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Assessment of Groundwater Quality in Abeokuta Southwestern, Nigeria

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Abstract: *Groundwater is required for continuity of life and sustainability of ecosystem. Hence, this study aimed at assessing the groundwater quality in Abeokuta with respect to drinking and irrigation uses. In-situ parameters (pH, EC, Temperature and TDS) were measured using a multiparameter portable meter (model Testr-35). Major cations-trace metals and anions were subsequently determined in the laboratory using ICPMS and titration methods respectively. Bacteriological analysis was carried out using Nutrient agar medium.Electrical conductivity, pH and TDS had average concentrations of 504.9µS/cm, 6.5 and 379mg/L, Ca, Mg, Na and K had average concentrations in mg/L of 30.5, 8.83, 46.65 and 11.78 while* HCO_3*,* SO_4*, Cl and* NO_3 *average concentrations in mg/L were 99.8, 40.3, 61.3, and 13.7 respectively. Trace metals; Al, Si, Fe and Mn average concentrations in mg/L were 0.37, 21.98, 24.3 and 0.07 while those of Li, Cu, Pb, Co, Cd and As in µg/L were 11.69, 3.50, 2.95, 0.98, 0.52 and 0.78 respectively. Total Bacteria Count (TBC) that ranged from 2 to 190cfu/100ml and coliform count from 1 to 120cfu/100ml had high positive correlation with* NO_3 *indicating similar source possibly from waste/faeces dumps. The concentrations of ions in the groundwater fell within acceptable limits of both WHO and NAFDAC standards. Estimated water quality index revealed that 22% of the water samples fell in good water quality category while 72.2% and 5.5% were in the medium and bad water quality categories respectively.This study has revealed the effectiveness of hydrochemical and bacteriological evaluations in groundwater quality assessment. Groundwater in the study area was not potable but had good irrigation quality.*

Keywords: *Groundwater, Quality, Assessment, Bacteriological and Coliform.*

I. Introduction

The prevailing state of unequal distribution of social amenities across major cities in most of the developing countries around the world had posed a lot of challenges to effectiveness and efficiency of infrastructures. In the light of this, pipe borne water distribution is badly affected; therefore, groundwater is considered alternative sources of water for domestic, industrial and agricultural purposes. In Abeokuta metropolis, with a population of 236,389 (projected from 2006, Census at a growth rate of 3.5 percent) and a daily water demand of 120 million liters per day, the water supply from the Ogun State Water Corporation is inadequate in terms of quantity hence the need for alternative source of water supply [1]. The new Abeokuta water scheme at Arakanga has a design capacity of 163 million liters per day but at present, it produces fewer than 80 million liters per day leaving a short fall of more than 40 million liters per day in the water demand of the city. In order to meet the daily water demand in Abeokuta, groundwater is being considered a better alternative to supply from public fountains. However, the importance of potable water supply in poverty alleviation and socio-economic development cannot be overemphasized. In fact, it has attracted increasing attention over the last decade and will still enjoy greater attention over the next decade [2].

This is because access to water and adequate sanitation is a core objective of the Millennium Development Goals of reducing poverty by the year 2015. In Africa, the World Health Organisation (WHO) estimated that if access to basic water and sanitation services were improved, the health sector would save more than US$11 billion in treatment cost. People would gain 5.5 billion productive days each year due to reduced diarrhoeal disease.The hydrochemical dynamism of groundwater results from the dissolution of ions from host rock minerals or from human discharges through urbanisation, industrialisation and agricultural activities. Since groundwater utilities and usability depend on its chemistry, it is therefore imperative to assess its quality in order to ascertain its suitability for different purposes and recommend remediation if necessary for sustainable management. The hydrochemical aspect of groundwater quality in Abeokuta was investigated by [3]. The study revealed the dominant water to be $Ca\text{-}HCO_3$ type and high chloride concentrations in part of the area which was attributed to the sea spray due to its proximity to the coast. High coliform bacteria above the recommended value of less than 10cfu/100ml were reported in the study. However, the chemical parameters of the water from both basement and sedimentary geological settings fell within approved limit for water quality standards, but the observed bacteria pollution rendered these waters questionable for consumption. An integration of geographic information system (GIS) was employed by [2] in modelling distribution variability of bacteria as an indicator of shallow well water pollution in Abeokuta. The research revealed that the inhabitants of Abeokuta who consumed water drawn from shallow wells without treatment stood the risk of infection from bacteria pollution as concentration of bacteria exceeded the WHO approved limit. In a study conducted by [2] on groundwater hydrochemistry around Agboh area of southern Nigeria, high total bacteria count, coliform count and pH were reported. The groundwater was classified as Ca-Cl, Ca-Mg- Cl, Mg- Ca-Cl, Na- Ca-Cl and NaCl water types. Several authors had worked on the groundwater quality assessment. They include, [4], [5]), [6], [7]), [8]), and [9]. These results generated a general revelation that the prevailing groundwater quality in any area was being controlled in one hand by contribution of solutes from the lithologies that form the aquiferous unit which the water interact with during storage or/and passage, and in the other hand by the effect of man activities such as improper waste disposal system, effluents from industries and agricultural wastes. Therefore, this study assessed the quality of hand dug wells water in Abeokuta and environ with respect to domestic and agricultural purposes.

II. Location And Geology

The study area Abeokuta metropolis is a millennium city and the state headquarter of Ogun state in southwestern Nigeria. It falls within Latitudes 7º 6′N to 7º 13′N and Longitudes 3º 16′E to 3º 25′E. Abeokuta is situated about 70km north of Lagos and together with its environ has an area coverage of about 212km^2. Abeokuta being a capital city and ancient town is a well-planned urban centre; the street roads provided easy access for Hydrogeological mapping (fig. 1). Geologically, the study area is said to be part of transition zones of the southwestern Nigeria. It is underlain in the north by basement rock while in the south by the sedimentary rocks of the eastern Dahomey basin. At the south-eastern part of the area is the outlier of the Ise formation of Abeokuta group. The basement rock of the area is unconformably overlained by organically rich friable reddish sand. The basement rock consist of ancient gneisss-migmatite suite (Complex) which has been distinguished into three major divisions due to the penetration of Pan-African (6ooMa) bodies of granodiorites, Porphyritic granites, Quartz diorites and pegmatites [10,11] The major division include; Biotite Granite Gneiss. Porphyroblastic Gneiss Porphyritic Biotite Granite, Biotite Schist and Migmatite. The remaining small portion are covered by the Ise Formation of the Abeokuta Group which consists of conglomerates and grits at base and in turn overlain by coarse to medium grained loose sands (fig. 2.). This formation is notable in the south-eastern and south-western parts of the study area. Hydrogeologicall**y,** Groundwater occurrence in the northern parts of the study area is limited to the fractured and in-situ weathered portions of the rocks. The in-situ weathered portion either overlies the fresh basement or occurs within the fresh basement [12]. In the former, the weathered materials constitute phreatic aquifers which are usually exploited through hand dug wells, while in the later, groundwater is confined in nature and can only be exploited through the construction of drilled wells. Movement of water is strongly influenced by topography and two common types of springs notably, overland and slope springs have been reported to occur in the area [13]. Recharge is mainly by percolating rainwater and in some places, by seepage from adjacent surface water. Recharge areas consist of decomposed and fractured rocks in which pressure heads quickly spread through local water-bearing fissures and interconnected voids, thereby leading to abrupt rise in discharges in response to precipitation. Spring discharges in the study area are very common in the rainy season but cease completely during the dry season. The area underlain by sedimentary formations are regarded as having good potential for groundwater due to the presence of aquiferous sandy layer.

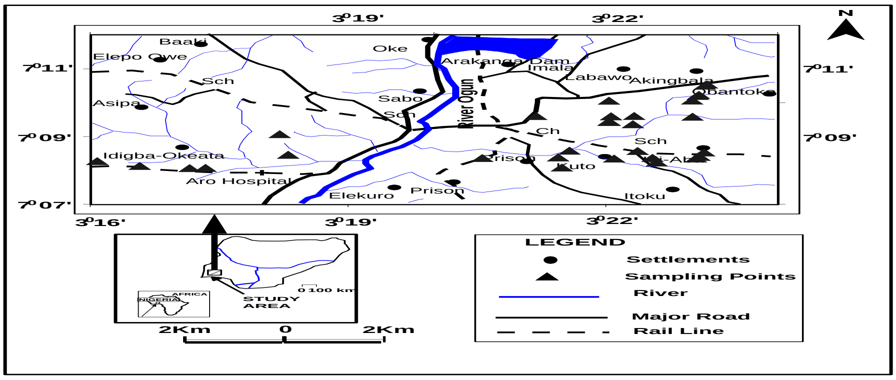

Fig.1. Location Map Showing Drainage, Road network and sampling points of the Study area

III. Methodology

Electrical Conductivity, Temperature, pH and TDS were measured with the aid of a multiparameter portable meter (model Testr-35) for every well sampled. Deep meter was also lowered into the well to determine both the depth to water surface and bottom of the well respectively. Other parameter such as turbidity, colour and odour were also determined right away on the field. At each location, clean and sterilized fetcher was use in the collection of water from the well and transferred into a clean polyethylene bottle. Three sets of samples were collected from each well. The first set of samples was acidified with about 1.0ml of concentrated nitric acid for cations determinations while the second and third sets unacidified were for the anions and bacteriological analyses respectively. All samples were refrigerated at temperature of 4^oC to preserve the cations and the microrganism in the well water before transported to the Laboratory for analyses. Water Hardness was estimated using TH= (Ca+ Mg) * 50 [16]. All ions concentrations were in Meq/ L.

3.1. Water Quality Index

Water quality index is a 100 point scale that summarizes results from a total of different hydrochemical measurements. Water quality indices provide a way to distil thousands of records of environmental data into meaningful values that indicate the health of water resources and create a yardstick for measuring and assessing water quality. Water quality indices incorporate data from multiple water quality parameters into a mathematical equation that rates the health of a water body with a single number. That number is placed on a relative scale that rates the water quality in categories ranging from very bad to excellent. Index values are determined by transforming selected water quality parameters (that have different units of measurement; e.g. mg/L) into a unit less sub- index value via a sub index rating curve. Each parameter has its own rating curve (on a scale of increasing water quality from 0 to 100) depending on what values for that parameter are considered “good” and “bad”.

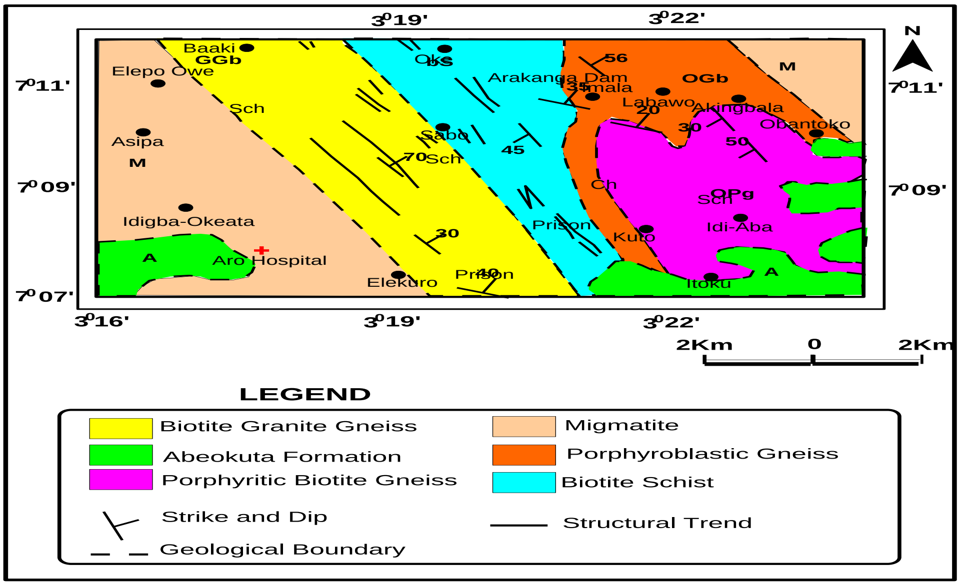

Fig. 2. Geology Map of the study area (Adapted from NGSA)

The objective of the rating curve is to link a parameter’s concentration to water quality. After sub-indices for each parameter are calculated by a rating curve, weights are assigned based on the significance of the selected parameters to the health status of people in a particular environment and a mathematical equation thus estimates the overall relative quality of the water. In this study a modified National Sanitation Foundation (NSF) approach was adopted to evaluate the quality of groundwater samples from the study area.One of the most respected and utilized water quality index method is [14] which uses a mathematical averaging function to calculate water quality. The process o f [14] calculation is as follows:

1. **Selection of water quality index parameters:** not all of these measured parameters are used to compute water quality index, hence there is a need to select the needed parameters on the basis of their importance.
2. **Conversion of each parameter into a unitless weight by the use of rating curve (q):** each parameter has its own rating curve (The rating curve for each parameter is shown in the appendix). The rating curves convert the measurements which were in their various standard units (e. g mg/l, μg/cm) into percentage.

3. **Assignment of weighing (w):** this is where a scale of importance is in play. Here, a factor is judged more important than the other based on the level of harm they can cause when present in groundwater. Those ones with high hazards are assigned high value while those with less harm are assigned lower value.
4. **Production of the final index score:** this is the water quality index. It is a mathematical equation which summed up all the products of the parameters weights and sub index values. The equation is shown below;

Water Quality Index (WQI) = $\sum_i^n$ wi qi. The weght assigned to chemical parameters used in the estimation of water quality index is presented in Table 1.

Table 1. Weight Assigned to water quality index chemical parameters.

Selected Parameters	**Assigned weight**
NO_3	0.13
PO_4	0.12
Cl	0.14
Conductivity	0.15
Temperature	0.15
pH	0.15
Faecal Coliform	0.16

3.2. Irrigation Parameters

The following irrigation parameters; sodium absorption ratio, soluble sodium percentage, residual sodium bicarbonate, permeability index, magnesium adsorption ratio and Kelly ratio were estimated in order to access the irrigation quality of sampled water from the study area.Sodium absorption ratio is a useful index to classify the suitability of groundwater for irrigation purposes. Salinity and Toxicity problems of irrigation water are attributed to SAR [15]. It is defined by [16] as sodium – rich water which may deteriorate the physical structure of the soil (pore clogging). The Sodium Adsorption Ratio (SAR) was calculated by the following equation given by [17] as:

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

Where, all the ions are expressed in meq/L.

Soluble Sodium Percentage (SSP) was calculated by the following equation [18]:

$$SSP = \frac{(Na+K)*100}{Ca+Mg+Na+K}$$

Where, all the ions are expressed in meq/L.

The Residual Sodium Bi-carbonate (RSBC) was calculated according to [19]:

$$RSBC = HCO_3 - Ca$$

Where, RSBC and the concentration of the constituents are expressed in meq/L.

The Permeability Index (PI) was calculated according to [20] by the following Equation:

$$PI = \frac{\left(Na+\sqrt{HCO_3}\right)*100}{Ca+Mg+Na}$$

Where, all the ions are expressed in meq/L.

Magnesium Adsorption Ratio (MAR) was calculated by the equation [21] as:

$$MAR = \frac{Ma*100}{Ca+Mg}$$

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

The Kelly's Ratio was calculated using the equation [22] as:

$$KR = \frac{Na}{Ca+Mg}$$

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

IV. Results And Discussions

Summary of all parameters measured from the study area is provided in Table 2. Field measurement revealed that the elevation of the study area ranged from 43 to 161 with average of 104.9m, that of water level ranges from 0.8 to 18.2 with average value of 5.14m, depth of the sampled wells range from 1.7 to 20.2 with average of 6.2 meters. Also, the pH ranged from 5.1 to 7.6 with average of 6.5, temperature from 27.5 to 33.1 with average of 29.1^{o}C while electrical conductivity and total dissolved solid range from 48 to1448µS/cm and 36 to 1086mg/L with average values of 514µs/cm and 386mg/l respectively. Major ions results revealed that concentration in mg/L of Ca^{2+} ranged from 1.12 to 112.23 with average concentration of 30.50mg/L, Mg^{2+} from 0.42 to 43.45, with average concentration of 8.83, Na^{+} from 6.55 to 143.40 with average value of 46.65 and K^{+} from 0.42 to 75.2 with average value of 11.78. For the major anions, HCO_3 ranged from 8.2 to 279mg/L with average concentration of 99.8mg/l, Cl^{-} from 6.5 to 198.5mg/L with average value of 61.3mg/l, $SO4^{2-}$ from 4.2 to 101mg/l with average value of 40.3mg/l and NO_3 from 0.6 to 44.4 with average value of 13.7mg/l (Table. 2). The result of the trace elements in mg/L revealed that Al ranged from 0.026 to 3.27 with average of 0.38, Si from 5.69 to 57.69 with average of 21.9, Ba from 0.01 to 0.56 with average of 0.15, Fe from 0.05 to 1.3 with an average of 0.39 and Mn from 0.002 to 1.21 with average of 0.07. Others, including Li, Cu and Pb, Zn, Ni and Cr in µg/L ranged from 0.3 to 129, 1.3 to 14.8 and 0.9 to 10.4, 1.31 to 65.1, 0.2 to 12.9 and 0.9 to 8.3 with average of 11.68, 3.5, 2.95 16.0, 1.3 and 2.4 respectively. Furthermore, B, Co, Cd, V, Mo and As in µg/L ranged from 0.5 to 92, 0.06 to 4.81, 0.05 to 0.12, 0.07 to 9.5,0.1 to 4.0 and 0.5 to 2.1 with average concentrations of 20.03, 0.98, 0.053, 3.19 and 0.58 respectively.

4.1 Groundwater Pollution in the study area

In the study area, all the analyzed major ions fell well within the permissible limit of [23] and [24] water quality standard except NO_3^{-} in a location with concentration of 44.4mg/l above [23] approved standard value for drinking water quality. Nitrate concentrations have positive correlation with the coliform and total bacteria counts signifying anthropogenic source of pollution from indiscriminate disposal of wastes or sewage water into the ground. Among all the trace metals analyzed, only Fe and Al have concentrations in few locations above [23] and [24] maximum permissible limit of 1 and 0.5mg/L respectively. The result of the correlation between Fe and Al revealed positive value of 0.91 (fig. 3) which was due to enrichment of their oxide as a result of oxidation. [25, 26]. These oxides when reduced produce more of their metallic ions in ground water.

4.2 Bacteriological Parameters

The summary of the results of the bacteriological analysis in the study area was presented in Table 3. The concentration of bacteria in a sample of water is usually expressed as the number of colonies per 100 ml (col/100ml). The results indicated that shallow wells in Abeokuta metropolis has high bacteria pollution and non of the sampled well showed results that fell within the permissible level for drinking water quality given by the [24]. All sampled well tested positive to bacteria count. The result indicated TBC of 2-190cfu/100ml and coliform count 1-120cfu/100ml. Correlating the bacterial count with well depth revealed reduction in total bacteria count with increasing depth. The positive correlation of both bacteria count and coliform count with nitrate in the sampled groundwater revealed that they are from organic source except on a few situation where the nitrate is low or absence compare to both. A reduction or absence of nitrate could be as a result of the action of bacteria on plant which lead to degradation or reduction in nitrate level within the regolith aquifers. Research studies by [2, 4] indicated that the origin of the bacteria pollution of the groundwater in Abeokuta was due to the indiscriminate waste and sewage disposals and this current research agreed with their finding.

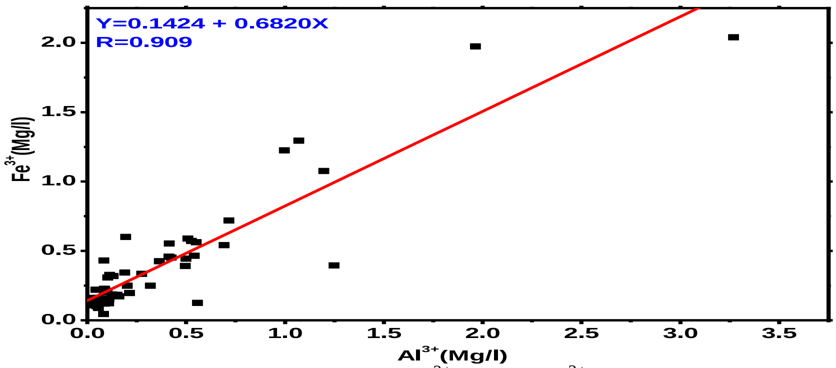

Fig. 3. Plot of Fe^{2+} against Al^{3+}

4.3 Overall Water Quality Index

In this study, NSFWQI rating was used in determining water quality index of the study area. The estimated water quality index revealed that 22.2% of groundwater in the study area fell in good water category, 72.2% and 5.56% were in medium and bad water categories respectively Table 4 and Fig.4). It can be said from this assessment that the groundwater in the study area was generally in medium-good water quality status as only very few samples (3) signified bad water quality status. This result was in agreement with previous hydrochemical results as reflected in the high EC and TDS of the samples.

V. Groundwater Usage

As part of groundwater suistainability program, continuous supply of quality water is essential for economic growth, improved quality of life, environmental sustainability and survival of man. Generally, groundwater in the study area was used for domestic, agricultural and industrial activities.

5.2 Domestic Consumption

Water hardness is primarily the amount of calcium and magnesium and to a lesser extent, iron in the water and is commonly expressed as milligrams of calcium carbonate equivalent per litre. The hardness ranged from 4.53 to 461.73 with average of 113.10meq/l (Table 5) . The study area contained soft – very hard water. Soft and moderately hard waters dominant with 23.1% and 36.5% representations respectively. Twenty five percent of the groundwater fell in hard water hardness while the remaining 15.4% was in the very hard water hardness (Fig. 5). Hard water do not easily form lather with soap. Water hardness has no known adverse health effect; however, some research indicated its role in heart disease [27]. Hard water might be expensive for domestic usage, and the cause of the water hardness of the study area can be said to be geogenic.

Table 2. Summary of measured parameters from the study area alongside with WHO and NAFDAC approved standard for drinking water

Parameters	Mean	Min	Max	Stdev	WHO Standard		NAFDAC Standard
					Highest Desirable	Max. Permissible	
Elevation (M)	104.85	43	161	29.35			
DTW(M)	5.14	0.8	18.2	2.96			
DTB(M)	6.21	1.7	20.2	3.1			
pH	6.48	5.1	7.6	0.59	7.0-8.9	6.5-9.5	6.5-8.5
Temp.°C	29.071	27.5	33.1	0.95	27	27	27
EC(µS/cm)	513.93	48	1448	325.45	900	1200	1000
TDS (mg/L)	385.5	36	1086	244.13	500	1500	500
TH(meq/L)	4.53	461.73	113.10	30.05			
Ca^{2+}	30.54	1.116	112.28	20.21	75	75	75
Mg^{2+}	8.83	0.418	43.45	7.055	20	20	20
Na^{+}	46.65	6.55	143.44	36.65	200	250	200
K^{+}	11.78	0.42	75.24	16.92	200		
HCO_3^{2-}	99.77	8.2	279	64.83	100	500	100
Cl^{-}	61.3	6.5	198.1	43.89	200	250	100
SO_4^{2-}	40.27	4.2	101	23.12	250	500	100
NO_3^{-}	13.67	0.6	44.4	10.07	10	50	10
Al (Mg/l)	0.375	0.026	3.27	0.554	0.2	0.2	0.5
Si(Mg/l)	21.921	5.684	57.647	13.112			
Ba (Mg/l)	0.153	0.011	0.553	0.116	0.05	0.07	0.05
Fe (Mg/l)	24.337	0.045	1294	176.04	1	1	3
Mn (Mg/l)	0.071	0.002	1.21	0.17	0.1	0.4	20
Li (µg/l)	11.687	0.3	129	20.98			
Cu(µg/l)	3.5037	1.3	14.8	2.082	0.5	2	1
Pb (µg/l	2.95	0.9	10.4	2.005	0.01	0.01	0.01
Zn (µg/l)	15.99	1.31	65.1	11.086	0.01	3	5
Ni (µg/l)	1.249	0.2	12.9	1.827	0.02		
Cr (µg/l)	2.4	0.9	8.3	1.351	0.05	0.05	0.05
B (µg/l)	20.03	0.5	92	19.402			
Co (µg/l)	0.977	0.06	4.81	0.962			
Cd (µg/l)	0.053	0.05	0.12	0.013	0.003	0.003	0.003
V (µg/l)	3.192	0.07	9.5	2.286			
Mo (µg/l)	0.58333	0.1	4	0.819			
As (µg/l)	0.78333	0.5	2.1	0.426			

Sample	Depth (m)	TBC (cfu/100ml)	Coliform count(cfu/100ml)	Remarks on well environment
Gb01	4.3	18	7	Not lined and well covered, contained Algae
Gb02	6.6	2	NIL	Lined, covered and neat surroundings but contain algae
Gb03	6.6	21	1	Neat, lined and covered
Gb04	6.16	7	3	Lined, covered and neat in the outskirt of the town
Gb05	1.7	0.5	1	Lined and very close to a stream
Gb06	11.5	6	2	Lined, neat and turbid
Gb07	4.7	122	120	Lined not covered, contain algae in a dirty environment
Gb08	4.3	11	7	Lined, covered in a neat environment
Gb09	8.7	21	7	Neat, Lined and Covered.
Gb10	7.3	6	NIL	Neat, lined and covered.
Gb11	6.5	58	12	Neat, lined and covered.
ST01	6.1	33	7	Neat, Lined and covered.
ST02	5.6	6	2	Neat, Lined and Covered
ST03	55	6	3	Not Lined but Covered.
ST04	7.2	16	13	Neat, Lined and Covered.
ST05	0	14	1	A borehole water stored in a plastic tank
M01	7.5	44	11	Neat, Lined and Covered.
M02	0	33	12	Well dug inform of reservoir. Not neat
M03	5.3	10	7	Neat, Lined and Covered.
M04	4.3	190	5	Neat, Lined and covered.
M05	5.8	14	2	Neat, Lined and Covered.
M06	5.1	12	7	Neat Lined and Covered.
M07	20.2	3	NIL	Neat, Lined and Covered.
Pg01	8.7	16	25	Lined, covered in a bushy surrounding.
Pg02	6.2	NIL	NIL	Neat, Lined and Covered.
Pg03	6.2	44	7	Neat Lined and Covered.
Pg04	15.8	32	14	Neat, Lined and Covered.
Pg05	9.3	20	1	Lined, Covered but in a dirty environment.
Pg06	6	20	1	Lined, not covered located in the downstream of soak away.
Pg07	4.8	8	NIL	Lined and Covered but located on an old waste dumping site
Pg08	3.6	10	5	Lined, Covered but located besides a stream.
Pg09	8.7	21	7	Neat, Lined and Covered.
Pg10	5	100	1	Neat, Lined and Covered.
Pg11	8	3	3	Neat, Lined and covered sited at the downstream of the soak away.
Pg12	4.8	11	8	Neat, Lined and Covered.
Pg13	6.5	58	12	Neat, lined and covered.
Pg14	9.1	3	NIL	Neat, Lined and Covered.
Pg15	8.2	26	5	Opened and not covered.
Pg16	5.2	28	3	Lined and covered but located at the downstream of a soak away.
Pg17	3.4	3	NIL	None lined, dirty but covered.
Pg18	2.1	NIL	NIL	Neat, Non Lined but covered
Pg19	6.5	2	NIL	Lined, covered and close to the stream.
Pg20	7.7	49	79	Neat, Lined and covered.
Pg21	3	NIL	NIL	BSA Positive
Pg22	5.6	NIL	NIL	Neat, Lined and Covered
Pg23	3.5	10	8	Neat, Lined and Covered
Pg24	5.1	14	2	Covered but not Lined in a dirty environment
Pg25	4.9	ND	1	Lined but not properly covered
Pg26	3.6	6	4	Neat, Lined and Covered
Pg27	5.4	135	10	Neat, Lined and Covered
Pg28	6.7	ND	NIL	Neat, Lined and covered
Pg29	3.8	ND	NIL	Lined, covered but close to a waste dumping site.
Pg30	3	2	NIL	Newly dug, lined, covered but located in a dirty environment
Bs01	5.5	2	NIL	Lined, not covered, in a dirty environment.
Min	0	0.5	1	
Max	55	190	120	
Mean	6.9	27.55	10.82	

DTW: Depth to water, DTB: Depth to bottom of well, EC: Electrical Conductivity, TDS: Total dissolved solid.

Table 3. Result of Bacteriological analysis of the study area

Table 4 Groundwater Characterisation using Modified NSFWQ.

Index range	Number of samples	%Samples	Wq status
>90	-	-	Excellent
70.1 – 90	12	22.2	Good
50.1 – 70	39	72.2	Medium
25.1 – 50	3	5.56	Bad
<25	-	-	Very bad

Table 5 Rating of water hardness (McGowan, 2000)

Hardness range	**Hardness status**	**Number of sample**
>180	Very Hard	8
120 – 180	Hard	13
60- 120	Moderately Hard	19
< 60	Soft	12

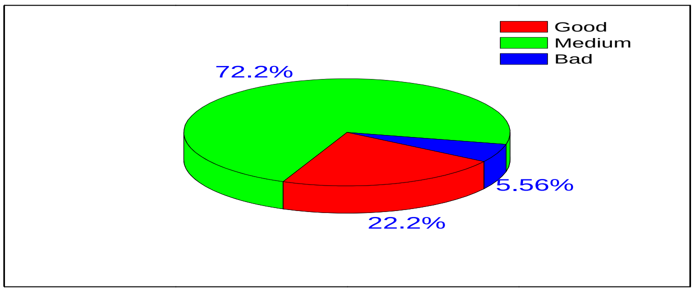

Fig. 4 Pie chart showing groundwater quality index of the study area

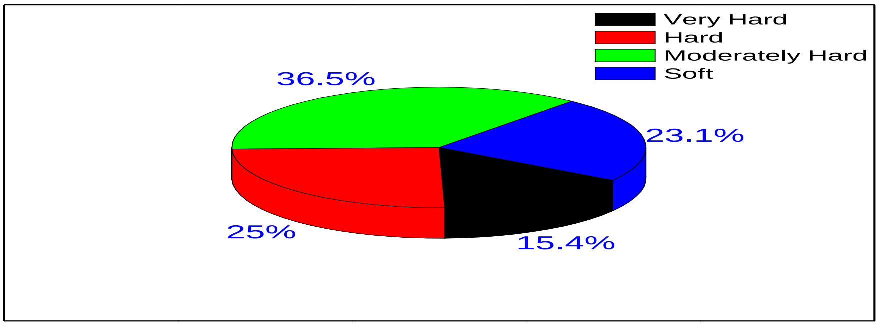

Fig. 5 Pie Chart showing water hardness classification in the study area

This is because these waters were taped from weathered aquifer horizons. The Calcium and magnesium were released from the weathering of the basement rocks which have minerals like feldspars. A few locations had EC and called for caution in consuming the water untreated. With the exception of Ca, Fe and Al in few locations all ions concentrations fell within [24] approved standard for drinking water quality. The few cations with concentrations above recommended standard values resulted from the weathering of mafic minerals like amphiboles and calcium rich olivine in this gneissic terrain of the study area. Quality deteriorated groundwater of the area was mostly from improper sanitation and waste dumping acts by the inhabitants of the study area.

VI. Agricultural Uses

Sodium content and specific conductivities of the waters are important parameters that control the waters' use in agriculture. A presence of Na^+ in irrigational water decreases the soil permeability. The groundwater in the study area is generally of excellent class as they all show SAR value of less than10 as in [28] plot fig. 6 while the salinity hazard revealed 16.7% low salinity, 64% of water within medium salinity and 18.51% high salinity [28]. There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. If water used for irrigation is high in sodium and low in calcium, the cation change complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of the clay particles. Besides, Soils containing large proportion of sodium with carbonate and chloride or sulphate are termed as alkali or saline water, respectively [18]. Presence of sodium ($Na^{+)}$ in irrigation water reacts with soil to reduce permeability and its repeated uses makes the soil impermeable. High sodium saturation also directly causes calcium deficiency. Frequent irrigation with high sodium water for a considerable duration makes the soil plastic and sticky in wet condition and form clods and crust on drying condition. In contrast, presence of calcium or magnesium salts in irrigation water retards the evil effect of sodium by increasing the permeability of the soils [29, 30].Based on the classification after [31] for SSP, all the water sample analysed i.e 100% fell under 'excellent' irrigation quality category. The quality of irrigation water depends primarily on the total concentration of dissolved constituents.

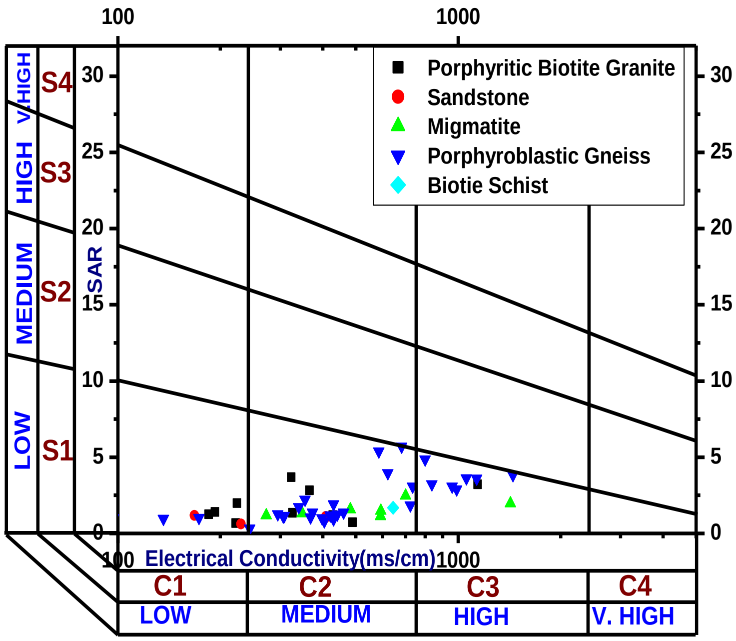

Fig. 6 Wilcox Diagram

The salts present in the water bodies affecting the growth of the plants directly, also affect the soil structure, permeability and aeration, which indirectly affect the plant growth. At the same level of salinity and SAR, adsorption of sodium by soils and clay minerals is more at higher Mg: Ca ratios. This is because the bonding energy of magnesium is less than that of calcium, allowing more sodium adsorption and it happens when the ratio exceeds more than 4 [32]. It was also reported that soils containing high levels of exchangeable magnesium causes infiltration problem [33]. In the present study, most of the samples contained the ratio of magnesium and calcium below 4 (90 out of 96). High MAR causes a harmful effect to soil when it exceeds 50. In the study area, the analysed samples contained values of MAR that fell well below 50 except only one location (sample ID Pg17) with value of 60.4meq/l.For irrigation water [23] suggested that the ratio should not exceed 1.0. In this study, 33 out of 54 i.e. 61% of the total samples were found less than the permissible value of 1.0 showing a good balance of sodium, calcium and magnesium ions. Based on the irrigation water rating by [33, 34, 18, and 35], RSBC of the sampled water from the study area fell below 1.25 which could be classified under excellent irrigation water. Permeability Problem (PI) occurs when normal infiltration rate of soil is appreciably reduced and hinders moisture supply to crops which is responsible for two most water quality factors as salinity of water and its sodium content relative to calcium and magnesium. Highly saline water increases the infiltration rate.

Relative proportions the different cations and anions defined by SAR, SSP, KR, MAR, TH, RSBC as presented in Table 6 and figure 7 clearly revealed that the groundwater in the study area was suitable for irrigation

Table 6 Statistical Summary of Indices

INDEX	AVE	MIN	MAX	STDEV
SAR	1.92	0.33	5.70	1.26
SSP	49.48	15.90	79.25	14.48
RSBC	0.11	-1.04	1.85	0.5409
PI	80.18	47.21	173.52	19.68
TH	113.13	4.53	461.74	75.85
MAR	32.32	2.81	60.37	10.45
KR	1.05	0.16	3.71	0.80

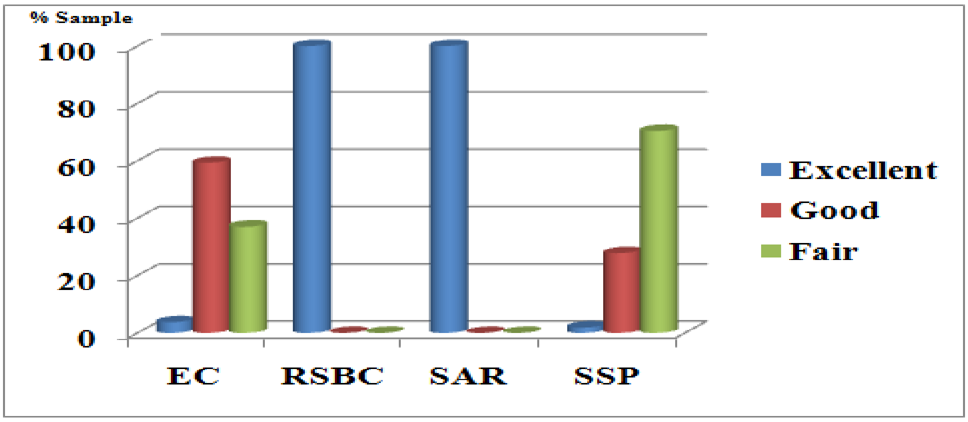

Fig. 7 Bar chart showing indices irrigation classification.

VII. Conclusions

A hydrochemical and bacteriological assessment of groundwater sampled from Abeokuta and it's environ have been studied. All the physicochemical parameters, major ions and trace metals fell well within acceptable limit of both WHO and NAFDAC standards except Ca, Al and Fe in few of the wells. Using [14] and total Hardness, the groundwater of Abeokuta and its environs was in good to excellent categories with respect toor domestic purpose. High Total Bacterial Counts (TBC) and Coliform Count which varied inversely with depth of the well were observed which rendered the water not to be potable. However, irrigation parameters using EC, RSBC, MAR, SSP, SAR and Wilcox plot indicated that the water was good for Irrigation purpose.The results have demonstrated that the shallow wells water in Abeokuta were suitable for irrigation purpose but not potable and need to be treated to remove the possible bacterial pollution before consumption. For effective groundwater management and sustainability, regular hydrochemical and bacteriological assessment should be adopted on regular basis to monitor the groundwater system of the area apart from health education hygiene related issues to reduce indiscriminate waste/faeces dump in the study area.

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