

Groundwater Quality Evaluation using Integrated Approach in Ose and Owo Local Government Areas of Ondo State, Southwestern Nigeria

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Abstract: Physico-chemical and biological/bacteriological analysis involving colour, odour, temperature, pH, turbidity, conductivity, total dissolve solute, total hardness, total alkalinity, calcium and magnesium hardness, nitrate, Iron, chloride, manganese, calcium, magnesium, sodium, chromium, sulphate, copper, fluoride, bicarbonate, total suspended solid, coliforms, E-coli, and Enterococcus faecalis were carried out on fifteen hand dug and borehole water in Ose and Owo local governments areas of Ondo State, Southwestern Nigeria with the aim of determining their suitability for drinking and irrigation purposes. The Water Quality Index and Canadian Water Quality Index were used to characterize the sampled waters. The Water Quality Index showed that the water samples are “very poor/unsuitable” for drinking while Canadian water Quality index characterized the samples as “marginal to fair drinking water” and with 50% correlation. The Wilcox plot showed that the sampled water are excellent for irrigation. The biological test recorded high total coliform and E-Coli values above the Standard Organization of Nigeria specification. However no trace of Enterococcus Faecalis was found in the water samples. The sequence of the abundance of the major ions is in the following order of $Ca^{2+} > Na^+ > Mg^{2+} > Fe^{2+}$ for cations and $Cl^- > HCO_3^- > SO_4^- > F^-$ for anions. The % Na rated the water as “permissible to Doubtful water” for irrigation. Sodium Absorption Ratio (SAR) and the Residual Sodium Carbonate (RSC) of the studied water samples rate the water as “excellent and good” for irrigation purpose. The Permeability index (PI) values fall within the First category of 50 – 100 % irrigation water which is rated as “Good – Excellent.” The variation of Chloride in the study indicates a brackish/brackish salt water Type. The electrical conductivity of the water ranges from 120 to 619 $\mu s/cm$ with an average of 310 $\mu s/cm$ which corresponds to moderate (medium salinity) and constitutes about 60 % of the study area. Subsequent, combining all these results, the water samples need comprehensive treatment for it to be suitable for drinking but have good/excellent potential for irrigation purpose.

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Keywords: Canadian Water Quality Index, Total Dissolve Solid, Coliform, Water Quality Index, Permeability Index

1. Introduction

Fresh water environments are of major importance to health issues in both direct (e.g., drinking water and sanitation) and indirect (e.g., industry, agriculture, and amenity/recreation) ways. However, water resources are finite, and, though renewable, demands have multiplied over the last 100 years due to escalating human populations and the growing requirements of industry and agriculture. Hence, there are increasing global concerns over the extent of present and future quality water resources (Neal, 1997).

Groundwater plays a vital role as an important source of potable water in both rural and urban areas of Nigeria. It remains the largest available source of fresh water, thus it forms a very important part of the water supply chain. There is a growing demand for groundwater in virtually all parts of Nigeria (Adeyemi *et al.*, 2003). Therefore due to high demand for human

and industrial activities, ground water is being contaminated daily. This is the serious problem now a days. Thus the analysis and evaluation of groundwater quality is very important to preserve and protect the natural eco system. Residential, municipal, commercial, industrial, and agricultural activities have proven to be the major sources of groundwater pollution.

In view of the above, the quality and the suitability of groundwater for human consumption and for irrigation are determined in this study for Owo and Ose Local Government areas of Ondo State by its physical, chemical and biological properties.

1.1 Description of the Study Area

The study area is located within Lat. 6° 43' N and 7° 30' N, and Long. 5° 18' E and 6° 04' E in southwestern Nigeria (Fig. 1). The terrain is characterized by moderately undulating topographic elevation ranging from 50 m to 360 m above sea level.

The area is situated within the tropical rain forest region, with a climate characterized by dry and wet seasons.

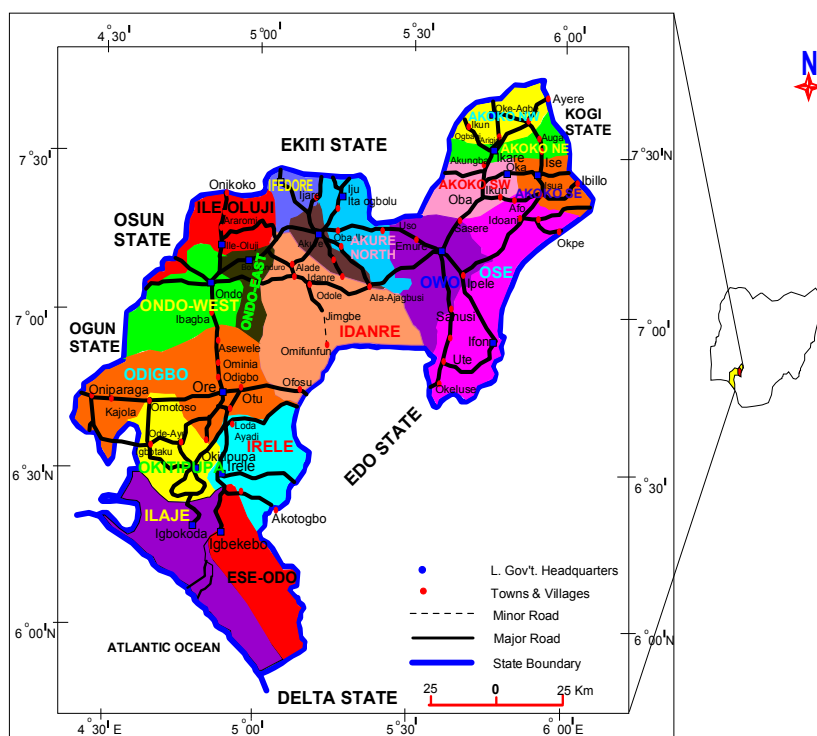


Figure 1. Simplified Map of Ondo State showing the study area at the northern part

Annual rainfall ranges between 1000 mm and 1500 mm, with average wet days of about 100. The annual temperature varies between 18°C to 34°C.

The study area lies within the basement complex of south-western Nigeria (Figure 2) and is characterized by migmatite gneiss and pelitic schist with quartzite layers (Rahaman, 1976). However, the southern parts of Ose Local Government area is characterized by flat lying sedimentary cretaceous sediment/rocks consisting of sand, sandstones, shale, clays and limestone. It lies on the eastern end of the Dahomey sedimentary basin. The local geological mapping of the study area reveals that the area is dominantly underlain mainly by migmatite, quartzite and quartz schist. The overburden is relatively thick within the study area ranging from 15 m to 40 m. Major episodes of mineralization and Pan African Orogeny have also produced major mineral veins and fracturing within the rocks observed in the area.

2. Material and Methods

Fifteen water hand-dug/borehole wells were randomly selected from the two Local Governments in the core areas and local government headquarters. The areas include Amurin, Emure, Isuada, Rufus Giwa Polytechnic Owo, Isijogun, Iyere, and Sanusi. Others

are Okeluse, Ute, Ifon, Ido Ani, Idogun, Imeri, and Afo (Fig. 3).

The selection criteria for the wells/boreholes were based primarily on construction pattern, depth and their mode of operation/serviceability of the wells. Other considerations include location in residential areas and accessibility. A plastic bottle was used to collect water samples for physico-chemical analysis, while a sterilized plastic bottle kept in an insulated cold box was used to collect samples for microbial analysis as specify by America Public Health Association (APHA, 1985) and Allen et al. (1974) were followed.. The analyzed physical, chemical and biological parameters include namely colour, odour, temperature, pH, turbidity, conductivity, total dissolve solute (TDS), total hardness (TH), total alkalinity, calcium hardness, magnesium hardness, nitrate, Iron, chloride, manganese, calcium, magnesium, sodium, chromium, sulphate, copper, fluoride, Bicarbonate and total suspended solid. Physico-chemical parameters such as pH, total dissolved solid (TDS) and electrical conductivity (EC) were measured by EC and pH meters in the field using the standard procedures. F^- was analyzed using Orion ion selective electrode 4 Star.

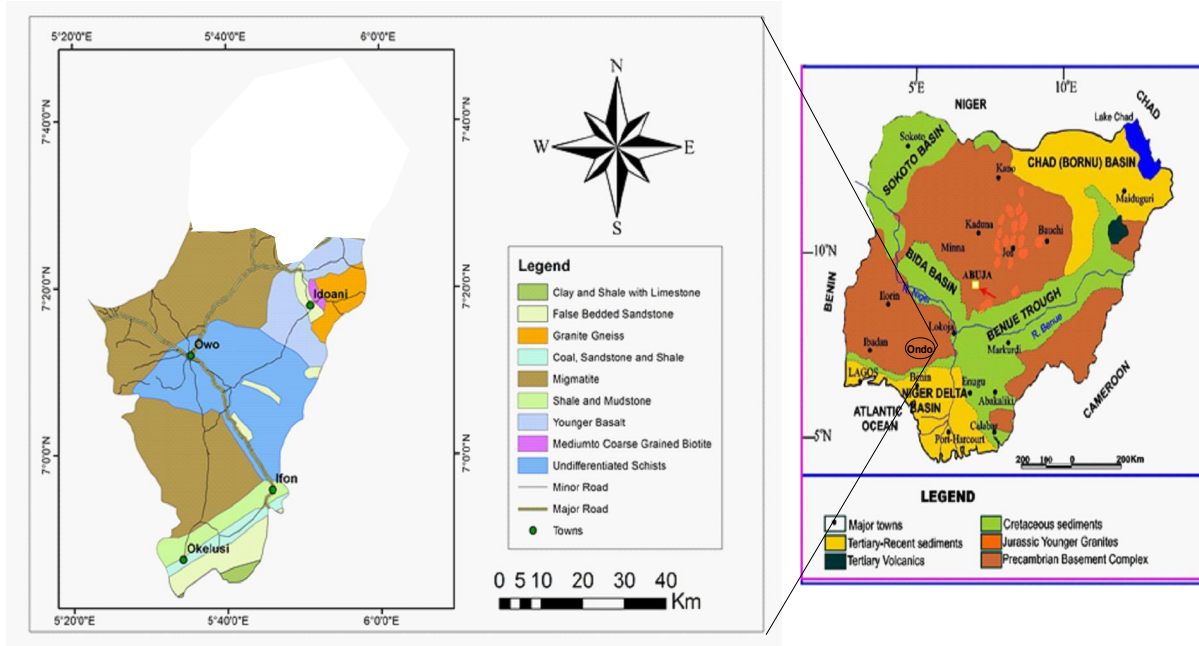


Figure 2. Geological Map of Nigeria and the Study Area

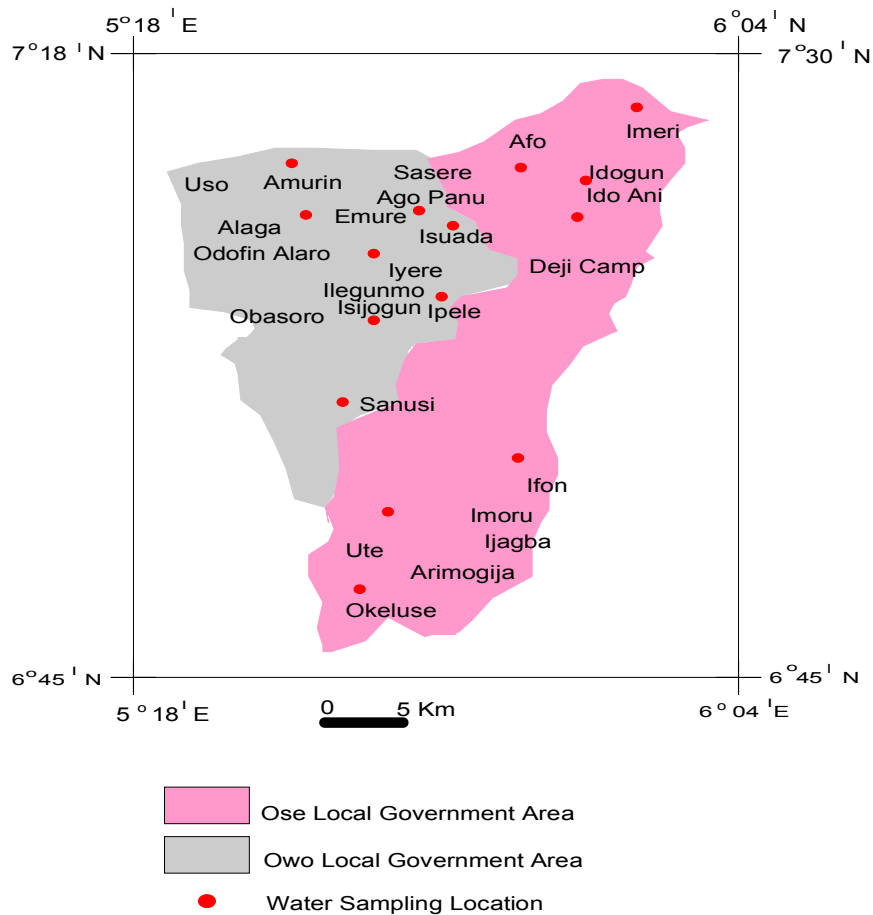


Figure 3: Map of the Study Area showing water sampling locations

Water Quality Assessment (WQA) based on Water Quality Index (WQI) as proposed by Horten, 1965; Li and Qian, 2010; Sudhakar et al., 2014; Srinivas and Nageswararao (2013) were adopted. Temperature, Electrical conductivity (EC) and pH were recorded in situ while on field with the appropriate instruments. TDS were determined using gravimetric method in which the sample was vigorously shaken and a measured volume was transferred into 100 ml graduated cylinder by means of a funnel. The sample was filtered through a glass fiber filter and vacuum applied for 3 minutes to ensure that water was removed as much as possible. The sample was washed with deionized water and suction continued for at least three (3) minutes. The total filtrate was transferred to a weighted evaporating dish and evaporated to dryness on a water bath. The evaporated sample was dried for at least one (1) hour at 180°C. The dried sample was cooled in desiccators and weighed. Drying and weighing process was repeated until a constant weight was obtained.

Total Alkalinity, Total hardness (TH) and Cl^- concentrations were determined using titrimetric methods. Alkalinity was determined by titration of 50 ml water sample with 0.1 M hydrochloric acid to pH 4.5 using methyl orange as indicator while TH was analyzed by titration of 50 ml water sample with standard EDTA at pH 10 using Erichrome black T as indicator. The Cl^- content was determined by argentometric method. The sample was titrated with standard silver nitrate using potassium chromate indicator (Adetunde *et al.*, 2011). The heavy metal content were determined using Atomic Absorption Spectrometer (AAS) unicam series model 969 with air acetylen flame after digestion with perchloric nitric and HCl^- . The chemical data of groundwater samples are subjected to compute the ionic-balance-error between the total concentration of cations and total concentration of anions for testing accuracy of chemical analysis of each groundwater samples, before the interpretation of the chemical data is undertaken. The value of the ionic-balance-error is observed to be within the acceptable limit of $\pm 5\%$ (Domenico and Schwartz, 1990)

The WQI is calculated through three steps. The first step is the assignment of weight (w_1) to each parameter measured in the water samples according to their relative importance in the overall quality of water for drinking purpose as proposed by Sakati and Sarma, 2007. In this study, a maximum weight of five (5) was assigned to NO_3^- , Fe^{2+} , TDS, Cl^- and Fl^- ; four (4) to pH, EC and Mn^{2+} ; three (3) was assigned to Ca^{2+} , Mg^{2+} , Cr^{6+} , HCO_3^- ; while Na^+ and Total Hardness (TH) assigned a weight of two (2) and Alkalinity assigned a weight of one (1).

The second step involves the determination of the relative weight (W_i) using the formulae;

$$W_i = \frac{w_i}{\sum_{i=1}^n w_i} \quad (1)$$

where, W_i is the relative weight, w_i is the weight of each parameter and n is the number of parameters. The third step is the calculation of the quantity rating scale (q_i) for each parameter by applying the equation;

$$q_i = C_i/S_i * 100 \quad (2)$$

where, q_i is the quality rating, C_i is the concentration of each chemical parameter in each water sample in milligrams per liter, S_i is the Nigerian drinking water standard for each chemical parameter in milligrams per liter according to the guidelines of the Standard Organization of Nigeria (SON, 2007). The final stage of the experiment is the calculation of WQI by applying the formulae;

$$WQI = \sum_{i=1}^n SL_i \quad (3)$$

Where SL_i is the product of W_i and q_i . Table 5 shows the WQI calculated and their corresponding remarks. The value of the ionic balance (IB) error was also calculated:

$$IB = \frac{\text{total cations} + \text{total anions}}{\text{total cations} - \text{total anions}} * 100 \quad (4)$$

The Canadian Water Quality index (CWQI) equation was also used to characterize the water quality for drinking. The equation is based on the water quality index (WQI) endorsed by the Canadian Council of Ministers of the Environment (CCME, 2001). The index allows measurements of the frequency and extent to which parameters exceed their respective guidelines at each sampling station in the study area.

Therefore the index reflects the quality of water for both health and acceptability, as set by the Standard Organization of Nigeria (SON, 2007). The index is determined on an annual basis resulting in an overall rating for each station per year. This will allow both spatial and temporal assessment of global water quality to be undertaken. The index equation generates a number between 1 and 100, with 1 being the poorest and 100 indicating the best water quality. Within this range, designations have been set by CCME (2005) to classify water quality as poor, marginal, fair, good or excellent. The CWQI equation is calculated using three factors as follows:

$$WQI = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \quad (5)$$

F_1 represents Scope. The % of parameters that exceed the guideline.

$$F_1 = \frac{\# \text{Failed parameters}}{\text{Total \# of parameters}} * 100 \quad (6)$$

F_2 represents Frequency: The percentage of individual tests within each parameter that exceeded the guideline

$$F_2 = \frac{\#Failed\ Tests}{Total\ \#\ of\ Tests} * 100 \quad (7)$$

F_3 represents Amplitude: The extent (excursion) to which the failed test exceeds the guideline. This is calculated in three stages:

$$Excursion = \frac{failed\ test\ value}{guideline\ value} - 1 \quad (8)$$

$$nse = \frac{\sum excursion}{total\ \#\ of\ tests} \quad (9)$$

F_3 is then calculated using a formula that scales the nse to range between 1 and 100:

$$F_3 = \frac{nse}{0.01nse+0.01} \quad (10)$$

For irrigation purpose, percentage sodium (%Na), Sodium Absorption Ratio (SAR), Residual sodium Carbonate (RSC) and Permeability Index (PI) were determined and rated according to standard.

$$Na\ \% = \frac{(Na+K)*100}{(Ca+Mg+Na+K)} \quad (11)$$

$$SAR = Na / \{(Ca + Mg)/2\}0.5 \quad (12)$$

$$RSC = (HCO_3 + CO_3) - (Ca + Mg) \quad (13)$$

$$PI = \frac{Na + (HCO_3)^2}{Ca + Mg + Na} * 100 \quad (14)$$

3. Results

Tables 1 and 2 show the results of laboratory analysis of the various water samples from different well locations. Figure 3 shows the spatial Distribution of Total Hardness, Electrical Conductivity, Chloride and Total Dissolved Solid obtained from the analyzed data. For irrigation purpose the spatial distribution of %Na, Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC) and Permeability Index (PI) were obtained for the study area (Fig. 4).

4. Discussion

The chemical composition of surface and groundwater is influenced by a wide range of processes, some of which are outside the influence of humans while others are a direct consequence of anthropogenic pollution or changing of the environment. The results of the investigation are compared with Standard Organization of Nigeria (SON, 2007) in Table 3. The appearance of the studied water samples is clear and odourless. The temperature of groundwater governs to a large extent the biological species present and their rate of activity. The temperature ranges from 26.4 to 29.5°C with an average of 27.9°C. The hydrogen ion concentration

(pH) of the water samples varies from 5.28 – 6.83 with a mean of 6.26, indicating a slightly acidic to slightly alkaline water. Turbidity of water ranges from 0 – 28NTU indicating low silt/clay and colloidal content. The electrical conductivity of water samples is between 120 and 619 $\mu s/cm$ and a mean value of 310 $\mu s/cm$. The highest values recorded for this parameter are found around Iyere and Isijogun in Owo local Government Area. (Fig. 3).

The total suspended solids (TDS) ranges 80 to 415 mg/L with an average of 208 mg/L. The TDS values showed that they are generally within the SON standard of 500 mg/L. Suspended solids in water may consist of inorganic or organic particles or of immiscible liquids. Total Hardness (TH) of the samples range from 44 to 226 mg/L and generally below the SON standard of 150 mg/L except at Idogun, Ido Ani, Sanusi, Isuada, Iyere, and polytechnic (Fig. 5). Total suspended solutes varies between 39.6 to 204 mg/L. Hardness is caused by polyvalent metallic ions dissolved in water, which in natural water are principally magnesium and calcium. Total Hardness is almost positively correlated with groundwater parameters except with Total Alkalinity, Iron and Nitrate.

Nitrate is produced from chemical and fertilizer factories, matters of animals, decline vegetables, domestic and industrial discharge. Nitrate is a naturally occurring form of nitrogen found in soil. Nitrate concentration in the study area ranges from 0.80 to 6.65 mg/L. The concentration in all the samples fall below the SON standard of 50 mg/L. However the little content of nitrate measured might be from agricultural practices (NPK fertilizer) since is the major occupation of the inhabitants, anthropogenic (improper sewage disposal near water sources) or by natural means of nitrogen fixation or from leguminous plants. A mean value of 0.068 mg/L was recorded for Iron with 100% compliance with SON standard.

Alkalinity is defined as the quantity of ions in water that will react to neutralize hydrogen ions. Alkalinity is introduced into the water by dissolving carbonate-containing minerals. Alkalinity control is important in boiler feed water, cooling tower water, and in the beverage industry (Kalpana, 2014).

Alkalinity of the samples varies between 4 and 46 mg/L, with an average of 22 mg/L. Alkalinity of water samples are in 100 % compliance with SON standard. Manganese, magnesium, and calcium range between 0 – 0.03 mg/L, 3.9 – 25.9 mg/L, and 8.82 – 48.1 mg/L, with mean values of 0.015 mg/L, 13.9 mg/L, and 25.76 mg/L respectively. All these parameters have 100 % compliance with SON standard.

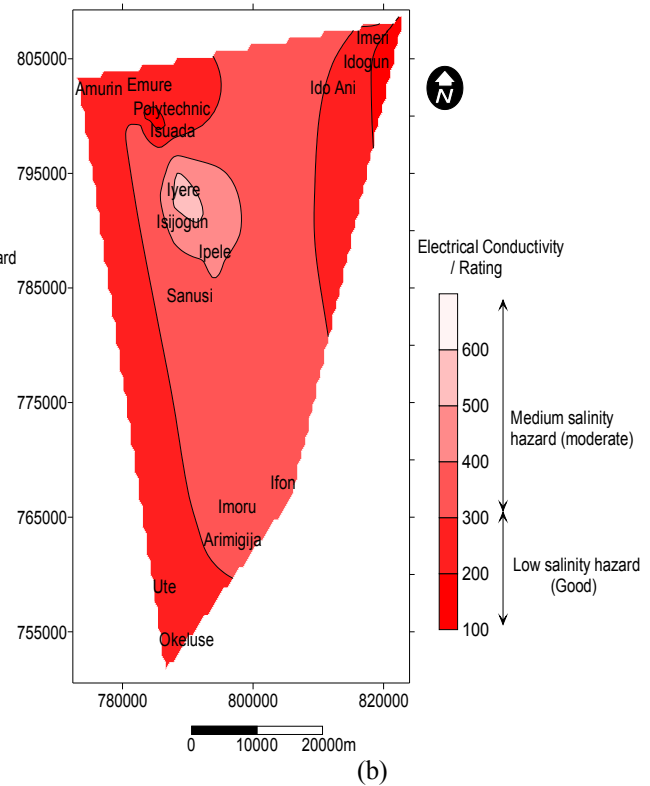
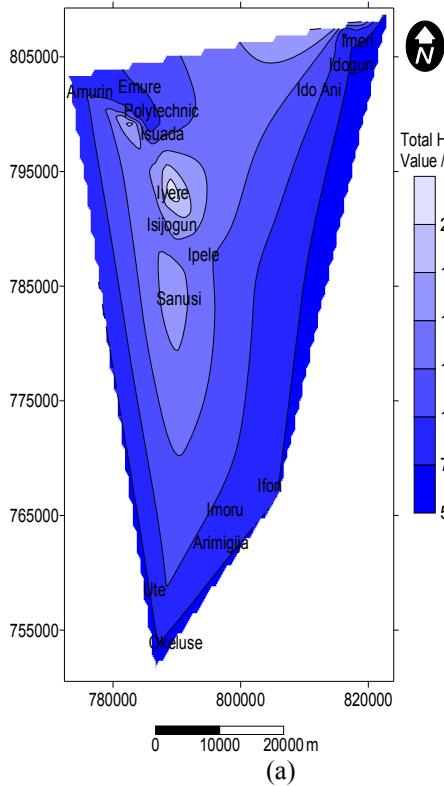
Table 1. Physical, chemical and Biological Results for Measured Parameters in Ose Local Government Area

Parameters/ Location	Imeri	Ute	Okeluse	Ifon	Idogun	Ido Ani	Afo
Northing (m)	0809265	0757627	0750530	0766321	0808351	0808313	0807115
Easting (m)	0823976	0788114	0786178	0806470	0819844	0815129	0816206
Sample No.	SP1	SP2	SP3	SP4	SP5	SP6	SP7
Appearance	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
Temperature (°C)	26.5	26.5	26.6	26.4	26.4	26.7	26.5
pH	6.01	6.12	6.38	5.28	6.23	6.33	6.77
Turbidity (NTU)	0.00	0.30	2.20	0.00	4.00	28.0	16.0
Conductivity ($\mu\text{s}/\text{cm}$)	120	266	196	380	352	410	188
TDS (mg/L)	80.4	178	131	255	236	275	126
Total Hardness (mg/L)	44.0	98.0	56.0	72.0	176	192	60.0
Calcium Hardness (mg/L)	22.0	48.0	26.0	56.0	84.0	106	30.0
Magnesium Hardness (mg/L)	22.0	50.0	30.0	16.0	92.0	28.0	30.0
Nitrate (NO_3) (mg/L)	2.10	0.80	2.60	1.90	3.70	6.65	2.20
Iron (Fe) (mg/L)	0.06	0.03	0.10	0.01	0.04	0.20	0.08
Total Alkalinity (mg/L)	12.0	6.00	10.0	4.00	24.0	26.0	12.0
Chloride (Cl^-) (mg/L)	14.0	30.0	23.0	42.0	27.0	18.0	18.0
Manganese (Mn^{2+}) (mg/L)	0.02	0.01	0.03	0.03	0.01	0.01	0.00
Calcium (Ca^{2+}) (mg/L)	8.82	19.2	10.4	22.4	33.7	42.5	12.0
Magnesium (Mg^{2+}) (mg/L)	5.37	12.2	7.32	3.90	22.5	20.0	7.32
Sodium (Na) (mg/L)	9.10	19.5	15.0	27.3	17.6	11.7	11.7
Chromium (Cr^{6+}) (mg/L)	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Sulphate (SO_4) (mg/L)	0.00	1.00	1.00	2.00	0.00	3.00	1.00
Copper (Cu^{2+}) (mg/L)	0.02	0.01	0.03	0.01	0.00	0.02	0.02
Fluoride (F) (mg/L)	0.07	0.31	0.62	0.08	0.14	0.25	0.44
Bicarbonate (HCO_3) (mg/L)	12.0	6.00	10.0	4.00	24.0	26.0	12.0
Total Suspended Solid (mg/L)	39.6	88.0	65.0	125	116	135	62.0
Total Coliform (Cfu/100ml)	6	7	16	5	21	43	39
E-Coli (Cfu/100ml)	1	5	0	0	4	28	26
Enterococcus Faecalis (Cfu/100ml)	0	0	0	0	0	0	0

Table 2: Physical, chemical and Bacteriological Results for Measured Parameters in Owo Local Government Area

Parameters/ Location	Emure	Sanusi	Isuada	Ipele	Iyere	Amurin	Isijogun	Polytechnic
Northing (m)	0777970	0784246	0799266	0788535	0793505	0803805	0791194	0799411
Easting (m)	0800825	0789150	0785382	0793482	0789082	0772387	0786821	0782596
Sample No.	SP8	SP9	SP10	SP11	SP12	SP13	SP14	SP15
Appearance	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
Temperature (°C)	28.9	28.7	29.4	29.5	28.9	29.4	28.8	28.9
pH	6.32	6.83	6.20	6.60	6.49	5.86	6.17	6.35
Turbidity (NTU)	10.00	4.00	0.00	24.0	6.00	2.00	3.00	4.00
Conductivity ($\mu\text{s}/\text{cm}$)	262	341	162	420	619	198	425	309
TDS (mg/L)	176	229	109	281	415	133	285	207
Total Hardness (mg/L)	114	168	78.0	132	226	78.0	134	192
Calcium Hardness (mg/L)	58.0	94.0	49.0	66.0	120	52.0	64.0	84.0
Magnesium Hardness (mg/L)	56.0	74.0	29.0	66.0	106	26.0	70.0	106
Nitrate (NO_3) (mg/L)	1.66	0.87	1.40	1.90	3.10	2.10	2.50	4.00
Iron (Fe) (mg/L)	0.26	0.04	0.06	0.01	0.03	0.01	0.02	0.05
Total Alkalinity (mg/L)	24.0	46.0	18.0	30.0	42.0	16.0	28.0	30.0

Parameters/ Location	Emure	Sanusi	Isuada	Ipele	Iyere	Amurin	Isijogun	Polytechnic
Chloride (Cl^-) (mg/L)	32.0	13.0	10.0	60.0	47.0	25.0	11.0	27.0
Manganese (Mn) (mg/L)	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01
Calcium (Ca^{2+}) (mg/L)	23.3	29.7	19.6	36.5	48.1	20.8	25.7	33.7
Magnesium (Mg^{2+}) (mg/L)	13.7	18.1	7.08	16.1	25.9	6.34	17.1	25.9
Sodium (Na) (mg/L)	20.8	8.45	6.45	39.0	30.6	16.3	7.15	17.6
Chromium (Cr^{6+}) (mg/L)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulphate (SO_4) (mg/L)	0.00	2.00	1.01	0.00	1.00	1.00	2.00	1.00
Copper (Cu^{2+}) (mg/L)	0.03	0.01	0.01	0.02	0.03	0.02	0.01	0.02
Fluoride (Fl) (mg/L)	0.85	0.36	0.46	0.22	0.09	0.53	0.17	0.35
Bicarbonate (HCO_3) (mg/L)	24.0	46.0	18.0	30.0	42.0	16.0	28.0	30.0
Total Suspended Solid (mg/L)	86.0	42.0	53.0	139	204	65.0	140	102
Total Coliform (Cfu/100ml)	41	35	12	45	37	27	22	38
E-Coli (Cfu/100ml)	12	7	0	27	10	4	6	31
Enterococcus Faecalis (Cfu/100ml)	0	0	0	0	0	0	0	0



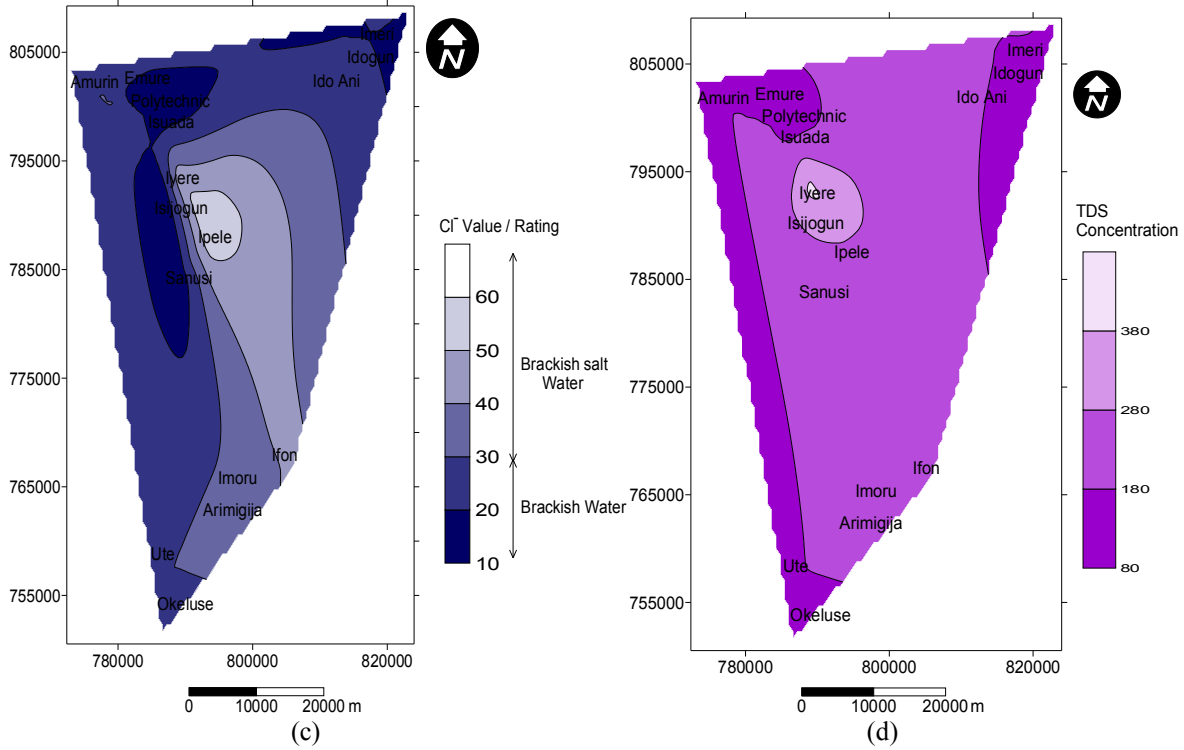
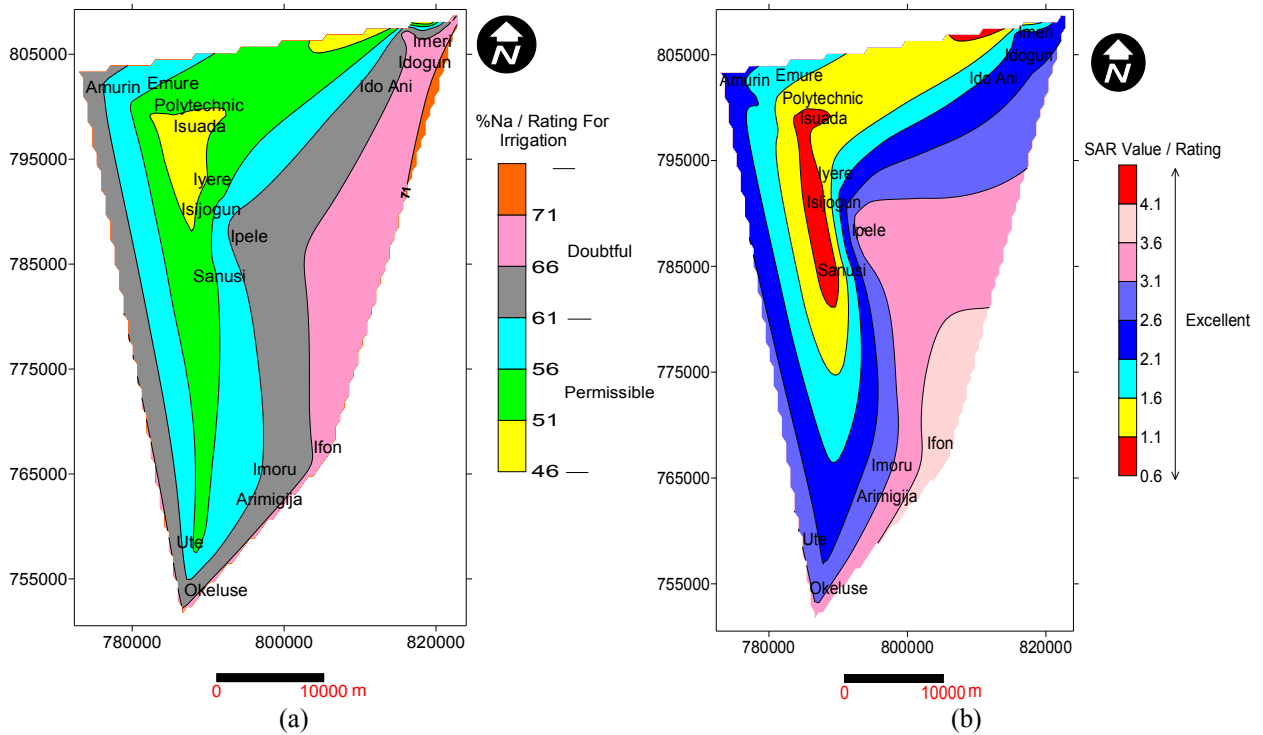


Figure 4. Spatial Distribution of: (a) Total Hardness; (b) Electrical Conductivity; (c) Chloride; and (d) Total Dissolved Solid obtained from the analyzed parameters



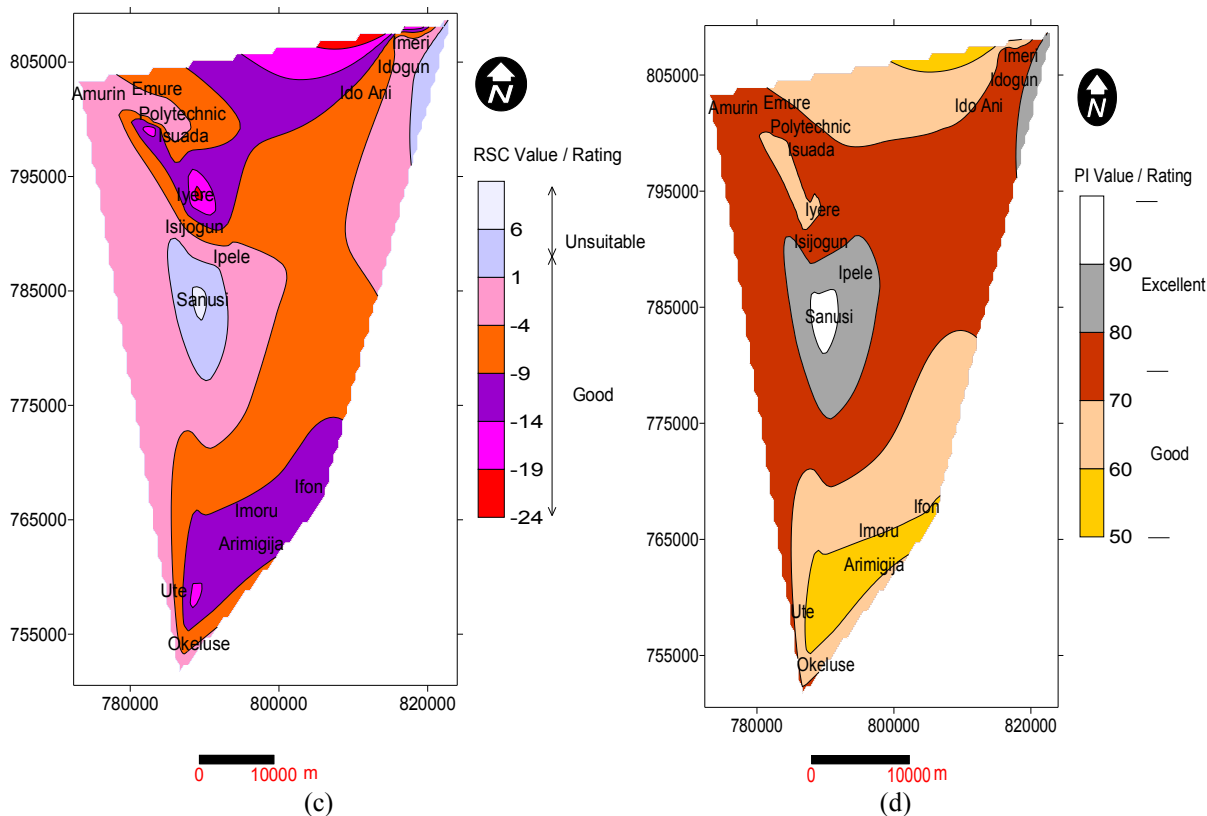


Figure 5: Spatial Distribution of: (a) %Na; (b) Sodium Absorption Ratio (SAR); (c) Residual Sodium Carbonate (RSC); and (d) Permeability Index (PI) obtained from the analyzed parameters

The concentration of the hexavalent chromium varies from 0.0 to 0.01 mg/L and agrees with 0.05 mg/L SON standard specified for chromium. Sodium concentration ranges of 6.45 – 39 mg/L. The Na^+ must have entered into the groundwater system in the study area by natural means, possibly through weathering of Na-rich feldspars and leaching of clay minerals (Spears and Reeves, 1975). Na^+ has different role in human body. It is related with the function of nervous system, membrane system and excretory system. Excess sodium causes high pressure, nervous disorder, etc.

The bi-carbonate concentrations in granitic rock can be accounted for the dissociation of water under the presence of carbon (IV) oxide, and prevailing pH (6.5 – 8.5) is one of the factors for the existence of the bi-carbonate as major dissolved inorganic constituents in the groundwater. HCO_3^- of the samples ranges from 4 to 46 mg/L with an average of 21.9 mg/L. The implication is that this ion will likely reduce the acidity level of the water.

The Chloride, which is the most abundant anion measured, has values that ranged between 11 and 121 mg/L. Chlorides are widely distributed in nature as salts of sodium, potassium and calcium. Chlorides are

leached from various rocks into soil and water by weathering. High Chloride content can corrode metals and affect the taste of food products. Chloride is almost positively correlated with groundwater parameters except with Iron and Sulphate. The variation of Chlorides in the study is shown in Figure 6 which indicate a brackish and brackish salt water types (Stuyfzand, 1991), with each accounting for 50% of the area. Chloride in all the samples is below the 100 mg/L limit. However, no adverse health effects on human being have been reported by the use of water having high chloride concentrations (Jain, 2010). Excess concentration of Cl^- in drinking water gives a salty taste and has a laxative effect in people not accustomed to it.

Fluoride (F^-) ranges from 0.07 – 0.85 mg/L with an average of 0.33 mg/L, while sulphate ranges between 0 and 3 mg/L and both in 100 % compliance with SON standard. Health concerns regarding sulphate in drinking water have been raised because of reports that diarrhea may be associated with the ingestion of water containing high levels of sulphate. Fluoride, on the other hand occurs as fluorospar (fluorite), rock phosphate, triphite, phosphorite crystals etc., in nature. Among factors which control

the concentration of fluoride are the climate of the area and the presence of accessory minerals in the rock minerals assemblage through which the ground water is circulating. Fluoride is an essential element for maintaining normal development of healthy teeth and bones. Deficiency F^- in drinking water below 0.6 mg/L contributes to tooth caries. An excess of over 1.2 mg/L causes fluorosis (ISI, 1983).

The biological test recorded total coliform value between 5 to 45 Cfu/100 ml with an average of 26.3 Cfu/100 ml. The E-Coli ranges between 0 and 31 Cfu/100 ml with a mean of 10.7 Cfu/100 ml. The values are more than 10 Cfu/100 ml and 3 Cfu/100 ml specified for total coliform and E-Coli respectively. However no trace of Enterococcus Faecalis was found in the samples. The sequence of the abundance of the major ions is in the following order of $Ca^{2+} > Na^+ > Mg^{2+} > Fe^{2+}$ for cations and $Cl^- > HCO_3^- > SO_4^- > F^-$ for anions.

The water quality index (WQI) obtained for the water samples (Fig. 5) ranges between 124 and 684. The map categorizes into two, the water samples analyzed which represented different towns within the study area, namely: very poor and unsuitable drinking water. The poor water accounts for about 40 % while unsuitable water constitute about 60 % of the study area. However the Canadian Water Quality index (CWQI) in Figure 6 classified the water into "Marginal – Fair" drinking water.

Moreover, for purpose of irrigation, the water samples are evaluated by %Na, Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), Permeability Index, and Electrical Conductivity. The %Na of the samples vary between 39 and 74. They generally have rating of "permissible to Doubtful" and constitute 50 % each of the study area. Excess sodium concentration in groundwater produces the undesirable effects because sodium reacts with soil to reduce its permeability and support little or no plant growth (Vasanthavigar *et al.*, 2010; Raju, 2009). Therefore the water can be rated/adjudged as fair for irrigation purpose.

Sodium Absorption Ratio (SAR) of the studied water samples varies from 0.67 to 4.15 with a mean of 2.03. The values are within 0 - 10 specified by Singh, 2015 as excellent water for irrigation purpose. Excess sodium concentration in groundwater produces the undesirable effects because Na reacts with soil to reduce its permeability and support little or no plant growth.

The Residual Sodium Carbonate (RSC) values ranges between - 26.5 and +8.2, with an average of - 7.15, which agrees with less than 2.5 specified by Singh, 2015 for the purpose of irrigation with rating of "Good".

The excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium influences the suitability of groundwater for irrigation. When the excess carbonate concentration becomes too high, the carbonate combines with calcium and magnesium to form solid

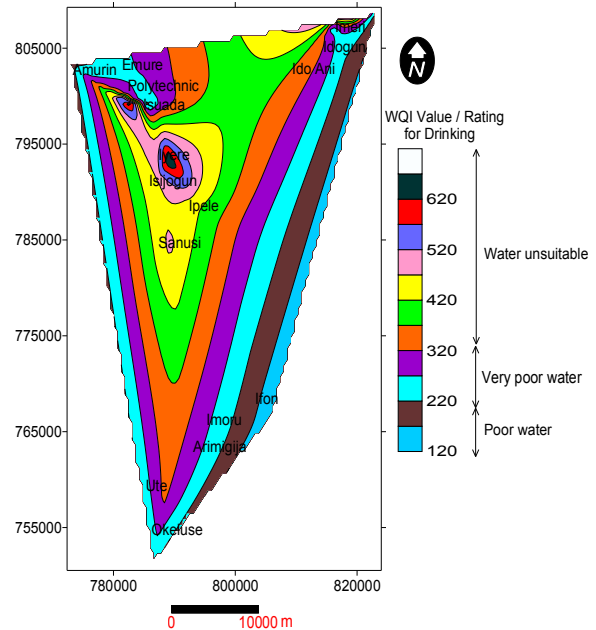


Figure 5. Water Quality Index Map obtained for the study area

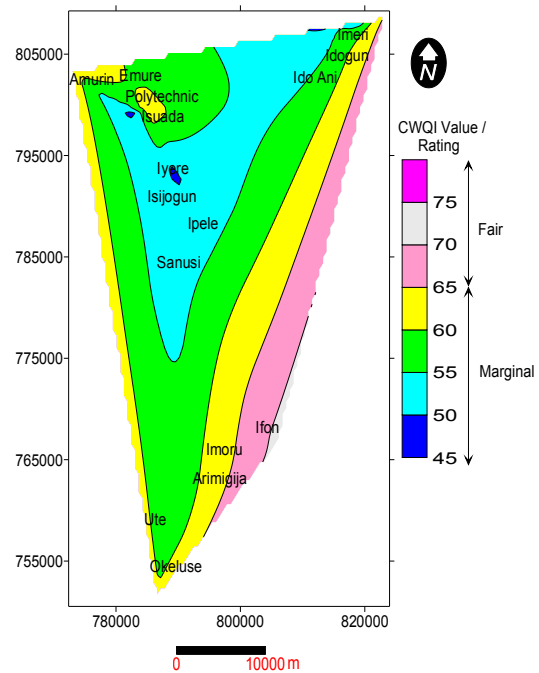


Figure 6. Canadian Water Quality Index Map obtained for the study area

materials which settles out of the water. The relative abundance of sodium with respect to alkaline earths and the quantity of bicarbonates and carbonate in excess of alkaline earths also influence the suitability of water for irrigation.

The permeability index (PI) of the water varies from 50 % to 97 %, with an average of 71 %. Soil permeability is affected by long-term use of irrigation water with high salt content as influenced by Na^+ , Ca^{2+} , Mg^{2+} , and HCO_3^- contents of the soil. The values fall within the First category of 50 – 100 % irrigation water which is rated as “Good – Excellent.”

The electrical conductivity of the water ranges from 120 to 619 $\mu s/cm$ with an average of 310 $\mu s/cm$ which corresponds to moderate (medium salinity) and constitutes about 60 %. However, from the map, the water in the study area shows variation of low salinity to high salinity. The Wilcox plot (1948) showed that the water samples have excellent – good irrigation potential (Fig. 7). Therefore combine all these results the water samples are good and suitable for irrigation purpose.

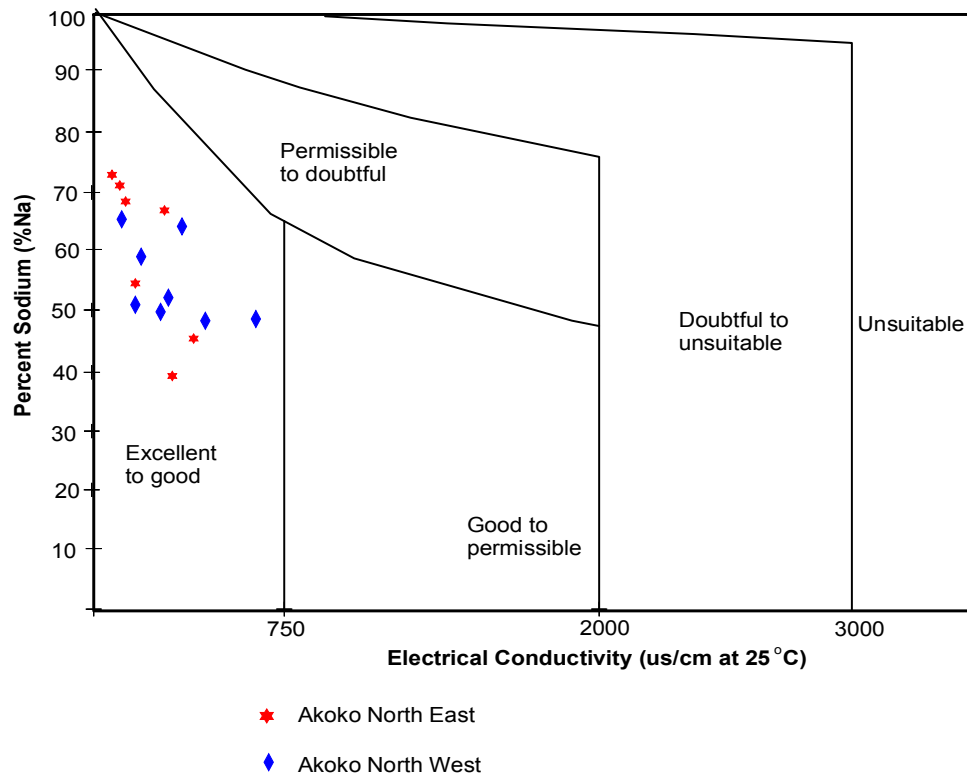


Figure 7: Wilcox Plot of the Analyzed Water Samples

5. Conclusion

The WQI criteria showed that the water samples are very poor/unsuitable for drinking while Canadian water Quality index characterized the samples as marginal to fair drinking water and with 50% correlation. The Wilcox plot showed the sampled water are excellent for irrigation. The biological test recorded high total coliform and E-Coli values, above the SON standard. However no trace of Enterococcus.

Faecalis was found in the samples. The sequence of the abundance of the major ions is in the following order of $Ca^{2+} > Na^+ > Mg^{2+} > Fe^{2+}$ for cations and $Cl^- > HCO_3^- > SO_4^- > F^-$ for anions. The % Na rated the water as “permissible to Doubtful water.” Sodium Absorption Ratio (SAR) and The Residual Sodium Carbonate (RSC) of the studied water samples

have values “excellent and good” for irrigation purpose.

The Permeability index (PI) values fall within the First category of 50 – 100 % irrigation water which is rated as “Good – Excellent.” The variation of Chlorides in the study is indicate a brackish water and brackish salt water Type. The electrical conductivity of the water ranges from 120 to 619 $\mu s/cm$ with an average of 310 $\mu s/cm$ which corresponds to moderate (medium salinity) and constitutes about 60 % of the study area. Subsequent, combining all these results, the water samples need treatment for it to be suitable for drinking but have good/excellent potential for irrigation purposes.

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