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GROUNDWATER QUALITY EVALUATION IN PARTS OF UMUCHIMMA, IMO STATE, SOUTHEASTERN NIGERIA

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ABSTRACT

This study was on evaluation of groundwater quality in selected areas using standard analytical methods.Six (6) borehole water samples were collected for laboratory analysis of the physico-chemical and biological parameters around Umuchimma. The result obtained show that except for phosphate (3.90mg/L), and pH which was slightly acidic with values ranging from 6.40 to 6.52 and a mean value of 6.45, all other measured parameters were within the acceptable limits as stipulated by the World Health Organization (WHO) 2011 Standard. The mean values for the major cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) were 3.21, 1.18, 6.62 and 1.33 mg/L respectively, while the mean values for the major anions (HCO_3^-, SO_4^-, NO_3^- and Cl^-) were 15.56, 4.89, 5.58 and 4.47mg/L respectively. The dominant cation is sodium, while the dominant anion is bicarbonate. The mean values for heavy metals such as Pb^{2+}, Zn^{2+} and Cu^{2+} found in the samples were 0.01, 2.65, and 0.02mg/L respectively. The mean values for heavy metals such as Pb^{2+}, Zn^{2+} and Cu^{2+} found in the samples were 0.01, 2.65, and 0.02mg/L respectively. The presence of the heavy metals found in the samples analysed could be attributed to leachates electronic wastes (E-waste) contamination from nearby open waste dumpsites. The sodium Absorption Ratio (SAR) varies from 0.35 to 0.59 with the mean value of 0.56, indicating that the water is excellent for irrigation purpose. Pollution index (PI) varies from 0.707 to 0.723 with a mean value of 0.715 indicating that water is within the critical value of 1. The Total Dissolved Solids (TDS) varies from 8.16 to 10.80 mg/L with the mean value of 9.47mg/L. The piper trilinear diagram, Stiff diagram, durov and schoeller diagram confirm that there is a close chemical relationship between the boreholes. However, the dominant cation is sodium + potassium (Na^{+} $+K^{+}$) and the dominant anion bicarbonate (HCO_3). From the geochemical plot (piper) the water type is sodium bicarbonate type. The plot also indicates that the water is also potable for drinking purpose. The general quality of the ground water can be described as slightly acidic (based on the mean pH value), soft (based on the total hardness value), fresh (based on TDS) and has no laxative effect based the chloride content. However, the pH of the groundwater can be improved further by treating the water using sodium bicarbonate (soda ash).

Keywords: Aquifer, groundwater, leachates, wastewater, physicochemical, umuchimma.

1.0 INTRODUCTION

The essentiality of water in our daily activities both domestically and industrially cannot be over emphasized. Water is a basic necessity for livelihood as well as socioeconomic development of any community. Water is an essential resource and forms the primary need of man in his environment (Vutukuru, 2005). Many communities in Nigeria, especially in the Imo River Basin area where this research was carried out rely on surface and groundwater for both domestic and agricultural water supplies. The quality of water generally refers to the component of water present at the optimum level for suitable growth of plants and animals. Aquatic organisms need a healthy environment to live and adequate nutrients for their growth; the productivity depends on the physicochemical characteristics of the water body. The maximum productivity can be obtained only when the physical and chemical parameters are present at optimum level. Water for human consumption must be free from organisms and chemical substances and such large concentrations may affect health. The pollution of water is increased due to human population, industrialization, the use of fertilizers in agriculture and man-made activity. As many communities in Imo River Basin begin to experience population increase and industrialization, there is a need for them to reverse these effects and prevent further damage so as to ensure a sustainable environment. EPA US, (2006), defines environmental sustainability as meeting today's needs without compromising the ability of future generation to meet their needs.

Groundwater is one of the Nigeria's precious natural resources, providing reliable water supplies for millions of people. The ability of groundwater to provide a buffer against climatic variability and its fairly constant water composition encourages its usability over surface water. Due to the ephemeral of surface water, groundwater still remains the only realistic and affordable means of providing portable water supply for poverty reduction and economic development. Groundwater occurs almost everywhere beneath the land surface and is largely controlled by the geology and geomorphology of the area. The widespread occurrence of potable groundwater and the natural process that tend to provide barriers to some types of contamination are some of the reasons why it is preferred by most Nigerians as their source of water supply (Amadi and Asehinde, 2008). Water is essential for life as well as socio-economic development of any human development. Many communities and cities in Nigeria rely on surface and groundwater for both domestic, agricultural, and industrial water supplies.

The primary aim of this work is to evaluate the groundwater quality using physicochemical parameters of the groundwater resource in parts of Umuchimma, Ihiagwa in order to determine their conformity to World Health Organisation (WHO) standard and suggest the possible treatment procedures/precaution that should be taken to provide potable water.

Location and Accessibility

The study area is located in Imo State within South eastern Nigeria. It is bounded by latitude 5^0 23' 0" and 5^0 23' 40'' N and longitude 6^0 59' 10" and 7^0 0' 10" E. The study area hasmotorable roads, major and minor roads with foot paths network enabled easy accessibility of the area.

Land use here mainly agriculture and residential including;houses, churches, bars, hotels, schools, shops, etc.

Climate

The area falls within the tropical rainforest belt of Nigeria. The prevalent climatic condition has two main regimes: the wet and the dry seasons. The wet season starts from (April to October) and this season is associated with the prevalent moisture-laden south-west trade wind from the Atlantic Ocean (Iloeje, 1981). This wet season is also characterized by double maximum rainfall during which the first peak occurs in July. Due to vagaries of weather, the August break sometimes occurs in July or early September. The dry season starts in November when the dry continental North-east wind blows from the Mediterranean Sea across the Sahara Desert and down to the southern part of Nigeria (Iloeje, 1981). The annual mean temperature varies between 26.5 and 27.3^{0}C, relative humidity varies between 65 and 75%. Evapo-transpiration in the area is above 1,450mm/year (National Root Crop Research Institute, 2017).

Geology of the Area

The study area is within the Coastal plain sands of Benin Formation (Reyment, 1995). The Benin Formation (Miocene - Recent) covers more than the half of the area of the Imo River Basin. It is an extensive stratigraphic unit in the South-eastern Nigeria Sedimentary Basin. Benin Formation has earlier been referred to as the coasting plain sand (Simpson, 1986), consisting of sands, sandstones and gravels, with intercalations of clay and sandy clay. The sands are fine-medium-coarse grained and poorly sorted. And was later formalized as Benin Formation by (Rayment, 1965).The sands and sandstones are coarse to fine partly unconsolidated with thickness ranging from 0 - 2100 m (Avbovbo, 1978).

The sediments represent upper deltaic plain deposits. The shales are few and they may represent upper deltaic plain deposit. However, the formation lacks faunal content and this makes it difficult to date, though an Oligocene-Recent age is generally accepted. The Benin Formation is composed mainly of high resistant fresh water-bearing continental sands and gravels with clay and shale intercalations (Onyeagocha, 1980).The environment of deposition is partly lagoonal and fluvio-lacustrine/deltaic (Rayment, 1965).

The formation which dips south-westward starts as a thin edge layer at its contact with the Ogwashi-Asaba Formation in the Northern part of the area and thickens Southwards to about 100 m in Owerri area (Reyment, 1965). The sandy unit which constitutes about 95% of the rock in the area is composed of over 96% of quartz (Onyeagocha, 1980). A marked banding of coarse and fine layers with a large scale cross bedding constitute the major sedimentary structures in the area.

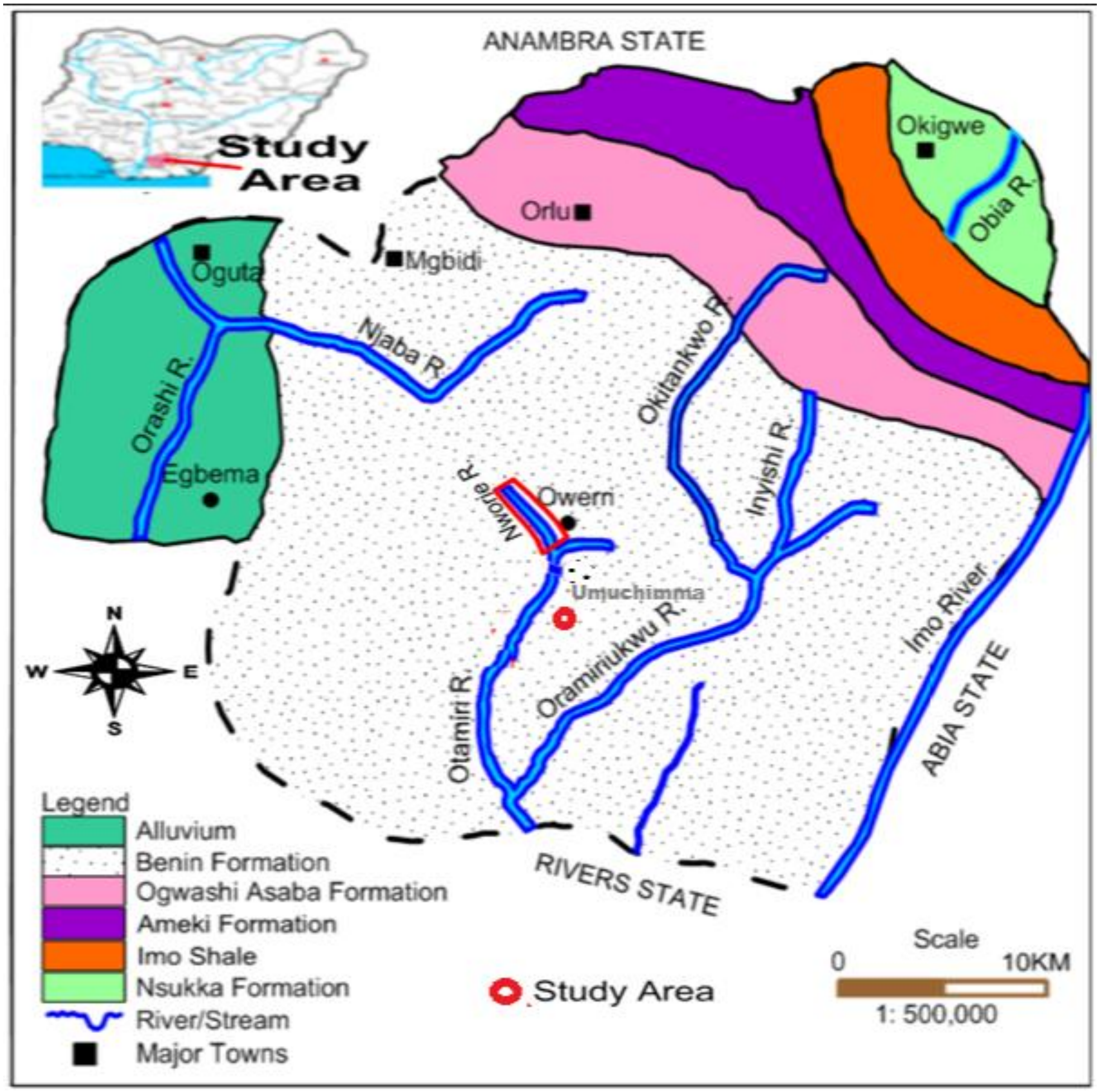

Figure 1: Geologic map showing the study area (Adapted fromIbeh, 2017)

2.0 MATERIALS AND METHODS

Materials

The following materials were used for field studies;

i. The ***location map*** of Imo.
ii. The ***Geologic map*** of Imo State for the purpose of identifying geologic features in the study area.
iii. Global Positioning System (GPS) for coordinates
iv. A ***measuring tape***
v. ***Sample bags*** labeled for collection and easy identification of different location samples.

vi. ***Field note book*** and other writing materials for the purpose of writing down observations in the field.

Methods

Topographic and geologic maps were obtained from Imo State Ministry of Environment, Owerri. Geological, hydrogeological and geomorphological observations were made. This includes the channel of the river, the accessibility, topography, slope and source of the river.

Six (6) samples were obtained at strategic locations (boreholes) designated L_1-L_6 strategically within the study area.

Samples were obtained with 1.5 litres sterilized plastic containers, and corked immediately after collection to avoid the oxidation of the constituents with oxygen. They were then sent to the laboratory within 24 hours for analysis.Atomic Absorption Spectrophotometer (AAS) was used for the analyses. The sampling points were geo-referenced with a global positioning system (GPS) device.

3.0 RESULTS AND DISCUSSION

The results of physicochemical characteristics of groundwater at six (6) strategic locations designated L_1-L_6 with their respective mean values are shown in table1 while the Pollution Index (PI) and Sodium Adsorption Ratio (SAR) are shown in tables 2 and 3 respectively.

Table 1: Physicochemical characteristics of groundwater samples at Umuchimma.

Parameters	**Sample Locations**							
	L1	**L2**	**L3**	**L4**	**L5**	**L6**	**Mean**	**WHO 4^{th} edition (2011) Guideline Value**
Coordinates	$N5^0$ 23.158^l $E6^0$ 59.998^l	$N5^0$ 23.158^l $E6^0$ 59.998^l	$N5^0$ 23.244^l $E6^0$ 59.958^l	$N5^0$ 23.202^l $E7^0$ 0.063^l	$N5^0$ 23.202^l $E7^0$ 0.063^l	$N5^0$ 23.202^l $E7^0$ 0.068^l		
Elevation (m)								
pH @ 25^0C	6.45	6.45	6.40	6.50	6.50	6.54	6.47	6.50-8.80
Turbidity (NTU)	0.60	0.54	0.50	0.56	0.62	0.50	0.55	< 1.0
Cfu/100ml Electrical Conductivity (µmhos)	16.00	15.50	14.00	18.20	16.80	16.00	16.08	1400

Total Hardness as $CaCO_3$, (mg/l)	12.35	13.35	11.16	13.89	14.89	12.92	13.09	100
TDS (mg/l)	9.60	9.30	8.40	10.92	10.08	9.60	9.65	1500
Total Iron mg/l	0.03	0.02	0.03	0.03	0.03	0.02	0.02	0.1 maximum
DO (mg/l)	5.00	5.50	5.00	6.00	6.00	5.00	5.41	
Ca^{2+} (mg/l)	3.20	3.10	2.98	3.40	3.20	3.40	3.21	200
Mg^{2+} (mg/l)	1.30	1.20	1.32	0.96	1.00	1.30	1.18	100
Na^{+} (mg/l)	7.20	7.00	6.00	6.48	6.46	6.60	6.62	200
K^{+} (mg/l)	1.40	1.30	1.60	1.20	1.30	1.20	1.33	50-70
HCO_3^{-} (mg/l)	18.00	16.00	16.40	14.60	14.40	14.00	15.56	500
SO_4^{2-} (mg/l)	5.20	5.10	4.80	4.72	4.74	4.80	4.89	400
Cl^{-} (mg/l)	5.04	5.00	4.00	4.20	4.60	4.00	4.47	400
NO_3^{-} (mg/l)	6.90	6.60	5.00	5.20	5.20	4.60	5.58	50
Mn^{2+}, mg/l	0.02	0.02	0.03	0.01	0.01	0.01	0.01	0.05 maximum
PO_3^{4-}, mg/l	4.00	4.00	4.60	3.80	3.40	3.60	3.9	0.05
Cd^{2+}, mg/l	ND	ND	ND	ND	ND	ND	ND	0.003
Pb^{2+} (mg/l)	0.01	0.02	0.03	0.01	0.01	0.02	0.01	0.01
Zn^{2+} (mg/l)	2.10	2.40	2.60	3.00	3.20	2.60	2.65	5.00
Cu^{2+} (mg/l)	0.01	0.01	0.02	0.03	0.04	0.02	0.02	2.00
Hg^{2+}, (mg/l)	ND	ND	ND	ND	ND	ND	ND	
Total Coli form count, Cfu/100ml	0	0	0	0	0	0	0	Absent

Hydrogeochemical models such as pollution index (PI) which is to evaluate the extent of degradation of the groundwater was employed. Although, the PI ranges from 0.717 to 0.728 with a mean value of 0.719 respectively, is yet to reach the critical value of 1, there is need to monitor the PI value since it is already tending to 1. For sodium adsorption ratio (SAR), the values were classified as excellent for irrigation purpose with values ranging from 0.35 to 0.59.

pH
The pH of the water samples ranges from 6.40 to 6.54, these shows a pH less than 7 thus indicating that thewater is slightly acidic, the mean value of the six sampled boreholes was 6.47 which is slightly below the WHO, 2011 standard for drinking water which has a lower limit of 6.5 pH. The high acidity could be from the open waste dumpsites within and around the area and due to the thin overburden and shallow aquifer nature, the leachates find it easy to infiltrate into the aquifer system.

Turbidity:
The turbidity which can be described as the amount of clarity of liquids, valuesvary between 0.5 to 0.62NTU. With the mean Turbidity value at0.55NTU.

Electrical Conductivity
This is a numerical expression of the ability of an aqueous solution or solid to carry an electric current. The ability depends on the presence of ions, concentration, mobility and valency (APHA, 1998).

Conductivity for Groundwatersamples at the six locationsrange from 14.0 to18.20 µS/cm respectively with a mean average value of 16.08 µS/cm.

Total Dissolved Solids (TDS)

Total Dissolved Solid concentrations of the samples ranges between 8.40 to 10.92 mg/l with the mean of 9.65 mg/L. The classification of water according to Carrol, 1962, (Table 4.2) shows that the water is fresh water based on the TDS values.

Table 2: Total Dissolved Solids (TDS) after (Carrol, 1962)

TDS (mg/l)	**Descriptions**
0 – 1000	Fresh water
1000 – 10000	Brackish water
10000 – 100000	Saline water
> 100000	Brine water

Dissolved Oxygen (DO)
This is the amount of oxygen (O_2) that is soluble in the water. It is a measure of aeration the water. The measured DO for the six samples collected and the mean were 5.0 to 6.0 mg/L and 5.41mg/L respectively.

CATIONS

Calcium (Ca^{2+}):
The calcium concentration of Groundwater at the six locations varies between 2.98 to 3.40mg/l, with a mean value of 3.21mg/l. High concentration of calcium can cause permanent hardness of the water and is most common where there is high deposit of gypsum, limestone and dolomite.

Magnesium (Mg^{2+}):
Magnesium has no negative health issue (Sharon, 2009). Therefore, it is not a threat to the environment.

The magnesium concentrationrange values were 0.96 to 1.32mg/l. The mean concentration value was 1.18mg/l.

Sodium (Na^{+})
The concentration of sodium in the water samples ranges from 6.0 to 7.20mg/L while the mean value was 6.62mg/L.

Potassium (K):
The concentration of potassium values of Groundwaterranges from 1.20 to 1.60mg/l respectively with a mean value of 1.33mg/l.

ANIONS
Bicarbonate (HCO_3^{-})
Bicarbonate is a weak acid produced from the chemical reaction of rain water with CO_2 in the atmosphere and it makes the pH of the water acidic by reducing the value.

The bi-carbonate concentration varies between 14.0 to 18.0mg/l, from the six sample locations, with a mean value of 15.56mg/l.

Nitrate ($NO\text{-}_3$)
The range concentration values of nitrate ($NO\text{-}_3$) at Groundwater were 4.60 to 6.90mg/l respectively with a mean value of 5.58mg/l.

Sulphate (SO_4^{2}-)
The concentration values of sulphate ranges from 4.72 to 5.20mg/l while the mean value at 4.89mg/l.

Total Chloride:
The concentration values range of chlorine for the Groundwater samples were 4.0 to 5.04mg/L with a mean value of 4.47mg/L.

HEAVY METALS
The heavy metals most likely from electronic wastes (e-waste) which are as a result of dumping of electronic materials on the surface dumpsites in the area. Some of these metals can cause serious health implications when ingested in high doses. The presence of heavy metals in the water samples collected from Groundwater are shown below:

Copper (Cu):
The range of copper values for the six locations were 0.01 to 0.04mg/l with a mean value of 0.02mg/L.

Zinc (Zn):
Zinc was seen to have range values of 2.10 to 3.20mg/L and a mean value of 2.65mg/L in the water samples analysis.

Lead (Pb):
The range values of lead for the six locations were 0.01 to 0.03mg/l with a mean value of 0.015mg.L.

Pollution Index (PI)

The pollution index (PI) varies between 0.717 to 0.728 with a mean of 0.719 (Table 3). According to (Horton, 1965), the critical value of pollution index is 1. Therefore, any value in the region of 1 is said to be highly polluted and needs urgent attention. Although, the PI is less than 1, there is need to monitor the PI value since it is already close to the critical point.

Table 3: Pollution index of water samples at Umuchimma

Parameters	**Lij (WHO)**	**Cij L1**	**Cij L2**	**Cij L3**	**Cij L4**	**Cij L5**	**Cij L6**	**Cij Mean**	**Cij/ Lij L1**	**Cij/ Lij L2**	**Cij/ Lij L3**	**Cij/ Lij L4**	**Cij/ Lij L5**	**Cij/ Lij L6**	**Cij/Lij Mean**
pH	**6.5**	6.45	6.45	6.40	6.50	6.50	6.54	6.47	**1.0**	**0.99**	**0.98**	**1.0**	**1.0**	**1.0**	**0.99**
TDS (mg/L)	**500**	9.60	9.30	8.40	10.92	10.08	9.60	9.65	**0.02**	**0.02**	**0.01**	**0.02**	**0.02**	**0.02**	**0.02**
Total Alkalinity (HCO_3), mg/L	**100**	18.00	16.00	16.40	14.60	14.40	14.00	15.56	**0.18**	**0.16**	**0.16**	**0.14**	**0.14**	**0.14**	**0.15**
Sulphate (mg/L)	**400**	5.20	5.10	4.80	4.72	4.74	4.80	4.89	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Chloride (mg/L)	**250**	5.04	5.00	4.00	4.20	4.60	4.00	4.47	**0.02**	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Mean Cij/Lij									**0.246**	**0.240**	**0.234**	**0.236**	**0.236**	**0.236**	**0.236**
Max Cij/Lij									**1.0**	**0.99**	**0.98**	**1.0**	**1.0**	**1.0**	**0.99**
PI									**0.728**	**0.717**	**0.724**	**0.725**	**0.725**	**0.725**	**0.719**

Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio (SAR) values of the groundwater at the six stations range from0.35 to 0.59 respectively as seen in table 4. Water with SAR value between 0 and 10 as in the case of the groundwater samples at the six stations, are classified as excellent for irrigation purpose while those with SAR of greater than 26 are classified as poor in terms of irrigation purposes, (Wilcox, 1955)(Table 4).

Table4: Sodium adsorption ratio values for water samples at Umuchimma

SAR	Description	Location	SAR values
0 – 10	Excellent	L1	0.59
10 – 18	Good	L2	0.59
18 – 26	Fair	L3	0.35
>26	Poor	L4	0.57
		L5	0.57
		L6	0.55
		Mean	0.56

Geochemical Models

The geochemical plots show the potability of the water by identifying the hydrogeochemical facie, type and chemical composition relationships. Also, it can assist in provenance studies. The stiff, piper, durov, and schoeller diagrams of the major cations and anions are drawn in the figures below.

Stiff Diagrams

The stiff shows similar shapes and size suggesting close chemical relationship which signifies dominance of Na^{+}+K^{+} – HCO_3^{-} + Cl^{-} (Figure 4) suggesting a marine source.

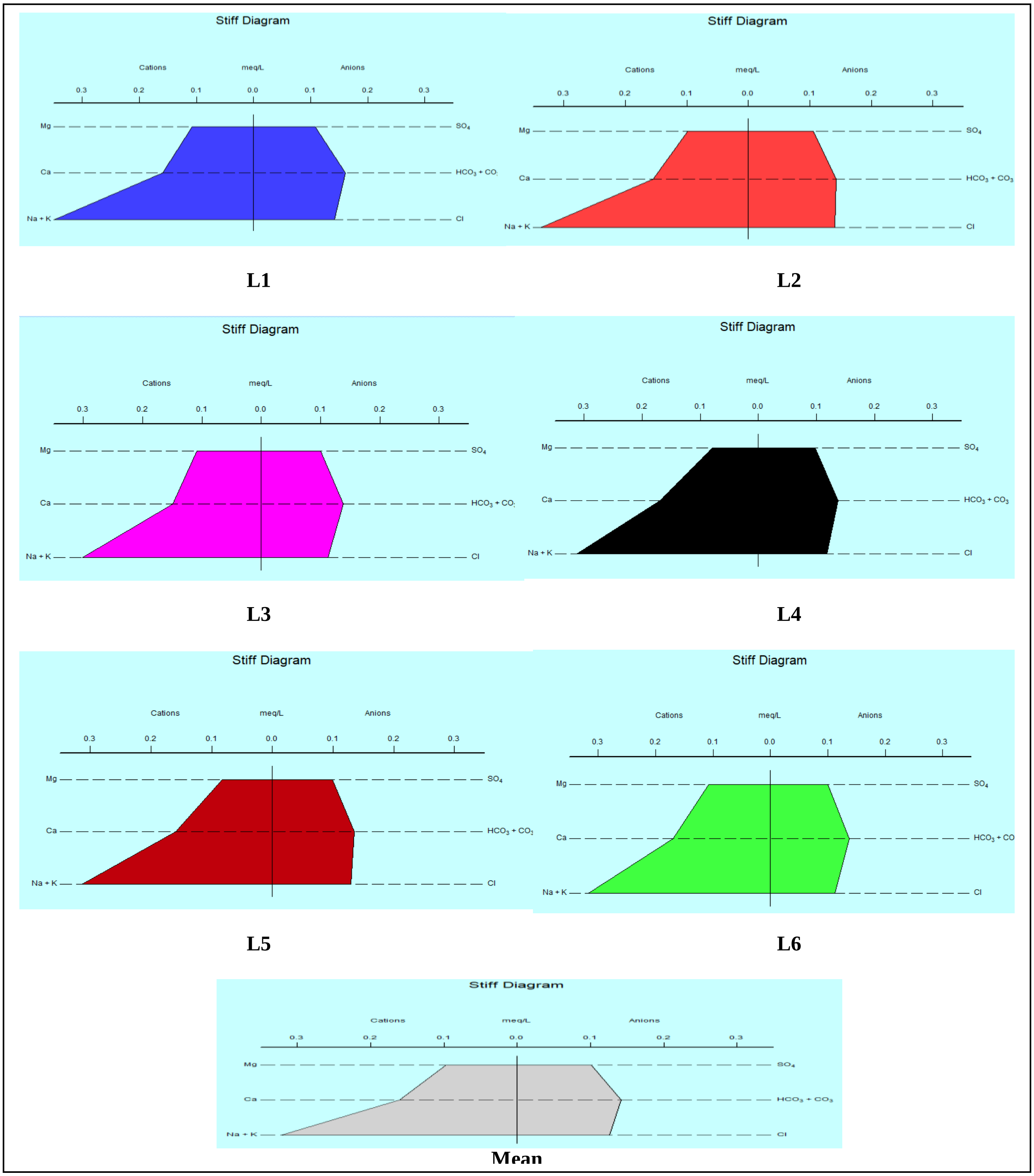

Figure 2: Stiff diagrams of the six water samples and the mean

Piper Diagram

From the piper drawn below (Figure 6), samples plot at the mid-right corner of the diamond portion of the piper diagram which shows that the water is potable and sodium-chloride (Na^{+}-Cl^{-}) dominant water.

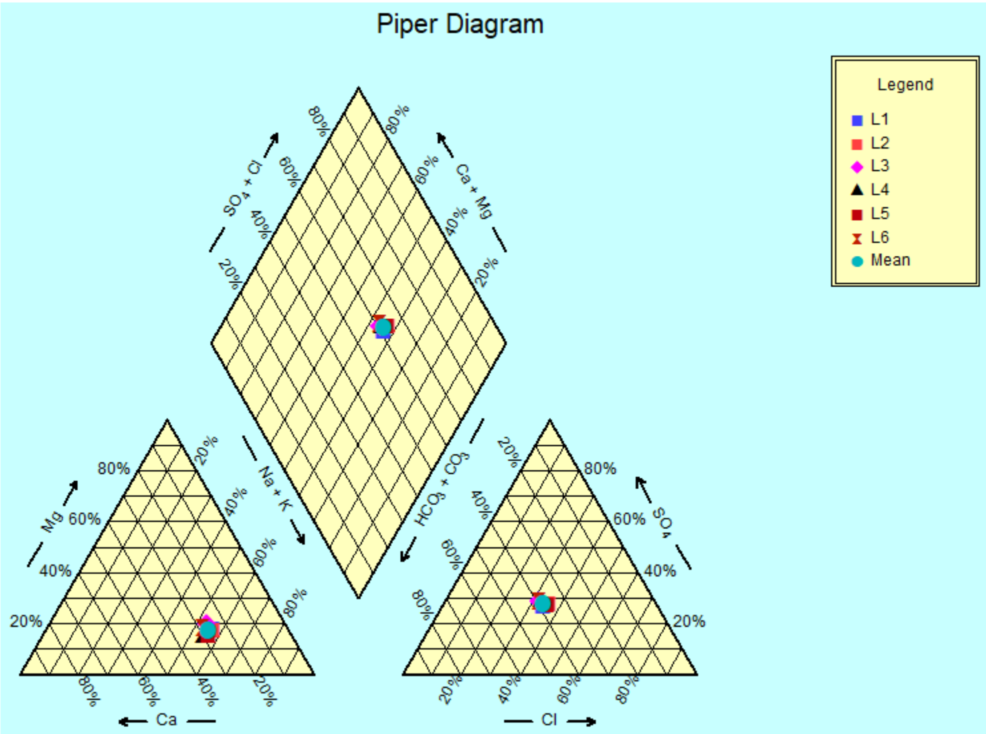

Figure 3: Piper diagram for all 6 stations and the mean

Scheoller Diagram

The schoeller plot shows a close chemical relationship/signature suggesting similar source of the water. The relative tendency of ions in meq/l shows Na^{+}> Ca^{2+}> Mg^{2+} > K^{+} and HCO_3^{-}>Cl^{-}> SO_4^{2}> NO_3. The hydrogeochemical facies identified in the study area is mainly the water type (Na^{+}+K –Cl^{-}) as shown in the plotted Scholler diagram below in Figure 4.

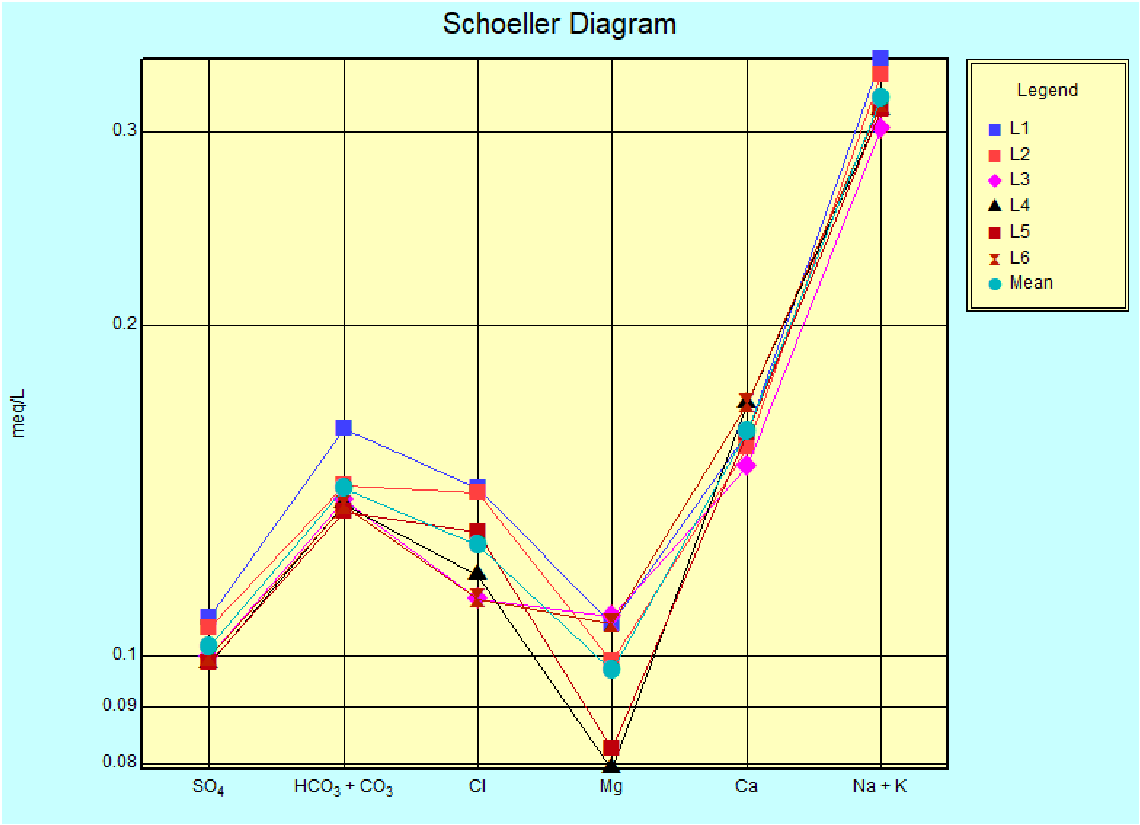

Figure 4: Schoeller diagram for all 6 stations and the mean

Durov Diagram

Durov, (1948) introduced this diagram which provides more information on the hydrochemical facies by helping to identify the water types and it can display some possible geochemical processes that could help in understanding quality of groundwater and its evaluation of the plot (Figure 5).

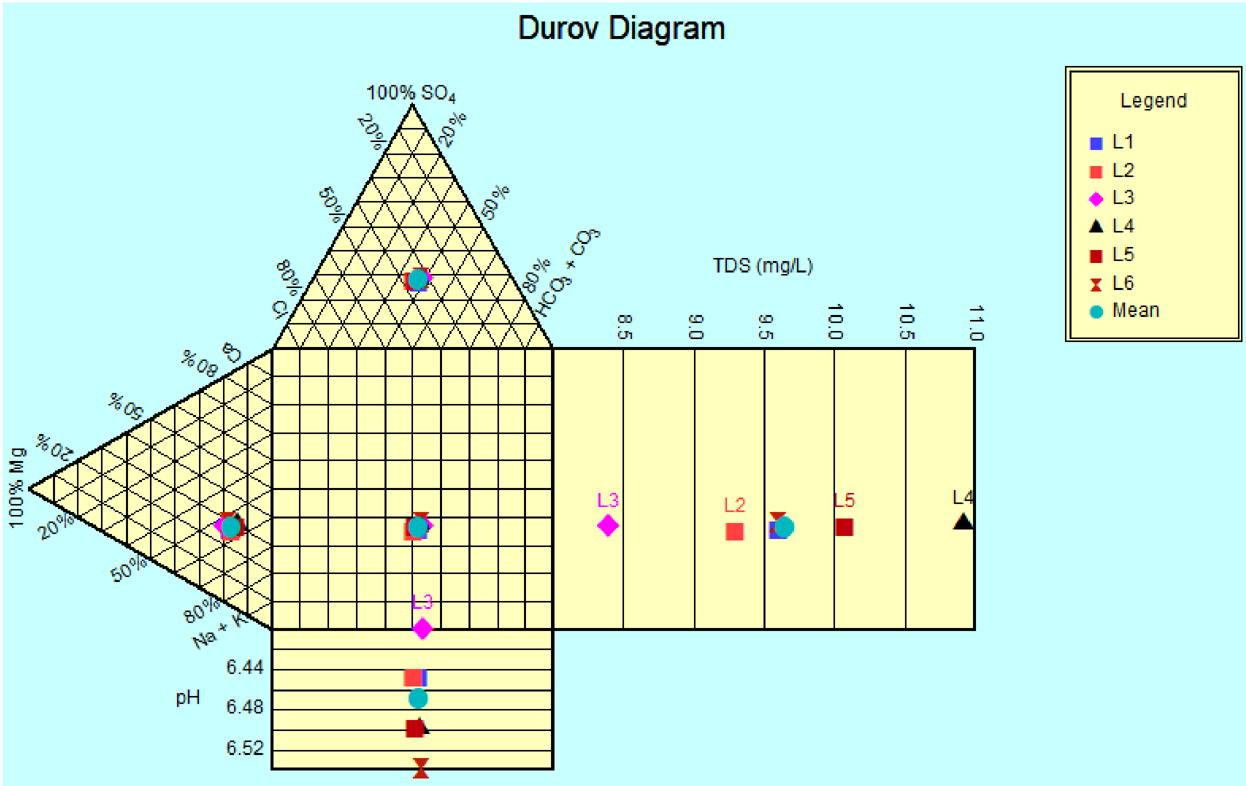

Figure 5: Durov diagram for all 6 stations and the mean

4.0 CONCLUSION AND RECOMMENDATIONS

The results of the hydrogeochemical analysis carried out at Umuchimma show that except for phosphate (3.90mg/L), and pH which was slightly acidic with values ranging from 6.40 to 6.54mg/L and a mean value of 6.47mg/L, all other measured parameters were within the acceptable limits as stipulated by the World Health Organization (WHO) 2011 Standard. The mean values for the major cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) were 3.21, 1.18, 6.62 and 1.33 mg/L respectively, while the mean values for the major anions (HCO_3^-, SO_4^-, NO_3^- and Cl^-) were 15.56, 4.89, 5.58 and 4.47mg/L respectively. The mean values for heavy metals such as Pb^{2+}, Zn^{2+} and Cu^{2+} found in the samples were 0.01, 2.65, and 0.02mg/L respectively. The presence of the heavy metals found in the samples analysed could be as a result of leachates electronic wastes (E-waste) from nearby open waste dumpsites.

Different calculations and plots ranging from numerical calculations of the chemical models such as pollution index (PI) which helps to evaluate the extent of degradation of the groundwater. Although, the PI ranges from 0.717 to 0.728 with a mean value of 0.719 respectively, is yet to reach the critical value of 1, there is need to monitor the PI value since it is closer to 1. Furthermore, sodium adsorption ratio (SAR), values were classified as excellent for irrigation purpose with values ranging from 0.35 to 0.59. While graphical methods such as: Piper indicated that the water is potable and sodium-chloride (Na^+-Cl^-) dominated water type. Schoeller (the relative tendency of ions in meq/l shows ($Na^+ > Ca^{2+} > Mg^{2+} > K^+$ and $HCO_3^- > Cl^- > SO_4^{2-} > NO_3$) and Stiff diagrams (the hydrogeochemical facies identified in the study area is mainly the water type Na^++K - Cl^-).

Finally, the study has evaluated the groundwater quality in parts of Umuchima using the physicochemical parameters which can be used to describe the water as generally potable for drinking and suitable for both domestic, industrial and agricultural purposes as well. However, treating with soda ash to correct the slight acidity is necessary.

In the analysis of the groundwater samples collected from the six stations (L1-L6), most of the physiochemical and geochemical parameters after comparison fell within the value of WHO (2011) standard for quality water showing that the water samples are safe for domestic, industrial and agricultural purposes with little exceptions for pH which was slightly acidic.

Recommendations

Following careful observations and interpretations from the analysis, some recommendations can be made on the chemical quality of the groundwater resource of the study area such as;

1. By ensuring proper treatment before consumption and for domestic use.
2. The pH of the water as observed to be acidic, this can be treated by adding lime ($Ca(OH)_2$) or soda ash as well as chlorinating the water before use.
3. A further detailed survey should be carried out in order to evaluate the mineralogical and geochemical composition of the rock through which the groundwater flows.
4. Constant and consistent monitoring of the groundwater resource should be established in order to know the physicochemical and biochemical status of the water at any given time.
5. Also, standard sanitary landfill should be built in the area to forestall leachate contamination of the shallow aquifer system in the area

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