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Assessment of Groundwater Quality in Akoko Southwest and Southeast Local Government Areas of Ondo State Using Water Quality Index Method and Statistical Approach

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Abstract: *Groundwater quality assessment involving physicochemical and biological analysis of thirteen well/borehole samples were undertaken in Akoko southwest and southeast local government areas of Ondo State in order to determine their suitability for drinking. Water quality index (WQI) was calculated from 17 parameters including pH, total hardness, calcium, magnesium, bi-carbonate, chloride, fluoride, nitrate, sulphate, iron, manganese, sodium, chromium, copper, conductivity, total dissolve solute, and alkalinity. The value of the ionic balance error is observed to be within acceptable limit of ± 5%. The analyzed water samples are clear in appearance and odourless with moderate temperature. The WQI obtained from the study ranges from 20 to 497. All the water samples generally failed the biological test due to high total coliform and Enterococcus Faecalis. Also, pH, Fe, total Hardness fall below the standard requirement of World Health Organization. Total Dissolved Solute (TDS) have strong interrelation with Conductivity and Total Suspended Solutes (TSS). Total hardness have strong correlation coefficient with calcium, magnesium, sodium, and chloride signifying permanent hardness in nature. The Water Quality Index map classified the water in the study area into "excellent – good" drinking water. The excellent water constitute about 90 % of the study area while good water constitutes about 10 % of the area notably around Aiyegunle and part of Oba-Akoko in Akoko northwest. The results of the trend analysis have been used to suggest models for predicting water quality, and it showed negative trends for major anions including sulphate, nitrate, and bi-carbonate. The analysis reveals that the groundwater of the area needs some degree of treatment before consumption, as it requires optimum protection from contamination by groundwater monitoring; proper site selection for activities and industries using hazardous chemicals; enhanced containment for storage of wastes and chemicals on vulnerable soils; and reduction of chemical use wherever possible.*

Keyword: *Physicochemical analysis, Biological test, Water Quality Index, WHO, Correlation Matrix, Drinking water*

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I. Introduction

Utilization of groundwater as a source for domestic, municipal, agricultural and industrial activities continue to increase tremendously with rapid increase in population and growth of industrialization (small scale factories and business), especially in Akoko southwest and southeast parts of Ondo state, southwestern Nigeria. This rapid growth has become a threat to groundwater quality due to disposal of domestic, urban and industrial solid wastes; as open dumping is the most common way to dispose municipal and industrial wastes especially during the raining season. Subsequent leaching of toxic contaminants through the dumping site also leads to extensive contamination of ground water at many places. Since variation of groundwater quality in an area is a function of physicochemical parameters that are greatly influenced by geological formations and anthropogenic activities, therefore thorough evaluation and assessments of all water wells/borehole in the area is needed to ascertain their suitability for drinking and other domestic usage

1.1 Description of the Study Area

Akoko southwest and southeast are located in northern senatorial district of Ondo State, southwestern, Nigeria. Expressed in Universal Traverse Mercator (UTM coordinates), the study area is located within Northings 816000 mN – 831000 mN, and Eastings 796000 – 826000 mE "Fig. 1". The major occupations of the people are agriculture, horticulture, and animal husbandry. The major industries are agro-industries, and food processing

industries. The area is characterized by rugged topography with elevation above 300 m above sea level. It is situated within the Precambrian Basement complex of southwestern Nigeria. The most predominant rock type in the area is migmatite and granite/granite gneiss. The annual rainfall ranges between 1500 – 2000 mm with a relative humidity of about 75 – 90 % [1]. The annual mean temperature varies between 22 - 28°C.

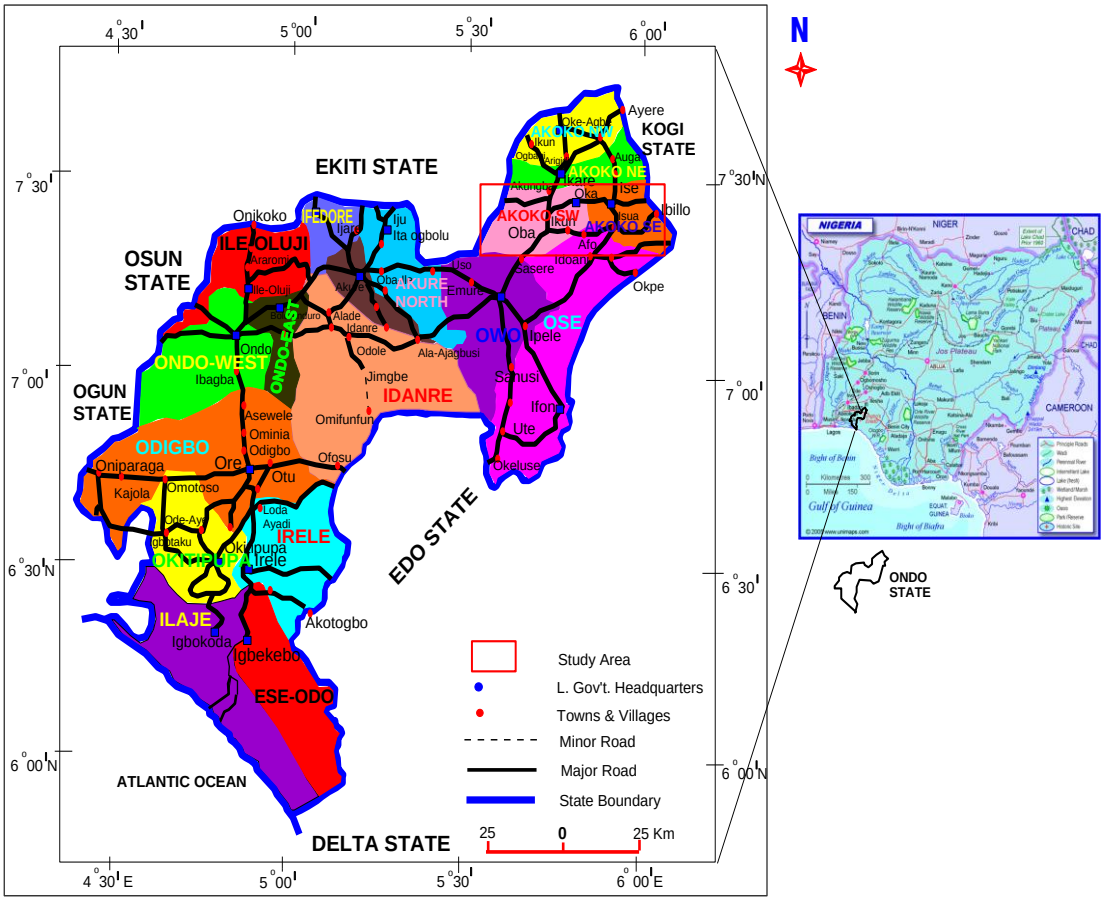

Figure 1: Location Map of the Study Area

II. Materials And Methods

It is necessary to assess the physico-chemical and bacteriological quality of ground water, as they are critical to restrict the usability of water for special purposes. About 100 ml of thirteen water samples were collected from major towns and villages within the study area "Fig. 2" in sterilized bottles using the standard procedure for grab (or) catch samples in accordance with standard methods of APHA [2]. The samples were then taken to Federal Ministry of Water Resources in Akure, Ondo State for analysis of physical, chemical and biological parameters/test 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 using the Buck Model 205 Atomic Absorption Spectrophotometer and flame photometer for the cations.

The microbial/biological tests involved analysis for coliforms, E-coli, and Enterococcus faecalis. The analysis were carried out as described in [3]. All the chemicals and reagents used were of analytical grade. De-ionized distilled water was used for the preparation of solutions. The calculation of Water Quality Index (WQI) involve the application of the three (3) fundamental steps as proposed by [4-7]. 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 [8]. In this study, a maximum weight of five (5) was assigned

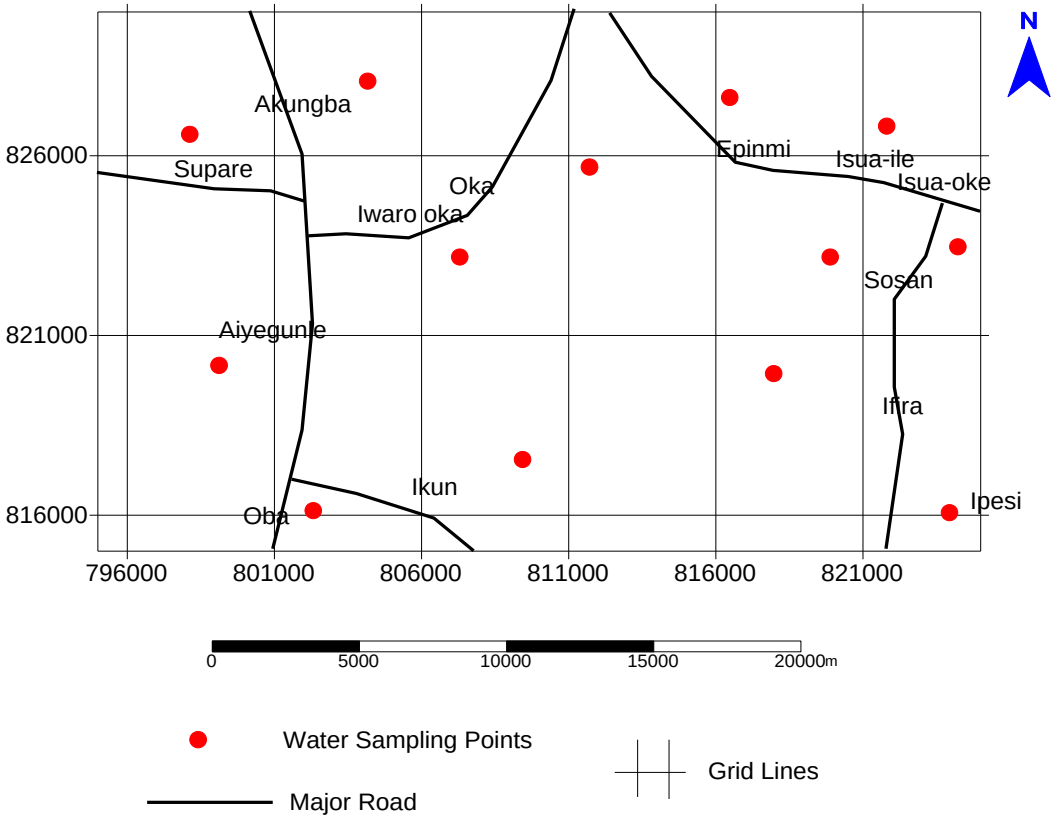

Figure 2: The Base map of the study showing water sampling points

to NO_3^-, 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 involves the determination of the relative weight (W_i) using equation (1);

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \text{ ……..... (1)}$$

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 equation (2);

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

where, *qi* 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 WHO standard for each chemical parameter in milligrams per liter according to the guidelines of the World Health Organization Standard [9]. The final stage of the experiment is the calculation of WQI by applying equation (3);

$$WQI = \sum_{i=1}^{n} SLi \text{ ……..……. (3)}$$

Where SLi is the product of W_i and q_i. "Table 4" shows the WQI calculated and their corresponding remarks.

III. Results And Discussion

The results of the analysis are presented in "Tables 1 – 3". The value of the ionic balance error is observed to be within acceptable limit of ± 5%. All the water samples have clear appearance and odourless. Temperature of water is basically important because it effects bio-chemical reactions. A rise in temperature of water leads to the speeding up of chemical reactions in water, reduces the solubility of gases and amplifies the taste and odour.

Table 1: Physical, chemical and Biological Results for Measured Parameters in Akoko Southwest

Parameters/ Location	Oka	Iwaro-Oka	Oba	Ikun	Aiyegunle	Supare	Akungba
Northing (m)	0824626	0823835	0815453	0816260	0820607	0825106	0826891
Easting (m)	0807733	0805641	0800749	0806467	0800971	0798953	0801994
Sample No.	S1	S2	S3	S4	S5	S6	S7
Appearance	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
Temperature (°C)	27.3	27.2	27.2	27.2	27.2	27.4	27.1
pH	5.73	5.92	6.40	7.06	6.88	6.77	5.93
Turbidity (NTU)	2.00	4.00	0.00	4.00	0.00	3.00	4.00
Conductivity ($\mu s/cm$)	391	667	326	341	255	271	567
TDS (mg/L)	242	447	218	229	171	186	380
Total Hardness (mg/L)	104	72.0	110	126	108	108	170
Calcium Hardness (mg/L)	70.0	46.0	50.0	78.0	51.0	52.0	110
Magnesium Hardness (mg/L)	34	26.0	60	48.0	57.0	56.0	60.0
Nitrate (NO_3) (mg/L)	6.50	0.80	0.24	3.50	1.30	19.0	2.40
Iron (Fe) (mg/L)	0.00	0.01	0.05	0.16	0.67	0.02	0.36
Total Alkalinity (mg/L)	8.00	10.0	26.0	10.0	24.0	22.0	16.0
Chloride (Cl^-) (mg/L)	45.0	15.0	30.0	38.0	26.0	20.0	85.0
Manganese (Mn^{2+}) (mg/L)	0.01	0.00	0.01	0.01	0.01	0.01	0.02
Calcium (Ca^{2+}) (mg/L)	28.1	18.4	20.0	31.3	20.4	20.8	44.1
Magnesium (Mg^{2+}) (mg/L)	8.30	6.34	14.6	11.7	13.9	13.7	14.8
Sodium (Na) (mg/L)	29.3	9.75	19.5	24.7	16.9	13.0	55.3
Chromium Cr^{6+}) (mg/L)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulphate (SO_4) (mg/L)	2.00	1.00	0.00	2.00	0.00	1.00	0.00
Copper (Cu^{2+}) (mg/L)	0.02	0.01	0.00	0.03	0.02	0.03	0.01
Fluoride (Fl) (mg/L)	0.13	0.28	0.44	0.07	0.57	0.30	0.22
Bicarbonate (HCO_3) (mg/L)	8.00	10.0	26.0	10	24.0	22.0	16.0
Total Suspended Solid (mg/L)	149	220	108	103	84.0	85.0	187
Total Coliform (Cfu/100ml)	13	10	6	13	7	14	35
E-Coli (Cfu/100ml)	1	2	0	10	0	0	4
Enterococcus Faecalis (Cfu/100ml)	0	0	0	0	0	0	0

Table 2: Physical, chemical and Bacteriological Results for Measured Parameters in Akoko Southeast

Parameters/ Location	Ifira	Epinmi	Isua-Ile	Ipesi	Isua-Oke	Sosan
Northing (m)	0818513	0825665	0825376	0815866	0824722	0822003
Easting (m)	0822373	0817309	0821440	0825547	0823791	0822239
Sample No.	S8	S9	S10	S11	S12	S13
Appearance	Clear	Clear	Clear	Clear	Clear	Clear
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
Temperature (°C)	27.1	27.3	27.3	27.2	27.1	27.1
pH	6.43	6.48	5.92	6.44	6.68	6.08
Turbidity (NTU)	4.00	2.00	4.00	10.00	8.00	12.0
Conductivity ($\mu s/cm$)	434	605	143	141	311	164
TDS (mg/L)	291	405	95.8	94.5	208	110
Total Hardness (mg/L)	170	164	76.0	58.0	128	76.0
Calcium Hardness (mg/L)	109	98.0	36.0	43.0	86.0	40.0
Magnesium Hardness (mg/L)	62.0	66.0	40.0	15.0	42.0	36.0
Nitrate (NO_3) (mg/L)	1.20	0.50	1.76	0.00	0.80	0.20
Iron (Fe) (mg/L)	0.08	0.02	0.05	0.15	0.01	0.03
Total Alkalinity (mg/L)	32.0	18.0	12.0	14.0	30.0	20.0
Chloride (Cl^-) (mg/L)	34.0	43.0	15.0	10.0	20.0	12.0
Manganese (Mn) (mg/L)	0.01	0.01	0.01	0.01	0.01	0.01
Calcium (Ca^{2+}) (mg/L)	43.3	39.3	14.4	17.2	34.5	16.0
Magnesium (Mg^{2+})	15.1	16.1	9.76	3.66	10.2	8.78

(mg/L)						
Sodium (Na) (mg/L)	22.1	28.0	9.75	6.50	13.0	7.80
Chromium Cr^{6+}) (mg/L)	0.00	0.00	0.01	0.00	0.00	0.00
Sulphate (SO_4) (mg/L)	2.00	0.00	1.00	1.00	3.00	1.00
Copper (Cu^{2+}) (mg/L)	0.02	0.02	0.02	0.01	0.02	0.01
Fluoride (Fl) (mg/L)	0.04	0.13	0.26	0.57	0.33	0.21
Bicarbonate (HCO_3) (mg/L)	32.0	18.0	12.0	14.0	30.0	20.0
Total Suspended Solid (mg/L)	143	200	47.2	46.6	103	54.0
Total Coliform (Cfu/100ml)	42	34	29	32	25	45
E-Coli (Cfu/100ml)	4	3	5	4	2	4
Enterococcus Faecalis (Cfu/100ml)	0	0	0	0	0	0

Table 3: Normal Statistics of the Water Quality Measured Parameters

Descriptive Statistics						
	Minimu	**Maximu m**	**Mean**	**Std. Deviation**	**WHO Standard**	**% Compliance**
Temperature	27.10	27.40	27.21	0.1	-	-
pH	5.73	7.06	6.36	0.42	7.0-8.5	15
Turbidity	0.00	12.00	4.39	3.59	-	-
Conductivity	141.00	667.00	355.08	173.10	-	-
TDS	94.50	447.00	236.72	115.58	1,000	100
T.H	58.00	170.00	113.08	37.72	100	31
Nitrate	0.00	19.00	2.93	5.14	50	100
Iron	0.00	0.67	0.12	0.19	0.1	60
Alkalinity	8.00	32.00	18.62	7.85	-	-
Chloride	10.00	85.00	30.23	20.18	250	100
Manganese	0.00	0.02	0.01	0.004	0.05	100
Calcium	12.00	44.10	26.14	11.30	75	100
Magnesium	3.66	16.10	11.30	3.821	30	100
Sodium	6.50	55.30	19.66	13.14	200	100
Chromium	0.00	0.01	0.0008	0.003	0.05	100
Sulphate	0.00	3.00	1.08	0.95	250	100
Copper	0.00	0.03	0.017	0.009	2.0	100
Fluoride	0.04	0.57	0.27	0.17	1	100
Bicarbonate	8.00	32.00	18.62	7.85	-	-
T.S.S	46.60	220.00	117.66	58.10	-	-
Total Coliform 00ml)	6	42	24.2	-	10/100 ml	15
E-Coli 00ml)	0	10	3	-	2.5 /100 ml	46
Enterococcus s (Cfu/100ml)	0	0	0	-	0	100

Table 4: Modified Water Quality Classification based on WQI

WQI Value	Water Quality
<50	Excellent
50-100	Good water
100-200	Fair water
200-300	Poor water
>300	Very Poor

The average temperature of the present study ranged from 27.10 – 27.4°C with mean value of 27.21°C signifying moderate temperature. The pH value of natural water changes due to the biological activity and industrial contamination. Higher pH includes the formation of trihalomethanes which are toxic [10]. The pH values of the present investigation (average of 6.36) were generally below the WHO standard (7.0 – 8.5). Turbidity is generally low and varies from 0 – 10 NTU with the highest value recorded in Ipesi Akoko. Turbidity is an important parameter for characterizing groundwater quality as it facilitates estimation of the concentration of undissolved substances. Conductivity is a measure of current carrying capacity. Thus, as concentration of dissolved salts

increases conductivity also increases. The values obtained are in the range 141 to 667 $\mu s/cm$ and an average of 355 $\mu s/cm$. This values are still within the WHO standard. Total Dissolve Solids (TDS) values ranged within 94.5 to 477 mg/L. The TDS values for ground water range from 19 to 1280 mg/L as per standards and in this respect this water is suitable for drinking purposes. Alkalinity value with less than 100mg/L is desirable for drinking and domestic uses. However, in large quantities, it imparts bitter taste to water. In the present investigation the total alkalinity of the water samples is in the range of 8 to 32 mg/L.

Hardness is a measure of the ability of water to cause precipitation of insoluble calcium and magnesium salts of higher fatty acids from soap solutions. The principal cations causing hardness are calcium/magnesium bicarbonate, carbonate, chloride and sulphate. The hardness values of the present study were found to range between 58 to 170 mg/L and an average of 113 mg/L which is slightly above 100 mg/L recommended by WHO [9]. The quantities of calcium in natural water depend up on the type of rocks. Small concentration of calcium is beneficial in reducing the corrosion in water pipes. Magnesium hardness particularly associated with sulphate ion has laxative effect on persons un-accustomed to it. In the present study calcium and magnesium contents are found in the range of 12 – 44.1 and 3.66- 16.10 mg/L respectively. Chloride occurs in all types of natural waters. The high concentration of chloride is considered to be an indication of pollution due to high organic waste of animal origin (Singh, 1995). Chloride values obtained in the study are found in the range between 10 - 85 mg/L with an average of 30.23 mg/L, while fluoride varied between 0.04 – 0.57 mg/L with a mean of 0.27 mg/L.

Sulphate ion does not affect the taste of water, if present in low concentrations. The sulphate ion concentration in the present investigation are low as they varied from 0 - 3 mg/L. Nitrate is the most important nutrients in an ecosystem. Generally water bodies polluted by organic matter exhibit higher values of nitrate. In the present study water samples from the studied area showed low concentrations of nitrate (0 to 19 mg/L) well below permissible levels as per WHO standard. The values obtained for iron, sodium, chromium, and copper ranged from 0 – 0.67 mg/L, 6.5 – 55.3 mg/L, 0.00 – 0.01 mg/L, 0.00 – 0.01 mg/L, and 0.00 – 0.03 mg/L respectively. The traces of these metals in the sampled waters are very low and within WHO standard.

The presence of traces of E-coli and Enterococcus Faecalis in groundwater tend to degrade the quality of groundwater. All the sampled water showed no traces of Enterococcus Faecalis, while total coliform ranges from 6 - 42 Cfu/100ml with an average of 24 Cfu/100ml. This mean value is above 10 Cfu/100ml recommended by WHO. Also the average E-Coli value is above 2.5 Cfu/100ml recommended by WHO. This shows that the water samples have been seriously affected or contaminated by microbes of bacterial origin.

"Figure 3" showed the regression models of the analyzed parameters. TDS is taken as dependent variable, while Calcium, Magnesium, Chloride, Fluoride, Nitrate, Sulphate, Bi-carbonate, Iron, and Copper as independent variables. Trend analysis represents the process of using the analyzed data for prediction. This may be used to forecast values of the dependent variable. The regression model can be used to find the ionic concentration of groundwater samples, if the dependent variable TDS is measured for different locations by inverse calculations. The regression analysis showed strong positive correlation coefficients between TDS and conductivity (0.999), TDS and TH (0.554), TDS and Chloride (0.552) and TDS and Calcium (0.571). Negative correlation coefficient was obtained between TDS and bi-carbonates, sulphate, and Nitrate. "Table 5" shows the degree of linear association between any two of the water quality parameters, as measured by the simple correlation coefficients(r). Total Dissolved Solute (TDS) have strong interrelation with Conductivity (CD) and Total Suspended Solutes (TSS). (TSS). Total hardness have strong correlation coefficient with calcium, magnesium, sodium, and chloride signifying permanent hardness in nature.

In this study, the calculated Water Quality Index (WQI) values ranges between 20 and 88.6. Therefore from the water quality index map, using a modified WQI "Table 4" and "Fig. 4" the water samples were categorized into two types varying from "excellent – good drinking water." The excellent water constitute about 90 % of the study area, found in areas such as while good water constitutes about 10 % of the area notably around Aiyegunle and part of Oba – Akoko in Akoko Northwest. The trilinear piper diagram "Fig. 5" shows a dominant sodium cation-type and chloride anion-rich water. The water tends towards primary hardness, as combined concentrations of calcium, magnesium and bicarbonate exceed 50 percent of the total dissolved constituent load in mg/L. Such waters are generally considered hard and are often found in aquifers or unconsolidated deposits containing abundant carbonate minerals.

IV. Conclusion

The WQI for the thirteen samples ranges from 20 to 497. All the samples generally failed the bacteriological test due to high total coliform and Enterococcus *Faecalis*. Also, pH, Fe, total Hardness fall below the standard requirement of World Health Organization. Total Dissolved Solute (TDS) have strong interrelation with Conductivity and Total Suspended Solutes (TSS). Total hardness have strong correlation coefficient with calcium,

magnesium, sodium, and chloride signifying permanent hardness in nature. The Water Quality Index map classified the water in the study area into excellent – fair water which constitute about 40 % of the study area, found in areas such as Aiyegunle, Ikun, Iwaro Oka; while poor to very poor water constitutes about 60 % of the area. The analysis reveals that the groundwater of the area needs some degree of treatment before consumption, as it requires optimum protection

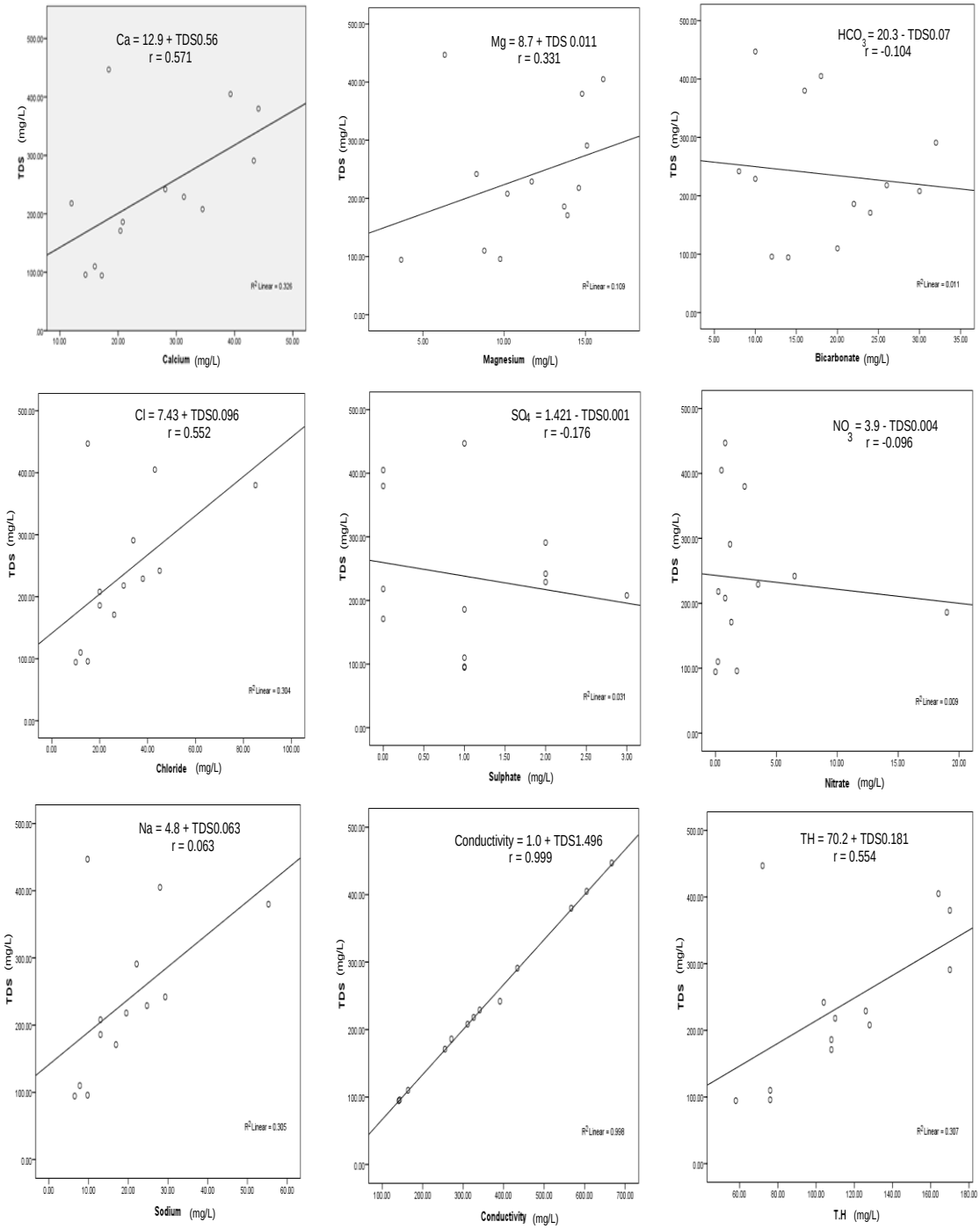

Figure 3: Regression Model/Trend Analysis of the measured parameters with Total Dissolved Solute

Table 5: Correlation Coefficients Matrix of Water Quality Parameters obtained in the Study Area

	pH	CD	TDS	TH	NO_3^-	Fe^{2+}	ALK	Cl^-	Mn^{2+}	Ca^{2+}	Mg^{2+}	Na^+	Cr^{6+}	SO_4^{2-}	Cu^{2+}	Fl^-	HCO_3^-	TSS
pH	1																	
CD	-.227	1																
TDS	-.203	.999	1															
TH	.215	.550	.554	1														
NO_3^-	.190	-.095	-.096	.008	1													
Fe^{2+}	.311	-.077	-.069	.150	-.155	1												
ALK	.424	-.123	-.104	.414	-.053	.101	1											
Cl^-	-.181	.562	.552	.750	.012	.299	-.105	1										
Mn^{2+}	.005	-.118	-.118	.530	.064	.373	.156	.708	1									
Ca^{2+},	.089	.573	.571	.892	-.048	.079	.209	.710	.464	1								
Mg^{2+}	.342	.317	.331	.818	.165	.263	.516	.541	.452	.490	1							
Na^+	-.182	.562	.552	.750	.012	.298	-.106	1.00	.708	.710	.541	1						
Cr^{6+}	-.318	-.368	-.366	-.295	-.069	-.116	-253	-.227	0.00	-.312	-.121	-.227	1					
SO_4^{2-}	.110	-.162	-.176	-.021	.092	-.439	.082	-.248	-.214	.230	-.348	-.248	-0.24	1				
Cu^{2+}	.492	-.089	-.089	.233	.576	.013	-.069	-.015	0.00	.319	.200	-.015	.108	.440	1			
Fl^-	.200	-.432	-.422	-.516	-.110	.451	.156	-.391	-.072	-.595	-.281	-.391	-.023	-.374	-.397	1		
HCO_3^-	.424	-.123	-.104	.414	-.053	.101	1.00	-.105	.156	.209	.516	-.106	-.253	.082	-.069	.156	1	
TSS	-.294	.994	.987	.530	-.096	-.095	-.147	.571	-.116	.565	.284	.572	-.365	-.144	-.109	-.433	-.147	1

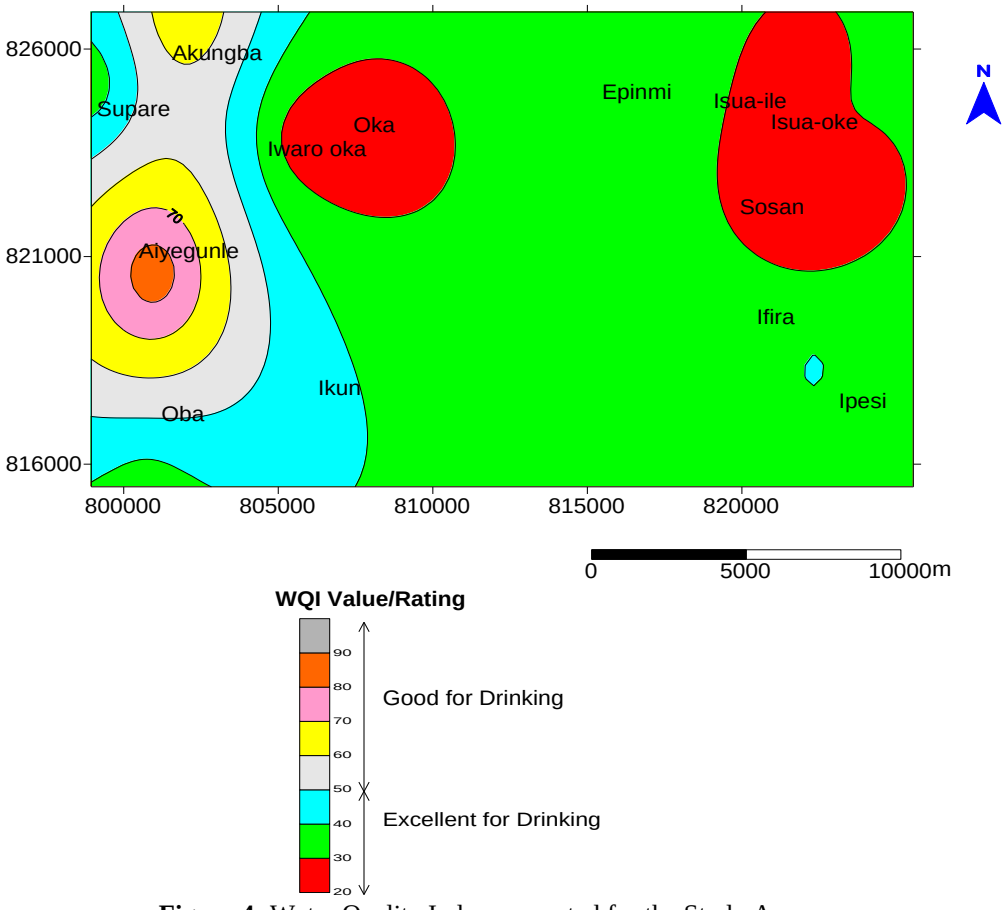

Figure 4: Water Quality Index computed for the Study Area

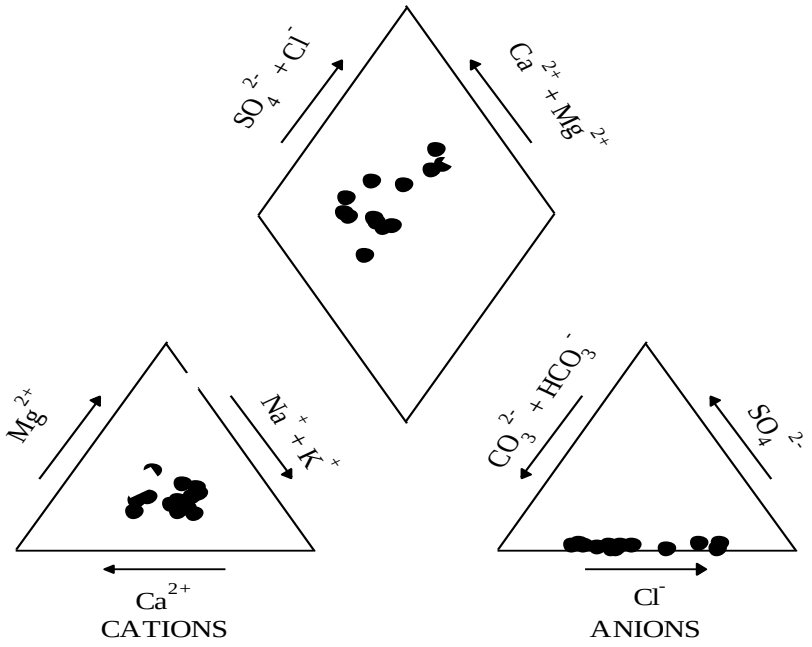

Figure 5: Trilinear Piper Diagram of the Water Sample

from contamination by groundwater monitoring, Proper site selection for activities and industries using hazardous chemicals, enhanced containment for storage of wastes and chemicals on vulnerable soils, reducing chemical use wherever possible.

Acknowledgement

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References

[1]. N.P. Iloeje, A new geography of Nigeria (New Revised Edition) published by Longman Nig. Ltd., Lagos, 1981, 201pp.
[2]. APHA, America Public Health Association Standard Methods for the Examination of Water and Waste water, NW, DC 20036, 1995.
[3]. APHA, America Public Health Association Standard Methods for the Examination of Water and Waste water, 20th ed. Washington, D.C.: American Public and Health Association, 2002.
[4]. R.K. Horten, An index number for rating water quality. J. Water Poll. Cont. Fed. 37(3): 1965, p300-306.
[5]. P. Li, H. Qian, J. Wu, Groundwater quality assessment based on improved water quality index in Pengyang County, Ningxia, Northwest China. E-Journal of Chemistry; 7(S1) 2010, S209-S216. DOI: 10.1155/2010/451304
[6]. G. Sudhakar, G. Swarnalatha, Z. Venkataratnamma, Vishnuvardhan, Determination of water quality index for groundwater of Bapatla Mandal, Guntur District, Andhra Pradesh, India. International Journal of Engineering Research and Technology; 3(3): 2014, 77-80.
[7]. R.G. Srinivas, and G. Nageswararao, Assessment of groundwater quality using water quality index. Arch. Environ. Sci.; 7: 2013, 1-5.
[8]. S.S. Kakati, and H.P. Sarma, Water quality index of drinking water of Lakhimpur District Indian J. Environ. Prot. 27(5): 2007, 425-428.
[9]. WHO, World Health Organization Guidelines for Drinking-Water Quality. 4th Ed. Geneva, Switzerland, 2011, pp. 541.
[10]. R.K. Trivedi, and P.K. Goel, Chemical and Biological Methods for Water Pollution Studies, Environmental Publication, India, 1986.

Falowo, O.O. "Assessment of Groundwater Quality in Akoko Southwest and Southeast Local Government Areas of Ondo State Using Water Quality Index Method and Statistical Approach." IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) , vol. 5, no. 4, 2017, pp. 68–76.