, with the lowest being 5.4 at Isuofia and the highest being 6.4 at Achina, this revealed pH level of an acidic water type [1-9].

Conflict of Interest

The authors, declare no conflict of interest.

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