IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 3, Issue 2 Ver. I (Mar - Apr. 2015), PP 12-18
www.iosrjournals.org

Qualitative Evaluation and Hydrogeochemical Attributes of Groundwater in Owerri Capital Territory, Southeastern Nigeria

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Abstract: *The qualitative evaluation and hydrogeochemical attributes of groundwater in Owerri Capital Territory Owerri was investigated to assess the quality for human consumption and agricultural purposes. A total of sixteen (16) groundwater samples were collected and analyzed for physicochemical and biological properties. The range of temperature (^oC), colour (Hz), and turbidity of groundwater in the study area are between: 20-28.3, 5-15, and 1-50 respectively. The average of pH , conductivity (us/cm),TDS (mg/l), and hardness (mg/l) are: 7.66, 0.135, 34.64, and 7.94 respectively. The result also reveals that the concentration of Na^+(mg/l), K^+(mg/l), Ca^{2+}(mg/l), Mg^{2+}(mg/l), Fe^+(mg/l), Pb^{2+}(mg/l),Cd^{2+}(mg/l), Cu^+(mg/l),and Zn^{2+} (mg/l) range between: 3.33-7.6, 0.2-6.8, 2.4-8.3,1.02-3.44, 0.001-0.59, 0.001-0.01, 0-0.16, 0.06-2.88 and 0.01-2.18 respectively. Water Classification result of the groundwater samples show the predominance of alkali bicarbonate water type ($Na^+ + K^+$) - HCO_3^- that is largely soft and therefore, mostly of acceptable quality for household uses. Sodium Absorption Ratio (SAR) of the groundwater samples in the study area showed that the samples fall below 1.4meq/l, indicating predominance of excellent water for irrigation purposes in accordance with recommended standard. This study recommends among other things that groundwater resources development in the area requires elaborate qualitative assessment, to ensure that any necessary pre-use treatment is effected.*

Keywords: *Qualitative Evaluation, Groundwater Quality, Hydrogeochemistry, Water types.*

I. Introduction

Quality of water is an important factor in development and use of groundwater as resources. Domestic and industrial discharges into groundwater and surface water bodies vary in nature, quality and quantity, thus contributing significantly to chemical, biological and physical pollution of these water bodies. Most of these pollutants enter the streams and rivers and are transported downstream passing through regional and international water bodies carrying with them wastes whose quality and quantity are yet to be determined (Akakuru, et. al 2013). The chemical constituents of groundwater is known to cause some health risks, so supply cannot be said to be safe if specific information on water quality which is needed for sustainable resource development and management is lacking. The hydrochemical processes and characteristics of the aquifer systems Owerri Capital Territory are generally not known due to an overall lack of hydrologic and hydrogeologic data, which complicates planning and management of groundwater abstraction. Large uncertainties also exist in the understanding of the main processes controlling the evolution of groundwater in the area. Increase in population and rapid urbanization has made groundwater the major source of water supply, hence, it is very essential to understand the hydrogeochemical processes that take place in the aquifer system.

Owerri Capital Territory is one the new urban centres of Nigeria with rapid growth in population, urbanization and industrialization. Due to the increasing demand for groundwater, many boreholes are being sunk into the more affordable shallow aquifer units. Consequently, regular evaluation of groundwater quality is of fundamental importance because about 95 percent of the inhabitants of Owerri Capital Territory rely on groundwater sources for daily water needs (Akakuru, et. al 2013).

II. Geology And Hydrology Of The Study Area

The study area is underlain by the Benin Formation (the Coastal Plain-Sands). The major rock types include sands, sandstone, and gravel with clay occurring as lenses. It lies between latitudes 5^o24^1 and 5^o35^1N and longitudes 6^o56^1 and 7^o08^1E, covering an area of about 740km^2. The area is predominantly low-lying with a good road network. The sand and sandstone are coarse to fine grained partly unconsolidated, with thickness ranging from 0-2100m. The sediments represent upper Deltaic Plain Deposits. The shales are few and they may represent Deltaic Plain Deposits. The Benin Formation is composed mainly of high resistant fresh water bearing continental sands and gravels, with clay and shale intercalations. The sandy unit (which constitutes about 95% of the rock in the area) is composed of over 96% of quartz (Onyeagocha ,1980). The study area is drained by Rivers Otamiri, Nworie, Mbaa, and Okitankwo with peak discharge occuring in September and October

(Ezeigbo, 1987). Surface water hydrology plays an important role, as it enhances groundwater recharge potential and determines water balance and hydrologic safe yields of aquifers.

Table 1: Stratigraphic succession in southern Nigeria (Uma and Egboka, 1985).

AGE		FORMATION
Quaternary	Recent	Alluvium, Mangrove Swamps, Meander Belts Sands, Marine Deltaic Deposits
Tertiary	Miocene-Recent	Benin Formation (Coastal Plains Sands)
	Oligocene-Miocene	Ogwashi Asaba Formation (Lignite Series)
	Eocene	Ameki Group including Nanka Sand
Upper Cretaceous	Paleocene	Imo Formation including Ebenebe Sandstone Nsukka Formation (Upper Coal Measures)
	Maastrichtian	Ajali Formation Mamu Formation (Lower Coal Measures)

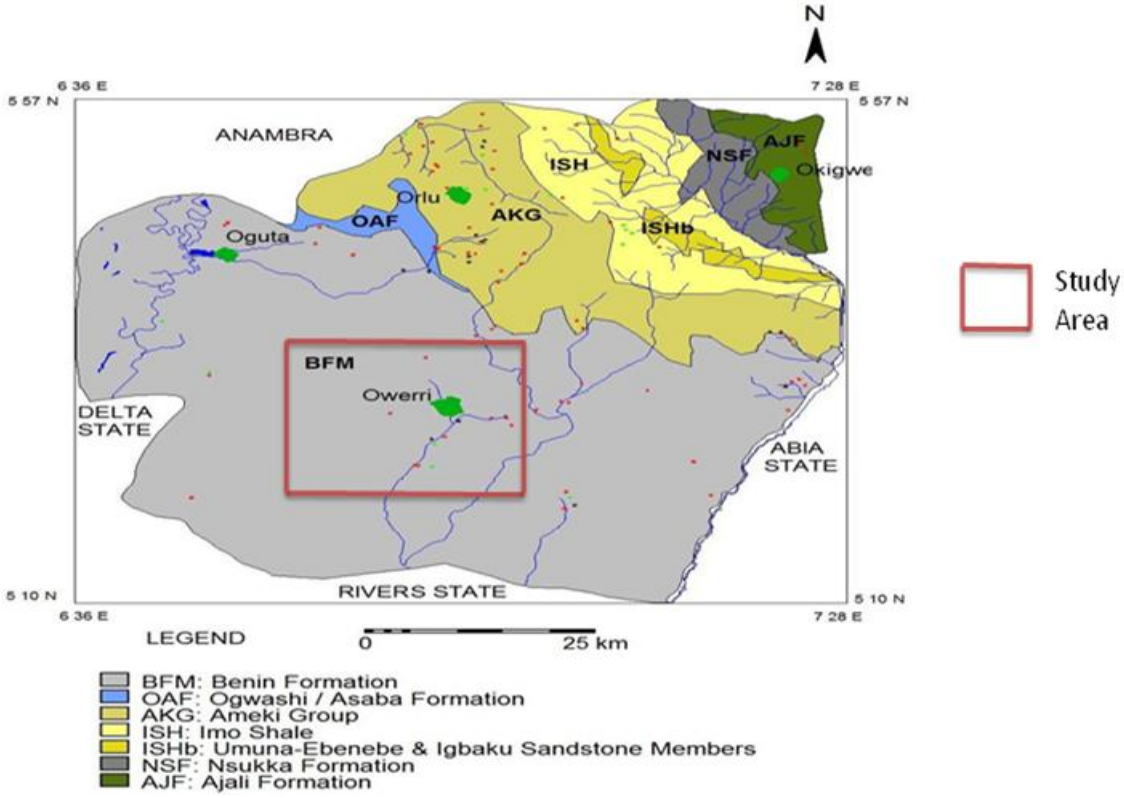

Fig. 1: Geological map of Imo State showing the study area.
(National Geohazard Monitoring Centre ,Awka 2008).

III. Methods Of Investigation

Sixteen (16) Groundwater samples were collected from boreholes after 5 minutes of pumping to ensure the samples were true representative from the aquifer. The samples were stored in sterilized two-litre containers with tightly fitting covers wrapped in a black polyethylene plastic bag labelled 1-16 and put in a cooler to ensure constant temperature. The containers were first washed with de-ionized water, and then several times with the sample water before collection in order to avoid any contamination.

Parameters like pH and temperature and electrical conductivity were determined in the field due to their unstable nature. The pH of the water sample was measured with a pH-meter. The glass tube in the kit was sterilized before been filled to its mark with water sample. The tube was then placed in the space provided in the equipment and a knob adjusted for colour matching, the pH was then read and recorded. The temperature was read using a mercury thermometer. The electrical conductivity was measured using a Mark electronic switchgear conductivity meter. All the samples were preserved by refrigeration and analyzed within 24hours of

collection. The analyses were carried out in accordance with American Public Health Association Standard (1992). The approach ensures that the samples collected were tested in accordance with agreed requirements using competent personnel as well as appropriate equipment and materials.

IV. Results And Discussions

The analytical results for groundwater samples from study area are presented in Table 2. The result revealed that the appearance and colour of the samples are clear (5) to not clear (10/15). Majority of the samples are odourless., pH values range from 6.2 – 10.7. According to the World Health Organization (2006), health effects are most pronounced in pH extremes. Drinking water with an elevated pH (above 11) can cause skin, eye and mucous membrane irritation. pH values below 4 can have corrosive effects of low pH levels. Conductivity values range from 0.03µs/cm - 0.44µs/cm, with an average of 0.0235 µs/cm. Conductivity is a measure of the total dissolved ionic constituents in water and it varies with temperature. Total Dissolved Solids (TDS) values range from 6mg/l – 67mg/l, with an average of 3.65mg/l. Total Hardness values ranges from 2.0mg/l – 12.8mg/l, with an average of 0.74mg/l. The TDS values in the water samples are far below the WHO permissible limits, thus indicating good quality. TDS is the quantitative measure of the sum total of organic and inorganic solutes in water.

Chloride concentration ranges from 0.04mg/l – 5.2mg/l, while sulphate and nitrate values range between 1.0 mg/l – 4.2 mg/l, and 0.01 mg/l – 4.06 mg/l, respectively. The chloride, sulphate and nitrate concentration levels in the study area fall below the WHO (2006) recommended highest permissible limit for drinking water, thus indicating good quality. Generally, nitrate content shows very low values, with undetectable values in some samples. The carbonate values range from 2.4 mg/l – 8.3 mg/l, with an average of 0.535 mg/l, while the bicarbonate shows concentration values of between 9.64 mg/l – 28.6 mg/l, with an average of 1.912 mg/l. The most important effect of bicarbonate ingestion is the change in acid-base balance as well as blood pH and bicarbonate concentration in biological fluids. Water which contains bicarbonate (>600 mg/l) may have an effect on acid-base balance.

Zinc concentration falls within the range of 0.01 mg/l – 2.18 mg/l. The zinc concentration of all the samples fall below the WHO permissible and maximum permissible limits .This indicates relatively good quality. Cadmium concentration falls within the range of 0.029 mg/l – 0.16 mg/l. About 80 percent of the samples fall above the Maximum Permissible Limit. Lead concentration falls within the range of 0.001 mg/l – 0.01mg/l. About 10 percent of the samples fall above the Maximum Permissible Limit. Results of bacteriological analysis of the water samples show that the surface water sources are contaminated with fecal coliform.

Table 2: Result Of The Physicochemical And Bacteriological Analyses Of Water Samples In The Study Area

Sample No. / Parameters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Colour (Hz)	10	10	15	5	5	5	10	5	5	5	10	5	10	15	5	5
Temperature(°C)	27	27	28.3	26	27	28	26.4	27.4	28	27.2	29	27	26	27	28	29
Conductivity (µs/cm)	0.04	0.1	0.07	0.05	0.2	NA	0.03	NA	NA	NA	NA	0.21	0.12	0.03	0.44	0.21
pH	6.4	9.9	6.6	6.8	10.2	6.4	6.2	6.3	6.2	7.3	6.3	8.3	7.3	7.2	6.8	6.5
Tubidity	2.2	5	0	0	10	12	4.8	5.2	3	5	2.3	16	4.2	11	40	1
Total Hardness(mg/l)	11.2	12.8	12.6	4.6	11.8	11.5	12.6	11.6	4.0	3.0	1.02	4.6	12.8	11.5	2.0	4.4
TDS(mg/l)	10	6	38	15	26	16.3	11	36	24.7	64.1	21.7	20	52.1	32.2	38.7	39
Ca^{2+}(mg/l)	2.8	3.5	7.6	7.8	4.1	2.88	2.89	2.89	8.3	3.5	4.5	7.6	2.7	2.4	4.6	2.8
Mg^{2+}(mg/l)	1.02	1.26	1.5	1.24	1.11	3.3	1.23	2.13	1.05	1.08	1.05	1.28	1.5	3.44	1.22	1.11
Na^{+} (mg/l)	4.59	5.35	3.95	3.32	4.36	4.27	4.21	7.6	5.34	3.92	4.32	3.3	4.21	4.28	6.2	5.5
K^{+}(mg/l)	1.1	0.85	2	1.74	0	0	1.9	2	2	0.9	0.3	1.15	0.5	0.6	0.4	0.2
Fe^{2+}(mg/l)	0.38	0.49	0.17	0.59	0.001	0.39	0.38	0.19	0.26	0.41	0.13	0.38	0.49	0.59	0.17	0.13
HCO_3^{-}(mg/l)	17.5	18.4	20.75	9.64	18.5	18.5	18.2	17.6	20.4	19.0	18.5	17.5	19.2	20.7	19.5	18.5
SO_4^{2-}(mg/l)	2.8	2	0	1	3.2	1.8	3	3.8	2.1	4.2	1.1	1	1.02	1.05	1.01	2.8
Cl^{-}(mg/l)	1.4	1.7	2.5	5.08	0.04	1.6	1.4	1.6	1.7	1.6	16.5	2	3	0.06	1.7	1.8
NO_3^{-}(mg/l)	0.08	0.07	0.09	3.06	4.06	0	0.1	0	0.05	0.04	0.08	0.04	0.09	0.02	0.01	0.01
Pb^{2+} (mg/l)	0	0.001	0	0.005	0	0.001	0.008	0	0	0	0	0.003	0.004	BDL	BDL	0.01
Cd^{2+}(mg/l)	0.15	0.16	0.14	-	-	0.12	0.16	0.02	0.01	0.03	0.05	0.03	0.16	-	-	0.041
Cu^{2+}(mg/l)	0.07	0.06	0.57	0.44	0.76	0.35	0.14	0.25	0.43	0.26	0.56	0.83	0.51	0.73	0.25	0.14
Zn^{2+}(mg/l)	0.18	0.21	0.08	0.13	0.17	0.06	0.02	0.18	0.01	2.51	1.95	2.10	2.05	2.18	0.78	0.68
Total Microbial Load	15	20	46	ND	ND	31	ND	6	15	48	49	ND	17	ND	ND	5
Total Coliform	5	10	13	ND	ND	15	ND	ND	5	20	18	ND	6	ND	ND	4

Table 3: Summary Of Physicochemical And Bacteriological Analyses Results Of Water Samples From The Study Area.

PARAMETER	Range	Mean	Std. Deviation	WHO Standard (2006)	
				PL	MPL
Colour (Hz)	5 – 15	8.5	4.0065	5	15
Temperature(°C)	20 – 28.3	26.6	4.0065	-	-
Tubidity	1 – 50	13.13	15.288	5	25
pH	6.2 – 10.7	7.66	1.6328	6.5	8.5
Conductivity (us/cm)	0.03 – 0.44	0.135	0.1113	200	400
TDS(mg/l)	6 - 67	34.64	19.578	600	1000
Total Hardness(mg/l)	2.0 – 12.8	7.94	4.1574	200	500
Na^{+} (mg/l)	3.33 – 7.6	4.886	1.0877	20	200
K^{+}(mg/l)	0.2 – 6.8	1.918	2.5095	-	-
Ca^{2+}(mg/l)	2.4 – 8.3	4.117	2.004	75	200
Mg^{2+}(mg/l)	1.02 – 3.44	1.726	0.8474	50	150
Fe^{+}(mg/l)	0.01- 0.59	0.292	0.1769	0.3	1.0
HCO_3^{-}(mg/l)	9.64 – 28.6	20.025	4.3028	<100	
Cl^{-}(mg/l)	0.04 – 5.2	2.1685	1.3684	250	600
SO_4^{2-}(mg/l)	1 – 4.06	2.319	1.2715	250	500
NO_3^{-}(mg/l)	0.01 – 4.06	0.815	1.2711	25	50
Pb^{2+} (mg/l)	0.001- 0.01	0.0055	0.0684	1.0ug/1	<0.02
Cd^{2+}(mg/l)	0 – 0.16	0.0628	0.0607	3.0ug/1	0.003
Cu^{+}(mg/l)	0.06 – 2.88	0.819	0.8988	1.0	5.0
Zn^{2+}(mg/l)	0.01 – 2.18	0.736	0.8767	3.0	5.0
Total Microbial Load	5- 120	31.1	37.300	<100	
Total Coliform	4 - 262	36	73.910	<10	

Water Classification

The chemical composition of water varies considerably. The concept of hydrogeochemical facies has been used to denote the diagnostic chemical character of water solutions in hydrologic systems. The facies reflect the effect of chemical processes occurring between the minerals of the lithologic framework and groundwater (Edet, 1993; Edet & Okereke, 2002). The subsequent flow patterns modify the facies and control their distribution. Piper trilinear diagram was used to classify groundwater types in the area. From the Piper trilinear and Schoeller semi logarithmic diagrams, the dominant water type is alkali bicarbonate water type, with bicarbonate as the predominant ion. The dominance of alkali bicarbonate water type could be attributed to the infiltration of carbon dioxide rich rainwater derived from the atmosphere and input of alkali salts from anthropogenic sources.

Table 4: Treated water analysis data (in meq/l) for the plotting of Schoeller semi logarithmic diagram in the study area

PARAMETERS / SAMPLE NO.	Ca^{2+} (meq/l)	Mg^{2+} (meq/l)	$Na^{+} + K^{-}$ (meq/l)	HCO_3^{-} (meq/l)	SO_4^{2-} (meq/l)	Cl^{-} (meq/l)
1	0.14	0.08	0.23	0.30	0.06	0.04
2	0.17	0.10	0.25	0.30	0.04	0.05
3	0.38	0.12	0.22	0.34	0	0.07
4	0.39	0.10	0.18	0.16	0.02	0.14
5	0.20	0.10	0.20	0.30	0.07	0
6	0.14	0.27	0.20	0.30	0.03	0.05
7	0.14	0.10	0.22	0.30	0.06	0.03
8	0.14	0.18	0.38	0.30	0.08	0.04
9	0.41	0.09	0.28	0.33	0.04	0.05
10	0.17	0.09	0.19	0.31	0.10	0.05
11	0.22	0.10	0.20	0.30	0.02	0.47
12	0.38	0.10	0.16	0.30	0.02	0.05
13	0.13	0.12	0.19	0.31	0.02	0.08
14	0.12	0.28	0.21	0.34	0.02	0
15	0.23	0.10	0.28	0.32	0.02	0.05
16	0.14	0.10	0.24	0.30	0.06	0.05

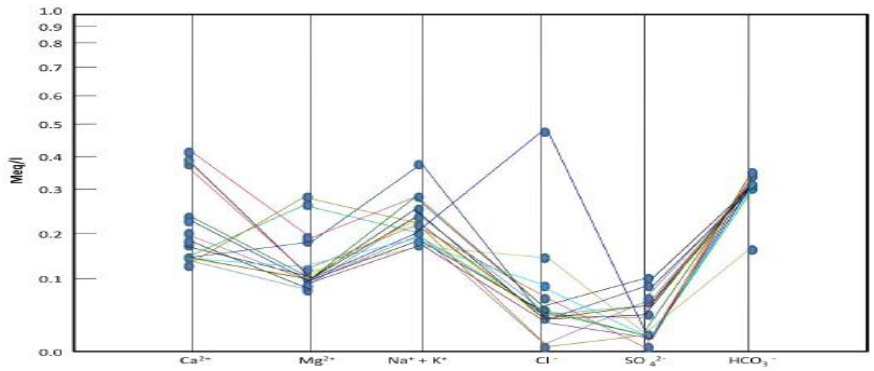

Fig. 2: Schoeller semi logarithmic diagram showing the relative abundance of cations and anions in groundwater sources in the study area

Table 5: Treated water analysis data (in meq/l) for the plotting of Piper diagram in the study area in percentage

PARAMETERS / SAMPLE NO.	Ca^{2+} (%)	Mg^{2+} (%)	$Na^{+} + K^{+}$ (%)	HCO_3^- (%)	SO_4^{2-} (%)	Cl^- (%)
1	31.11	17.78	51.1	75	15	10
2	32.70	19.23	48.08	76.92	10.26	12.88
3	52.77	16.66	30.61	82.93	0	17.07
4	58.18	14.92	26.84	50.0	6.25	43.75
5	40	20	40	81.06	18.91	0
6	23.78	45.87	33.98	78.93	7.89	13.15
7	30.43	21.74	47.82	76.92	15.38	7.70
8	20.04	25.70	54.26	71.43	19.05	9.52
9	52.56	11.53	35.9	78.57	9.52	11.90
10	37.77	20.00	42.21	67.40	21.74	10.87
11	42.30	19.23	38.46	37.97	2.53	59.50
12	59.37	15.62	25.00	81.09	5.40	13.51
13	29.53	27.26	43.16	75.60	4.87	19.51
14	19.66	45.90	34.41	94.41	5.55	0
15	37.70	16.40	45.90	82.04	5.12	12.82
16	29.16	20.83	50.00	73.17	14.63	12.19

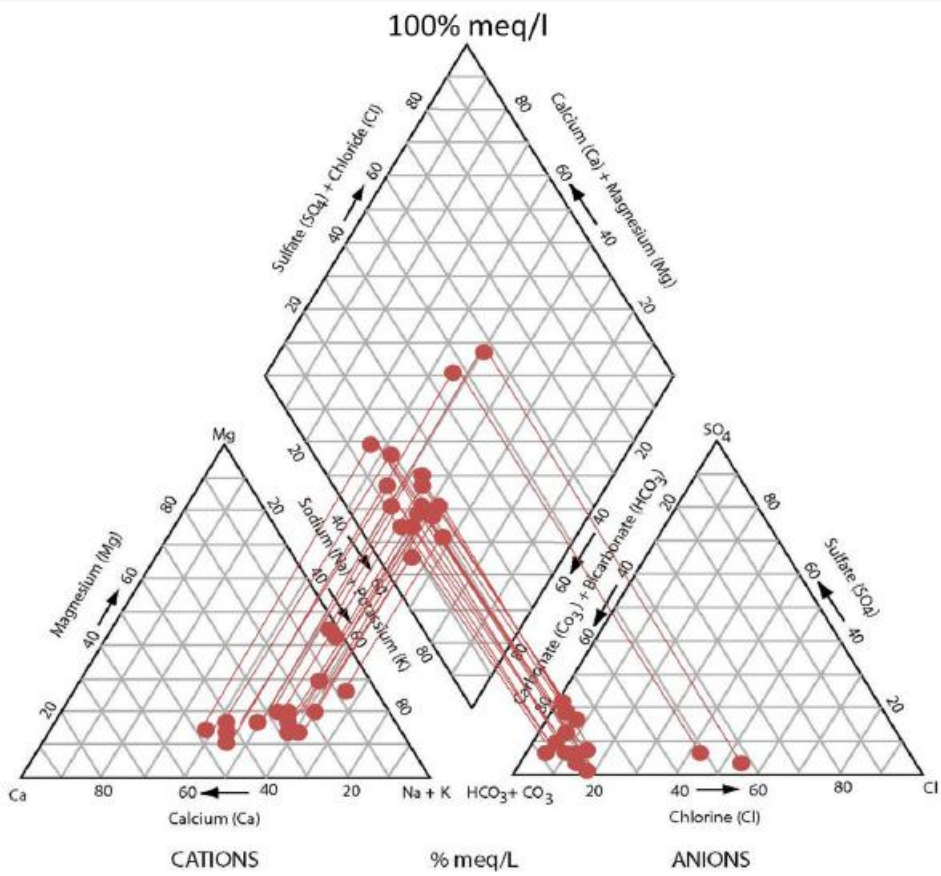

Fig. 3: Piper trilinear diagram showing the water types of the groundwater sources in the study area.

Sodium Absorption Ratio (SAR)

Sodium is an essential component of most groundwater since it is readily soluble in water. High concentration of sodium in the soil is considered unfavourable for plant growth. It renders the soil alkaline by replacing calcium and magnesium. The percentage of sodium to calcium and magnesium in a soil is thus a measure of the suitability of the soil for irrigation. Sodium Adsorption Ratio (as described by the Richards, 1954), has been evaluated for the study area using the relevant chemical parameters analyzed (Table 6).

$$\boldsymbol{SAR} = \frac{[Na^{+}]}{\sqrt{\frac{[Ca^{2+}] + [Mg^{2+}]}{2}}} \qquad (1)$$

where: $[Na^{+}]$= sodium concentration (in meq/l)
$[Ca^{2+}]$ = calcium concentration (in meq/l)

$[Mg^{2+}]$ = magnesium concentration (in meq/l)

According to Offodile (2002) the recommended irrigation water classification based on SAR are:

	SAR	**Water Class**
Less than	10	Excellent, No Problem
	10-18	Good (Medium) Increasing Problems
About	18-26	Poor (High) Sever Problem

From the result below, 100% of the water samples fall below 1.4meq/l, indicating predominance of excellent water for irrigation purposes in accordance with recommended standard.

Table 6: Calculated SAR of the water samples (in meq/l) in the study area.

PARAMETERS / SAMPLE NO.	Ca^{2+} (meq/l)	Mg^{2+} (meq/l)	Na^{+} (meq/l)	SAR (meq/l)
1	0.14	0.08	0.20	0.7
2	0.17	0.10	0.23	0.67
3	0.38	0.12	0.17	0.44
4	0.39	0.10	0.14	0.36
5	0.20	0.10	0.20	0.51
6	0.14	0.27	0.20	0.44
7	0.14	0.10	0.18	0.63
8	0.14	0.18	0.33	0.95
9	0.41	0.09	0.23	0.56
10	0.17	0.09	0.17	0.52
11	0.22	0.10	0.20	0.5
12	0.38	0.10	0.14	0.32
13	0.13	0.12	0.18	0.53
14	0.12	0.28	0.20	0.33
15	0.23	0.10	0.27	0.68
16	0.14	0.10	0.24	0.7

V. Conclusion

Results of water quality analysis compare favourably with WHO (2006) standards for drinking water. Some important water quality problems identified in parts of the study area are high concentrations of lead (Pb^{2+}), and cadmium (Cd^{2+}) which may have adverse pathogenic consequences. Bacteriological analysis of groundwater in the study area show satisfactory result, showing appreciable microbial filtration during recharge. The results of microbial tests on surface water sources are predominantly objectable. This shall be of great concern to various agencies and arms of government linked with water supply to the population since the surface water sources constitute a common and affordable source of water supply to the less privileged group of the population. Results of hydrochemical analysis of water samples show the predominance of alkali bicarbonate water type that is largely soft. Also, the SAR of the study area shows excellent water for irrigation purposes in accordance with recommended standard. Based on the chemistry, the water is considered acceptable for many household uses except for drinking purposes where pre-use treatment is required.

VI. Recommendations

1. Though the availability of the resources is relatively assured, quality sustainability should be a priority hence, qualitative evaluation of water in the study area is of fundamental importance.
2. Pre-use treatment programmes shall be incorporated in cases of water resources development in Owerri Capital Territory.
3. Environmental Impact Assessment should be done before setting up any category of industry in the area. Both surface and sub-surface investigations shall be done (among others) if water safety is considered a priority.

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