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# PHYSICO-CHEMICAL EVALUATION OF GROUNDWATER IN OGBIA, BAYELSA STATE, NIGERIA

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**ABSTRACT:** *This study evaluates the physico-chemical properties of groundwater in Ogbia, Bayelsa State, Nigeria. Standard field and laboratory methods were followed. The results of the study revealed that the pH value ranges from 6.4 to 7.1 with an average of 6.86 indicating a slightly acidic condition. The concentration level of iron in the study area ranges from 0.1mg/l to 4.2mg/l with a mean value of 1.89mg/l. 13.3% of iron in sampled locations satisfy the World Health Organization (WHO) and Nigerian Standards for Drinking Water Quality (NSDWQ) highest desirable level of 0.3mg/l. The concentration of calcium ranges between 3.0mg/l to 13.1mg/l, with a mean value of 8.83mg/l, while magnesium concentration was from 1.8mg/l to 9.0mg/l, with a mean value of 5.6mg/l. The concentration level of phosphate in the study area ranges from 0.02mg/l to 0.19mg/l, with a mean value of 0.12mg/l. Chloride concentration level in the sampled locations was between 10mg/l to 39mg/l, with a mean of value of 23.8mg/l, all the values recorded were within the permissible WHO and NSDWQ standard of 250mg/l. The low concentration level of chloride in the area indicates that there is no salt water intrusion, hence all the locations have freshwater. The cations were in order of abundance as* $Na^+ > Ca^{2+} > Mg^{2+} > Fe^{2+} > Mn^{2+}$*, while anions were in the order of abundance as* $SO_4 > Cl > NO_3 > F > NH_3 > PO_4$*. Piper Trilinear Diagram for the study area showed that there were mixtures of two types of water with variable concentrations of major ions. These were sodium-chloride type and sodium- sulphate type of water, an indication that the water was from a marine source. Based on the result from this study, there is the need for regular ground water quality monitoring and effective management strategies in the area.*

**KEYWORDS:** Water Quality, Groundwater, Major Ions, Freshwater, Contamination, Ogbia

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## INTRODUCTION

Water plays an important role in promoting agricultural production and standard of human health (Raju *et al*., 2013). Water of good quality is a basic necessity of life. The need to ascertain the quality of water used by humans has become very intense in the past decade and it is difficult to imagine any programme for human development that does not require a readily available supply of water (Fashola *et al.*, 2013). The overexploitation of groundwater and degradation of quality has adversely affected the socio-economic structure of many parts of the world, including the ecologically sensitive Niger Delta regions of Nigeria. A good number of towns, cities and megacities in Nigeria derive a major component of domestic, irrigation and industrial water supply from groundwater, both from municipal well fields and from large number of private boreholes.

The water quality may yield information about the dynamics of the environment. Each groundwater system in an area has a unique chemistry, acquired as a result of chemical alteration of water recharging the system (Drever, 1982). The chemical alteration of the rain water depends on several factors, such as soil-water interaction, dissolution of mineral species and anthropogenic activities (Nwankwoala & Udom, 2011). Study of a relatively large number of groundwater samples from a given study area, offers clues to various chemical alterations, which the groundwater undergoes, before acquiring distinct chemical characteristics.

The study area (Fig.1) in Bayelsa State, is located within the lower section of the upper flood plain deposits of the sub-aerial Niger Delta (Allen, I965). It lies between latitudes $4^0$ 33’N and $5^0$ 00’N and longitudes $6^0$ I5’E and $6^0$ 29’E (Fig.1 and Fig. 2).

The area is bounded on the north by Yenagoa, the capital of Bayelsa State and Mbiama town in Rivers State, and on the south by Brass and Nembe local government areas of Bayelsa State. It is also bounded on the west by southern Ijaw and Ahoada-west local government areas of Bayelsa State and Rivers State respectively. The area can be accessed on the north by the Mbiama-Yenagoa road and on the south by the Nembe and Brass Rivers. Most part of the area is motorable, hence there is a network of roads that links the different parts of the area and its environs.

It is interesting to note that a considerable land area of the state is under water at high tide. This implies that as much as 60% of the region is inundated at every high tide. The entire Niger Delta topography is characterized by creeks and swamps, criss-crossing low lying plains in varying dimensions. However, the area is mainly drained by the Ogbia and the Ekoli creeks. These creeks empty into the Brass River.

The Benin Formation (overlain by Quaternary deposits in some places) is the water bearing zone of the area. The sand and sandstones of the Benin Formation are coarse to fine, commonly granular in texture and can be partly unconsolidated. The sands may represent upper deltaic plain deposit and/or braided stream point bars and channel fills. The Shales are few and thin and may represent back swamp deposits (Short & Stauble, 1967). It is overlain by quaternary deposits (40-150m thick) and generally consists of rapidly alternating sequence of sands and silty clays with the latter become increasingly more prominent seawards (Etu-Efeotor & Akpokodje, 1990).

The clayey intercalations within the Benin Formation have given rise to multi- aquifer system in the area (Etu-Efeotor 1981, Etu-Efeotor and Odigi, 1983, Etu-Efeotor and Akpokodje, 1990). The first aquifer is commonly unconfined while the rest are confined. The average depths for boreholes in the study area are between 50 and 60 meters (Udom & Amah, 2006).

Deep boreholes in the study area tap water from the confined aquifer from depths up to about 200m. The study area has been noted to have poor groundwater quality due to objectionable high concentration of certain groundwater parameters and encroachment of saltwater or brackish water into the freshwater aquifers (Ngerebara & Nwaankwoala, 2008; Udom 1999, and Nwankwoala *et al.*, 2011). The static water level in the area ranges from 0-Im during the rainy season and I- 3m during the dry season. The main source of recharge is through direct precipitation where annual rainfall is as high as 3000mm (Amajor, 1987). The water infiltrates through the highly permeable sands of the Benin Formation to recharge the aquifers. Groundwater in the area occurs principally under water table conditions (Udom and Amah, 2006; Nwankwoala, 2011).

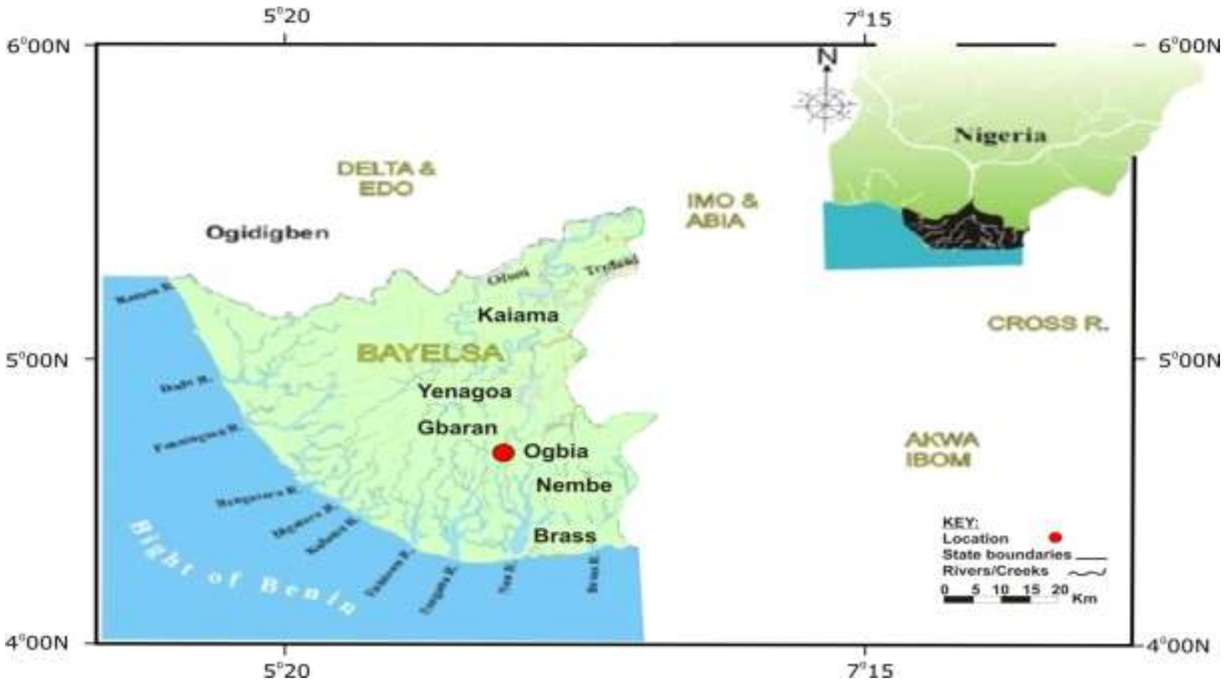

Fig. 1: Map of Bayelsa State Showing the Study Area (Ogbia)

Fig I.2: Map of the Study Area (Source: Office of the Surveyor-General, Yenagoa)

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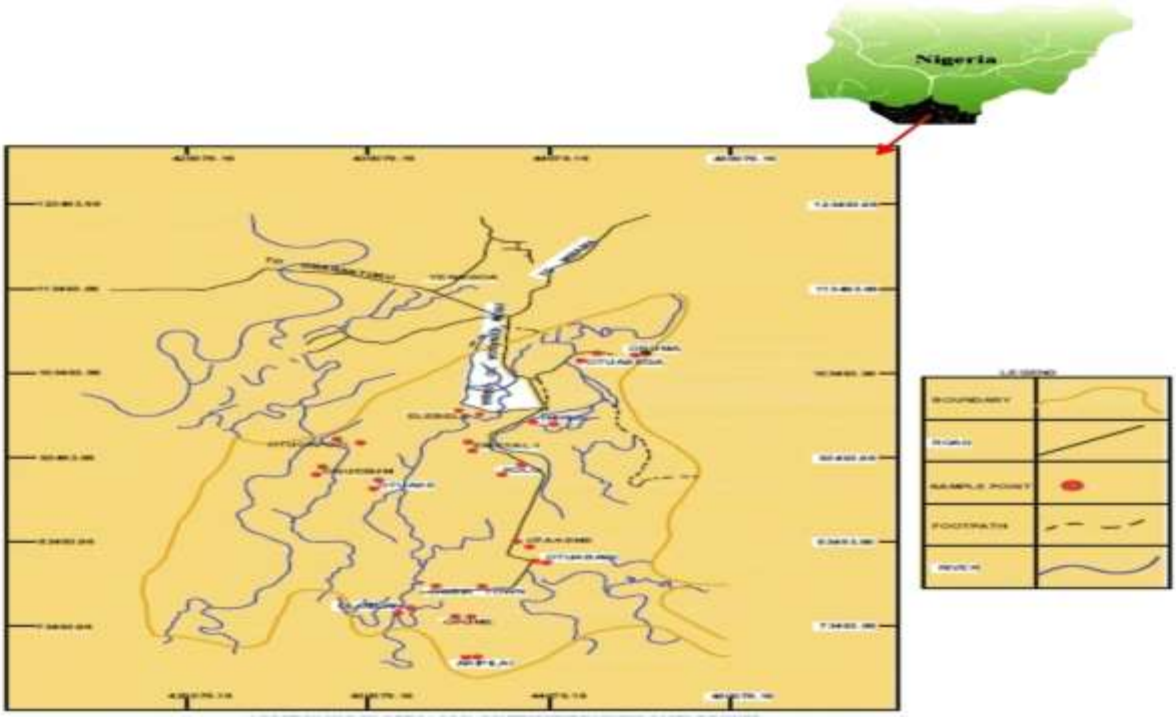


Fig. 2: Map of Ogbia Showing the Sampling Locations

## MATERIALS AND METHODS

### Sampling

Thirty (30) groundwater samples were collected from functional boreholes selected randomly within the study area. The depths of the boreholes were between 45m-95m deep while their screen depth ranges from 35m-75m respectively. These thirty (30) groundwater samples were collected within fifteen (I5) communities. In each community, two groundwater samples were collected. This is to ensure that every part of the study area was covered. Fig 3.I shows the sampling locations within the study area. A total of thirty (30) functional boreholes were sampled. Prior to the all sample collection in the field, the sample containers were rinsed with the groundwater to be collected before sampling. The sample was then collected with the I.5 liters plastic bottles after allowing the borehole to run for about five (5) minutes.

The sample was collected close to the well head and the bottle filled to the brim. After each sample collection, the bottle lid was immediately replaced to minimize oxygen contamination and the escape of dissolved gases. The sample so collected was transported to the laboratory for analysis within twelve (12) hours.

Samples meant for anion determination were acidified and the choice of acid depended on the anion. For example, sample meant for Iron determination was primed with 0.5M solution of nitric acid to keep the Iron in solution. All groundwater samples were properly labeled and the co-ordinates of all the sampling locations were recorded using Geographic Positioning System (GPS) garmin channel 78 model. The temperatures of the samples were also recorded in the field using thermometer.

## RESULTS AND DISCUSSION

The results of the physico-chemical analysis of parameters carried out in the study area are shown in Table 1 while Table 2 shows descriptive statistics of the results obtained. The pH value ranges from 6.4 to 7.1 with an average of 6.86 indicating a slightly acidic condition (Todd *et al.*, 2005, Udom *et al.*, 1999, 2002). The pH values in the study area are within the acceptable limit of WHO and NSDWQ standard as shown in Table 1. Acidity in the groundwater in the study area has been attributed partly to gas flaring. This industrial activity releases carbon dioxide which reacts with atmospheric precipitation to form carbonic acid. This acid infiltrates underground into the groundwater system, thereby reducing the pH of the water and slightly increases the acidity of the groundwater (Nwankwoala, 2013).

The groundwater temperature of the study area ranges from $25^{oC}$ to $30^{oC}$ with a mean of value of $27^{Oc}$ and falls within the acceptable limit of $27^{oC}$ of the World Health Organization standard (WHO, 2006) as shown in Table 1. Comparing with the electrical conductivity values, the temperature is sensitive for the hydro geological characterization of the area.

Electrical conductivity in the study area ranges from 54 to 110µs/cm, with a mean value of 80.6µS/cm. Electrical conductivity of water is directly related to the concentration of ions and their mobility. Studies showed that electrical conductivity is indicative of dissolved ionizable solids. The moderate values of electrical conductivity in all the sampled locations indicates presence of low concentration and enrichment of dissolved ions and ionic activities in the groundwater.

The concentration of total dissolved solids in all the sample locations ranges from 24 to 150mg/l, with a mean value of 89.23mg/l. Maximum concentration is found in groundwater sample collected from location 3 (Emeyal Community) which is 150mg/l. Minimum concentration is 24mg/l found in groundwater sample from location 24 (Imiringi Community). All the values recorded are within the prescribed WHO and NSDWQ standard of 500mg/l for drinking water and showed that the groundwater is fresh in all the locations.

The term total dissolved solids (TDS) refers mainly to the inorganic substances that are dissolved in water. The effects of total dissolved solids on the quality of drinking water depend on the levels of its individual components such as excessive hardness, taste, mineral deposition and corrosion which are the common properties of highly mineralized water. Total dissolved solids in groundwater though generally not harmful to humans, however, high concentrations may affect persons suffering from kidney and heart diseases (Gupta *et al*., 2004). Groundwater containing high total dissolved solids may also cause laxative or constipation effects (Todd, I980).

The groundwater total hardness (TH) in the study area ranges from 4.8mg/l to 21.2mg/l, with a mean value of 14.57mg/l. All the values were found to be within the prescribed WHO (2006) and NSDWQ (2007) limit of 100mg/l. According to Sawyer and McCarthy's (1970) Classification for hardness, all the groundwater samples collected falls under the soft class of 0 to 75mg/l, signifying very soft water in accordance with the classification scheme. Hardness is caused by polyvalent metallic ions dissolved in water, which in natural water are principally magnesium and calcium.

The concentration level of iron in the study area ranges from 0.1mg/l to 4.2mg/l with a mean value of 1.89mg/l. The minimum concentration of iron value was found in location 28 (Otakeme Community), while the maximum value was in location 5 (Otuokpoti Community). 13.4% of the sampled locations in the study area satisfy the WHO (2006) and NSDWQ (2007) highest desirable level of 0.3mg/l. However, 86.6% of the sampled locations indicate high concentration of iron which is above the WHO standard for drinking water. Exposure of water samples to air could cause ferrous ($Fe^{2+}$) ion in them to oxidize to ferric ($Fe^{3+}$) ion which would precipitate a rust-coloured ferric hydroxide which stains plumbing materials, clothes and cooking utensils (Udom *et al*., 1999). According to Etu-Efeotor (1981); Olarewaju *et al*, (1996); Ibe and Sowa (2002), high iron content in water may cause staining of laudry, metals pipes for reticulation and scaling in pipes and may also give undesirable taste.

According to Ngah and Allen (2005), deposits of ferruginous materials in a water distribution system can contribute to the growth of iron bacteria which in turn could cause further water quality deterioration by producing slimes or objectionable odours, frothing tastes, colour as well as increase in turbidity. The primary source of the iron contamination is from weathering processes of Igneous and Metamorphic rocks (geologic origin). The laterites in the Benin Formation are ferruginous and probably stained by limonite, goethite and haematite (Etu-Efeotor, 1981). WHO (2004) stated that iron may also come from man activities such as the use of coagulants and the corrosion of steel and cast pipes in water distribution system.

Industrial activities that could introduce iron into the soil are industrial waste and disposal of hazardous wastes and materials (Ngah & Allen, 2005). During percolation, water can wash iron from these materials into the groundwater system which is the Benin Formation, where water is tapped in the study area.

The concentration of calcium ranges between 3.0mg/l to 13.1mg/l, with a mean value of 8.83mg/l, while magnesium concentration is from 1.8mg/l to 9.0mg/l, with a mean value of 5.6mg/l. All the values are within the prescribed WHO and NSDWQ limit of 70mg/l and 30mg/l for drinking water respectively.

According to Todd (I980), a higher concentration of magnesium in household water has laxative effect, especially on new users of the supply. Excess of calcium ions in form of calcium bicarbonate form temporary hardness while sulphates, chlorides and nitrates form permanent hardness (Twort *et al*., 2000). Offodile (2002) observed that high concentration of calcium in water tends to precipitate soap and is objectionable in laundry and other domestic and industrial purposes. High calcium content in water causes excessive scale formation.

Generally, high calcium and magnesium concentrations make the groundwater ‘hard’. This significant hardness gives the water a very high buffer capacity against acid input, which is useful, for instance, to buffer the formation of acid from the nitrification of ammonium. From a technical point of view, hardness is very undesirable due to the potential incrustation build up in pipelines and household appliances. This needs to be taken into consideration practically when considering the construction of a central water supply system.

The concentration level of fluoride in the groundwater sampled ranges from 0.04mg/ to 1.2mg/l, with a mean value of 0.30mg/l. All the values were within the prescribed WHO (2006) and NSDWQ (2007) standard of 1.5mg/l. The variation of fluoride is dependent on a variety of factors such as the duration of contact of water with rocks and soil, temperature, rainfall and oxidation-reduction process (Amadi & Tukur, 2014). Easy accessibility of circulating water to the weathered products during irrigation dissolves and leaches the minerals, including fluorine, contributing fluoride concentration to the groundwater. The presence of small quantities of fluoride in drinking water may prevent tooth decay. Fluoride is poisonous at high levels, thereby causing mottled teeth.

Nitrate concentration levels in the sampled locations ranges from 0.0 to 2.7mg/l, with a mean value of 0.96mg/l. About 16 locations (53.3%) of nitrate concentration were not detected. All the values are within the prescribed WHO (2006) and NSDWQ (2007) standard of I0mg/l. Sources of nitrate contamination may be due to seepage from dilapidated septic tanks, dumpsites, and run off from agricultural wastes etc. The low concentration level of nitrate in the sampled locations may be attributed to the decrease of nitrate by the consumption in redox processes, little or no seepage of sewage treatment plants and wastes from dump sites.

Nitrogen is essential component of amino acids and therefore all proteins and nucleic acids are needed for all cell division and reproduction. Nitrate compounds can prevent hemoglobin from binding with oxygen at levels above the permissible limit. Thus, the drinking water that is contaminated with nitrates can prove fatal especially to infants as it restricts the amount of oxygen that reaches the brain causing the ‘blue baby’ syndrome.

Chloride concentration level in the sampled locations is between 10mg/l to 39mg/l, with a mean of value of 23.8mg/l. All the values recorded were within the permissible WHO and NSDWQ standard of 250mg/l. The low concentration level of chloride in the area indicates that there is no salt water intrusion, hence all the locations have freshwater. A highest desirable level of 100mg/l have been recommended by WHO (2006) for this parameter in drinking water. Chloride in excess of 100mg/l imparts a taste on drinking water and can cause physiological damage. Chloride is a conservative ion and has mobility similar to that of water molecule with one important exception, where water molecule is removed by evapo-transpiration, chloride is concentrated in the residual solution (Todd, 1980). It is interesting to note from the results of this study, that 100% of the groundwater sampled locations have chloride concentration below 40mg/l. Chloride contents of 40mg/l and below are indicative of absent of salt water contamination (Nwankwoala, 2013).

The concentration level of sulphate in the area ranges between 3.5mg/l to 96mg/l with a mean value of 17.0mg/l. All values are within the permissible WHO (2006) standard of 200mg/l. Sulphate concentration in the area is low and therefore poses no problem for the groundwater quality. The low values are mostly due to the removal of $SO_4$ by the action of bacteria (Amadi *et al.*, I989). The low concentration of sulphate suggest absence of any or little linkage of sewage plants in the area. The sulphate probably owes its source in the area to industrial waste from adjoining areas.

The concentration level of phosphate in the study area ranges from 0.02mg/l to 0.19mg/l, with a mean value of 0.12mg/l. About 10% (3 locations) of the sampled locations are within the permissible WHO (2006) standard of 0.05mg/l, while 90% (27 locations) of the sample water are above the WHO standard for drinking water. The maximum concentration was found in location 5 (Otuokpoti Community), while a minimum of 0.02mg/l was in location 1 (Otuoke Community). Phosphate levels greater than 1.0 mg/l may interfere with coagulation in water treatment plants. As a result, organic particles that harbor micro-organism may not be completely removed before distribution (Todd, 1980). Phosphate is an essential nutrient for human and animal life. It is fundamental to growth, maintenance, and repair of all body tissues and is necessary, along with calcium and magnesium, for proper growth and formation of bones in infants and children. Sufficient phosphorus intake is important throughout life to ensure proper balance of essential minerals in order to promote remineralization of bones and teeth to keep them in a healthy state.

The concentration of sodium in the sample water ranges from 90mg/l to 110 mg/l, with a mean value of 100.4 mg/l. All the recorded values are within the WHO and NSDWQ standard of 200 mg/l for drinking water. The low sodium concentration recorded in all the locations generally agrees with Todd (I980) contention that the concentration of sodium in the groundwater is commonly less than 100 mg/l.

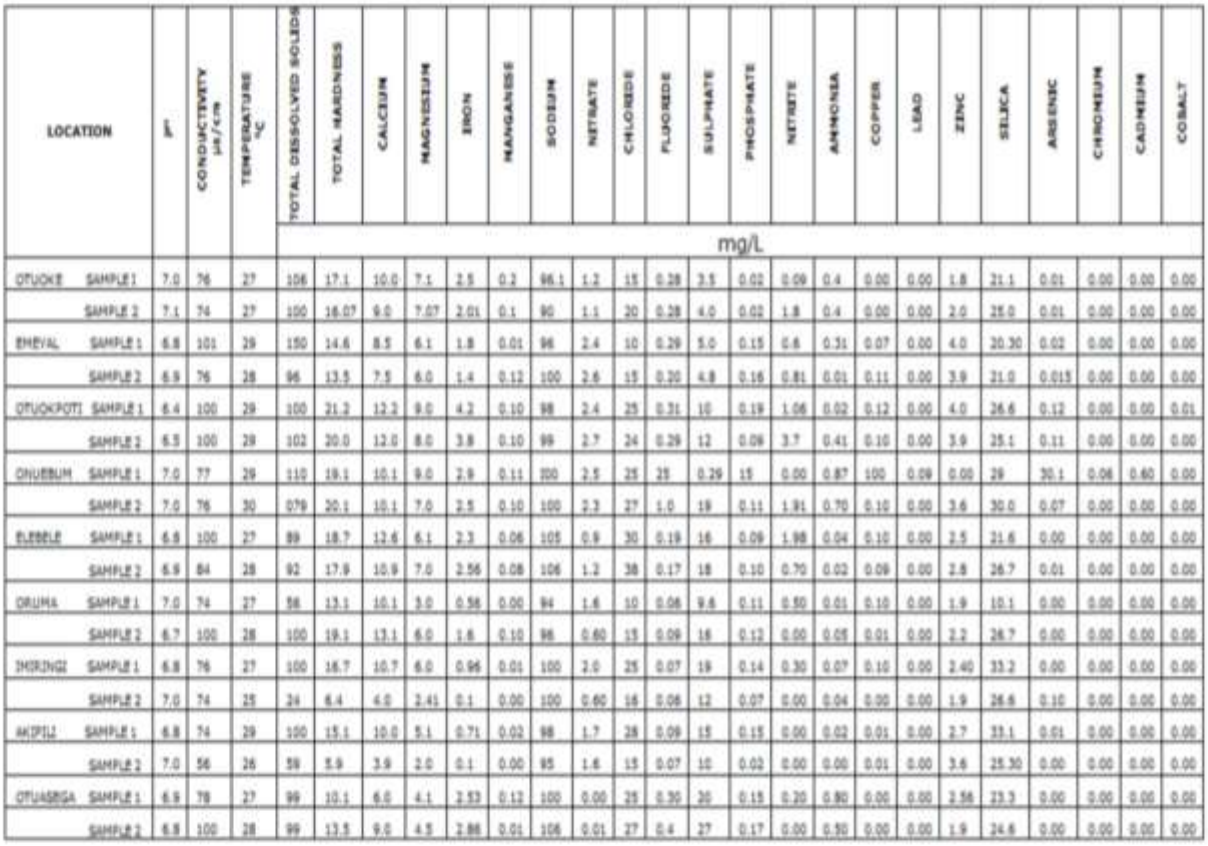
According to Freeze and Cherry (1979), Hem (1980), and Udom, *et al* (1999), Punmia *et al* (2002) Egbunike (2007), sodium is the most abundant of all the cations in groundwater. High concentration of sodium more than 200 mg/l makes water unsuitable for domestic use (unacceptable taste), causes foaming in the presence of suspended matter, and accelerating scale formation and corrosion in boiler (Todd, 1980; Udom, *et al.*, 1999). This deteriorates domestic plumbing and municipal water works equipment. Sodium level in drinking water is usually low and unlikely to be significant contribution to adverse health effects (Minnesota Department of Health, 2008). The results of this study also revealed that the concentration levels of manganese were between 0.00 mg/l to 0.2mg/l, while nitrite ranges from 0.00 to 3.70 mg/l. Silica concentration ranges from between 10.1 mg/l to 39.1mg/l, while ammonia ranges from 0.00 to 0.80 mg/l.

The concentration of zinc, copper, and arsenic ranges from 1.5 mg/l to 4.0 mg/l, 0.00 to 0.12 mg/l and 0.00mg/l to 0.12 mg/l respectively. However, the concentration of chromium, cadmium, cobalt and lead were not detected. All the values were within the permissible WHO standard limit except that of copper and arsenic which were a little bit above the WHO (2006) standard limit of 0.05mg/l. This indicates that the groundwater is polluted which might be as a result of industrial or crude oil pollution or landfill contamination.

The cations were in order of abundance as Na$^+$ > Ca $^{2+}$ > Mg $^{2+}$ > Fe $^{2+}$ > Mn $^{2+}$, while anions were in the order of abundance as $SO_4$ > Cl > $NO_3$ > F > $NH_3$ > $PO_4$ as indicated in Table 2. According to Piper (1944), Piper Trilinear diagram (Fig. 4) for the study area showed that there was mixture of two water types with variable concentrations of major ions. These were sodium-chloride type and sodium- sulphate type of water, an indication that the water was from a marine source. Fig.3 showed the variation plot of some sampled parameters in the study area.

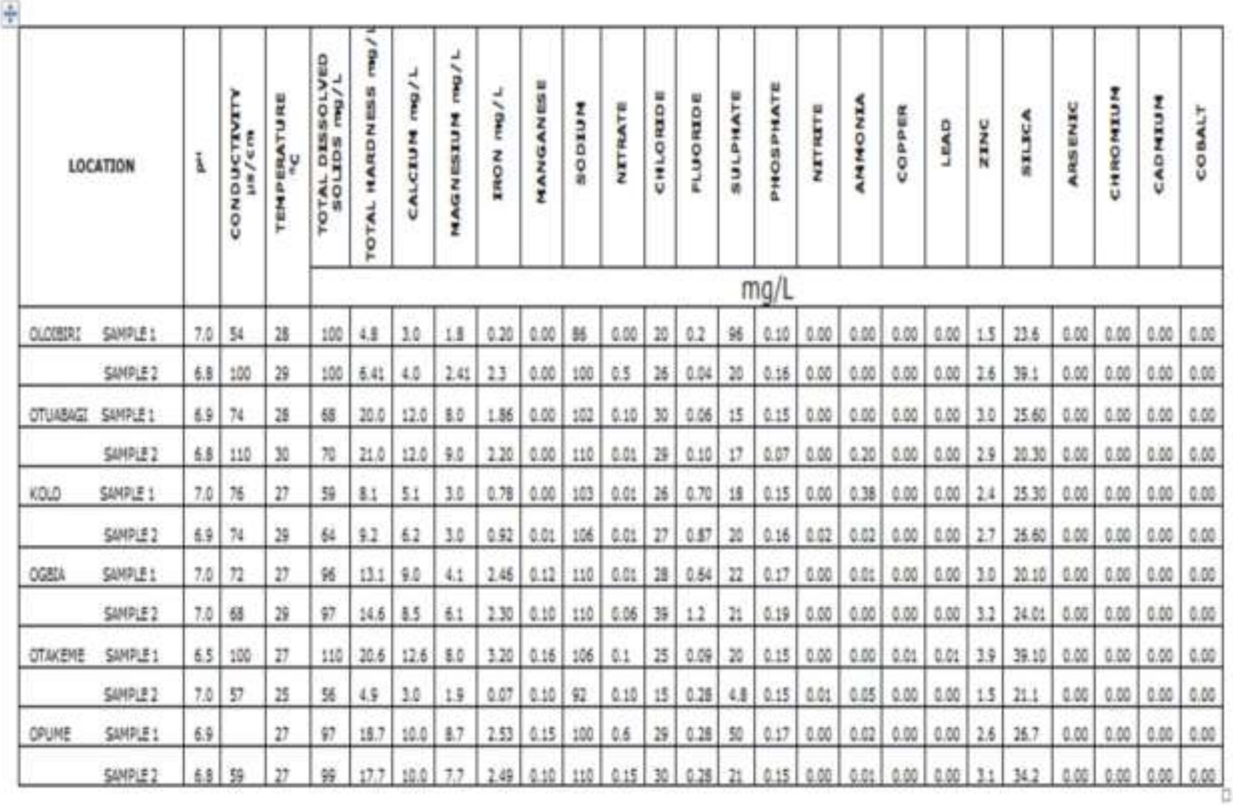
Correlation coefficient is a commonly used measure to assess the relationship between two variables. It is a simple measure to exhibit how well one variable predicts the other. The correlation matrixes for the different variables for the parameters are shown in Table 3. A correlation coefficient (r) of +1 indicates that two variables are perfectly related in a positive linear sense, but if r = -1 indicates a negative linear correlation. However, no relationship between two variables exist if r = 0 (Fashiola *et al.*, (2013). Thus, two variables having a positive correlation coefficient infer that they have a common source, while negative correlation coefficient indicates different source. The chemical parameters in the study area indicates positive correlation as follows: Ca$^+$, Mg$^{2+}$ Fe$^{2+}$ Mn$^{2+}$ TH, and Na$^+$ (r= 0.9 to 0.3) and $S0_4{}^{2-}$ , $P0_4{}^{2-}$ , EC, $N0_3{}^{2-}$, Cu, Ar, and TDS (r = 0.7 to 0.3). The positive correlation between the chemical parameters is an indication of common source. This analysis is tried to determine the contamination and its source, indicating that the area is not contaminated by any of the chemical parameters, hence are within tolerable level.

**Table 1: Physico-Chemical Parameters of Groundwater Samples**



| LOCATION | pH | CONDUCTIVITY µs/cm | TEMPERATURE °C | TOTAL DISSOLVED SOLIDS | TOTAL HARDNESS | CALCIUM | MAGNESIUM | IRON | MANGANESE | SODIUM | NITRATE | CHLORIDE | FLUORIDE | SULPHATE | PHOSPHATE | NITRITE | AMMONIA | COPPER | LEAD | ZINC | SILICA | ARSENIC | CHROMIUM | CADMIUM | COBALT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | mg/L | | | | | | | | | | | | | | | | | | | | | |
| OTUOKE SAMPLE 1 | 7.0 | 76 | 27 | 106 | 17.1 | 10.0 | 7.1 | 2.5 | 0.2 | 96.1 | 1.2 | 15 | 0.28 | 3.5 | 0.02 | 0.09 | 0.4 | 0.00 | 0.00 | 1.8 | 21.1 | 0.01 | 0.00 | 0.00 | 0.00 |
| SAMPLE 2 | 7.1 | 74 | 27 | 100 | 16.07 | 9.0 | 7.07 | 2.01 | 0.1 | 90 | 1.1 | 20 | 0.28 | 4.0 | 0.02 | 1.8 | 0.4 | 0.00 | 0.00 | 2.0 | 25.0 | 0.01 | 0.00 | 0.00 | 0.00 |
| EMEVAL SAMPLE 1 | 6.8 | 101 | 29 | 150 | 14.6 | 8.5 | 6.1 | 1.8 | 0.01 | 96 | 2.4 | 10 | 0.29 | 5.0 | 0.15 | 0.6 | 0.31 | 0.07 | 0.00 | 4.0 | 20.30 | 0.02 | 0.00 | 0.00 | 0.00 |
| SAMPLE 2 | 6.9 | 76 | 28 | 96 | 13.5 | 7.5 | 6.0 | 1.4 | 0.12 | 100 | 2.6 | 15 | 0.20 | 4.8 | 0.16 | 0.81 | 0.01 | 0.11 | 0.00 | 3.9 | 21.0 | 0.015 | 0.00 | 0.00 | 0.00 |
| OTUOKPOTI SAMPLE 1 | 6.4 | 100 | 29 | 100 | 21.2 | 12.2 | 9.0 | 4.2 | 0.10 | 98 | 2.4 | 25 | 0.31 | 10 | 0.19 | 1.06 | 0.02 | 0.12 | 0.00 | 4.0 | 26.6 | 0.12 | 0.00 | 0.00 | 0.01 |
| SAMPLE 2 | 6.5 | 100 | 29 | 102 | 20.0 | 12.0 | 8.0 | 3.8 | 0.10 | 99 | 2.7 | 24 | 0.29 | 12 | 0.09 | 3.7 | 0.41 | 0.10 | 0.00 | 3.9 | 25.1 | 0.11 | 0.00 | 0.00 | 0.00 |
| ONUEBUM SAMPLE 1 | 7.0 | 77 | 29 | 110 | 19.1 | 10.1 | 9.0 | 2.9 | 0.11 | 100 | 2.5 | 25 | 25 | 0.29 | 15 | 0.00 | 0.87 | 100 | 0.09 | 0.00 | 29 | 30.1 | 0.06 | 0.60 | 0.00 |
| SAMPLE 2 | 7.0 | 76 | 30 | 079 | 20.1 | 10.1 | 7.0 | 2.5 | 0.10 | 100 | 2.3 | 27 | 1.0 | 19 | 0.11 | 1.91 | 0.70 | 0.10 | 0.00 | 3.6 | 30.0 | 0.07 | 0.00 | 0.00 | 0.00 |
| ELEBELE SAMPLE 1 | 6.6 | 100 | 27 | 89 | 18.7 | 12.6 | 6.1 | 2.3 | 0.06 | 105 | 0.9 | 30 | 0.19 | 16 | 0.09 | 1.98 | 0.04 | 0.10 | 0.00 | 2.5 | 21.6 | 0.00 | 0.00 | 0.00 | 0.00 |
| SAMPLE 2 | 6.9 | 84 | 28 | 92 | 17.9 | 10.9 | 7.0 | 2.56 | 0.08 | 106 | 1.2 | 38 | 0.17 | 18 | 0.10 | 0.70 | 0.02 | 0.09 | 0.00 | 2.8 | 26.7 | 0.01 | 0.00 | 0.00 | 0.00 |
| ORUMA SAMPLE 1 | 7.0 | 74 | 27 | 56 | 13.1 | 10.1 | 3.0 | 0.56 | 0.00 | 94 | 1.6 | 10 | 0.06 | 9.6 | 0.11 | 0.50 | 0.01 | 0.10 | 0.00 | 1.9 | 10.1 | 0.00 | 0.00 | 0.00 | 0.00 |
| SAMPLE 2 | 6.7 | 100 | 28 | 100 | 19.1 | 13.1 | 6.0 | 1.6 | 0.10 | 96 | 0.60 | 15 | 0.09 | 16 | 0.12 | 0.00 | 0.05 | 0.01 | 0.00 | 2.2 | 28.7 | 0.00 | 0.00 | 0.00 | 0.00 |
| IMIRINGI SAMPLE 1 | 6.8 | 76 | 27 | 100 | 16.7 | 10.7 | 6.0 | 0.96 | 0.01 | 100 | 2.0 | 25 | 0.07 | 19 | 0.14 | 0.30 | 0.07 | 0.10 | 0.00 | 2.40 | 33.2 | 0.00 | 0.00 | 0.00 | 0.00 |
| SAMPLE 2 | 7.0 | 74 | 25 | 24 | 6.4 | 4.0 | 2.41 | 0.1 | 0.00 | 100 | 0.60 | 16 | 0.06 | 12 | 0.07 | 0.00 | 0.04 | 0.00 | 0.00 | 1.9 | 26.6 | 0.10 | 0.00 | 0.00 | 0.00 |
| AKIPILI SAMPLE 1 | 6.8 | 74 | 29 | 100 | 15.1 | 10.0 | 5.1 | 0.71 | 0.02 | 98 | 1.7 | 28 | 0.09 | 15 | 0.15 | 0.00 | 0.02 | 0.01 | 0.00 | 2.7 | 33.1 | 0.01 | 0.00 | 0.00 | 0.00 |
| SAMPLE 2 | 7.0 | 56 | 26 | 59 | 5.9 | 3.9 | 2.0 | 0.1 | 0.00 | 95 | 1.6 | 15 | 0.07 | 10 | 0.02 | 0.00 | 0.00 | 0.01 | 0.00 | 3.6 | 25.30 | 0.00 | 0.00 | 0.00 | 0.00 |
| OTUASEGA SAMPLE 1 | 6.9 | 78 | 27 | 99 | 10.1 | 6.0 | 4.1 | 2.53 | 0.12 | 100 | 0.00 | 25 | 0.30 | 20 | 0.15 | 0.20 | 0.80 | 0.00 | 0.00 | 2.56 | 23.3 | 0.00 | 0.00 | 0.00 | 0.00 |
| SAMPLE 2 | 6.8 | 100 | 28 | 99 | 13.5 | 9.0 | 4.5 | 2.86 | 0.01 | 106 | 0.01 | 27 | 0.4 | 27 | 0.17 | 0.00 | 0.50 | 0.00 | 0.00 | 1.9 | 24.6 | 0.00 | 0.00 | 0.00 | 0.00 |

## Table 1: Physico-Chemical Parameters of Groundwater Samples (Contd)



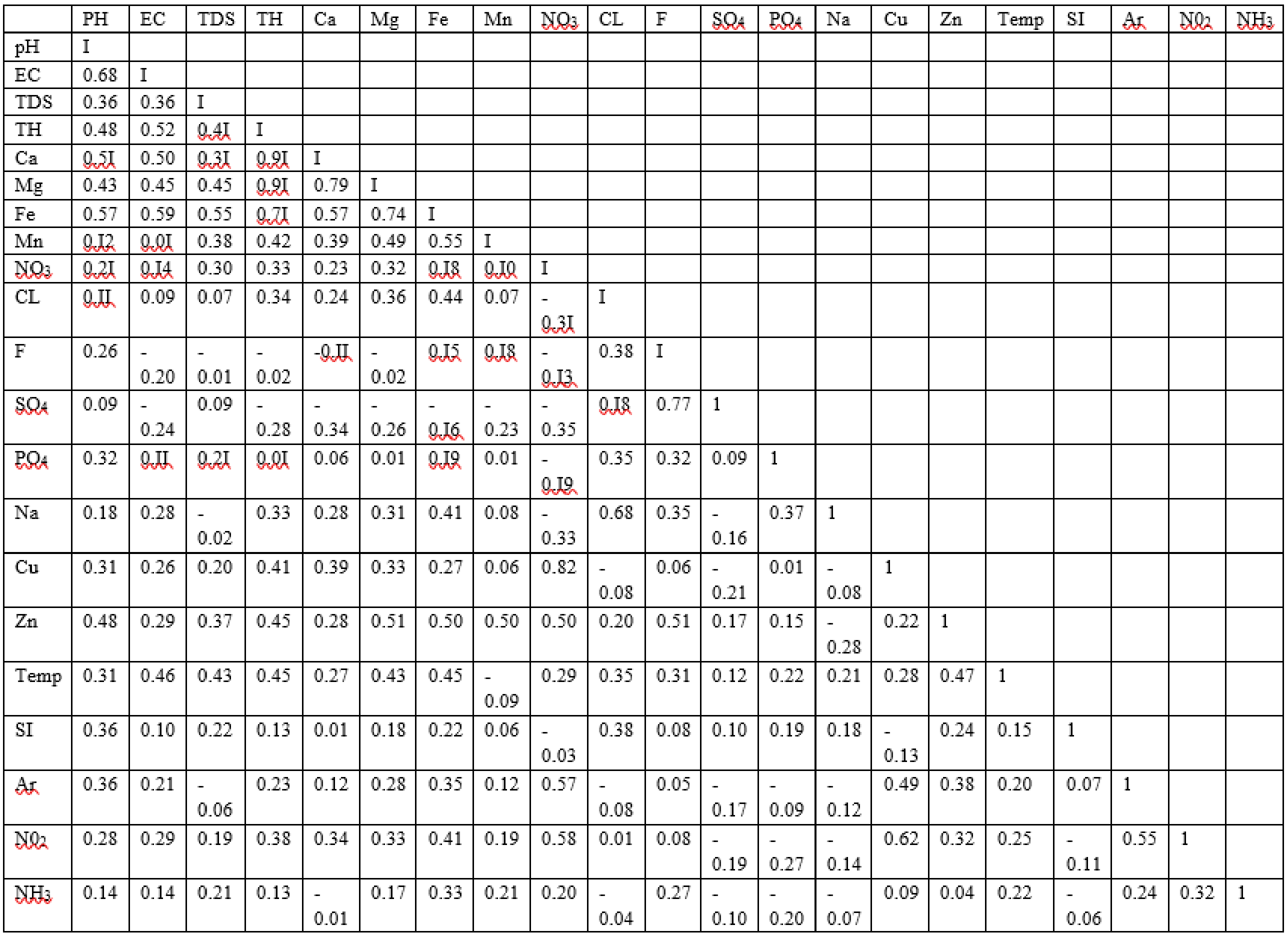
| LOCATION | | pH | CONDUCTIVITY µs/cm | TEMPERATURE °C | TOTAL DISSOLVED SOLIDS mg/L | TOTAL HARDNESS mg/L | CALCIUM mg/L | MAGNESIUM mg/L | IRON mg/L | MANGANESE | SODIUM | NITRATE | CHLORIDE | FLUORIDE | SULPHATE | PHOSPHATE | NITRITE | AMMONIA | COPPER | LEAD | ZINC | SILICA | ARSENIC | CHROMIUM | CADMIUM | COBALT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | mg/L | | | | | | | | | | | | | | | | | | | | | |
| OLOBIRI | SAMPLE 1 | 7.0 | 54 | 28 | 100 | 4.8 | 3.0 | 1.8 | 0.20 | 0.00 | 86 | 0.00 | 20 | 0.2 | 96 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 1.5 | 23.6 | 0.00 | 0.00 | 0.00 | 0.00 |
| | SAMPLE 2 | 6.8 | 100 | 29 | 100 | 6.41 | 4.0 | 2.41 | 2.3 | 0.00 | 100 | 0.5 | 26 | 0.04 | 20 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 2.6 | 39.1 | 0.00 | 0.00 | 0.00 | 0.00 |
| OTUABAGI | SAMPLE 1 | 6.9 | 74 | 28 | 68 | 20.0 | 12.0 | 8.0 | 1.86 | 0.00 | 102 | 0.10 | 30 | 0.06 | 15 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 3.0 | 25.60 | 0.00 | 0.00 | 0.00 | 0.00 |
| | SAMPLE 2 | 6.8 | 110 | 30 | 70 | 21.0 | 12.0 | 9.0 | 2.20 | 0.00 | 110 | 0.01 | 29 | 0.10 | 17 | 0.07 | 0.00 | 0.20 | 0.00 | 0.00 | 2.9 | 20.30 | 0.00 | 0.00 | 0.00 | 0.00 |
| KOLO | SAMPLE 1 | 7.0 | 76 | 27 | 59 | 8.1 | 5.1 | 3.0 | 0.78 | 0.00 | 103 | 0.01 | 26 | 0.70 | 18 | 0.15 | 0.00 | 0.38 | 0.00 | 0.00 | 2.4 | 25.30 | 0.00 | 0.00 | 0.00 | 0.00 |
| | SAMPLE 2 | 6.9 | 74 | 29 | 64 | 9.2 | 6.2 | 3.0 | 0.92 | 0.01 | 106 | 0.01 | 27 | 0.87 | 20 | 0.16 | 0.02 | 0.02 | 0.00 | 0.00 | 2.7 | 25.60 | 0.00 | 0.00 | 0.00 | 0.00 |
| OGBIA | SAMPLE 1 | 7.0 | 72 | 27 | 96 | 13.1 | 9.0 | 4.1 | 2.46 | 0.12 | 110 | 0.01 | 28 | 0.64 | 22 | 0.17 | 0.00 | 0.01 | 0.00 | 0.00 | 3.0 | 20.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| | SAMPLE 2 | 7.0 | 68 | 29 | 97 | 14.6 | 8.5 | 6.1 | 2.30 | 0.10 | 110 | 0.06 | 39 | 1.2 | 21 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 | 3.2 | 24.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| OTAKEME | SAMPLE 1 | 6.5 | 100 | 27 | 110 | 20.6 | 12.6 | 8.0 | 3.20 | 0.16 | 106 | 0.1 | 25 | 0.09 | 20 | 0.15 | 0.00 | 0.00 | 0.01 | 0.01 | 3.9 | 39.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| | SAMPLE 2 | 7.0 | 57 | 25 | 56 | 4.9 | 3.0 | 1.9 | 0.07 | 0.10 | 92 | 0.10 | 15 | 0.28 | 4.8 | 0.15 | 0.01 | 0.05 | 0.00 | 0.00 | 1.5 | 21.1 | 0.00 | 0.00 | 0.00 | 0.00 |
| OPUME | SAMPLE 1 | 6.9 | | 27 | 97 | 18.7 | 10.0 | 8.7 | 2.53 | 0.15 | 100 | 0.6 | 29 | 0.28 | 50 | 0.17 | 0.00 | 0.02 | 0.00 | 0.00 | 2.6 | 26.7 | 0.00 | 0.00 | 0.00 | 0.00 |
| | SAMPLE 2 | 6.8 | 59 | 27 | 99 | 17.7 | 10.0 | 7.7 | 2.49 | 0.10 | 110 | 0.15 | 30 | 0.28 | 21 | 0.15 | 0.00 | 0.01 | 0.00 | 0.00 | 3.1 | 34.2 | 0.00 | 0.00 | 0.00 | 0.00 |

## Table 2: Descriptive Statistics of all the Sampled Locations

| s/n | Parameters | Minimum | Maximum | Mean | Median | Standard deviation | C.V % | WHO (2006) | NSDWQ (2007) |
|---|---|---|---|---|---|---|---|---|---|
| I | Temperature | 25.00 | 30.00 | 27.76 | 27.50 | 3.97 | 6.90 | 27.00 | 27.00 |
| 2 | Ph | 6.40 | 7.I0 | 6.86 | 6.9I | 0.I8 | 36.60 | 6.5-7.5 | 6.5-8.5 |
| 3 | Total dissolved solids | 24.00 | I50.00 | 89.23 | 79.50 | I2.45 | 7.40 | 500 | I000 |
| 4 | Electrical conductivity | 54.00 | II0.00 | 80.60 | 65.00 | II.08 | 7.20 | I80 | I80 |
| 5 | Total Hardness | 4.80 | 2I.20 | I4.57 | I0.50 | 8.42 | I.70 | I00 | I50 |
| 6 | Magnesium | I.80 | 9.00 | 5.63 | 3.50 | 2.40 | 2.50 | 30 | 30 |
| 7 | Iron | 0.10 | 4.20 | I.89 | 0.40 | I.I3 | I.6I | 0.30 | 0.30 |
| 8 | Manganese | 0.00 | 0.20 | 0.06 | 0.0I | 0.35 | 0.I7 | 0.I0 | 0.2 |
| 9 | Sodium | 90.00 | II0.00 | I00.47 | 96.5 | 3.99 | 25.00 | 200 | 200 |
| I 0 | Calcium | 3.00 | I3.I0 | 8.83 | 6.95 | 3.55 | 2.60 | 70 | 70 |
| II | Fluoride | 0.04 | I.20 | 0.30 | 0.08 | 0.28 | I.52 | I.50 | I.50 |
| I2 | Sulphate | 3.50 | 96.00 | I7.69 | I2.50 | I7.04 | I.04 | 200 | I00 |
| I3 | Phosphate | 0.02 | 0.I9 | 0.I2 | 0.08 | 0.05 | 2.4I | 0.05 | 0.05 |
| I4 | Chloride | I0.00 | 39.00 | 23.80 | 2I.50 | I0.I3 | 2.3I | 250 | 250 |
| I5 | Nitrate | 0.00 | 2.70 | 0.96 | I.65 | I.06 | 0.90 | I0 | 50 |
| I6 | Copper | 0.00 | 0.I2 | 0.07 | 0.0I | 0.02 | 3.50 | 0.02 | I.00 |
| I7 | Lead | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.0I |
| I8 | Zinc | I.50 | 4.02 | 2.78 | 3.I5 | 0.86 | 3.30 | 5.00 | 3.00 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| I9 | Silica | I0.0I | 39.I0 | 25.87 | 29.20 | I0.64 | 2.50 | 40 | 40 |
| 20 | Arsenic | 0.00 | 0.I2 | 0.04 | 0.0I | 0.02 | 2.00 | 0.05 | 0.0I |
| 2I | Chromium | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.05 |
| 22 | Ammonia | 0.00 | 0.80 | 0.2I | 0.02 | 0.22 | I.00 | 0.05 | 0.05 |
| 23 | Nitrite | 0.00 | 3.70 | 0.97 | 0.00 | 0.68 | I.40 | I.00 | 0.20 |
| 24 | Cadmium | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.005 | 0.003 |
| 25 | Cobalt | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | I.0 | I.00 |

## Table 3: Correlation Matrix between Major ions in the Study Area



| | PH | EC | TDS | TH | Ca | Mg | Fe | Mn | $NO_3$ | CL | F | $SO_4$ | $PO_4$ | Na | Cu | Zn | Temp | SI | Ar | $N0_2$ | $NH_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | I | | | | | | | | | | | | | | | | | | | | |
| EC | 0.68 | I | | | | | | | | | | | | | | | | | | | |
| TDS | 0.36 | 0.36 | I | | | | | | | | | | | | | | | | | | |
| TH | 0.48 | 0.52 | 0.4I | I | | | | | | | | | | | | | | | | | |
| Ca | 0.5I | 0.50 | 0.3I | 0.9I | I | | | | | | | | | | | | | | | | |
| Mg | 0.43 | 0.45 | 0.45 | 0.9I | 0.79 | I | | | | | | | | | | | | | | | |
| Fe | 0.57 | 0.59 | 0.55 | 0.7I | 0.57 | 0.74 | I | | | | | | | | | | | | | | |
| Mn | 0.I2 | 0.0I | 0.38 | 0.42 | 0.39 | 0.49 | 0.55 | I | | | | | | | | | | | | | |
| $NO_3$ | 0.2I | 0.I4 | 0.30 | 0.33 | 0.23 | 0.32 | 0.I8 | 0.I0 | I | | | | | | | | | | | | |
| CL | 0.II | 0.09 | 0.07 | 0.34 | 0.24 | 0.36 | 0.44 | 0.07 | -0.3I | I | | | | | | | | | | | |
| F | 0.26 | -0.20 | -0.01 | -0.02 | -0.II | -0.02 | 0.I5 | 0.I8 | -0.I3 | 0.38 | I | | | | | | | | | | |
| $SO_4$ | 0.09 | -0.24 | 0.09 | -0.28 | -0.34 | -0.26 | -0.I6 | -0.23 | -0.35 | 0.I8 | 0.77 | 1 | | | | | | | | | |
| $PO_4$ | 0.32 | 0.II | 0.2I | 0.0I | 0.06 | 0.01 | 0.I9 | 0.01 | -0.I9 | 0.35 | 0.32 | 0.09 | 1 | | | | | | | | |
| Na | 0.18 | 0.28 | -0.02 | 0.33 | 0.28 | 0.31 | 0.41 | 0.08 | -0.33 | 0.68 | 0.35 | -0.16 | 0.37 | 1 | | | | | | | |
| Cu | 0.31 | 0.26 | 0.20 | 0.41 | 0.39 | 0.33 | 0.27 | 0.06 | 0.82 | -0.08 | 0.06 | -0.21 | 0.01 | -0.08 | 1 | | | | | | |
| Zn | 0.48 | 0.29 | 0.37 | 0.45 | 0.28 | 0.51 | 0.50 | 0.50 | 0.50 | 0.20 | 0.51 | 0.17 | 0.15 | -0.28 | 0.22 | 1 | | | | | |
| Temp | 0.31 | 0.46 | 0.43 | 0.45 | 0.27 | 0.43 | 0.45 | -0.09 | 0.29 | 0.35 | 0.31 | 0.12 | 0.22 | 0.21 | 0.28 | 0.47 | 1 | | | | |
| SI | 0.36 | 0.10 | 0.22 | 0.13 | 0.01 | 0.18 | 0.22 | 0.06 | -0.03 | 0.38 | 0.08 | 0.10 | 0.19 | 0.18 | -0.13 | 0.24 | 0.15 | 1 | | | |
| Ar | 0.36 | 0.21 | -0.06 | 0.23 | 0.12 | 0.28 | 0.35 | 0.12 | 0.57 | -0.08 | 0.05 | -0.17 | -0.09 | -0.12 | 0.49 | 0.38 | 0.20 | 0.07 | 1 | | |
| $N0_2$ | 0.28 | 0.29 | 0.19 | 0.38 | 0.34 | 0.33 | 0.41 | 0.19 | 0.58 | 0.01 | 0.08 | -0.19 | -0.27 | -0.14 | 0.62 | 0.32 | 0.25 | -0.11 | 0.55 | 1 | |
| $NH_3$ | 0.14 | 0.14 | 0.21 | 0.13 | -0.01 | 0.17 | 0.33 | 0.21 | 0.20 | -0.04 | 0.27 | -0.10 | -0.20 | -0.07 | 0.09 | 0.04 | 0.22 | -0.06 | 0.24 | 0.32 | 1 |

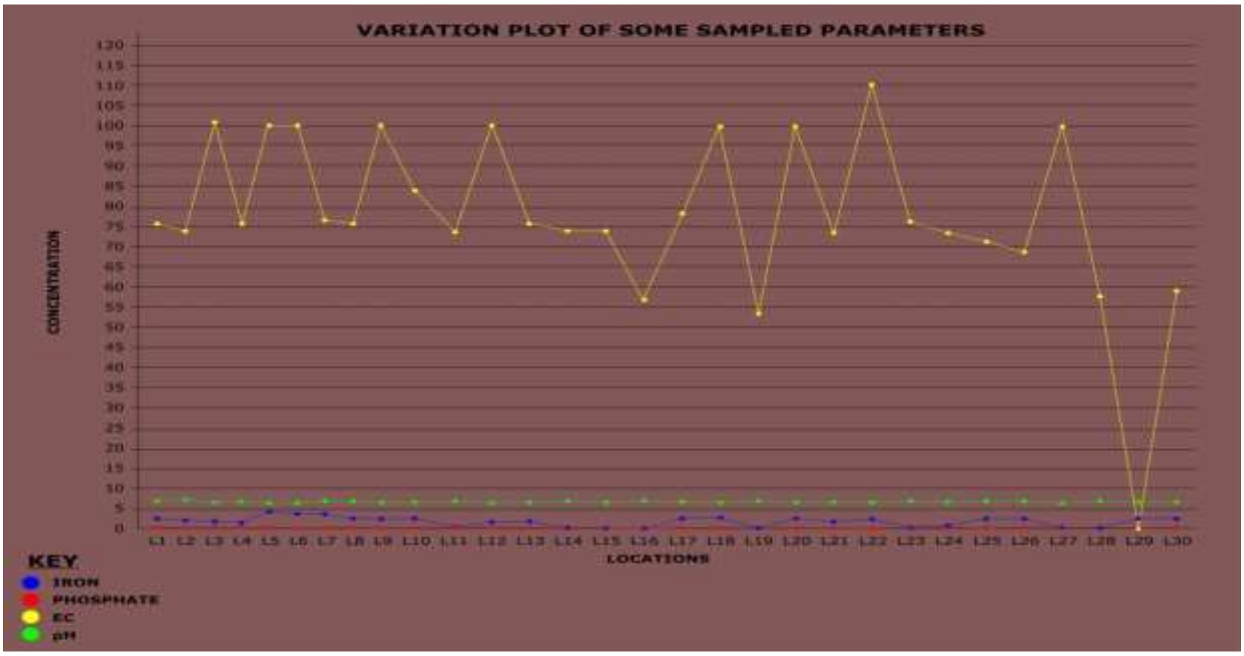


Fig. 3: The variation plot of some sampled parameters in the study area

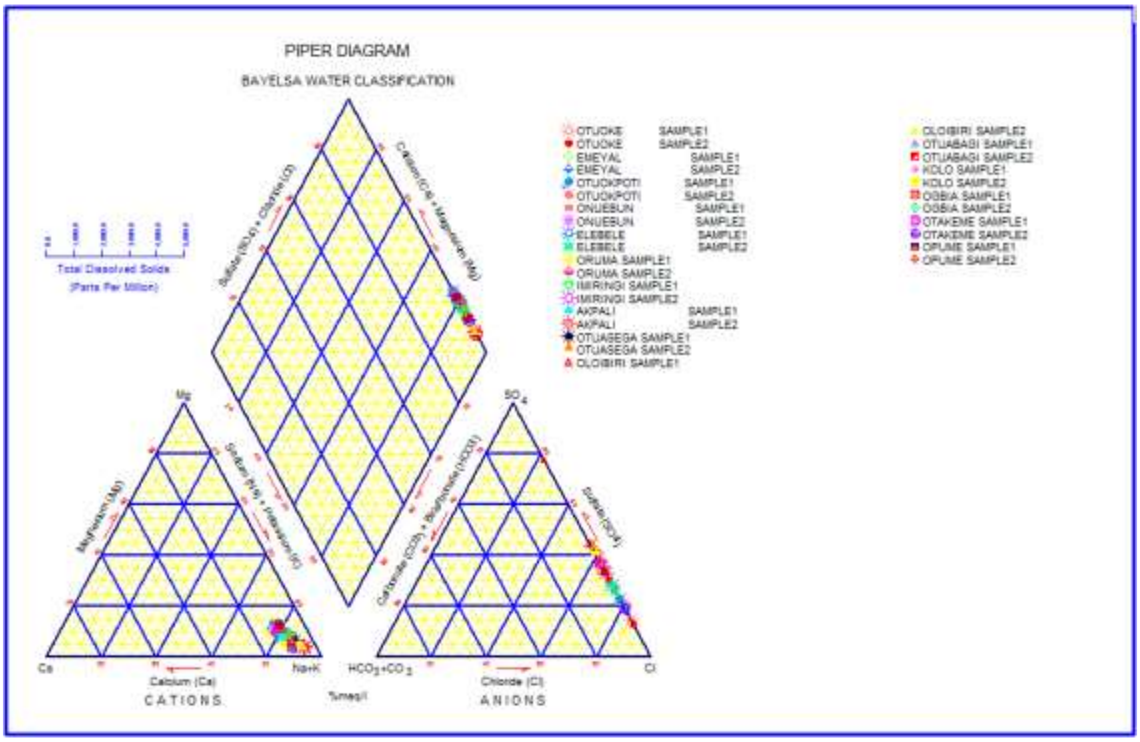


Fig. 4: Piper Trilinear diagram of the water Samples in the Study Area

## CONCLUSION

The results of the study showed that all the chemical parameters are within the WHO (2006) permissible limit for drinking water with the exception of iron, phosphate and copper which are above the WHO permissible limit. The result of the investigation revealed that the groundwater in the area consist of mainly of fresh water. This is seen in the low values of calcium, magnesium and chloride which are all below the WHO standard for drinking water. This means that there are no traces of salt water intrusion.

However, the study shows poor quality of ground water in most sampled locations. This is demonstrated in the high values of Iron, phosphate and electrical conductivity and also slightly acidic as indicated in the pH values. Based on these, the water will always have objectionable tastes and could stain plumbing materials. The water requires treatment for these parameters to make it potable. The ground water in the area is slightly acidic, based on this, poly vinyl chloride (PVC) materials and other non-corrosive materials should be used for borehole installations, because acidic water can be aggressive. Based on the result from this study, there is the need for regular ground water quality monitoring and effective management strategies in the area.

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