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Irrigation and Drinking Water Quality Index Determination for Groundwater Quality Evaluation in Akoko Northwest and Northeast Areas of Ondo State, Southwestern Nigeria

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Abstract: In order to understand the suitability of groundwater for drinking and irrigation purposes in Akoko northwest and Akoko northeast, water quality index calculation, % Na, Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), Permeability Index (PI) and Electrical Conductivity were determined from thirteen water samples. The sequence of the abundance of the major ions is in the following order of $K^+ > Na^+ > Ca^{2+} > Mg^{2+}$ for cations and $Cl^- > HCO_3^- > SO_4^- > F^-$ in anions. The water quality index (WQI) obtained for the water samples ranges between 22.7 and 88.6. The water quality index classified the water into "excellent" and "good" drinking water and account for about 85% and 15% of the study area respectively. The % Na of the samples varies between 49 and 79%. Sodium Absorption Ratio (SAR) of the studied water samples varies from 1.40 to 3.56 with a mean of 2.44. The values are within 0 - 10 specified as excellent water for irrigation purpose. The Residual Sodium Carbonate (RSC) values ranges between – 51.6 and +10.57, with an average of -14.5, which agrees with less than 2.5 specified for the purpose of irrigation. The permeability index (PI) of the water varies from 2.27 to 19.9, with an average of 7.93. The values fall within the Third category of 0 – 25 irrigation water which is rated as poor. The electrical conductivity of the water ranges from 117 to 789 $\mu s/cm$ with an average of 378 $\mu s/cm$ which corresponds to moderate (medium salinity). Also, the water in the study area shows variation of low salinity to high salinity. The Wilcox plot showed that the water samples have excellent – good irrigation potential except a sample taken from Arigidi Akoko which fall within "good to permissible limit." Therefore combine all these results the water are moderately suitable for irrigation purpose and good for drinking.

Keywords: Wilcox Plot, Water Quality Index, Physicochemical, Biological Test, Total Dissolve Solids

1. Introduction

Three fourth of the earth's surface is covered by water. In spite of this apparent abundance of water, less than one percent is available for human use in the form of surface water as 97 percent is contained in oceans etc. and 2 percent is locked up in ice-caps and glaciers [1]. However as civilization and population increases man recognizes the importance of water from a quantity view point for agriculture, transportation, drinking and domestic usage with less significance given to its chemical and biological importance. Ground water contamination is nearly always the result of human activity. In areas where population density is high and human use of the land is intensive, ground water is especially vulnerable. Virtually any activity whereby chemicals or wastes may be released to the environment, either intentionally or accidentally, has the potential to pollute ground water. When ground water becomes contaminated by the dissolved elements and gases and by presence of suspended solids, bacteria, and viruses, it is difficult and expensive to clean up. Such water is no longer fit for a specific use, such as drinking, the water is said to be contaminated. If the water becomes heavily contaminated it is said to be polluted [2].

The source of about 90% of drinking and irrigation water is from groundwater resources in the study area and exploited through shallow wells, borehole/drilled wells, hand pump operated wells. However, this water resource is facing

problems including quality hazard in many areas where the exposure to pollution from agriculture and urbanization in shallow groundwater wells makes the water unfit for human consumption. Land use for urbanization and agricultural purpose in Akoko northeast and northwest has increased at an alarming rate during the last few decades. Hence a need for routine groundwater quality assessment. The aim of the study was to investigate the quality of ground water by determining water quality index and classify the groundwater for drinking/ domestic and irrigation purposes. Generally speaking, the presence of water with high purity in the nature is rare, even the rain water contains some dissolved gases, small particles of the soil and bacteria that are suspended in the air. In addition, after the rain water has touched the surface of the earth it will wash and carry along some organic and inorganic pollutants to groundwater.

Water quality index is one of the most effective tools that helps in communicating information on the quality of water to the concerned citizens and policy makers (especially governments at all levels). It thus becomes an important parameter for the assessment and management of groundwater. WQI is defined as a rating, reflecting the composite influence of different water quality parameters. WQI is calculated from the point of view of the suitability of groundwater for human consumption [3-7]. Also, important irrigation parameters such as percentage sodium (%Na), Sodium Absorption Ratio (SAR), Residual sodium Carbonate (RSC) and Permeability Index (PI) were determined and corroborated with Wilcox plot [7-8] so as to have comprehensive understanding of the suitability of groundwater in the study area for human consumption and irrigation purpose based on computed, groundwater characteristics, quality assessment and water quality index values.

Description of the Study Area

The study area is Akoko northeast and northwest Local Government Areas of Ondo State, Nigeria. Their headquarters are located in the towns of Ikare and Isua respectively. These areas are located in the northern part of Ondo state "Figure 1". The study area lies within longitudes 5° 30¹ and 5° 20¹ E, and latitude 7° 20¹ and 7° 50¹ N. The area is within the tropical rain forest region of Nigeria characterized by wet and dry seasonal variations, with a mean annual rainfall of 150 cm, mean temperature of 24°C, and mean humidity of 80% [9].

It is situated within the Precambrian Basement Complex with the outcrops which are gneiss and migmatite. The rocks in the study environment is predominantly migmatitic, with the most predominant components being the granite-gneiss and grey gneiss. These rocks are covered by regoliths with thickness variation across the area. Topographically, the area is relatively rugged and undulating, with elevation of 300 - 800 m above sea level. The area under study is situated in the deciduous rain forest area within south-western Nigeria. It has evergreen vegetation and urban settlement. The vegetation is characterized by different plants and trees which may reach a height of 10 m and even more. They consist of light forests, shrubs, scattered cultivation, trees and plants like timber, oil palm, kolanut, rubber, cocoa and citrus are very prominent in the area.

2. Material and Methods

Thirteen (13) water samples were collected from seven boreholes and six open - hand pump operated water wells were collected in the study area "Figure 2". The samples were then taken to Federal Ministry of Water Resources in Akure, Ondo State, Nigeria for analysis of physico-chemical and biological parameters 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, total suspended solid, total coliform, E-Coli, and Enterococcus Faecalis test.

Physico-chemical parameters such as pH, and electrical conductivity (EC) were measured by EC meter and pH meter respectively in the field using the standard procedures. F^- was analyzed using Orion ion selective electrode 4 Star. The procedures for water sample collection as specified by America Public Health Association [10] were followed. Water Quality Assessment (WQA) based on Water Quality Index (WQI) proposed by [11-15] were adopted.

Temperature, Electrical conductivity (EC) and pH were recorded in situ while on field with the appropriate instruments. Total Dissolve solids (TDS) was 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 1800°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 determine by argentometric method. The sample was titrated with standard silver nitrate using potassium chromate indicator [16].

The heavy metal contents 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 ±5% [17].

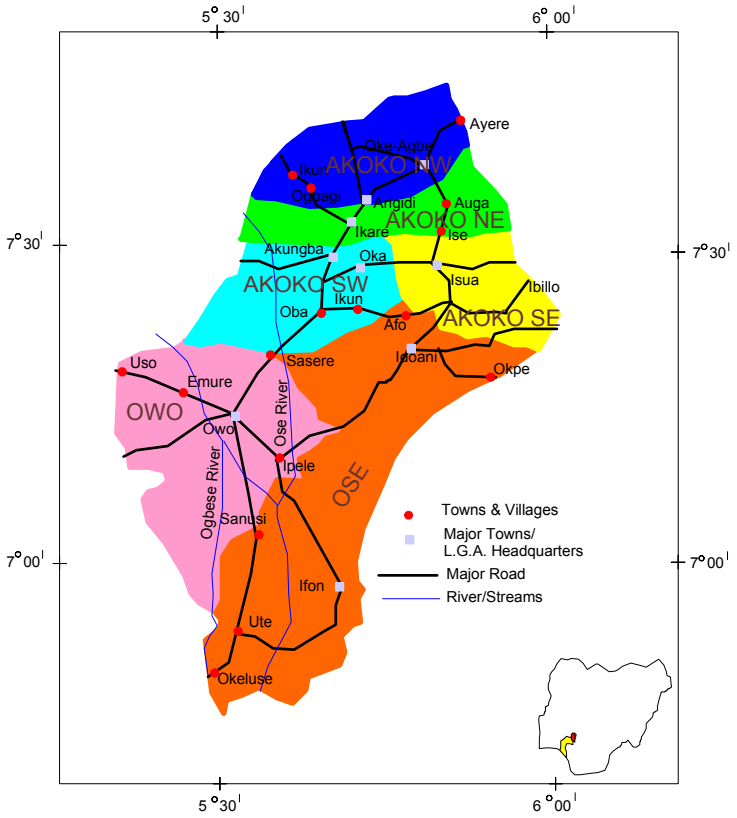

Figure 1. *Location Map of the Study Area on the Map of Nigeria and Ondo State.*

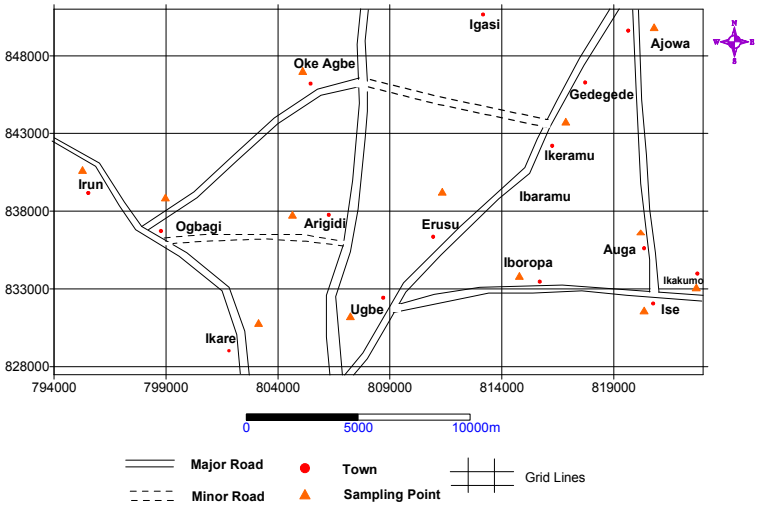

Figure 2. *Base Map of the Study Showing the Water Sampling Points.*

The Water Quality Index (WQI) was calculated through three steps. The first step was 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 [17-18]. In this study, a maximum weight of five (5) was assigned to NO_3^-, K^+, Fe^{2+}, TDS, Cl^-, and Fl^-; four (4) to pH, EC and Mn^+; 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 involved the determination of the relative weight (W_i) using equation 1;

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

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 was the calculation of the quantity rating scale (q_i) for each parameter by applying equation 2;

$$q_i = {}^{C_i}/_{S_i} * 100 \quad (2)$$

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 Federal Ministry of Works and Housing (FMWH) [19]. The final stage of the experiment was the calculation of WQI by applying equation 3;

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

Where SLi 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:

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

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 [4].

$$Na\% = \frac{(Na+K)*100}{(Ca+Mg+Na+K)} \quad (5)$$

$$SAR = {}^{Na}/_{\{(Ca+Mg)/2\}0.5} \quad (6)$$

$$RSC = (HCO_3 + CO_3) - (Ca + Mg) \quad (7)$$

$$PI = {}^{Na + (HCO_3)^2)}/_{Ca + Mg + Na * 100} \quad (8)$$

The results of the investigation are presented in form of table, graph, and maps using Surfer Software.

3. Results and Discussion

The understanding of groundwater quality is important because it is the main factor which decides its suitability for domestic, agricultural and industrial purposes. The results of the analysis are presented in "Tables 1 – 2" the summary and% compliance with the Federal Ministry of Works and Housing standard (FMWH) of Nigeria is shown in "Table 3".

The appearance of the studied water samples is clear and odourless. These can affect positively its marketability for domestic, agriculture and industrial use. The temperature of groundwater governs to a large extent the biological species present and their rate of activity. The temperature of the water samples ranges from 26.9 to 27.3°C with an average of 27.1°C. The hydrogen ion concentration (pH) of the water samples varies between 6.19 – 6.93 with a mean of 6.54, signifying a slightly acidic to slightly alkaline water. Turbidity of water ranges from 2 – 14 NTU indicating low silt/clay or colloidal content.

The electrical conductivity of water samples has a mean value of $378\,\mu s/cm$. The highest values recorded for this parameter: 789 $\mu s/cm$ and 717 $\mu s/cm$ are found in Arigidi and Ogbagi Akoko respectively. The total suspended solids (TDS) ranges 78.4 to 539 mg/L with an average of 253 mg/L. The TDS values showed that they are generally within the FMWH standard of 500 mg/L and with compliance value of 92%. Suspended solids in water may consist of inorganic or organic particles or of immiscible liquids. The most contributing ions in areas with high TDS (Arigidi and Ogbagi) are Ca^{2+}, Mg^{2+} for cations, and HCO_3^- and Cl^- anions. These ions are also responsible for the high values of Turbidity and electrical conductivity of the water samples.

Total Hardness (TH) of the samples range from 56 to 250 mg/L with 77% compliance. Hardness is a property of water to consume soap without forming lather freely. All metals are soluble to some extent in water. While excessive amounts of any metal may present health hazards, only those metals that are harmful in relatively small amounts are commonly labelled toxic. Sources of metals in natural water include dissolution from natural deposits and discharge of domestic, industrial or agricultural waste waters. The concentration of nitrate ranges from 0.40 to 4.40 mg/L. The concentration in all the samples fall below the FMWH standard of 45 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 0.07 mg/L was recorded for Iron with 77% compliance with FMWH standard.

Table 1. *Physical, Chemical and Biological Results for Measured Parameters in Akoko Northwest.*

Parameters/ Location	Ogbagi	Ajowa	Ikeramu	Arigidi	Oke Agbe	Erusu	Irun
Northing (m)	0838283	0849151	0842513	0837452	0844552	0841165	0839681
Easting (m)	0798119	0819358	0816220	0805453	0804851	0814482	0795071
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)	27.0	27.1	26.9	27.0	27.0	27.0	27.1
pH	6.69	6.63	6.93	6.65	6.64	6.19	6.07
Turbidity (NTU)	4.00	7.00	8.00	6.00	12.00	8.00	3.00
Conductivity ($\mu s/cm$)	717	344	508	789	341	117	281
TDS (mg/L)	480	230	340	529	228	78.4	188
Total Hardness (mg/L)	248	80.0	240	296	96.0	66.0	116
Calcium Hardness (mg/L)	186	65.0	180	170	60.0	40.0	90.0

Parameters/ Location	Ogbagi	Ajowa	Ikeramu	Arigidi	Oke Agbe	Erusu	Irun
Magnesium Hardness (mg/L)	62.0	15.0	60.0	126	36.0	26.0	26.0
Nitrate (NO_3) (mg/L)	2.50	3.40	2.20	2.70	0.40	1.80	2.60
Iron (Fe) (mg/L)	0.04	0.00	0.03	0.18	0.14	0.05	0.08
Total Alkalinity (mg/L)	28.0	12.0	44.0	50.0	32.0	12.0	24.0
Chloride (Cl^-) (mg/L)	96.0	36.0	47.0	121	30.0	12.0	29.0
Manganese (Mn^{2+}) (mg/L)	0.00	0.01	0.03	0.01	0.02	0.01	0.01
Calcium (Ca^{2+}) (mg/L)	74.5	26.1	72.1	68.1	24.1	16.0	36.1
Magnesium (Mg^{2+}) (mg/L)	15.1	3.66	14.6	30.7	8.78	6.34	6.34
Sodium (Na) (mg/L)	62.4	23.4	30.6	78.7	19.5	7.80	18.9
Potassium (K) (mg/L)	72	83	51	64	15	65	43
Chromium Cr^{6+}) (mg/L)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulphate (SO_4) (mg/L)	1.00	3.00	2.00	1.00	1.00	1.00	2.00
Copper (Cu^{2+}) (mg/L)	0.01	0.01	0.02	0.00	0.01	0.03	0.01
Fluoride (Fl) (mg/L)	0.75	0.06	0.10	0.28	0.33	0.47	0.32
Bicarbonate (HCO_3) (mg/L)	28.0	12.0	44.0	50.0	32.0	12.0	24.0
Total Suspended Solid (mg/L)	237	114	168	260	113	38.6	93.0
Total Coliform (Cfu/100ml)	37	21	34	18	20	14	10
E-Coli (Cfu/100ml)	11	4	3	0	2	0	0
Enterococcus Faecalis (Cfu/100ml)	0	0	0	0	0	0	0

Table 2. *Physical, Chemical and Bacteriological Results for Measured Parameters in Akoko Northeast.*

Parameters/ Location	Ikare	Iboropa	Ugbe	Ise	Auga	Ikakumo
Northing (m)	0829632	0834207	0833003	0831553	0835928	0835973
Easting (m)	0803301	0814161	0807669	0821966	0821817	0821985
Sample No.	SP8	SP9	SP10	SP11	SP12	SP13
Appearance	Clear	Clear	Clear	Clear	Clear	Clear
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
Temperature (°C)	27.3	27.1	27.2	27.1	27.2	27.2
pH	6.87	6.54	6.27	6.68	6.47	6.48
Turbidity (NTU)	3.00	14.0	5.00	2.00	3.00	6.0
Conductivity ($\mu s/cm$)	135	326	177	578	300	300
TDS (mg/L)	90.5	218	119	387	201	201
Total Hardness (mg/L)	58.0	102	56.0	250	106	108
Calcium Hardness (mg/L)	36.0	46.0	24.0	86.0	48.0	56.0
Magnesium Hardness (mg/L)	22.0	56.0	32.0	164	58.0	52.0
Nitrate (NO_3) (mg/L)	0.90	3.60	2.60	4.40	3.70	3.60
Iron (Fe) (mg/L)	0.05	0.03	0.07	0.11	0.03	0.10
Total Alkalinity (mg/L)	14.0	12.0	18.0	15.0	18.0	18.0
Chloride (Cl^-) (mg/L)	11.0	44.0	14.0	68.0	35.0	36.0
Manganese (Mn) (mg/L)	0.00	0.01	0.00	0.02	0.03	0.02
Calcium (Ca^{2+}) (mg/L)	14.4	18.4	9.62	34.5	19.2	22.4
Magnesium (Mg^{2+}) (mg/L)	5.37	13.7	7.81	40.0	14.2	12.7
Sodium (Na) (mg/L)	7.15	28.6	9.10	44.2	28.8	23.4
Potassium (K) (mg/L)	25	75	55	75	81	82
Chromium Cr^{6+}) (mg/L)	0.00	0.00	0.00	0.00	0.02	0.00
Sulphate (SO_4) (mg/L)	1.00	1.00	1.00	3.00	0.00	1.00
Copper (Cu^{2+}) (mg/L)	0.01	0.00	0.01	0.01	0.00	0.02
Fluoride (Fl) (mg/L)	0.46	0.22	0.16	0.11	0.09	0.28
Bicarbonate (HCO_3) (mg/L)	14.0	12.0	18.0	15.0	18.0	18.0
Total Suspended Solid (mg/L)	44.5	106	58.0	191	99.0	99.0
Total Coliform (Cfu/100ml)	11	32	18	22	28	26
E-Coli (Cfu/100ml)	0	7	4	3	2	3
Enterococcus Faecalis (Cfu/100ml)	0	0	0	0	0	0

Table 3. *Summary of the Measured Parameters and Their Compliance with FMWH Standard.*

	Minimum	Maximum	Mean	FMWH Drinking water Standard	% Compliance
Temperature	26.9	27.3	27.1	-	-
pH	6.19	6.93	6.54	8.5	100
Turbidity	2.00	14.00	6.23	2.5	8
Conductivity	135.00	789.00	378	-	-
TDS	78.4	539.00	253	500	92
T.H	56.00	250.00	140	200	77
Nitrate	0.40	4.40	2.65	45	100
Iron	0.00	0.18	0.07	0.1	77
Alkalinity	12.00	50.00	22.9	100	100
Chloride	11.00	121.00	44.5	200	100
Manganese	0.00	0.03	0.01	0.05	100

	Minimum	Maximum	Mean	FMWH Drinking water Standard	% Compliance
Calcium	9.62	74.5	33.5	75	100
Magnesium	3.66	40.0	13.8	30	85
Sodium	7.15	78.7	29.4	200	100
Potassium	15	82	60.1	12	0
Chromium	0.00	0.02	0.0	0.05	100
Sulphate	0.00	3.00	1.39	200	100
Copper	0.00	0.03	0.011	0.05	100
Fluoride	0.06	0.75	0.28	1.0	100
Bicarbonate	12.00	50.00	22.85	500	100
T.S.S	38.60	260.00	125	-	-
Total Coliform (Cfu/100ml)	10	37	22.4	10/100 ml	8
E-Coli (Cfu/100ml)	0	11	3	2.5 /100 ml	46
Enterococcus Faecalis (Cfu/100ml)	0	0	0	0	100

Alkalinity is defined as the quantity of ions in water that will react to neutralize hydrogen ions. Alkalinity is thus a measure of the ability of water to neutralize acids [1]. Alkalinity of the samples varies between 12 and 50 mg/L, with an average of 22.9 mg/L. Alkalinity of water samples are in 100% compliance with FMWH standard. Manganese, magnesium, and calcium range between 0 – 3 mg/L, 3.66 – 40 mg/L, and 9.62 – 74.5 mg/L, with mean values of 0.01 mg/L, 13.8 mg/L, and 33.5 mg/L respectively. All these parameters have 100% compliance with FMWH standard except Mg^{2+} (85%).

Sodium has the highest concentration of all the cations, with range of 7.15 – 78.7 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 [20]. Na^+ has different role in human body. It is related with the function of nervous system, membrane system and excretory system. The K^+ recorded varies between 15 and 82 mg/L with a mean value of 60 mg/L greater than 12 mg/L specified by FMWH. Therefore K^+ might have contaminated the groundwater system through agricultural practice with the use of NPK fertilizer or from orthoclase or microcline feldspars, mica, and clay minerals. The values obtained for chromium and copper vary from 0 to 0.02 mg/L and 0 to 0.03 mg/L respectively with 100% compliance.

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 12 to 50 mg/L with an average of 22.9 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 range between 11 and 121 mg/L. The evapo-transpiration processes of mineral salts might be an important source of this anion in the area, while anthropogenic source is not ruled out.

Chloride in all the samples is below the 200 mg/L limit "Table 3". However, no adverse health effects on human being have been reported by the use of water having high chloride concentrations [21]. Excess concentration of Cl^- in drinking water gives a salty taste and has a laxative effect in people not accustomed to it. Based on Cl^- classification [22], it indicates brackish / brackish salt water category.

Fluoride is seldom found in appreciable quantities in surface waters and appears in groundwater in only a few geographical regions. F^- ranges from 0.06 – 0.75 mg/L with an average of 0.28 mg/L, and 100% compliance with FMWH standard; while sulphate ranges between 0 and 3 mg/L. 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 problem. An excess of over 1.2 mg/L causes fluorosis [23].

The biological test recorded total coliform value between 10 to 37 Cfu/100 ml with an average of 22.4 Cfu/100 ml. The E-Coli ranges between 0 and 11 Cfu/100 ml with a mean of 6.54 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. Effects of the presence of E. coli in water include: urinary tract infections, bacteremia, meningitis, diarrhea (one of the main cause of morbidity and mortality among children), acute renal failure and haemolytic anaemia. 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 $K^+ > Na^+ > Ca^{2+} > Mg^{2+}$ for cations and $Cl^- > HCO_3^- > SO_4^- > F^-$ in anions. The water quality index (WQI) obtained for the water samples "Figure 3" ranges between 22.7 and 88.6. The WQI map categorizes into two, the water samples analyzed which represented different towns within the study area, namely: Excellent drinking water and Good drinking water. The excellent water accounts for about 85% while good water constitute about 15% of the study area.

However for purpose of irrigation, the water samples are evaluated by % Na "Figure 4", Sodium Absorption Ratio (SAR) "Figure 5", Residual Sodium Carbonate (RSC) "Figure 6", Permeability Index "Figure 7", and Electrical Conductivity "Figure 8". The % Na of the samples varies between 49 and 79. They generally have rating of moderate to high % Na 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 [24-25]. Therefore the water can be rated as average for irrigation purpose on the basis of % Na.

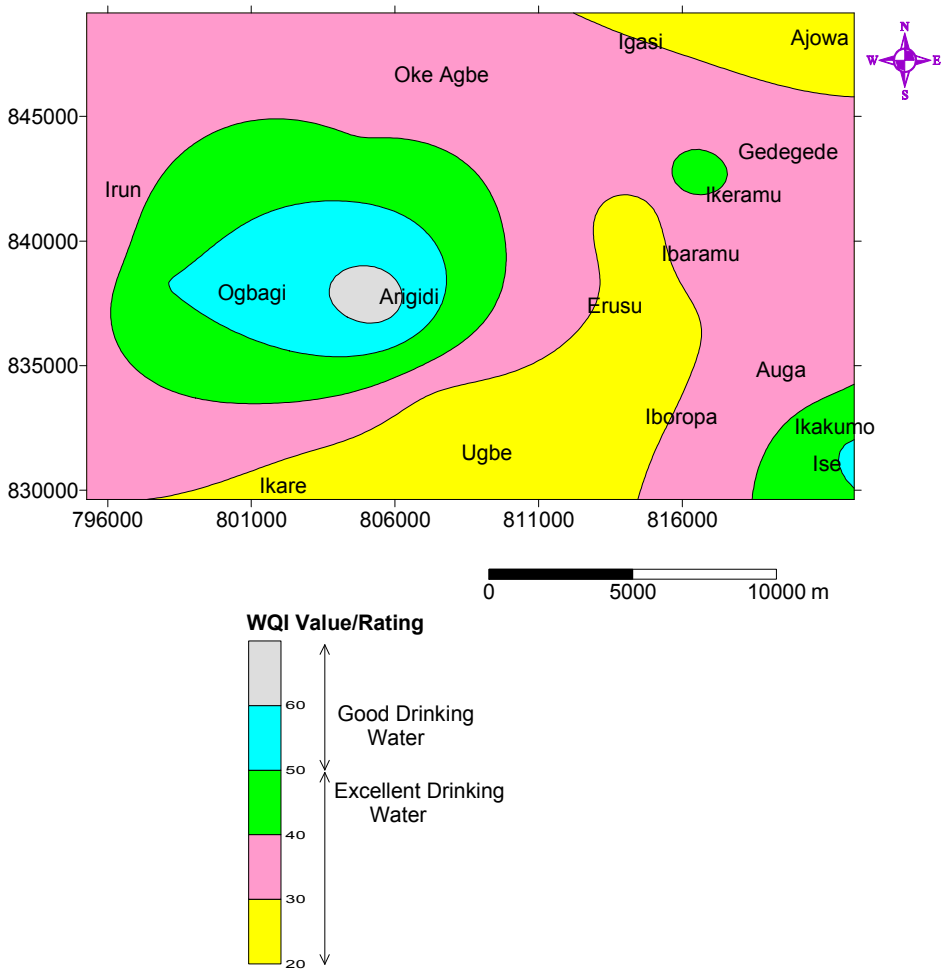

Figure 3. *Water Quality Index/Rating Map of the Study Area.*

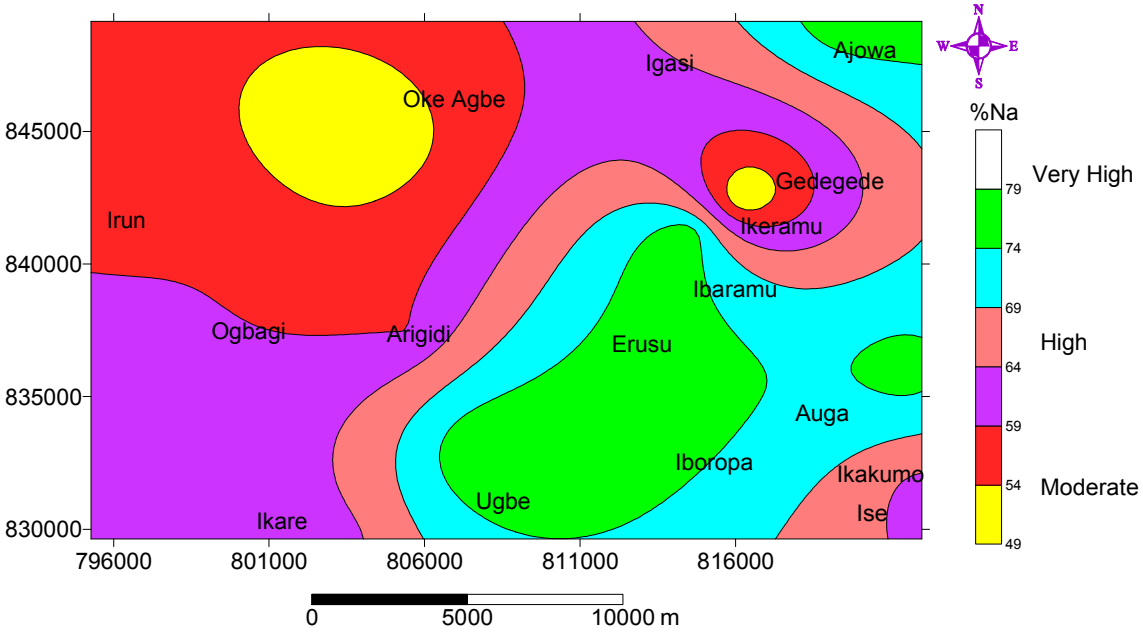

Figure 4. *Spatial Distribution of%Na in the Study Area.*

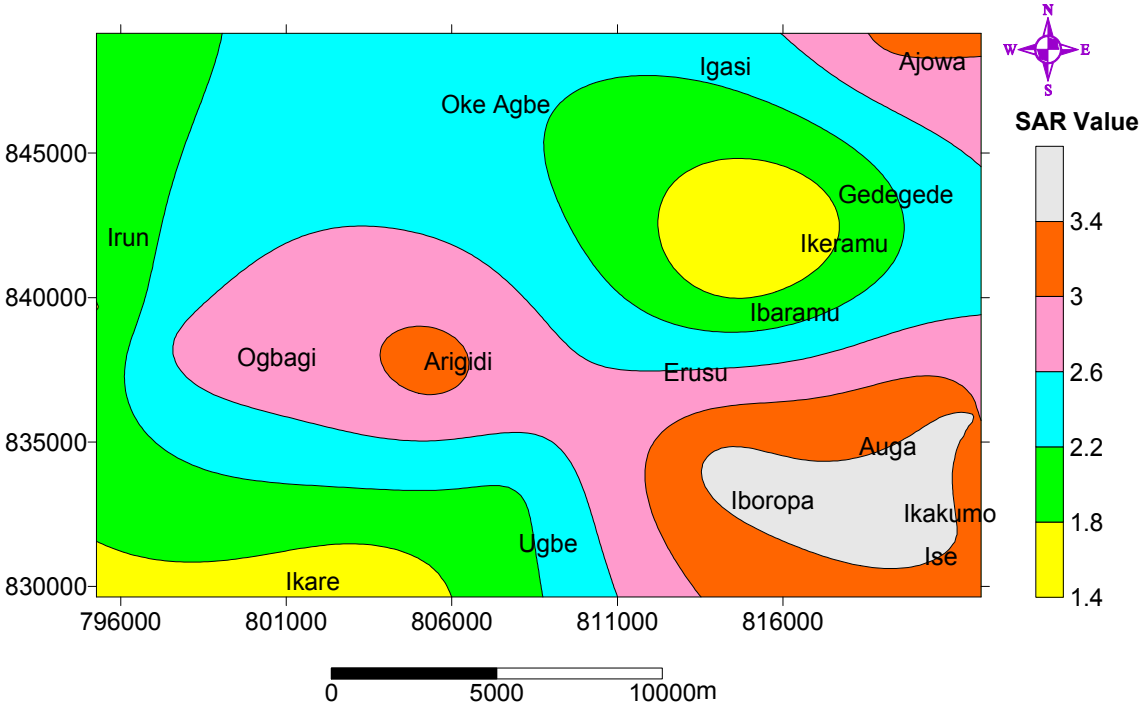

Figure 5. *Sodium Absorption Ration Map of the Study Area.*

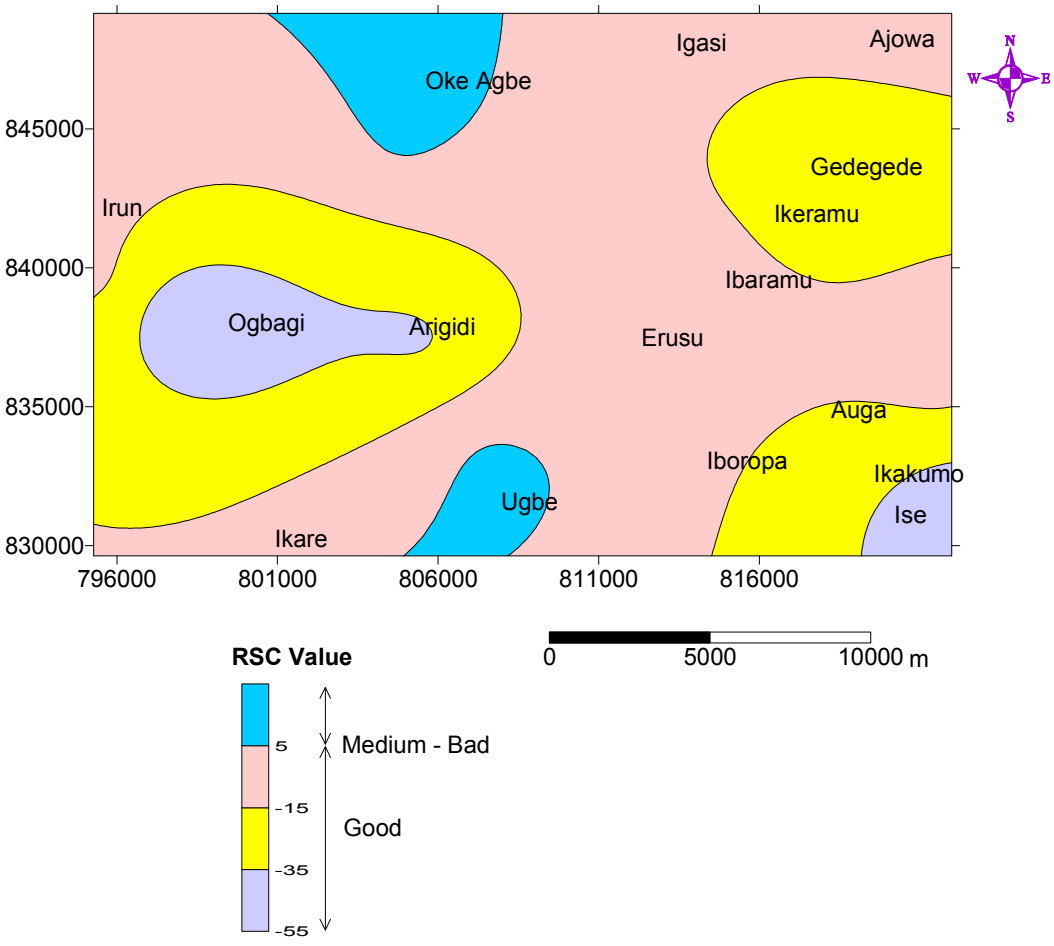

Figure 6. *Residual Sodium Carbonate Map of the Study Area.*

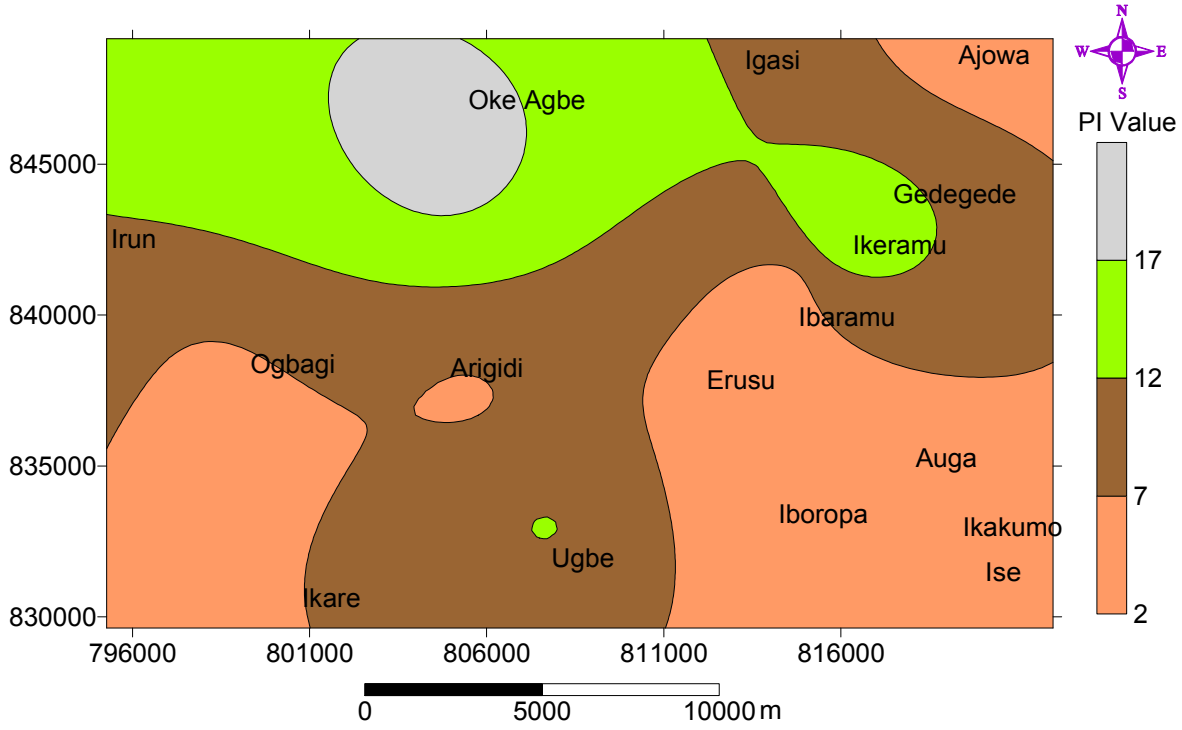

Figure 7. *Permeability Index Map of the Study Area.*

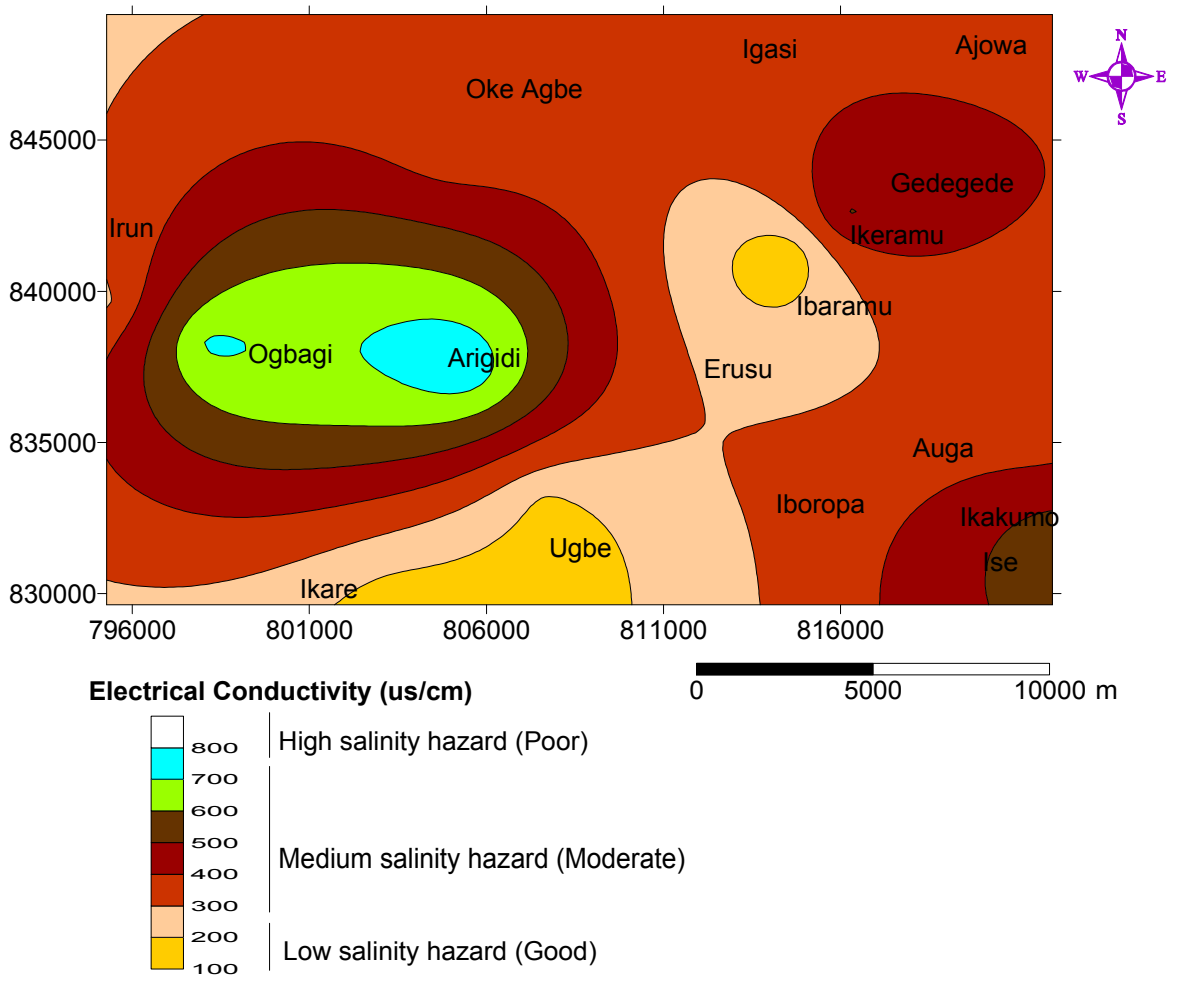

Figure 8. *Electrical Conductivity Map of the Study Area.*

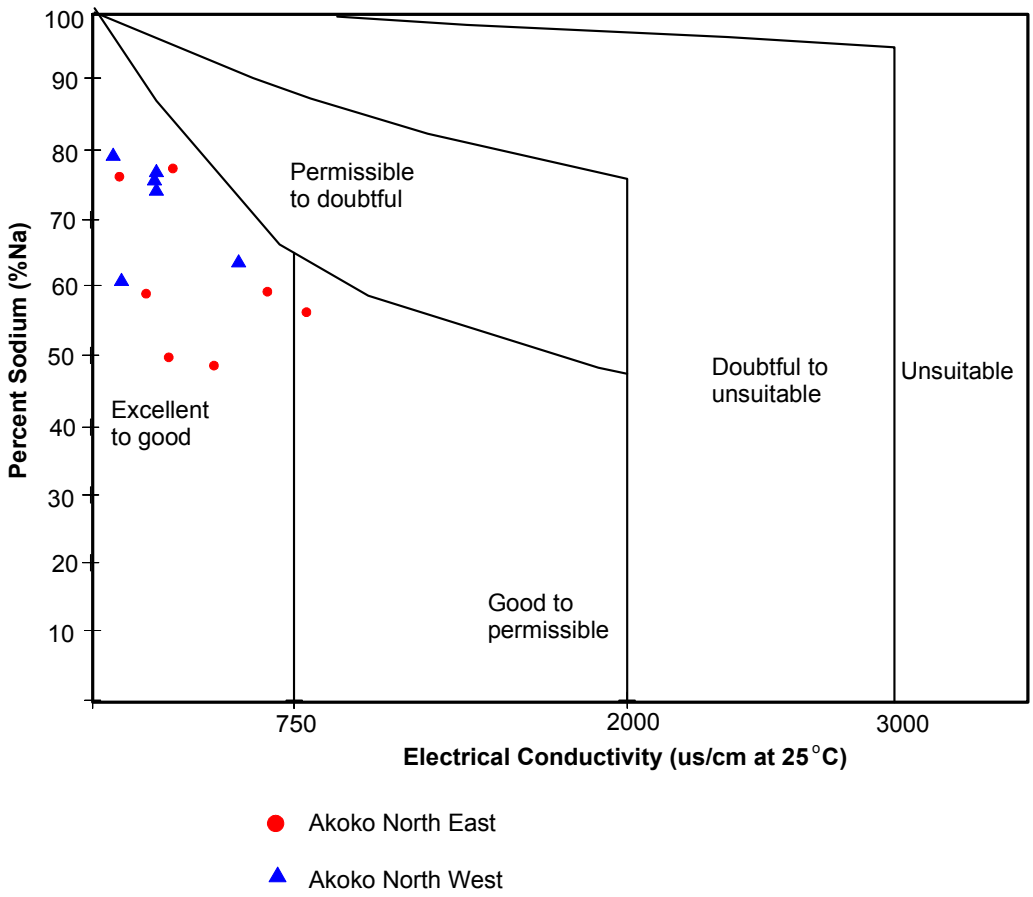

Figure 9. *Plot of % Na Against Electrical Conductivity of the Sampled Water (After [31]).*

Sodium Absorption Ratio (SAR) of the studied water samples varies from 1.40 to 3.56 with a mean of 2.44. The values are within 0 - 10 specified by [4] as excellent water for irrigation purpose.

The Residual Sodium Carbonate (RSC) values ranges between – 51.6 and +10.57, with an average of -14.5, which agrees with less than 2.5 specified by [4] for the purpose of irrigation. 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 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 2.27 to 19.9, with an average of 7.93. 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 Third category of 0 – 25 irrigation water which is rated as "poor".

The electrical conductivity of the water ranges from 117 to 789 µs/cm with an average of 378 µs/cm which corresponds to moderate (medium salinity). However, from the map, the water in the study area shows variation of low salinity to high salinity. The Wilcox plot [8] showed that the water samples have excellent – good irrigation potential "Figure 9". Therefore combine all these results the water are moderately suitable for irrigation purpose.

4. Conclusion

In order to understand the suitability of groundwater for drinking and irrigation purposes in Akoko northwest and Akoko northeast, water quality index calculation,%%Na, Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), Permeability Index (PI) and Electrical Conductivity were determined from thirteen (13) water samples. The sequence of the abundance of the major ions is in the following order of $K^+ > Na^+ > Ca^{2+} > Mg^{2+}$ for cations and $Cl^- > HCO_3^- > SO_4^- > F^-$ in anions. The water quality index classified the water into excellent and good drinking water. The% Na, SAR, and RSC rated the water as excellent for irrigation purpose. The PI values of the water samples are categorized as poor. However Wilcox plot which combines two important parameters consisting of sodium and electrical conductivity in evaluation of irrigation water rated the water as excellent – good except a sample taken from Arigidi Akoko which fall within "good to permissible limit". Therefore combining all the results of the investigation the water in the study area is good for drinking and irrigation agriculture.

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