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Comparative Assessment of Groundwater Suitability for Irrigation and Drinking Purposes in Agbara and Ota area of Southwestern Nigeria

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Abstract

The quality of water is measured in terms of its physical, chemical and bacteriological characteristics. Agbara and Ota area of southwestern Nigeria hosts many industries. These industries generate effluents which are discharged into the environment without any form of treatment, hence the need to ascertain the quality of water in the area for domestic and irrigation purposes. Water samples were collected and analyzed using standard laboratory techniques for physico-chemical and bacteriological parameters and the results were subjected to geostatistical analysis. The result revealed that the pH in the area is slightly acidic (5.70-6.90). The concentration of the major cations and anions falls within the permissible limit postulated by WHO. The high concentration of BOD. COD, total coliform and E.coli in water are testimonies the water in the area is poor bacteriologically and an indication of the presence of human faeces in the water. Prolong drinking of such kind of water can result to water borne diseases in the area. The high concentration of manganese in the water may be attributed to the industrial effluent from the in the area. The water index for irrigational suitability (SAR, SSP, PI, RSC, MAR and KR) suggest that the water in the area to be fairly good. The overall water quality index calculated also confirmed the poor quality status of water in the area. Good sanitary habit and proper treatment of industrial effluent before discharge into the environment is advocated. Boiling of water before use is recommended to ameliorate the effect of bacteriological contamination of the water.

Keywords: *Comparative Study; Groundwater Quality; Domestic and Irrigation Uses; Agbara Otta Area; Southwestern Nigeria.*

1.0 INTRODUCTION

Water is essential to life and demand for water is second only to oxygen. The quality of water determines its application for domestic, irrigational and industrial purposes. Agbara and Ota area are characterized by chains of industries which discharge their effluent into the surrounding environment, thereby deteriorating the ecosystem. Apart from industrial effluent, poor sanitation and indiscriminate dumping of refuse pose serious threat to the groundwater regimes in the area and hence the need for this study. It accounts for 65% of adult weight and acts as an intermediary in all life activities of animals. Water in the body improve digestion, excretion, blood circulation, balance body temperature, transform nutrients and nourish cells. In developing countries, about 75% of all diseases are directly related to poor drinking water and unsanitary conditions (Nag and Das, 2014). The evaluation of water quality is necessary as it is the determinant of the intended water use. The monitoring of water quality cannot be has gained relevance for the sustainable development and proper management of this precious natural resources (Amadi *et al*., 2014). Interestingly, Water quality depends on a number of factors such as the local geology, degree of weathering, prevalent climatic conditions, groundwater migration pathway and resident time as well as the anthropogenic activities domiciled in the area (Amadi *et al*., 2015). Poor sanitary condition and indiscriminate dumping of wastes deteriorates water quality. Various water quality indices and parameters are now being used to ascertain the quality of water leading to the determination of its suitability for domestic, irrigational or industrial purposes. The present study employs these tools in the assessment of groundwater for in parts Agbara and Otta area, southwest Nigeria for domestic and irrigation purposes.

1.1 Study Area Description

The study area is between Agbara and Ota axis of southwestern part of Nigeria and lies between longitude 3°03'00''E to 3°08'30''E and Latitude 6°28'00''N to 6°33'00''N covering an area of about 86 km^2 (Figure 1). The area is accessible through Orile-Badagry road, Badagry-Cotonu road as well as Aton-Lusida road. Geographically, the area lies within the tropical rainforest belt. The geology of the area comprises of alluvium belonging to the Dahomey Basin of southwestern Nigeria (Figure 1).

2.0 METHODOLOGY

A total of 48 set of water samples were collected within Agbara and Ota area in plastic bottles for the determination of major metals. To each of these water samples, two drops of concentrated HNO_3 acid were added for homogenization and prevention of absorption/adsorption of the metals to the walls of the plastic container (Amadi, *et al*., 2010). To the other 48 water samples in the glass container were used for the determination of the anions. Prior to the collection of the water samples in the various bottles, the physical were measured in the field using appropriate equipment.

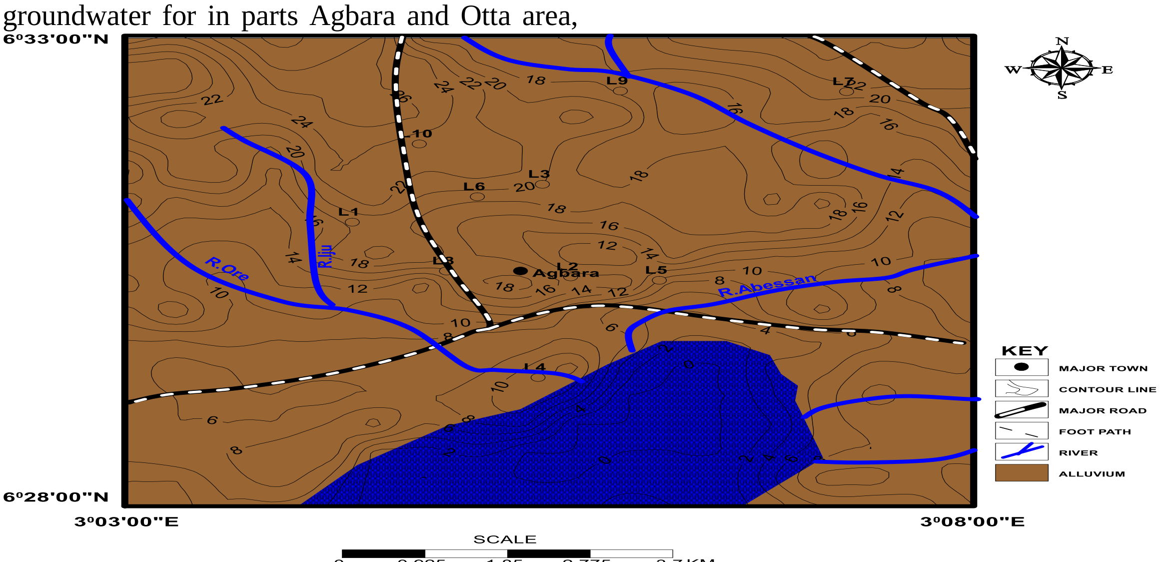

Figure 1. Geology Map of the study area.

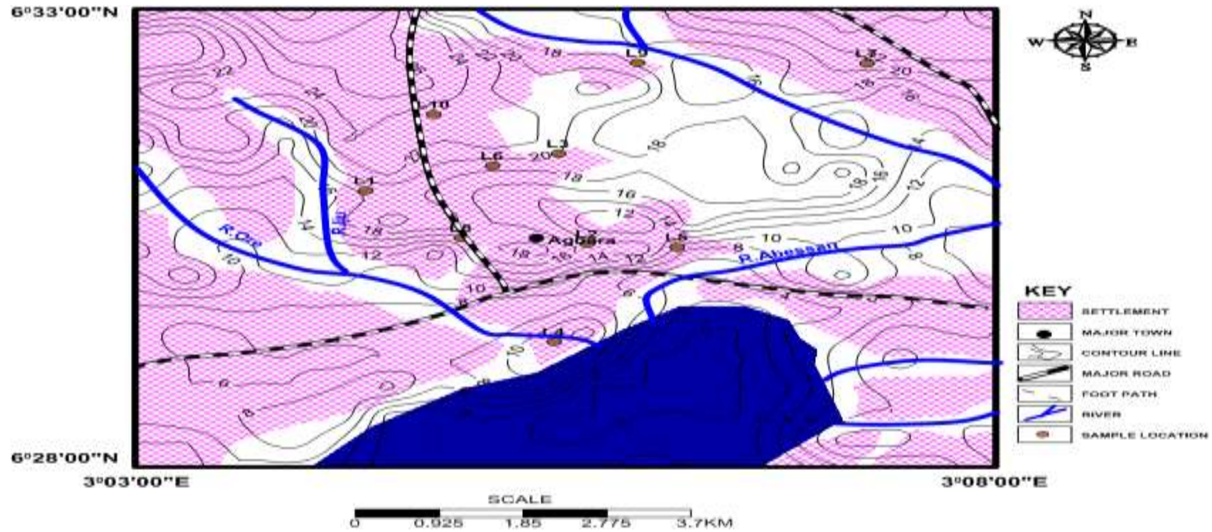

Figure 2. Map of the study area showing the sampling location.

After the field measurement, the samples were sent to laboratory where each sample was filtered to prevent the blockage of the nebulizer of the AAS and other equipments by suspended particles and ready for the chemical analysis in accordance with American Public Health Association techniques for the analyses of water and waste-water (AHPA, 2008). For the bacteriological analysis, a MacConkey broth media was then prepared by dissolving 35.0 g of the media in 1000 ml of water. To each of the 15 bottles, 10 ml of media was added. The 15 bottles and all glass wires to be used were put in an autoclave and allowed to attain a temperature of 105°C for sterilization. After the bottles were brought out, they were allowed to attain back the room temperature. They were then grouped into 5-5-5 and labelled for addition of water sample in the order of 10 ml, 1 ml and 0.1 ml respectively. All the bottles were then put in an oven (Plate 1) set at 35°C and allowed an incubation period of 48 hours. At the end of the time, bacteriological growth was observed by trapping of air bubbles and de-colorization of the media. The de-colorized bottles were then compared with a standard chart. The analysis was extended to determine whether the bacteria detected above is E.coli or not. This was done by dissolving 38.0 g of MacConkey broth (purple in colour) in 1000 ml of water and using it as an indicator in the same procedure as above but with an incubation temperature and period of 40°C and 24 hours respectively. Further de-colorization of the media shows presence of the E.coli.

3.0 RESULTS AND DISCUSSION

The statistical summary of the physical, chemical and bacteriological parameters analyzed is shown in Table 1. The pH values varied from 5.70 - 6.90 with an average value of 6.31 while the temperature ranged between 23.00 – 27.00 ºC with a mean value of 25.00 ºC (Table 1). The low pH values observed implies that the groundwater in the area is slightly acidic and can be attributed to the discharge of untreated wastes from industries on the soil, surface and groundwater. Low pH and high temperature enhances the dissolution and mobility of metals in soil and water. The value of total dissolved solid (TDS) ranged between 21.80 - 456.50 mg/l with a mean value of 155.35 mg/l as against the recommended limit of 500.00 mg/l while the value of suspended solid (SS) varied from 20.00 - 79.00 mg/l with a mean value of 40.10 mg/l. The electrical conductivity (EC) value ranged from 38.00 - 709.00µs/cm with an average value of 241.80 µs/cm (Table 1). The TDS, EC and SS are important water quality parameters used to infer groundwater pollution as the presence of ions in water makes it conductive.

Table 1. Statistical summary of physico-chemical and bacteriological data.

Parameters	Minimum	Maximum	Mean	Std Deviation	Variance	WHO	NSDWQ
Temperature	*23.00*	27.00	25.00	0.00	0.00	ambient	ambient
Colour	20.00	179.00	74.80	58.40	3410.40	15.00	15.00
Ph	5.70	6.90	6.31	0.40	0.16	6.50-8.50	6.50-8.50
Conductivity	38.00	709.00	241.80	229.43	52639.51	1000.00	1000.00
TDS	21.80	456.50	155.35	147.76	21835.5	500.00	500.00
Suspended Solid	20.00	79.00	40.10	19.21	369.21	5.00	15.00
Bicarbonate	15.00	82.00	44.90	24.49	599.88	100.00	100.00
Chloride	3.50	45.00	17.30	14.15	200.46	250.00	250.00
Manganese	0.04	1.60	0.52	0.51	0.26	0.20	0.20
Iron(III)	0.16	0.43	0.27	0.08	0.007	0.30	0.30
Sulfate	6.50	33.00	13.45	7.55	57.03	100.00	100.00
Nitrate	7.90	24.00	14.31	5.96	35.53	50.00	50.00
Magnesium	1.70	10.30	5.45	2.93	8.58	150.00	0.20
Calcium	4.10	20.10	11.31	5.15	26.50	200.00	200.00
Total Hardness	42.00	84.00	64.50	14.42	207.83	200.00	200.00
Potasium	0.50	9.10	2.31	2.54	6.89	100.00	100.00
Sodium	0.01	1.89	0.38	0.57	0.32	200.00	200.00
BOD	0.00	516.00	99.50	166.00	27593.39	6.00	6.00
COD	0.00	171.00	47.40	64.76	4193.82	10.00	8.00
E. Coli /100ml	0.00	15.00	6.80	2.25	.5.07	0.00	0.00
Total Coliform	28.00	250.00	183.10	151.66	288.0	10.00	10.00

TDS-total dissolved solids, BOD-biochemical oxygen demand, COD-chemical oxygen demand, E.Coli-Escherichia coli.

The concentration of chemical oxygen demand (COD) ranged from 0.0 - 171.0 mg/l with a mean concentration of 47.40 mg/l as against the maximum permissible limit of 10.0 mg/l (WHO, 2006). It accounts for the amount of oxygen that will be required for oxidation of organic and inorganic substance in water. The high concentration of COD in the water suggests the presence industrial effluent and other solid waste in the water (Egharevba *et al*., 2010). The biochemical oxygen demand (BOD) explains the oxygen required in the decomposition of organic substance. The concentration of BOD varied from 0.00 - 516.00 mg/l with an average value of 99.50 mg/l and these values by far exceeds the permissible limit of 6.0 mg/l (NSDWQ, 2007).

This elevated concentration of BOD may be the result of microbial action taking place during decomposition of organic matter in water (Olasehinde *et al.*, 2014). Sodium content in water ranged between 0.01 - 1.89 mg/l with a mean content of 0.38 mg/l and concentration of potassium varied from 0.50 - 9.10 mg/l with a mean value of 2.31 mg/l. Calcium has values ranging from 4.1 - 20.1 mg/l and a mean value of 11.31 mg/l while magnesium concentration ranged from 1.7 - 10.3 mg/l with an average value of 5.45 mg/l. The concentrations of these major cations are extremely low compared to their respective permissible limits (WHO, 2006). Calcium is necessary in animals for the formation of strong tooth and its high in water does not have any negative impact on human health (Aminu and Amadi, 2014; Okunlola *et al*., 2014). Chloride concentration ranged from 3.5 - 45.0 mg/l with a mean concentration of 17.30 mg/l while the value of bicarbonate ranged between 15.00 - 82.00 mg/l with an average value of 44.90 mg/l. Sulphate values varied from 6.50 - 33.00 mg/l with a mean value of 13.45 mg/l and the concentration of nitrate ranged between 7.90 - 24.00 mg/l with a mean value of 14.31 mg/l.

The concentrations of the major anions were also found to be very low and this explains the average concentration of TDS and EC. Elevated concentration of nitrate in drinking water can lead to infant methaemoglobinaemia (blue-baby syndrome), metabolic disorder, poisoning of livestock and gastric cancer (DanHassan *et al*., 2012). The concentration of iron ranged from 0.16 - 0.43 mg/l with a mean value of 0.27 mg/l while The concentration of manganese ranged from 0.04 - 1.60 mg/l with an average value of 0.52 mg/l. Iron is an essential element and its concentration does not constitute any known problem except that it impairs the colour and taste of the water while high manganese content in water can cause neurological disorder (Amadi, *et al*., 2013; Nwankwoala *et al*., 2014; Olasehinde *et al*., 2015; Nag and Das, 2014).

The value of Escherichia coli (E.coli) varied between 0.0 - 15.0 cfu/ml with an average value of 6.80 cfu/ml while concentration of total coliform ranged between 28.00 - 250.00 cfu/100ml with a mean concentration of 183.10 cfu/100ml (Table 1). The presence of Escherichia coli and total coliform in water is a clear indication of faecal contamination of the shallow groundwater. Such bacteriological contamination of water is responsible for most water borne disease such as meningitis, cholera and diarrhea as well as morbidity and mortality among children. It also leads to acute renal failure and haemolytic anaemia in adults (Aminu and Amadi, 2014).

3.1 Water Quality Index for Irrigation Purposes

The irrigational quality of the groundwater samples was assessed using six index parameters namely: sodium adsorption ratio, soluble sodium percentage, magnesium adsorption ratio, permeability index, residual sodium carbonate and Kelly's ratio. The calculations of these parameters are in meq/l.

3.2 Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio (SAR) is a measure of the sodicity of the soil determined through quantitative chemical analysis of water in contact with it. Sodium hazard results when the excess amount of carbonate and bicarbonate in water reacts with sodium in soil (Subramani *et al*., 2005). The SAR was calculated using the formula:

SAR = [Na+] / {([Ca2+] + [Mg2+]) / 2}1/2 …………………. Richard Formula.

In the present study, the SAR values range from 0.001 – 0.09 with an average value of 0.02 (Table 2). Based on the SAR values, the samples fall within the low sodium hazard (S1) in United States Salinity diagram (Figure 3). The water samples fall in the C1-S1 region are very good for irrigation purposes while the location appearing in the C2-S1 category are fairly good for irrigational use (Figure 3). The suitability for irrigation decreases from C1-C4 and S1-S4.

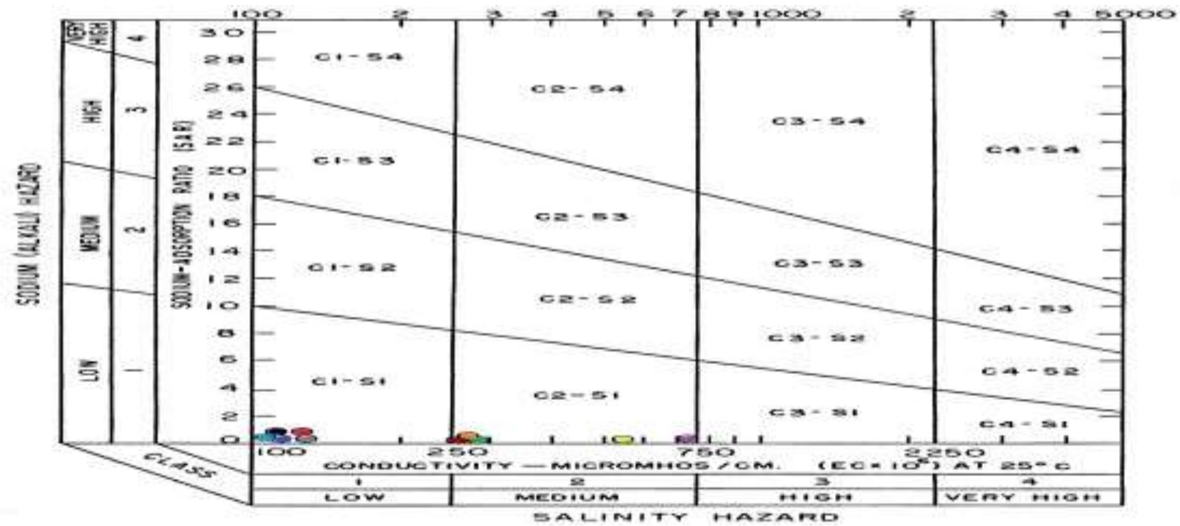

Figure 3. United States Salinity Diagram for the study area.

3.3 Soluble Sodium Percentage (SSP)

High sodium ion concentration in soil affects the internal drainage patterns in soil as release of calcium and magnesium ions are facilitated due to adsorption of sodium by clay particles. High sodium content in soil results in leaf burn and dead tissue along the outside edges of leaves. The SSP was calculated using the equation:

$SSP = [(Na^{+} + K^{+}) * 100] / [Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}]$ …………….Wilcox Formula

The SSP values ranged from 1.62 – 23.65 with a mean value of 6.92 and these values are plotted against the EC values on the Wilcox diagram and were found to fall under the Excellent to Good categories (Figure 4).

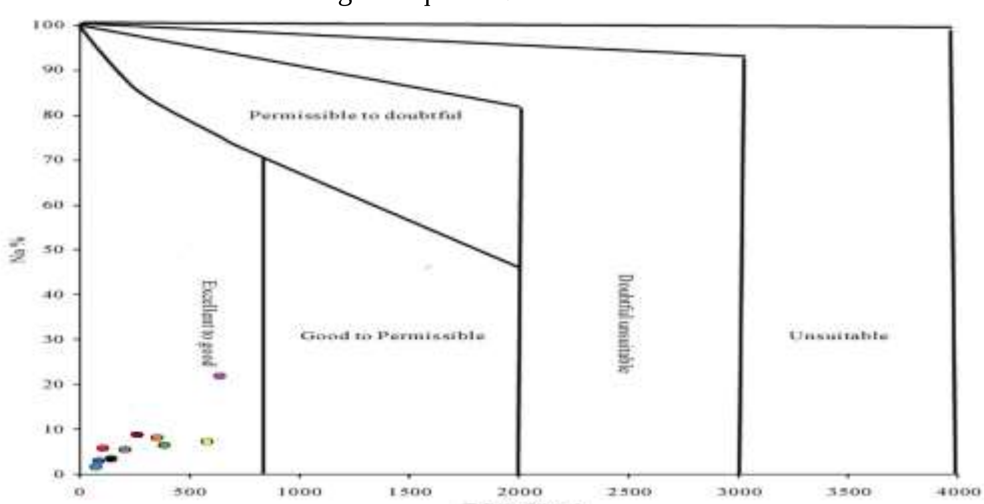

Figure 4. Wilcox Diagram for the study Area.

3.4 Permeability Index (PI)

According to Gupta and Gupta (1987), Permeability index is a criterion based on the solubility of salt and the reaction occurring in the soil solution from cation exchange for estimating the quality of agricultural waters. Soil permeability is affected by long term use of irrigation water and it is a function of total dissolved solids, sodium content and bicarbonate content. Doneen, (1964) developed an empirical formula for determining permeability index of soil with respective to irrigation water and permeability index were categorized into three groups.

The permeability index is given by the formula:

$$PI = Na^{+} + [\{HCO_3^{-})^{1/2} / (Ca^{2+} + Mg^{2+} + Na^{+})\} * 100] \ldots\ldots\ldots\ldots\ldots \text{ Doneen Formula}$$

The value of the permeability index ranged from 45 - 151 with a mean value of 89.3. The plot of permeability index against total ion concentration was illustrated on Doneen's chart (Figure 5). Permeability Index is classified into 3 groups: Class I (100% permeability), Class II (75% permeability) and Class III (25% permeability). The Classes I and II are categorized as excellent and good irrigation water respectively while Class III waters are judged unsuitable for irrigation for having only 25% of maximum permeability. This implies that water in this soil will hardly infiltrate into the plants for their use.

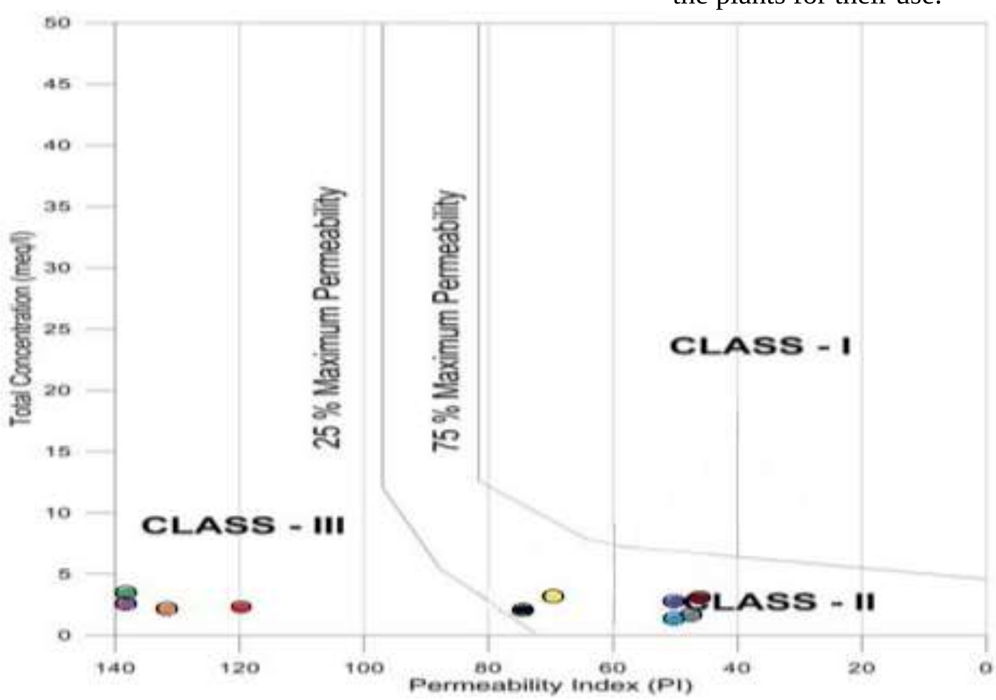

Figure 5. Doneen's Chart for Permeability Index for the study area.

3.5 Residual Sodium Carbonate (RSC)

The residual sodium carbonate index of water/soil signifies the alkalinity hazard posed by it and it finds the suitability of water for irrigation in case of clay soils (Raju, 2007). It is given by the equation:

$$RSC = (HCO_3^{-} + CO_3^{2-}) - (Ca^{2+} + Mg^{2+}) \ldots\ldots\ldots\ldots\ldots\ldots \text{ Raju Formula}$$

The value of residual sodium carbonate values should preferably be less than 1.25 to be considered suitable for irrigational purposes (Raju, 2007; Nag and Das, 2014) and good enough in the present study the RSC values ranged from -0.91 – 0.58 with a mean value of 0.27. This implies that the groundwater in this area does not pose any alkaline hazard and thus can be considered suitable for irrigation.

3.6 Magnesium Adsorption Ratio (MAR)

In most groundwater regimes, the Ca^{2+} and Mg^{2+} ions maintain a state of equilibrium. In situation where the equilibrium is not attained, more Mg^{2+} in groundwater adversely affects the soil quality rendering it alkaline which result in decrease of crop yield (Kumar et al., 2007). Paliwal (1972) developed an index for calculating the magnesium hazard called MAR and it is calculated using the formula:

$MAR = (Mg^{2+} * 100) / (Ca^{2+} + Mg^{2+})$ ……………………………… Paliwal Formula

The MAR values ranged between 12.28 – 73.2 with a mean value of 44.64. MAR classified water for irrigation use into two broad groups: suitable (MAR value < 50) and unsuitable (MAR value > 50). Based on this classification, about 650% of the water are suitable for irrigation and while 35% are unsuitable as irrigation water.

3.7 Kelly's Ratio (KR)

Kelly's ratio was devised by Kelly in (1940) and is a measure of sodium ion concentration against calcium and magnesium ion concentrations. Kelly's ratio is given by the formula:

$KR = Na^{+} / (Ca^{2+} + Mg^{2+})$ ………………………… Kelly's Formula

Water with a KR value <1 are considered suitable for irrigation while those with values >1 are considered unsuitable. In this study, Kelly's ratio ranged from 0.0003 - 0.060 with a mean value of 0.014. Based on the computed values, the water in the area are suitable for irrigation.

Table 2: Statistical Summary of Computed Irrigation Water Quality Index.

Parameters	Minimum	Maximum	Range	Mean	Std Deviation	Variance
SAR	0.001	0.09	0.089	0.0216	0.026	0.00069
SSP	1.62	23.65	22.03	6.923	6.359	40.44
PI	45.00	151.00	106.00	89.30	42.64	1817.79
RSC	-0.91	0.58	1.49	-0.275	0.54	0.29
MAR	12.28	73.20	60.92	44.64	20.55	422.43
KR	0.0003	0.06	0.0597	0.014	0.0175	0.0003

3.8 Hydrochemical Facies

The Hydrochemical evolution of groundwater can be understand by plotting the major cations and anions present in groundwater over the Piper trilinear diagram. The diagram reveals similarities and differences among water samples as those with similar qualities tends to plot together as groups (Apambire *et al*., 1997). The diagram is useful in bringing out chemical relationships among water in more definite terms (Amadi *et al.*, 2013). It is a graphical representation of the dominant cations (Ca, Mg, Na and K) and anions (Cl, SO_4, HCO_3 and CO_3) and is used to predict the water type in an area (Amadi, 2009). These major ions are plotted as cations and anions in percentages of miliequivalent in two base triangles by grouping (Na + K) and (HCO_3 + CO_3) together (Figure 6). The water in the area falls under the normal earth alkaline (Ca/Mg-HCO_3 type), signifying shallow fresh water.

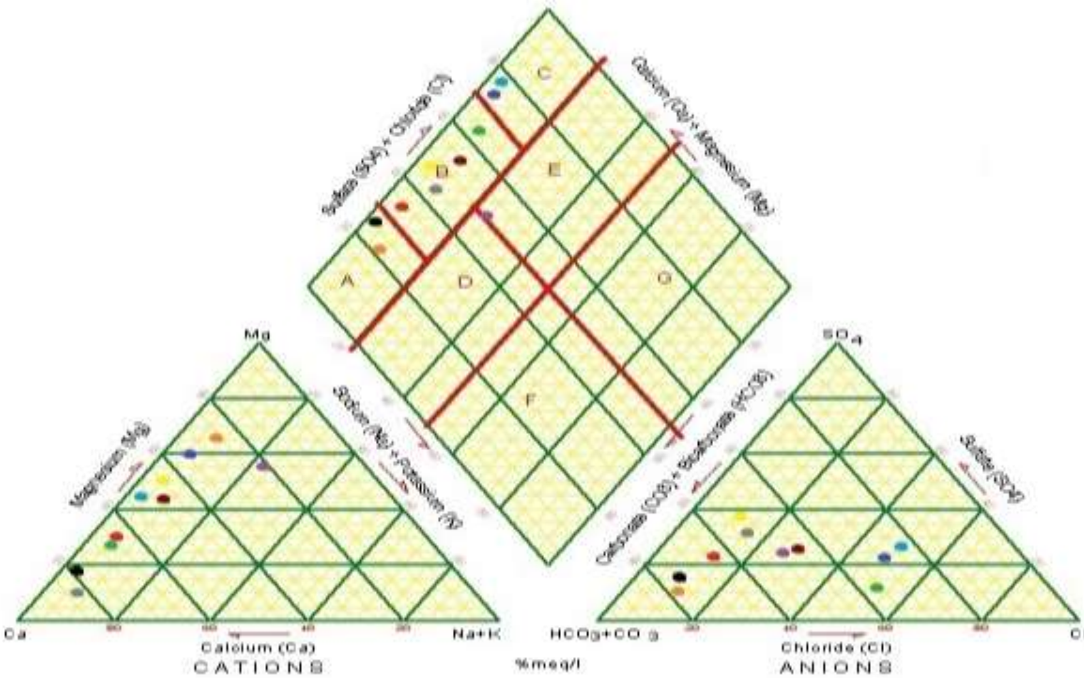

Figure 6. The Piper trilinear diagram for the study area.

3.9 Water Quality Index (WQI)

Water quality index is a very efficient and effective tool used to convey information on the overall quality of water in an area based on water quality parameters. It expresses the overall water quality at a given place over a period of time on the basis of water quality parameters (Amadi *et al*., 2012). The goal of WQI is to transform complex water quality data into information that is understandable and useable by stake holders in the water sector as well as the general public.

3.10 Calculation of WQI

The weighted arithmetic index method was used to calculate WQI. The quality rating scale q_i for each parameter was calculated using the expression below:

$$q_i = (C_i / S_i) \times 100$$

where: C_i = mean concentration of the parameters;

S_i = Nigerian Standard for Drinking Water Quality (NSDWQ, 2007).

Relative weight (W_i) was calculated by a value inversely proportional to the standard value (S_i) of each respective parameter:

$$W_i = 1/S_i$$

Generally, WQI is estimated for a definite and planned use of water and it is a function of the anthropogenic activities domiciled in the area over a given period of time. In the present study the WQI was estimated (Tables 3 and 4) for domestic purposes using the formula:

$$\text{Overall WQI} = \frac{\sum q_i w_i}{\sum w_i}$$

Where: q_i: the quality of the ith parameter,

w_i: the unit weight of the ith parameter

n: the number of the parameter considered.

The computed overall WQI value was 166.81 and this indicates that the water in the area is poor in terms of quality. The high concentration of manganese, COD, BOD, coliform bacteria and E.coli in the groundwater from the area are the factors responsible for the poor water condition observed.

$$\text{Overall } WQI = \frac{\sum q_i w_i}{\sum w_i} = \frac{2003.516}{12.011} = 166.81.$$

Table 3: Computed WQI values for the study area.

Parameters	Ci	Si	Qi	W_i	Qiwi
pH	6.31	6.5-8.5	84.13	0.133	11.19
Conductivity	241.8	1000.00	24.18	0.001	0.024
TDS	155.35	500	31.07	0.002	0.062
Suspended Solid	40	15	266.67	0.067	17.87
Chloride	17.30	250	6.92	0.004	0.028
Manganese	0.52	0.20	260	5	1300
Iron(III)	0.27	0.30	90	3.33	299.70
Sulfate	13.45	100	13.45	0.01	0.135
Nitrate	14.31	50	28.70	0.02	0.574
Magnesium	5.45	0.20	3.63	0.007	0.025
Calcium	11.31	150	5.66	0.05	0.283
Total Hardness	64.50	200	32.25	0.005	0.161
Potasium	2.31	100	2.31	0.01	0.023
Sodium	0.38	200.00	0.19	0.005	0.001
BOD	99.50	6.00	1658.30	0.167	276.94
COD	47.40	10.00	474.00	0.10	47.40
E.Coli /100ml	6.80	0.00	0.00	0.00	0.00
Total coliform	28.10	10.00	183.00	0.1	183

BOD-biochemical oxygen demand, COD-chemical oxygen demand, TDS-total dissolved solids, Ecoli-Escherichia coli;

Table 4: Classification of water based on WQI value.

WQI value	Water quality
<50	Excellent
50-100	Good water
100-200	Poor water
200-300	Very poor water
>300	Unsuitable for drinking

4.0 CONCLUSION AND RECOMMENDATIONS

The water in Agbara and Otta area has been investigated using hydrogeological, hydrogeochemical and bacteriological principles. The study identifies manganese, BOD, COD, total coliform and E.coli as the contributing factor for the poor water status in the area. Poor sanitary conditions and effluents from the various industries domiciled in the area are responsible for water deterioration in the area. The study concludes that the water in the area is fairly good for irrigation purposes and poor for domestic use. Treatment of industrial effluent before discharge into the environment is advocated. Boiling of water and good hygiene practice is recommended.

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