Investigative study of seasonal changes in Quality Parameters of Oluwa River Water, Agbabu area of Nigeria

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Abstract— *Physico-chemical parameters of River Oluwa water in Agbabu, Nigeria were investigated to determine its quality characteristics and establish seasonal effects on the water. Water from the river was collected at five different points in dry season (March, 2008 and 2009) and rainy season (July, 2008 and 2009). Insitu parameters (pH, EC and Turbidity) were measured using Horiba Water Checker Model U-10 while TDS was by Lovibond CM – 21 Tintometer. Subsequently in the Laboratory, Na^+ and K^+ were determined using flame photometric methods while Ca^{2+}, Mg^{2+}, HCO_3^-, SO_4^{2-}, Cl-, PO_4^{2-} and NO_3^- were determined by wet analysis. River Oluwa water was alkaline with average pH of 7.41 and 7.53 in dry and rainy seasons respectively. Electrical conductivity (EC) was high during dry season (av. 630.44 µS/cm), but low in the rainy season (av. 317.58 µS/cm) due to long residence time in dry season allowing more water-rock interaction. Turbidity's average values of 0.14 NTU and 2.29 NTU in dry and rainy seasons respectively suggested moderate pollution with particulate matter. The order of average cations concentrations in the dry and rainy seasons was $Ca^{2+} > K^+ > Na^+ > Mg^{2+}$ while that of the anions was $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^-$. The ions concentrations though lower in rainy season, Ca^{2+}-HCO_3^- water was dominant in both seasons. Quality evaluation for irrigation revealed that the water was suitable for all irrigation purposes. River Oluwa water was soft, low mineralized, chemically potable, suitable for irrigation but with lower ionic concentrations in rainy season.*

Keywords— ***Insitu parameters, wet analysis, electrical conductivity, alkaline, low mineralized, irrigation.***

I. INTRODUCTION

Over 400 inhabitants of Agbabu and it's env iron depend on the Oluwa River for their daily usage for domestic and farming activities. The quality of river water in a place is mostly influenced by both geogenic processes (such as precipitation rate, weathering and soil erosion) and anthropogenic activities (i.e. urban, industrial and agricultural activities and the human improper management of river water system) (Liao et al., 2007; Manjappa et al., 2008; Nirmal et al., 2009). The water quality characteristics also depend upon the chemical composition of natural water in the study area (Shetty et al., 2013).

Bitumen (in tar sands), which is also in combination of clay, sand and water is found in the study area. The bitumen in tar sands cannot be pumped from the ground in its natural state; instead tar sand deposits are mined, usually using strip mining or open pit techniques or the oil is extracted by underground heating with additional upgrading. History has it that water in the southern part of Agbabu town were contaminated due to loading and discharging of petroleum products which started a decade ago (Fagbote and Olanipekun, 2010). The seepage of bitumen, a natural resource found in abundance in the Nigerian Dahomey belt is gradually becoming a source of concern due to contamination of surface waters and soil. Even small amount of bitumen can spread rapidly across large areas of water because of the immiscibility of the product with water.

Clearly, coastal pollution has the capabilities to disrupt life in the coastal environment and by extension the planet earth to a great extent. In addition, temporal changes of river contamination attributed to natural or anthropogenic inputs like agricultural wastes, domestic wastewaters and waste products from loading activities of petroleum products could aid development of bacteria that could lead to bio-degradation of bitumen. Adesanya et al., (2014), worked on isolating and identifying bacterial species from bitumen contaminated sites in Ondo State, Nigeria and concluded that Pseudomonas aeruginosa had the greatest ability to degrade diesel while Staphylococccus aureus had the least capacity.

Naturally, the presence of River Oluwa and bitumen in the area has led to increased population and by extension anthropogenic activities. Consequently, physico-chemical parameters of River Oluwa water in Agbabu community were investigated during dry seasons (February, 2013 and 2014) and rainy season (July 2013 and 2014) to ascertain the level of contamination and the effects of seasonal variations on the water' quality.

II. GEOLOGY AND LOCATION OF STUDY

Agbabu is located on latitude 6° 35' 19" N and longitude 4° 50' 03" E in Ondo State of Nigeria (Fig. 1). It has tropical climate with two distinct seasons; the wet season (April - October) and the dry season (November - March). The study area has elevations that range from 50 – 250m while the annual rainfall ranged between 1000 mm and 1500 mm (Ogunribido and Kehinde – Philips, 2011). Geologically, the area is part of the Dahomey sedimentary basin that lies unconformably on the Basement Complex. Shales and sandstones constitute the major rock units while the minor rocks are mainly limestones and unconsolidated sediments with age range of Albian to recent (Omosuyi, 2001). The stratigraphic sequence of Dahomey Basin comprises of horst and graben that are filled with Ise, Afowo and Araromi formation gently dipping cretaceous formation (Omatsola andAdegoke, 1981).

III. MATERIALS AND METHOD

The sampling operations in this study came up in the dry and rainy seasons of 2013 and 2014. Water samples were collected at five different points along River Oluwa in Agbabu community Ondo State, Nigeria (Fig. 1) in dry season (February 2013) and rainy season (July 2013). The same sampling operations were repeated in the dry season (February 2014) and the rainy season (July 2014). The samples were collected in duplicate from each location in both seasons for cations and anions determinations following standard methods (APHA, 1998). Prior to sampling at each location in the two seasons, pH, EC and Turbidity were determined were measured using Horiba Water Checker Model U-10 while TDS was by Lovibond CM – 21 Tintometer.

3.1Analytical Procedures

The river water samples were analyzed using standard techniques (APHA, 1998). The river water samples obtained from different sampling points (Figure. 1) were kept in plastic bottles and stored in an icebox jars to prevent alterations in physico-chemical properties of the water during transportation to the laboratory. In the Laboratory, Na^+ and K^+ were determined using flame photometric methods while Ca^{2+}, Mg^{2+}, HCO_3^-, SO_4^{2-}, Cl-, PO_4^{2-} and NO_3^- were determined by wet analysis. Average concentrations of physico-chemical parameters for the dry seasons (February 2013/2014) and rainy seasons (July 2013/2014) were calculated and compared with approved standard values for drinking water (WHO, 2011).

In this study, apart from appraising the absolute values of ions for irrigation purpose, few irrigation parameters including pH, alkalinity, sodium percent (Na%), sodium adsorption ratio (SAR), magnesium absorption ratio (MAR), and Kelly ratio (KR) were estimated to ascertain the suitability of River Oluwa water for irrigation.

3.1.1 Sodium Percent (SP):

Sodium Percent (SSP) is an index defined as the ratio of sodium to the total cation expressed as:

$$SP = \frac{Na^+ \times 100}{Ca^{2+} + Mg^{2+}\ Na^+ + K^+} \quad \text{(Wilcox, 1955)} \qquad (1)$$

Where, all the ionic concentrations are expressed in meq/L.

3.1.2 Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio is a measure of salinity hazard that easily measures property that gives information on the comparative concentrations of Na^+, Ca^{2+}, and Mg^{2+} in soil solutions. Sodium adsorption ratio is computed as:

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

(2)

All ionic concentration is in meq/L.

3.1.3 Magnesium Absorption Ratio (MAR):

It is expressed as

$$MAR = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \qquad (3)$$

All ionic concentration is in meq/L.

3.1.4 Kelly Ratio

The hazardous effect of sodium on water quality for irrigation usage in terms of Kelly's ratio (KR) was computed as stipulated by Kelly (1940);

$$\text{Kelly Ratio (KR)} = Na^+/Ca^{2+} + Mg^{2+} \qquad (4)$$

The SP was plotted against conductivity to obtain Wilcox diagram.

Data from this study was subjected to statistical evaluation employing Microsoft excel 2007. Graphical plots were carried out using SPSS 16 except Piper diagram that was plotted employing GW – Chart.

IV. RESULTS AND DISCUSSION

Summary statistics of the two years average concentrations of physico-chemical parameters and irrigation quality indices of River Oluwa water are presented in Table 1 while Table 2 represents its average physico-chemical parameters for the two seasons (dry and rainy) of 2013 and 2014.

Results in this study revealed that the turbidity varied between 0.00 – 1.33 NTU (av.0.34 NTU) during dry season and 0.00 – 4.34 NTU (av. 1.91 NTU) during rainy season respectively (Table 1). The lower average values of turbidity during dry season imply cessation of the surface runoff which led to the settling of suspended matter. The turbidity values in rainy season were found to be above permissible limit (0.3 NTU) suggested by WHO for drinking water in 80% of samples whereas only 40% samples exceeded the value in dry season. Turbidity and suspended solids are major parameters when considering the mobility and bioavailability of contaminants (Hannouche, et al., 2011). Turbidity can be influenced by silt and clay partciles, organic matter, and plankton in river water. Mobility of contaminants was high in the rainy season season due to high turbidity.

The average pH values varied between 6.52 – 8.11 (av. 7.59) during dry season and 7.25 – 8.14 (7.56) during rainy season (Table 1). Only one sampling location has average pH<7 i.e pH of 6.52. Therefore River Oluwa's water was alkaline and the relatively high pH values in rainy season were due to dilution from rain water (fresh water input), low temperature and organic matter decay (Trivedy, 1984; Adefemi et al., 2007). The average pH values for both seasons fell within the acceptable WHO standard range of 6.50 - 8.50. Acidity levels higher than 7 revealed an increasing level of alkalinity in the solutions. The acidity levels of river water have impact on the solubility of many poisonous and nutritive chemical compounds and consequently would affect the availability of these constituents to aquatic organisms.

The average levels of electrical conductivities (EC) varied between 110.21 – 3028.75 µS/cm (av. 630.44 µS/cm) during dry season and 50.92 – 1636.34 µS/cm (av. 317.58 µS/cm) during rainy season (Table 1). The average level of electrical conductivity (EC) was high during dry season, but low in the rainy season as there was long residence time in dry season allowing more water-rock interaction. Water with EC<1000 µS/cm is fresh water (Freeze and Chery, 1979). Oluwa water was fresh except in two locations (WD1 and WR1) with values greater than 1000 µS/cm. In the oceanographic conditions, the change of conductivity is mostly controlled by temperature (Shetty et al., 2013). The electrical conductivities test measure the ability of water to transmit an electric current. This largely depends on the number of ions or charged particles available within the water system (WHO, 2011). Many salts dissolve easily in water at high temperature leading to increased electrical conductivity. Electrical conductivity is measured by the electrical potential of ions in solution which depends on available concentrations charges as well as their mobility. Ionic mobility depends on viscosity which also is dependent on temperature (Barron and Ashton, 2016). The average temperature of River Oluwa was 24.97 °C ± 0.03 (Ayandiran et al., 2014). This temperature is ambient and as such temperature had no significant influence on the conductivity of Oluwa River water.

The calculated average TDS in the dry seasons (2013 and 2014) varied between 78.29 and 2031.46 mg/L while in the rainy seasons of the same years, the range was 35.17 – 368.29 mg/L (Table 1). The statistical average TDS for dry and rainy seasons were 427.16 and 93.14 mg/L respectively. The TDS result trend followed a comparable pattern as EC. Total dissolved solids obtained for all seasons fall within maximum desirable limits recommended by WHO which is 600 mg/L. The TDS mostly illustrate the occurrence of different kinds of chemical compound like ammonia, nitrite, NO_3^-, PO_4^{3-}, alkalis, some acids, SO_4^{2-} and metallic ions etc. These comprises of both colloidal and dissolved solids in water. It is also an essential chemical property of water (Kabir et al., 2002).

Dissolved oxygen (DO) concentration is controlled by the source, temperature, treatment and chemical or biological processes occurring in the distribution system. In the river system with high rates of respiration and organic decomposition, the DO values typically remain lower than the system where the rate of photosynthesis is high (Mishra et al., 2009). Dissolved oxygen varied between 4.76 – 9.69 mg/L (av. 6.87 mg/L) and 4.40 – 7.39 mg/L (av. 5.13 mg/L) during dry and rainy seasons respectively. No health-based guideline value is recommended (WHO, 2011). Dissolved oxygen content show higher values during dry season suggesting increase amounts of organic matter caused by anthropogenic inputs from the surrounding areas. This agreed with available data in the literature (Vaishali and Punita, 2013). Pollution of water with enormous amount of organic matter would consume great amount of dissolved oxygen during biological aerobic decay which would alter the water quality, reduced DO and ultimately affect the aquatic lives (Chhatwal, 2011). In this study, biological oxygen demand (BOD) varied between 1.56 – 10.55 mg/L during dry season and 1.66 – 4.84 mg/L during rainy season respectively (Table 1). The average BOD for dry and rainy seasons were 5.08 mg/L and 3.13mg/L respectively indicating moderately polluted river water. The variation in BOD followed a similar pattern as DO. High BOD levels suggest reduction in dissolved oxygen content because the available oxygen is being used by the bacteria which pose danger to survival of fish and other aquatic organisms (Vaishali and Punita, 2013).

Calcium ion concentration ranged between 8.44 – 17.94 mg/L (av. 11.35 mg/L) during dry season and 2.96 – 9.29 mg/L (av. 5.20mg/L) during rainy season (Table 1). The

Ca^{2+} concentrations were below permissible limit of 75 mg/L (WHO, 2011). Magnesium ion concentrations varied between 0.59 and 4.64 mg/L (av. 1.74 mg/L) during dry season and from 0.74 – 2.77 mg/L (av. 1.35mgL) during rainy season. The concentrations of Mg^{2+} fell within the approved maximum desirable limit of 30 mg/L (WHO, 2011).

Water hardness is the amount of dissolved calcium and magnesium in the water and is the traditional measure of the capacity of water to react with soap, hard water requiring considerably more soap to produce lather. Water containing calcium carbonate at concentrations below 60 mg/L is generally considered as soft; 60–120 mg/L, moderately hard; 120–180 mg/l, hard; and more than 180 mg/L, very hard (McGowan, 2000). The values of hardness varied between 22.32 – 63.42 mg/L during dry season and 10.19 – 34.19 mg/L during rainy season (Table 1) signifying that River Oluwa water was soft except in only one location (WD1) with TH (63.42) which is slightly greater than 60mg/L. The total hardness of water is comparatively high if Ca^{2+}, Mg^{2+}, Cl^{-} and SO_4^{2-} ions are present (Lalitha et al., 2004). High concentration of Ca^{2+} and Mg^{2+} in river water is attributed to the seepage of effluent and domestic wastes or cationic exchange with Na^{+}. Nonetheless, low hardness values with presence of pollutants may be ascribed to the cationic exchange with sodium (Lalitha et al., 2004).

Sodium ion concentration ranged between 4.72 and 9.67 mg/L (av. 6.18 mg/L) during dry season while it ranged from 1.57 – 4.44 mg/L (av. 2.43 mgL) in the rainy season. A maximum permissible Na^{+} concentration in drinking water is 50 mg/L (WHO, 2011). All Na^{+} concentrations fell below this value in this study and as such River Oluwa water does not constitute threat with respect to Na^{+} concentrations. Increase in Na^{+} concentrations in water could arise due to human activities like discharges from water softness, human or animal waste disposal, etc. (Barot and Patel, 2014). Potassium ion concentrations varied from 2.51 – 10.77 mg/L (av. 6.58 mg/L) during dry season and 1.58 – 8.80 mg/L (av. 3.16 mg/L) during rainy season. Potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans (WHO, 2011).

Bicarbonate ion concentrations ranged from 28.9 – 48.40 mg/L (av. 38.18 mg/L) during dry season and 24.20 – 39.20 mg/L (av.30.44 mg/L) during rainy season (Table1). Seasonal variations of bicarbonate revealed higher concentration during dry season than rainy season indicating that there was longer period of time for water – rock interactions to take effects which obviously resulted into breakdown of the minerals components of the rocks in the river system. The most plausible explanation of the bicarbonate in River Oluwa water was from flow of bicarbonate ions from rocks weathered by the carbonic acid in rainwater. Bicarbonate has been useful in human health as it serves much in the digestive system as it raises the internal pH of the stomach, after highly acidic digestive juices have finished in the digestion of food (Merritts et al., 1998). Sulphate ion concentration ranged between 1.25 and 13.26 mg/L (av. 5.05 mg/L) during dry season while it was from 0.80 – 2.43 mg/L (1.51 mg/L) during rainy season. Seasonal variations in sulphate revealed higher concentration during dry season than rainy season indicating discharge of domestic sewage into Oluwa River water. Similar results pattern were reported during summer in the Chehelchey River, Golestan province, Iran (Zare Garizi et al., 2011). Nevertheless, the sulphate concentration for all the locations fell within the permissible limits (250 mg/L) recommended by WHO (2011). The other major anions; Cl^{-} and NO_3^{-} have concentrations that ranged from 5.80 – 67.49 mg/L (av. 19.87 mg/L) and 0.05 – 0.90 mg/L (av. 0.34 mg/L) respectively in the dry season. In the rainy season Cl^{-} concentrations ranged between 2.82 and 536.38 mg/L (av. 110.43 mg/L) while NO_3^{-} was from 0.12 – 0.31mg/L (av. 0.18 mg/L). Phosphate ion concentration ranged between 0.00 and 0.56 mg/L during dry season while it ranged from 0.08 – 0.27 mg/L during rainy season. The average concentration for dry and rainy season was 0.25 mg/L and 0.18 mg/L respectively. Phosphate ion has higher content during dry season than rainy season. This is ascribed to indiscriminate discharge of domestic sewage into the river from surrounding areas and reduction in dilution rate compared with rainy season. The order of average cations concentrations in the dry and rainy seasons was $Ca^{2+} > K^{+} > Na^{+} > Mg^{2+}$ while that of the anions was $HCO_3^{-} > Cl^{-} > SO_4^{2-} > NO_3^{-}$. The ions concentrations were low in both seasons with rainy season recording lower concentrations. Generally, River Oluwa water was soft, low mineralized and chemically potable.

4.1 River Oluwa water classification

Schoeller and Piper digrams were employed in the classification of River Oluwa water. Both Schoeller and Piper diagrams permit the cation and anion compositions of many samples to be represented on a single graph in which major groupings or trends in the data can be discerned visually (Freeze and Cherry, 1979). The Schoeller semi logarithmic diagram shows the total concentrations of the cations and anions (Schoeller, 1955) while a Piper diagram is a graphical representation of the chemistry of a water sample or samples (Piper, 1944). The cations and anions are shown by separate ternary plots. The apexes of the cation plot are calcium, magnesium and sodium plus potassium cations. The apexes of the anion plot are sulfate, chloride and carbonate plus bicarbonate anions. The two ternary plots are then projected up onto a diamond. The diamond is a matrix transformation of a graph of the anions and cations. In Piper diagrams the concentrations are expressed as %meq/L. In this study, the Schoeller diagram is presented in Figure 2 while the Piper diagram is in Figure 3. The Schoeller diagram revealed the dominance of Ca^{2+} and Na^{+} as cations while HCO_3^- and Cl^- dominated the anions. Thus, Ca^{2+}-HCO_3^- water type was predominant in River Oluwa water. The Piper diagram discriminated the dry season water from the rainy season. It clearly revealed four water types; Ca^{2+}-HCO_3^- type representing 58% of the sampled water, mixed Ca^{2+}-Mg^{2+}-Cl^- water type covering 25% while each of the mixed Ca^{2+}-Na^{+}-HCO_3^- and Ca^{2+}-Cl^- types had 8.33% representation. The influence of rainfall was obvious as five water samples plotted in the Ca^{2+}-HCO_3^- type in the rainy season as against three samples in the dry season.

4.2 Irrigation evaluation of River Oluwa's water

The primary goal of water analysis is to judge the effect of the water on the soil and ultimately on the plants grown on the soil. Thus, much of the interpretation of the water analysis is based on a prediction of the consequences on the soil. The interpretation of the test results is, in many cases, dependant on the intended use of the water as some plant species have much different tolerance levels.

The pH in this study ranged from 6.52 – 8.47 in dry season and 7.25 – 8.14 in the rainy season. The normal pH range for irrigation water is 6.5 – 8.4 (Bauder et al., 2010). When the pH is outside of this range, it indicates that special actions may need to be taken to improve crop performance. Based on pH, River Oluwa water is suitable for irrigation both in the dry and rainy seasons. Employing absolute concentrations of ions, the maximum permissible limit of Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} in irrigation water is 80, 35, 200 and 30 mg/L respectively(Duncan et al., 2000 and Sharifi and Safari Sinegani 2012). The listed cations have concentrations that fall within the maximum permissible limits and River Oluwa water is considered suitable for irrigation in both dry and rainy season. Considering the anions, the maximum permissible limit of HCO_3^-, Cl^- and SO_4^{2-} in irrigation water is 250, 250 and 180 mg/L respectively (Duncan et al., 2000; SAI, 2010; Sharifi and Safari Sinegani, 2012). According to the grading standards all the water samples are suitable for irrigation usage with respect to HCO_3^-, Cl^- and SO_4^{2-} respectively. For example, the mean concentrations of HCO_3^- in dry and rainy seasons were 36.88 mg/L and 30.18 mg/L respectively. The mean HCO_3^- content of River Oluwa water was low compared to the maximum permissible standard and the water is suitable for irrigation. However, the fact that the absolute concentration of ions by itself is not enough for assessing suitability of ions for irrigation usage, other irrigation parameters that take into consideration the effects of interactions among the ions are presented below.

Water salinity is a measure of the total dissolved salts and several hazards could arise from the use of saline water for irrigation. In the first instance, saline water will increase the salinity of soil. Subsequently, plants will have increasing difficulty absorbing water. Excess Na has been reported to be the primary cause of water salinity as Na accumulates in the soil; it can compete with other nutrients for uptake by the plants and may become directly toxic. Soil structures are lost and permeability is significantly reduced leading to poor plant growth due to the dispersion of the clay particles (Todd, 1980) and reduces the plant growth. Excess salinity reduces the osmotic activity of plants (Subramani et al., 2005). Sodium replacing adsorbed calcium and magnesium is a hazard, as it causes damage to the soil structure resulting in compact and impervious soil (Arveti et al., 2011). One of the most important criteria in determining sodium hazard is sodium adsorption ratio (SAR) (Todd and Mays, 2005). The SAR in River Oluwa water samples ranged between 0.36 and 0.52 (av. 0.45) in the dry season and from 0.12 – 0.60 (av.0.27) in the rainy season. Lower salinity was recorded during rainy season which may be ascribed to enormous volumes of freshwater inflow. This would ultimately lead to water dilution and salinity reduction (Prasad and Patil, 2008). The salinity of water reveals the existence of ionic constituents that may come from the reaction of metals and acids in the water (Shetty et al., 2013). The SAR values of the River oluwa water samples were less than 10 and are classified as excellent for irrigation (Richards 1954) irrespective of the season. When we have water with a Sodium Percentage greater than 60%, it can cause a breakdown in the soil's physical properties (Khodapanah et al., 2009). The sodium percentage values of the water samples from the study area varied from 17.28 to 28.58% with an average value 22.28 % in the dry season while in the rainy season it was from 6.63 – 42.84% with an average value 21.36%. All SP values of River Oluwa water were less than 60% and the water was suitable for irrigation.

Sodium percentage is plotted against conductivity ((Wilcox, 1955), which is designated as Wilcox diagram and is illustrated in Figure 4. The figure clearly revealed that 10 samples (5each from dry and rainy season) fell into excellent to good irrigation water. Out of the remaining two samples, one rainy season sample fell into good to permissible irrigation class while the remaining one dry season sample was in unsuitable class. The plotting clearly indicated that River Oluwa water was suitable for irrigation. An equilibrium state is maintained by Ca^{2+} and Mg^{2+} in most waters (Nagaraju et al., 2014). However, when there is more magnesium in water, the crop yield is adversely affected due to poor soils' quality. High Mg ratio in the ground water samples leads to surface and subsurface water interact with country rock (Pandian and Sankar, 2007).The magnesium ratio in River Oluwa water samples varied from 10.17 to 58.59 (av. 24.5) in the dry season while it ranged between 25.17 and 50.27 (av. 32.91) in the rainy season (Table 3). From the above table, the Magnesium ratios were found to be less than the permissible limit (50) in all water sample locations (Paliwal, 1972). A Kelly's ratio of more than one indicates excessive sodium in water. Therefore, water with a Kelly's ratio less than one are suitable for irrigation, while those with a ratio more than one are unsuitable. From the Table 3, it is observed that the Kelly's ratio for all water samples were less than 1 except for the control sample. Thus, River Oluwa water is suitable for irrigation.

V. CONCLUSIONS

Seasons had effects on ionic concentrations of River Oluwa water with rainy season recording lower values except chloride ion with lower value in dry season. All considered physico-chemical parameters of River Oluwa water fell within WHO maximum desirable limits for drinking water. The BOD and turbidity values suggest moderately polluted surface water but the dry season recorded increased amount of contaminants. The dominant water type was Ca^{2+}-HCO_3^- water followed by mixed Ca^{2+}-Mg^{2+}-Cl^- water type while each of the mixed Ca^{2+}-Na^+-HCO_3^- and Ca^{2+}-Cl^- types had equal representation. All estimated irrigation parameters indicated that River Oluwa water was in the excellent to good category for irrigation.

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Table.1: Summary of Average values of Physico – chemical and Irrigation parameters of River Oluwa Water

	Dry Season (n = 10)				Rainy Season(n = 10)				WHO
Parameters	Min	Max	Mean	Stdev	Min	Max	Mean	Stdev	(2011)
PH	6.52	8.11	7.41	0.58	7.25	8.14	7.53	0.36	6.50 - 8.50
EC (µS/cm)	110.21	3028.75	701.99	1300.72	50.92	1636.34	370.25	707.78	
TDS (mg/L)	78.29	2031.46	474.46	870.41	35.17	368.29	103.97	147.78	600
Turbidity (NTU)	0.00	0.34	0.14	0.15	0.67	4.34	2.29	1.33	0.3
TH (mg/L)	22.32	63.42	35.00	16.26	10.19	34.19	17.22	9.64	
BOD	1.56	10.55	5.08	4.79	1.96	4.84	3.13	1.27	
DO	4.76	9.69	6.87	2.00	4.40	7.39	5.13	1.28	-
Ca (mg/L)	8.44	17.94	11.35	3.88	2.96	9.29	5.20	2.42	75
Mg (mg/L)	0.59	4.64	1.74	1.69	0.74	2.77	1.35	0.82	30
Na (mg/L)	4.72	9.67	6.18	2.03	1.57	4.44	2.43	1.24	50
K (mg/L)	2.51	10.77	6.58	2.97	1.58	8.80	3.16	3.16	-
HCO_3^- (mg/L)	28.90	48.40	38.18	7.74	24.20	39.20	30.44	5.47	-
SO_4^{2-} (mg/L)	1.25	13.26	5.05	5.28	0.80	2.43	1.51	0.62	250
Cl^- (mg/L)	5.80	67.49	19.87	26.66	2.82	536.38	110.43	238.11	250
NO_3^- (mg/L)	0.05	0.90	0.34	0.33	0.12	0.31	0.18	0.08	50
PO_4^{3-} (mg/L)	0.00	0.56	0.25	0.22	0.08	0.27	0.18	0.08	

Table.2: Physico – chemical parameters of River Oluwa's Water

Parameters	Dry Season (n = 10)					Rainy Season (N = 10)				
	WD1	WD2	WD3	WD4	WD5	WR1	WR2	WR3	WR4	WR5
PH	8.11	7.59	7.28	7.54	6.52	8.14	7.39	7.56	7.25	7.29
EC	3028.75	110.21	118.17	119.17	133.67	1636.34	52.38	50.92	59.38	52.21
TDS	2031.46	78.29	83.29	84.17	95.09	368.29	37.67	35.17	41.63	37.09
Turbidity	0.00	0.34	0.00	0.17	0.21	0.67	4.34	1.92	2.50	2.04
TH	63.42	22.32	27.84	31.57	29.84	34.19	10.19	13.45	14.81	13.44
BOD	1.56	10.55	10.10	1.61	1.59	4.12	4.84	2.33	1.96	2.41
DO	9.69	5.71	6.07	8.14	4.76	4.44	7.39	4.40	4.51	4.91
Ca	17.94	8.44	9.67	11.63	9.05	9.29	2.96	4.46	4.12	5.15
Mg	4.64	0.59	0.87	0.79	1.82	2.77	0.74	0.90	1.15	1.18
Na	9.67	5.03	5.22	4.72	6.26	1.57	4.44	1.65	1.68	2.82
K	10.77	6.95	6.98	5.70	2.51	8.80	1.58	1.76	1.92	1.72
HCO_3^-	48.40	38.60	28.90	42.40	32.60	39.20	28.80	24.20	30.60	29.40
SO_4^{2-}	7.50	1.88	1.38	1.25	13.26	1.75	1.24	1.32	2.43	0.80
Cl^-	67.49	5.80	8.01	8.23	9.84	536.38	3.69	2.82	4.95	4.31
NO_3^-	0.90	0.20	0.05	0.21	0.36	0.31	0.12	0.15	0.16	0.14
PO_4^{3-}	0.00	0.125	0.39	0.557	0.195	0.185	0.11	0.237	0.27	0.08

Table.3: Irrigation parameters of River Oluwa water

Code	Dry Season				Code	Rainy Season			
	SAR	SP	MAR	KR		SAR	SP	MAR	KR
WD1	0.52	20.71	30.12	0.86	WR1	0.12	6.63	33.20	0.38
WD2	0.45	24.29	10.44	0.57	WR2	0.60	42.84	29.41	1.37
WD3	0.43	22.82	13.04	0.54	WR3	0.19	16.96	25.17	0.40
WD4	0.36	20.02	10.17	0.42	WR4	0.19	16.87	31.75	0.45
WD5	0.50	28.58	25.10	0.75	WR5	0.29	23.11	27.63	0.57
Min	0.36	17.28	10.17	0.42	Min	0.12	6.63	25.17	0.38
Max	0.52	28.58	58.59	1.48	Max	0.60	42.84	50.27	1.37
Mean	0.45	22.28	24.58	0.77	Mean	0.27	21.36	32.91	0.66
Stdev	0.06	3.91	18.59	0.38	Stdev	0.17	12.01	8.98	0.38

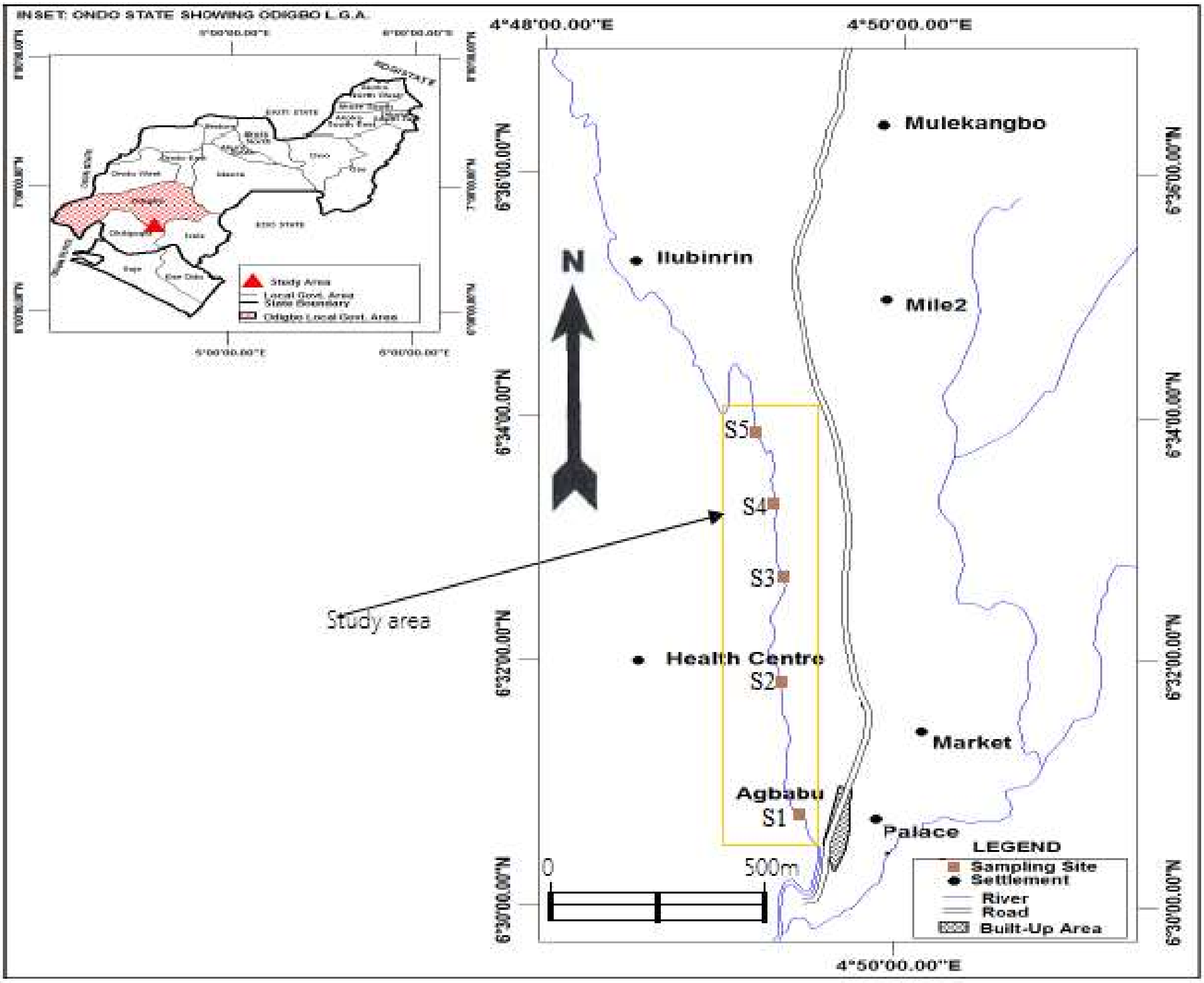

Fig.1: Location of study (Modified after Abatyough et al., 2016)

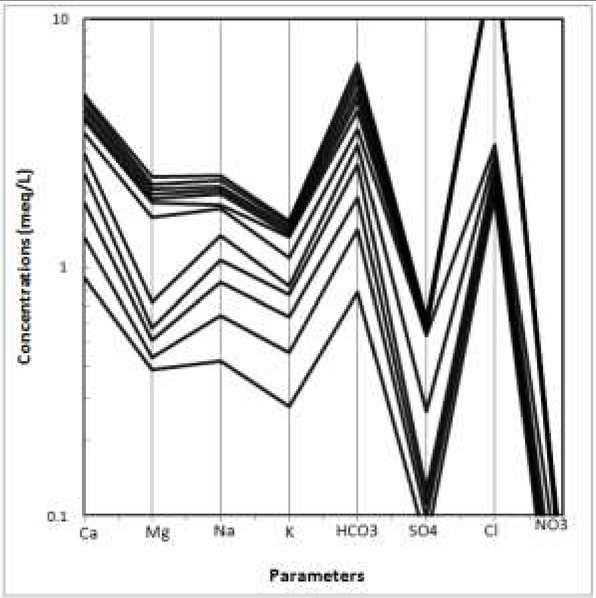

Fig.2: Schoeller Diagram of River Oluwa's water samples

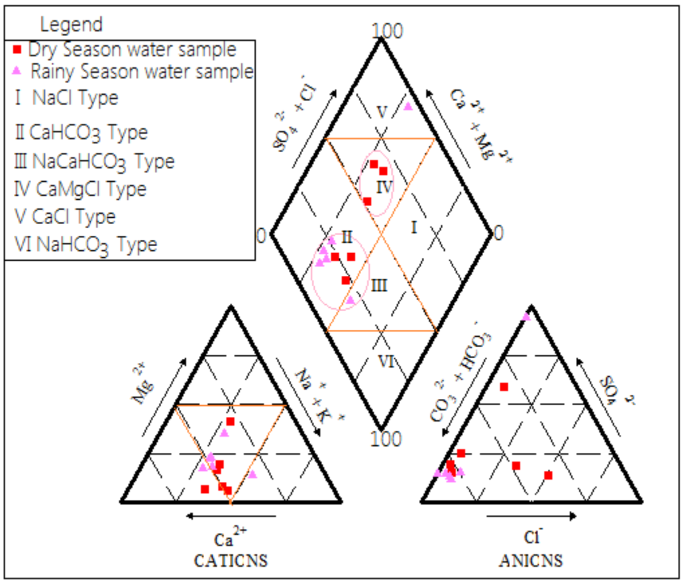

Fig.3: Piper Trilinear Diagram

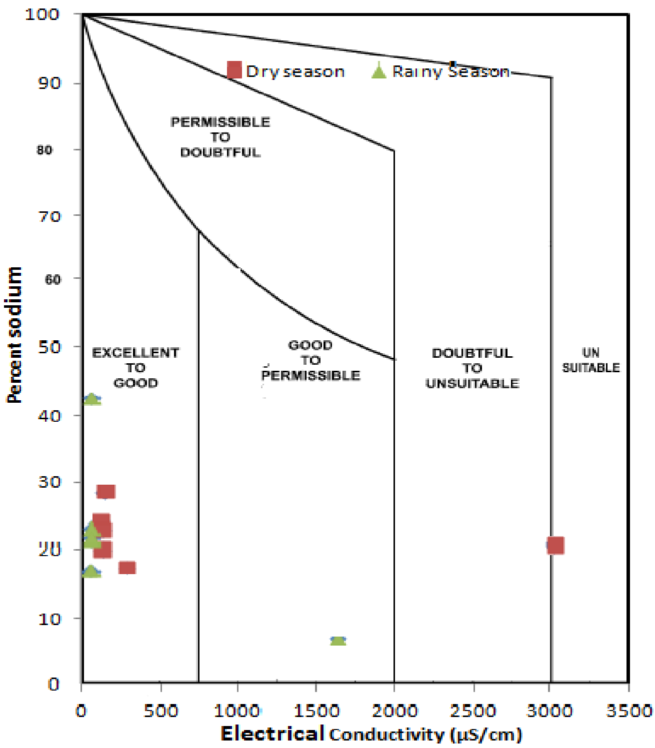

Fig.4: Wilcox diagram