Journal of Environmental Chemistry and Ecotoxicology Vol. 1(1), pp. 010-022, November, 2009
Available online at http://www.academicjournals.org/jece

Full Length Research Paper

Hydro-geological characteristics and groundwater quality assessment in some selected communities of Abeokuta, Southwest Nigeria

G. C. Ufoegbune[1]*, K. I. Lamidi[1], J. A. Awomeso[1], A. O. Eruola[2], A. O. Eruola[1], O. A. Idowu[1] and C. O. Adeofun[1]

[1]College of Environmental Resources Management, University of Agriculture, Abeokuta, Nigeria.
[2]Yaba Polytechnic, Yaba, Lagos State, Nigeria.

Accepted 9 September, 2009

This study examined the hydro-geological characteristics and groundwater quality of four communities in Abeokuta, South-Western Nigeria. Water samples were collected from 18 sampling points, comprising of shallow wells and boreholes in the four communities, with four geophysical surveys done each community. Tests were carried out in the water samples for heavy metals (zinc, cadmium, arsenic, iron and lead) and physico-chemical parameters (pH, electrical conductivity, total dissolved solids, total hardness, alkalinity, chloride, sodium and potassium). The geophysical examination revealed that the depths of all the wells were below the standard recommended depth for deep wells in the basement complex area. Generally water samples do not conform to WHO maximum desirable standard, especially for parameters like Zn, Pb and Cd, but were still within the highest desirable levels recommended by WHO and NAFDAC. This meant that the water, from which the samples were taken, needed to be subjected to treatment before drinking.

Key words: Geophysical survey, portable water, shallow wells, boreholes, heavy metals.

INTRODUCTION

Groundwater is widely distributed under the ground and it is a replenishable resource unlike other resources of the earth. Groundwater includes all water found beneath the earth's surface. It is part of the earth's natural hydrological cycle. It is the body of water derived primarily from percolation and contained in pore spaces of a permeable rock. Groundwater is an economic resource and more than 85% of the public water for consumption is obtained from groundwater. This source of water is of great uses for domestic, industrial, irrigation and agricultural purposes.

Ayoade (2003) described hydrogeology as the scientific study of groundwater with emphasis on the geology and its occurrence, movement and chemical characteristics of groundwater. According to Houston (1995) the bedrock over much of Africa is of Precambrian formations, which are dominated by relatively impermeable crystalline rocks such as granites, schist, gneiss and quartzite. It was often necessary to drill 60 - 80 m deep, with wells often yielding less than 2 m^3/day (Dijon, 1981). Selby (1985) reported that rocks often break down quickly, producing a zone of weathered materials of saprolite or laterite and the surface soils are often underlain by red-brown silty clay, which does not function as a good aquifer.

According to Farquharson and Bullock (1992), the basement aquifers occur within the weathered residue overburden (the regolith) and the fractured bedrock. Development of the regolith components is by wells and shallow boreholes, which are liable to be drilled by lightweight percussion rigs. Viable aquifer wholly within the fractured bedrock are of occurrence because of the typically low strativity of fracture systems that is less than < 1%. In order to be effective, development of bedrock components requires interaction with storage available in overlying adjacent saturated regolith or other suitable formations such as alluvium. Ayoade (2003) reported that

*Corresponding author. E-mail: gidufoes2000@yahoo.co.uk.

all groundwater can be said to originate as atmospheric or surface water and principal sources of natural recharge of groundwater are falling precipitation that eventually percolates, and seepage from the stream flow in channels, lakes and reservoirs.

In Abeokuta, as in many areas underlain by the basement complex rocks, the populace depend largely on the surface water, which is supplied by the water corporations from the River Ogun. This source of water supply is not sufficient and therefore does not meet the demand of the populace. This surface water, which is the major source of water consumption in Abeokuta, has a very low output especially during the dry season when the evaporation rate is high (and precipitation is lower than annual average). Normally, most sachet water industries depend on the water from the state water corporations; this has increased the problem of water scarcity because the demand for the water becomes greater than the supply especially during dry season. Again, people use hand dug wells, but this poses problem during dry season because the required depth would not be reached due to the terrain and the cost of drilling borehole is very high. For these reasons, groundwater should have been an alternative source of water but there is a great problem about locating high productive aquifers in different parts of Abeokuta.

Abeokuta lies within the Basement Complex rocks. These rocks are of Precambrian age to early Palaeozoic age and they extend from the north-eastern part of the Ogun state (which Abeokuta belongs) running southwest ward and dipping towards the coast (Ako, 1979). The basement complex metamorphic rocks are characterized by various folds, structures of various degree of complexity, faults, foliation and many more. These structural features have a predominant North-South or North-North-East-South-South-West orientation which is particularly strong within the low grade metamorphic. The common metamorphic rocks encountered are gneiss, schist, quartzite and amphiboles.

Abeokuta occupies about 40.63 km^2 area lying between latitudes 7°10′ N and 7°15′ N and longitudes 3° 17′ E and 3° 26′ E (Figure 1a) and it is characterized by various rock types ranging from, granite granitic gneiss and pegmatite. The individual rock has various hydro-geologic characteristics. Abeokuta belongs to the stable plate which was not subjected to intense tectonics in the past. Therefore, the underground faulting system is minimal and this has contributed to the problem of underground water occurrence in this area.

The northern side of Abeokuta like Lafenwa side is characterised by pegmatite underlain by granite and therefore has good hydro-geological history. The southern part (made up of granitic gneiss) enters into the transition zone with the sedimentary basin and is characterised by fairly satisfactory hydro-geological history. The western part is characterised by granitic gneiss which is less porous and various quartzite intrusions (Key, 1992). This area is highly problematic and it is prone to low yield groundwater supply (Omorinbola, 1982).

This study investigated the hydro-geological variation and its effect on the groundwater quality of some selected areas in Abeokuta. The selected areas belong to the densely populated parts of Abeokuta Metropolis and the study examined the weathered and fractured conditions found in those areas to determine if the occurrence of groundwater in these areas is structurally controlled or porosity and permeability dependent. There was the need also, to examine if the chemical composition of groundwater in the selected areas of study conforms to the W.H.O. and National Food and Drug Commission (NAFDAC) standards.

The study area covers the North East, the South West and North West of Abeokuta. The selected study areas are Adigbe, Ibara, Lafenwa and Obantoko (Figure 1b).

These areas were high density areas with great problem of potable water scarcity (Omorinbola, 1982).

METHODOLOGY

Reconnaissance survey: Reconnaissance survey was carried out on the selected areas of study to identify some physical hydro geological features. The study area is characterised by various rock types. Areas where the geophysical survey is to be carried out were located and marked. Points of wells and boreholes were geo-located.

Geophysical survey: A total of 16 Schlumberger vertical electrical soundings (VES) were carried out in the study area near the existing shallow/ deep wells around the study area. The VES points were located between 0.5 and 1 m from the wells. The current electrode (AB/2) spacing ranged from 1.0 - 100.0 m while the potential electrode (MN/2) varied between 0.25 and 5.0 m. There were four locations of the well/VES points per community as shown in the data acquisition map (Figure 1b). Eighteen water samples were collected in all, each in a separate bottle for chemical analysis. Seven samples were taken at Adigbe to check the influence of mining, five at Obantoko and three each from Lafenwa and Ibara. The depths of the wells in each community were compared with the geophysical interpretation results.

The geophysical data acquired were analysed and interpreted using the usual manual curve matching method, the results of which served as initial parameters for the computer iteration technique using the commercially available software, Offix and Resist. The detailed results of the interpretation are presented in Tables 1 - 4 and this was compared with the total depths of all wells within the study area. In the case of chemical analysis, cleaned water bottles were used to collect water samples from shallow wells and community boreholes. These water samples were taken to the laboratory for physical and chemical analyses within 24 h of collection. The results of the analysis are presented in Tables 5 and 6.

Tests were carried out in the water samples for heavy metals (zinc, cadmium, arsenic, iron and lead) and physico-chemical parameters (pH, electrical conductivity, total dissolved solids, total hardness, alkalinity, chloride, sodium and potassium). Eighteen samples were taken from the four communities in this format:

Adigbe well 1 (AW1), Adigbe well 2 (AW2), Adigbe well 3 (AW3), Adigbe well 4 (AW4) Adigbe borehole 1 (AB1), Adigbe borehole 2 (AB2), Adigbe borehole 3 (AB3), Obantoko well 1 (OBW1), Obantoko well 2 (OBW2), Obantoko well 3 (OBW 3), Obantoko borehole 1 (OBB1), Obantoko borehole 2 (OBB2), Ibara well 1 (IBW1), Ibara borehole 1 (IBB 1), Ibara borehole 2 (IBB2), Lafenwa borehole 1 (LB 1), Lafenwa well 1 (LW1), Lafenwa well 2 (LW2).

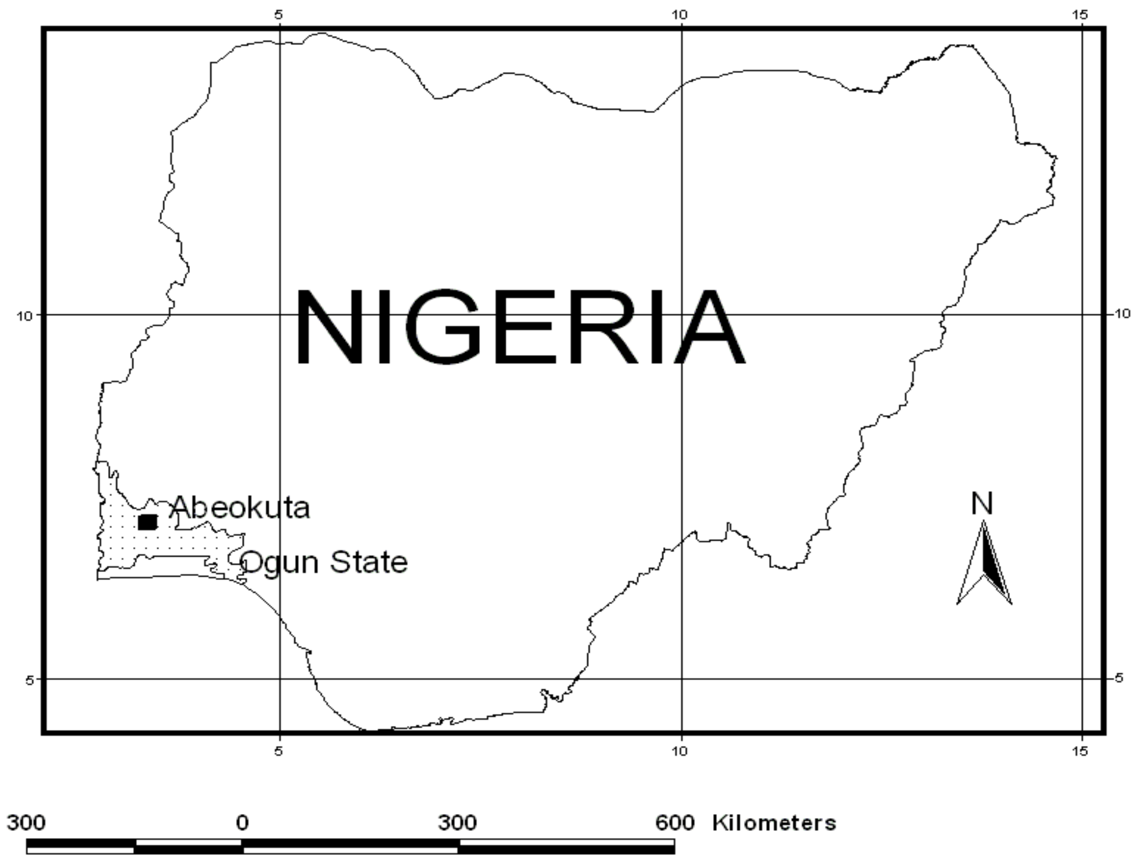

Figure 1a. Map of Nigeria showing the position of Abeokuta.

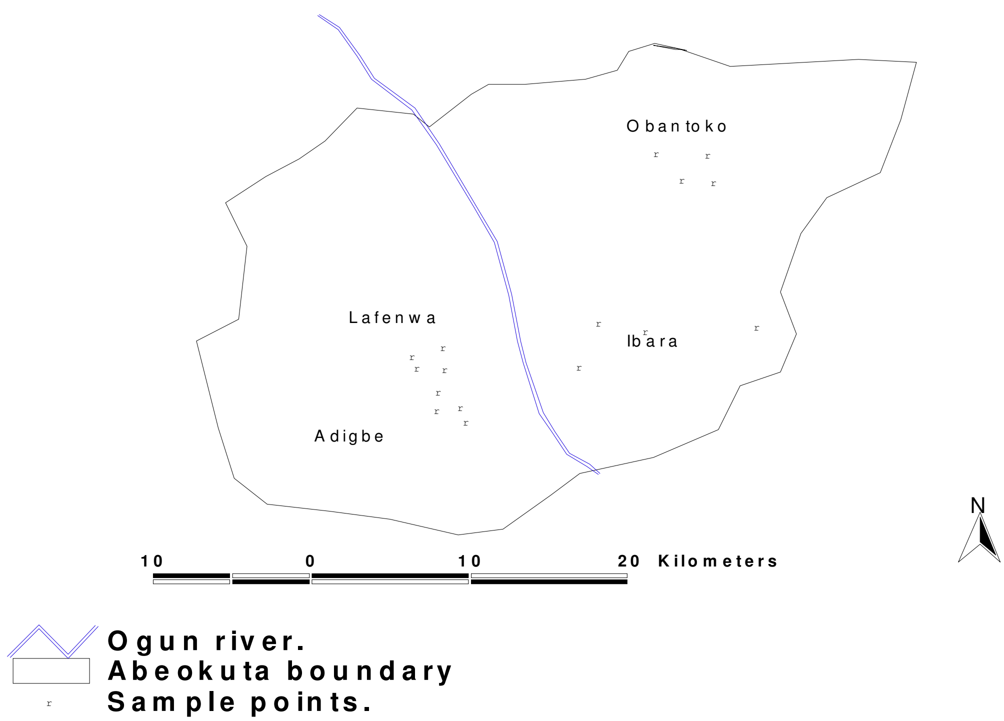

Figure 1b. Map of Abeokuta showing the sample communities and sample points.

Table 1. Summary of location description, layer resistivity and thickness, depth of hand dug wells and lithology at Adigbe.

VES Locations	Layer 1		Layer 2		Layer 3		Layer 4		Layer 5		Average dept of hand dug wells
	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	
	Top soil		Sandy clay		Highly weathered basement		Weathered basement/ fracture		Fresh basement		
1	100.8	1	29.1	2.1	206.7	12.0	2937.2	52.9	2012.1		8.3
	Top soil		Sandy clay		Highly weathered basement		Weathered basement/ fracture		Massive bedrock		
2	172.3	1.1	27.4	1.2	1040.5	1.5	13079.2	6.2	48122.3		4.5
	Top soil		Sandy clay		Highly weathered basement		Weathered basement/ fracture		Fresh basement		
3	813.7	0.2	41.8	0.6	4.8	1.4	260.0	2.6	6658.1		3.7
	Top soil		Sand stone		Weathered basement		Fracture		Massive bedrock		
4	381.5	1.7	82.9	3.8	143.8	3.7	2128.0	8.8	11198.3		4.2

Table 2. Summary of location description, layer resistivity and thickness, depth of hand dug wells and lithology at Lafenwa.

VES Locations	Layer 1		Layer 2		Layer 3		Layer 4		Layer 5		Average dept of hand dug wells
	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	
	Top soil		Sandy clay		Weathered basement		Fresh rock				
1	359.9	1.3	42.5	3.9	83.9	8.1	1177.1		1797.9		9.6
	Top soil		Sandy soil		Sandy Clay		Weathered basement				
2	423.4	0.7	5.5	0.7	153	3.4	36.2	14.6	Fresh bedrock		5.5
	Top soil		Sandy clay		Weathered basement		Fresh bedrock				
3	494.3	1.2	35.9	2.1	113.7	19.5	3910.5				16.7
	Top soil/silty sand		Sandy soil		Sandy clay		Weathered basement		Fresh bedrock		
4	117.3	0.9	449.8	1.7	20.4	6.9	225.5	8.1	780.6		8.2

Table 3. Summary of location description, layer resistivity and thickness, depth of hand dug wells and lithology at Ibara.

VES Locations	Layer 1		Layer 2		Layer 3		Layer 4		Layer 5		Average dept of hand dug wells
	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	
	Top soil/silty clay		Highly weathered basement		Weathered basement		Weathered basement/fracture		Fresh basement		
1	500.4	1.4	26.0	4.4	92.7	14.1	540.4				8.3
	Top soil		Sandy clay		Highly weathered basement		Weathered basement/fracture		Massive bedrock		
2	145.6	1.4	222.2	8.5	66.8	26.0	439.5				6.9
	Top soil		Highly weathered basement		Weathered basement/fracture		Fresh basement				
3	142.4	1.7	65.1	21.4	22.4	19.2	587.5				8.9
	Top Soil/ sandy clay		Weathered basement		Weathered basement fracture		Fresh basement				
4	329.1	1.1	52.7	7.4	1071.0	4.5	27388.7				5.6

Table 4. Summary of location description, layer resistivity and thickness, depth of hand dug wells and lithology at Obantoko.

VES Locations	Layer 1		Layer 2		Layer 3		Layer 4		Layer 5		Average dept of hand dug wells
	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	Resistivity (Ωm)	Thickness (m)	
	Top soil		Sandy soil		Lateritic sand		Weathered basement		Fresh basement		
1	303.1	0.7	305.4	2.0	253.9	15.3	61.2	22.8			6.7
	Top soil		Clay soil		Lateritic sand		Weathered basement		Fresh basement		
2	60.3	1.8	3.7	1.5	21.0	1.2	960.2	4.2			5.6
	Top Soil		Highly weathered basement		Highly weathered basement		Weathered basement/fracture		Fresh basement		
3	706.0	0.8	41.3	2.0	463.9	39.5	749.4				4.9
	Top Soil		Sandy soil		Lateritic soil		Weathered basement		Massive bedrock		
4	687.6	0.8	37.6	1.8	459.1	12.4	502.2	40.1	735.7		5.8

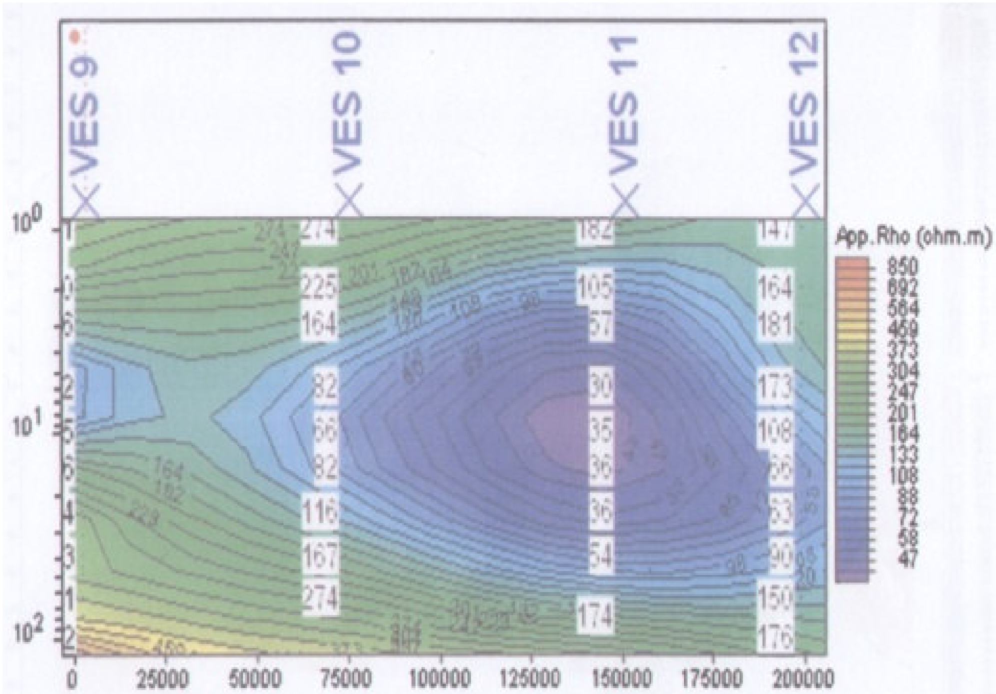

Figure 2a. Resistivity variation with elevation at Adigbe.

ANALYSIS OF RESULTS AND DISCUSSIONS

The topsoil at Adigbe (Table 1) has resistivity values ranging between 100.8 and 813.7 Ωm and thickness between 0.2 and 1.7 m. The second geo-electric layer revealed a clayey sandy formation (except at VES 4 with sandstone) with resistivity values between 27.4 and 82.9 Ωm and a thickness range of 0.6 and 3.8 m. The layer third geo-electric layer is highly weathered. The current penetration terminated at the fourth geo-electric layer at these locations as shown in the geo-electric section. When the depths of penetration obtained from the field data were compared to the total depths of the shallow wells dug close to the VES points, the results reveal with clear distinction that all the wells at this section were not drilled to the aquifer level; the wells were terminated just slightly above the overburden (Table 1 and Figure 2a).

The topsoil at Lafenwa (Table 2) has resistivity values ranging between 117.3 and 494.3 Ωm and thickness between 0.7 and 1.3 m. The second geo-electric layer revealed a clayey sandy formation with resistivity values between 5.5 Ωm and 449.8 Ωm; thickness range of 0.7 and 3.9 m. The layer is highly weathered in two of the locations (VES 01 and VES 03) while it was sandy clay at two others. The current penetration terminated at the fourth geo-electric layer at VES 01 and VES 03 while at VES 02 and VES 04, it was weathered basement. When the depths of penetration obtained from the field data were compared to the total depths of the shallow wells dug close to the VES points, the results reveal with clear distinction that all the wells at this section were not drilled to the aquifer level; the wells were terminated just slightly above the overburden (Table 2: Figure 2b).

The topsoil at Ibara (Table 3) has resistivity values ranging between 329.1 and 500.4 Ωm and thickness between 1.1 and 1.7 m. The second geo-electric layer revealed a highly weathered basement at two locations, weathered basement at one and sandy clay in the fourth. The third layer consists of weathered basement and fracture. The current penetration terminated at the fourth geo-electric layer at VES 03 and VES 04 while at VES 01 and VES 02, it was weathered basement/fracture. When the depths of penetration obtained from the field data were compared to the total depths of the shallow wells dug close to the VES points, the results reveal with clear distinction that all the wells at this section were not drilled to the aquifer level; the wells were terminated just slightly above the overburden (Table 3 and Figure 2c).

The topsoil at Obantoko (Table 4) has resistivity values ranging between 60.3 and 706.0 Ωm and thickness between 0.7 and 1.8 m. The second geo-electric layer revealed a clayey sandy formation with resistivity values between 3.7 and 305.4 Ωm. The third layer is lateritic soil and sand. The current penetration terminated at the fourth geo-electric layer, which was weathered basement. When the depths of penetration obtained from the field data were compared to the total depths of the shallow wells dug close to the VES points, the results reveal with clear distinction that all the wells at this section were not drilled to the aquifer level; the wells were terminated just

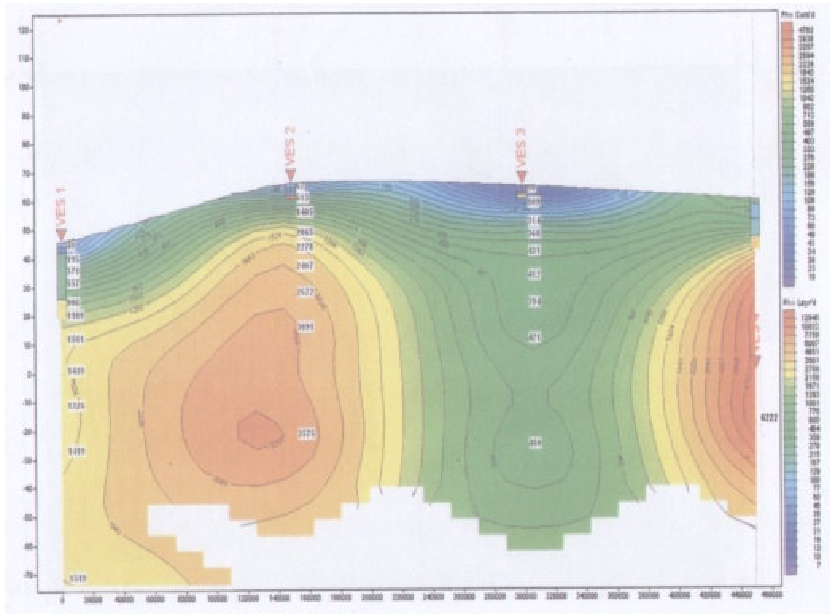

Figure 2b. Resistivity variation with elevation at Lafenwa.

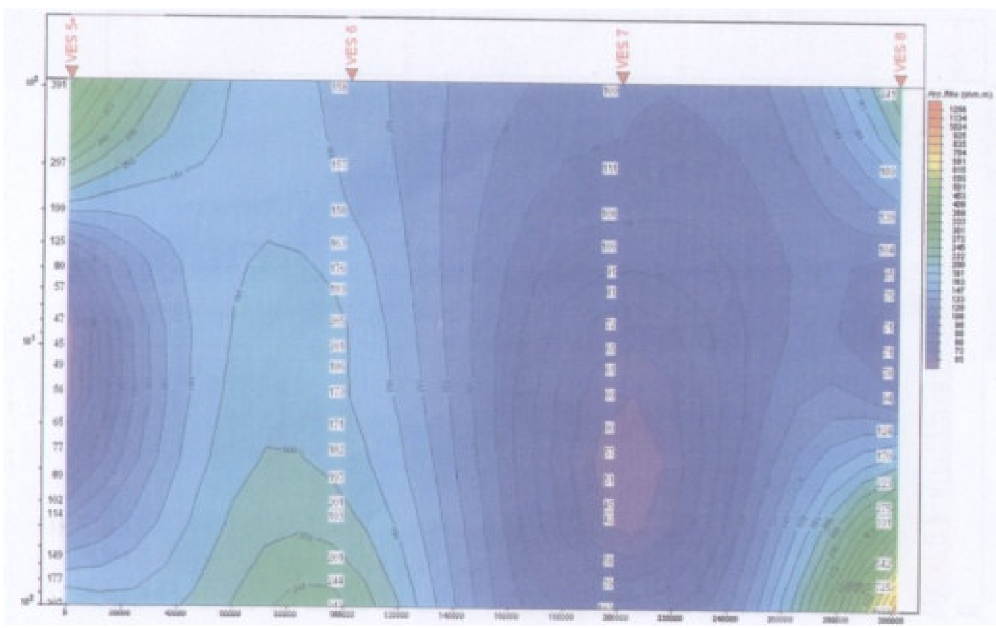

Figure 2c. Resistivity variation with elevation at Ibara.

slightly above the overburden (Table 4 and Figure 2d).

Result of heavy metal and physico-chemical analysis

Table 5 and 6 shows the results of the analysis of physcio-chemical and heavy metal parameters (Table 6 is in the appendix).

Zinc

The result showed that zinc was prominent in all the water samples analyzed and its composition does not conform to the World Health Organisation (WHO) standard; although it conforms to the National Food and Drug Administration Commission (NAFDAC) maximum allowed limits. Zinc content is more prominent in the shal-

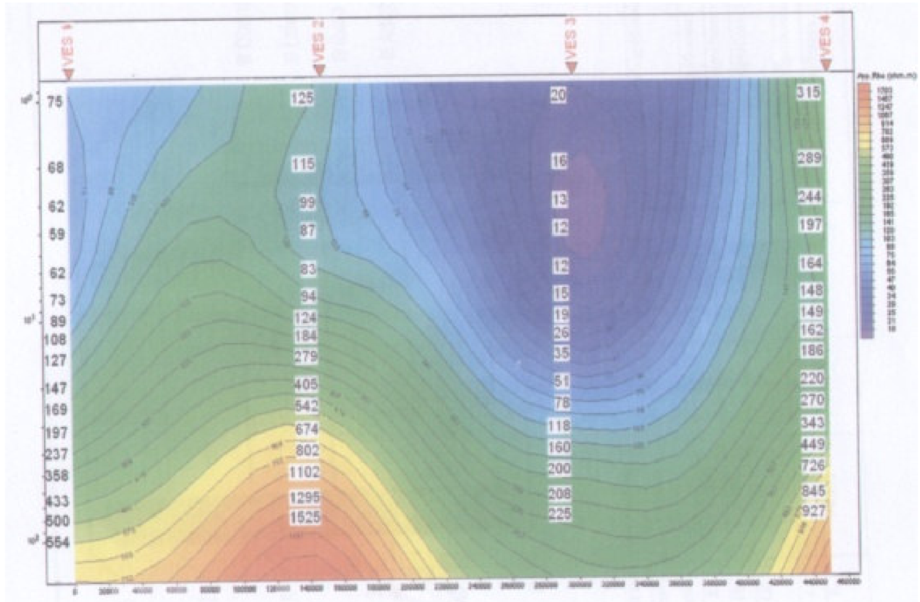

Figure 2d. Resistivity variation with elevation at Obantoko.

low wells (AW1, AW2, AW3, LW1, LW2, OBW1, IBW1 and AW4) than in the borehole samples (LB1, AB2, IB2 and AB3). The lowest amount though was recorded for one of the shallow wells at Obantoko (OBW3). The incidence of zinc could be from acid igneous rocks and metamorphic rocks into which acid igneous rocks have intruded. The maximum permissible level recommended by WHO is 3.0 mg/L while the highest desirable level is 0.01 mg/L. The NAFDAC maximum allowed limit is 5.0 mg/L. All the water samples analysed are above the highest desirable limit but are within the maximum permissible level. High zinc content in portable water gives an undesirable taste. A water softening system should be adopted to lower the content of zinc to make the water palatable for drinking.

Iron

Iron content was prominent in the shallow wells when compared with the situations in the boreholes. The highest content of iron was recorded at Ibara well 1(IBW1) and Adigbe well 1(AW1); while the lowest content of 0.11 was recorded at Adigbe borehole 2. The possible explanation that could be given for the high iron content in the shallow wells is the tapping of water from weathered basement without reaching the required depth of aquifer. Iron can be found in most hydro-geological environments, but are only dissolved in groundwater under reducing (anaerobic) conditions. Solubility increases in low pH (more acidic) groundwater. In cured conditions, concentration of iron ions may reach more than 10 mg/L. The weathered crystalline basement regions are particularly prone to low pH and high iron concentrations. The iron content of water are about the WHO standard, which could be as a result of tapping the water from weather basement without reaching the required aquifer depth and used of steel made pumps in boreholes.

When iron-contained water is exposed to air, it is oxidised and produce an objectionable reddish-brown

Table 5. Table showing result of heavy metal analysis.

Samples	Zn	Pb	Cd	As	Fe
AW1	0.84	0.11	0.05	0.009	0.56
AW2	0.68	0.18	0.08	0.002	0.48
AW3	0.72	0.13	0.06	0.001	0.50
AW4	0.63	0.17	0.07	0.001	0.39
OBB1	0.47	0.06	0.01	0.00	0.36
OBB2	0.33	0.05	0.01	0.00	0.18
AB1	0.41	0.02	0.00	0.00	0.4
AB2	0.29	0.04	0.00	0.00	0.11
AB3	0.36	0.08	0.02	0.00	0.16
LB1	0.24	0.03	0.00	0.00	0.16
LW1	0.66	0.10	0.05	0.011	0.32
LW2	0.59	0.14	0.04	0.02	0.41
OBW1	0.71	0.16	0.06	0.001	0.53
OBW2	0.50	0.13	0.03	0.00	0.29
OBW3	0.05	0.15	0.04	0.00	0.34
IBW1	0.80	0.09	0.01	0.00	0.63
IBB1	0.43	0.04	0.00	0.00	0.45
IB2	0.31	0.07	0.01	0.00	0.19
Mean	.501	.097	.54	.0025	.358
Stan Dev	.216	.051	.27	.0054	.153

Table 6. Table showing result of physico-chemical parameters analysis.

Physico-Chemical Parameters	AW1	AW 2	AW 3	AW 4	AB 1	AB 2	AB 3	OBW 1	OBW 2	OBW 3	OBB 1	OBB 2	IBW 1	IBB 1	IBB 2	LB1	LW1	LW2	WHO Standard	NAFDAC Standard	Mean	Stan Dev
pH^0	5.9	6.1	6.3	5.9	7.3	6.9	7.6	6.1	6.5	5.4	6.0	5.5	5.5	5.4	6.3	6.3	6.2	6.4	6.5-9.5	6.5-8.5	6.2	.61
Electrical Conductivity 25℃ (µs/cm)	1080	260	170	60	520	370	450	506	550	130	310	190	150	130	240	110	70	100	1200	1000	299.7	253.25
Total Dissolved Solids (mg/L)	530	130	80	30	250	180	220	250	270	60	150	90	70	60	110	50	30	50			145	125.1
Total Hardness(mg/L)	338	154	163	40	364	172	262	150	532	230	146	78	70	134	108	92	38	50	500mg	100mg	173.39	130.26
Total Alkalinity(mg/L)	4.0	6.0	10.0	8.0	10.0	6.0	8.0	2.0	1.6	4.0	6.0	4.0	8.0	10.0	6.0	6.0	4.0	12.0	100mg	100mg	6.42	2.91
Chloride(mg/L)	850	13	13.5	5.0	28	16	24	28.5	44.5	40	4.5	12	11	10	16	4.5	4.0	9.0	250	100	62.97	196.8
Sodium(mg/L)	0.30	Nil	0.09	0.16	0.16	0.18	0.08	0.05	0.05	0.17	0.14	0.06	0.08	0.11	0.09	0.06	0.2	0.03			0.118	.07
Potassium(mg/L)	1.32	Nil	Nil	0.65	0.39	Nil	Nil	Nil	Nil	0.77	0.42	Nil	Nil	0.35	0.38	Nil	0.61	0	Ns	10	0.543	.365

Note: Adigbe well 1 (AW1),Adigbe well 2 (AW2),Adigbe well 3 (AW3),Adigbe well 4 (AW4)Adigbe borehole 1 (AB1),Adigbe borehole 2 (AB2),Adigbe borehole 3 (AB3), Obantoko well 1 (OBW1), Obantoko well 2 (OBW2), Obantoko well 3 (OBW 3), Obantoko borehole 1 (OBB1), Obantoko borehole 2 (OBB2), Ibara well 1 (IBW 1), Ibara borehole 1 (IBB 1), Ibara borehole 2 (IBB2), Lafenwa borehole 1 (LB 1)Lafenwa well 1 (LW1), Lafenwa well 2 (LW2).

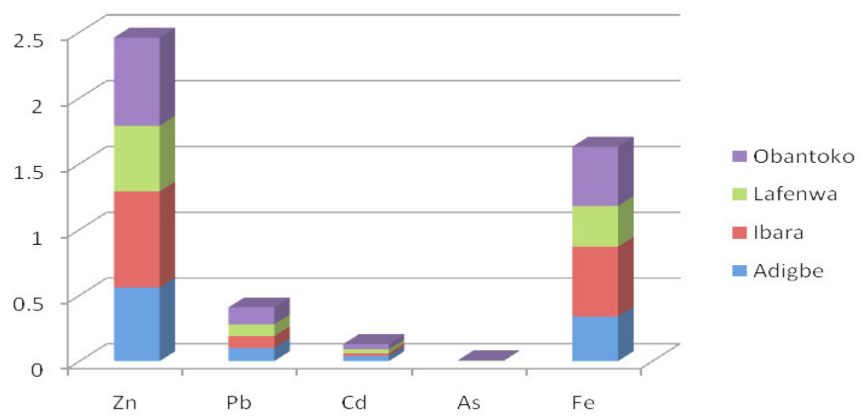

Figure 3. Bar chart revealing the variations of heavy metals in the study areas.

colour. This water stains cloths when used to wash as well as utensils and food, boreholes cased with mild steel and galvanized iron and also with the use of case iron pumps. This water when oxidised can stain cloths, utensil and food and may also taste bitter.

Arsenic

The arsenic content in the 18 water samples are within the WHO standard except for the shallow wells (AW1, AW2, AW3 and LW1).

Health effect of arsenic has long been recognized as a toxin and carcinogenic. Long term ingestion of high concentrations of arsenic from drinking water can give rise to various health problems, particularly skin disorders such as pigmentation changes (dark/light skin spots) and karatosis (warty nodules, usually on the hands and feet.) Other symptoms include more serious dermatological problems (for example; skin cancer, and Bowen's disease) cardiovascular problem hypertension and heart disease) and Raynand's syndrome, black foot disease and gangrene, neurological, respiratory, renal and hepatic disease as well as diabetes mellitus. Internal cancer, particularly of the lung, bladder, liver and kidney had been linked with arsenic in drinking water (Ajayi and Osibanjo, 1981). The WHO guideline value for arsenic in drinking water was reduced in 1993 from 50 to 10 µg/L, so also the US and EC standards have been similarly reduced in groundwater occurrence.

The arsenic constituents in the selected areas of study are below the WHO standard and the maximum permissible limits. Arsenic forms anionic (negatively charged) species in water, which are stable in soluble from neutral to alkaline pH (6.5 - 8.5) (Awomeso et al., 2009) characteristic of most groundwater. The arsenic constituent in this area could be as a result of human activities like use of arsenical pesticides, which migrate into the soil and because groundwater moves slowly, it continue to dissolve and concentrate in the aquifer.

Cadmium

The maximum permissible level by WHO in drinking water is 0.003 mg/L and for NAFDAC maximum allowed limit is also 0.003 mg/L of all the samples analyzed, only 6 are within the limit with 8 samples having values above the maximum recommended value. Adigbe well 2 (AW2) has the highest values. The metal cadmium was not present in 4 samples. The shallow wells had higher cadmium content compared to the boreholes which could be as a result of the depth at which the water was tapped and exposure to contamination.

Cadmium is a potentially toxic element. It is a notorious metal for its high renal toxicity due its irreversible accumulation in the kidney.

Lead

The maximum permissible level by WHO and NAFDAC in drinking water is 0.01 mg/L. It was observed by the lead content that very high lead levels exist for most of the samples because they were all above the maximum permissible limit except for 9 samples which were high but still tolerable. The shallow wells had higher lead concentrations compared to the boreholes. Lead is strong neurotoxin in unborn, newborn and young children, leading to irreversible impairment of intelligence.

pH

The pH of all the water samples conforms to WHO standard. Since most of the pH values is below 6.5 (Table 6), this signifies that the water samples were slightly acidic especially those from the boreholes. This can be corrected by treating the water with hydrolyte before supplying such waters to the communities.

Electrical conductivity

The sample values were below the WHO and NAFDAC standards with the exception of Adigbe well 1 (AW1)

Potassium

This is an essential nutritional element. The maximum allowed limits by NAFDAC is 10 mg/L. Nine of the analysed samples are within this limit while there is absence of potassium in five shallow wells and four boreholes. It's absent is probable due to the resistance of potassium minerals to the decomposition by weathering and the fixation of potassium in clay minerals to the decomposition by weathering.

Total dissolved solids (TDS)

The TDS values of sample water are still within WHO guideline of 100 mg/L on account of taste. Although, groundwater with high TDS is often an unrecognised problem, high concentration of TDS could result to salty and unpalatable taste in water. High concentration of TDS could result to gastrointestinal irritation.

Total hardness

When water is described to be hard, it has high dissolved minerals, specifically calcium and magnesium. Hard water is not a health risk, but a nuisance because of mineral building on fixtures, hindering performance. As water moves through soil and rocks it dissolves very small amount of minerals and usually forms solution. Calcium and Magnesium are the most common minerals found in hard water.

Sodium

This occurs widely in water and many igneous rocks. It is an essential component of most groundwater. In compound form, sodium is readily soluble in water. High concentration of sodium in the soil is generally favourable for plant growth. It is useful to plant though in excess could be toxic.

Chloride

The WHO maximum permissible level is 250 mg/L and the highest desirable limit is 200 mg/L. The maximum allowed limit is 100 mg/L. All the water samples are within the limit except for AW1 which has 850 mg/L of chloride. This may be as a result of pollution by sewage and waste, leaching of saline residues in the soil and because the shallow wells are usually highly exposed.

From the geophysical survey carried out, it was observed that in most of the locations of the study, the groundwater potential are structurally controlled except for Obantoko area where the groundwater potential is structurally controlled as well as porosity and permeability dependent. It was also found out that groundwater was not tapped at desirable depth, which could be a cause of high water scarcity in dry season due to low recharge rate.

Some of the water samples do not conform to WHO standards, especially for parameters like Zn, Pb and Cd. The samples were still within the maximum permissible levels. The Arsenic (As) content is within the highest desirable level and none was observed in many samples (OBW1, IBW1, IBW2, IBB1, IBB2, LB1, AB1, AB2, AB3, OBB1 and OBB2). This showed that the water samples analyzed were free from toxic elements at the rate that can cause harm to the human body. Cadmium was also recorded to be absent in 4 samples which are boreholes (AB1, AB2, LB1 and IBB1) and the lowest values recorded in borehole samples as well.

The physico-chemical analysis showed that 6 shallow wells and 5 boreholes have hardness above 100 mg/L (which is WHO standard) which meant that those sampled wells and boreholes could be regarded as hard. The highest value was recorded in OBW2. The pH values from the samples ranged from 5.4 to 7.3 with the highest values recorded in borehole samples. This implied that all the analysed samples were within the WHO standard for drinking water. The high pH values recorded for boreholes could be adjusted by treatment of the water. The highest total dissolved solids (TDS) value was recorded in AW1. This could be because of pollution from industrial discharge and municipal waste. Generally the water samples were within the permissible WHO standards but needed to be subjected to treatment before drinking.

Conclusion

This work on hydro-geological characteristics and groundwater assessment in some selected parts of Abeokuta had these interesting observations:

From the geophysical survey carried out, it was observed that in most of the sample points of the study, the groundwater potentials are structurally controlled except for the Obantoko area, which is structurally controlled as well as porosity and permeability dependent. From the average depth of wells it was observed that groundwater is not tapped at desired depths, leading to high water scarcity in the dry season due to low recharge rates. The shallow wells were dug to water table except where the overburden thickness is high.

The result of the heavy metal analysis showed that most of the water samples do not conform to the WHO standard especially for Zn, Pb, and Cd though; they are still within the maximum permissible level. Arsenic (As) content is within the highest desirable level and none was observed in these points; OBW2, IBW1, IBW2, IBB1, IBB2, LB1, AB3, AB2, AB1, OBB1 and OBB2. This meant that the water samples analysed were free from the toxic element at the rate that can cause harm to human body. Cadmium was also recorded absent in four samples which were boreholes (AB1, AB2, LB1 and IBB1) and the lower values were recorded in the borehole samples compared to samples from wells.

The physico-chemical analysis showed that six shallow wells and five boreholes were hardness above 100 mg/L WHO standard therefore; these samples could be regarded as hard water. The highest value was recorded in OBW2, followed by AB1 and AW1. The hardness could be as a result of dissolution of rock and soil minerals while through thereby forming solution. The p^H values range between 5.4 and 7.3 where the highest value were recorded in borehole samples. This implied that all the analysed samples were within the WHO standard for drinking water. The highest p^H values recorded for boreholes are natural and could be adjusted by using hydrolite in their treatment. The water samples could generally be regarded as fair, with regards to WHO standards, but needed to be treated before drinking.

REFERENCES

Ajayi SO, Osibanjo O (1981). Pollution studies on Nigeria Rivers II. Water quality of some Nigerian rivers. J. Environ. Pollut. 2: 87-95.

Ako BD (1979). Geophysical prospecting for groundwater in parts of south-western Nigeria. Unpublished PhD Thesis. Department of Geology, University of Ife, Ile-Ife, Nigeria p. 371.

Awomeso JA, Ufoegbune GC, Oluwasanya GO, Ademola-Aremu OO (2009). 'Impact of industrial effluents on water, soils and plants in the Alakia industrial area of Ibadan, South West Nigeria', Toxicol. Environ. Chem. 91(1): 5 -15.

Ayoade JO (2003). Tropical Hydrology and Water Resources. Macmillan Ltd. p. 276.
Dijon R (1981). "Groundwater Exploration in Crystalline Rocks in Africa", Proc. Am. Soc. Civil Eng. pp. 11-15.
Faniran A, Omorinbola EO (1980). Evaluating the shallow groundwater resources in basement complex areas: A case study of southwestern Nigeria. J. Min. Geol. 17(1): 65-79.
Farquharson F, Bullock A (1992). "The Hydrology of Basement Complex Regions of Africa with Particular Reference to Southern Africa", in Wright, E. and Burgess, W. (eds) Hydrogeology of Crystalline Basement Aquifers in Africa, Geological Society Special Publication London. 66: 59-76.
Houston J (1995). Exploring Africa's Groundwater Resources. Int. Groundwater Technol. 1(1): 29-32.
Key R (1992). "An Introduction to the Crystalline Basement of Africa", in Wright, E. and Burgess, W. (eds) Hydrogeology of Crystalline Basement Aquifers in Africa, Geological Society Special Publication London 66: 29-57.
Omorinbola EO (1982). Verification of some geo-hydrological implications of deep weatherings in basement complex of Nigeria. J. Hydrol. 56(2): 347-368.
Selby MJ (1985). Earth's Changing Surface. Clarendon Press, Oxford. p. 607.
WHO (2004). Guidelines for drinking water quality: Recommendations, 3rd ed. Geneva: WHO.