

ASSESSMENT OF POLLUTION HAZARDS OF GROUNDWATER RESOURCE IN ABEOKUTA NORTH LOCAL GOVERNMENT AREA, OGUN STATE, SOUTHWESTERN NIGERIA

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ABSTRACT

Pollution of wells and borehole water, either from point or non-point sources, has become a matter of health concern both in urban and rural areas. Groundwater is tapped for domestic uses through the construction of hand dug wells and boreholes. However, while providing an alternative to the public water supply sources; most of the boreholes are often located too close to possible contamination sources. Various land use and human activities such as solid waste landfills, cemetery and animal wastes, among others can result in ground water contamination. In an open or buried dumping solid waste or sanitary landfill, the organic and inorganic by-products resulting from the decomposition of wastes are leached out by the infiltration of rainfall. A release of leachate to the surrounding soil without proper collection and treatment could contaminate groundwater resources. Many of the wells and boreholes in the study area were found to be indiscriminately located and scattered among such impairing lands/features. This study was therefore aimed at assessing the pollution hazards and vulnerability of groundwater resource in Abeokuta North Local Government Area (LGA) by sampling some boreholes from selected locations in the area. Water samples were collected and analyzed for water quality parameters using standard procedures. The parameters determined were Turbidity, Temperature, Electrical Conductivity (EC), pH, Total Dissolved Solids (TDS) Total Suspended Solids (TSS), Total Solids (TS), Total hardness, cations {Potassium (K), Sodium (Na), Calcium (Ca), Magnesium (Mg), Manganese (Mn), iron (Fe)}, anions {Chloride (Cl⁻), Nitrate (NO₃⁻), Sulphate (SO₄²⁻), Phosphate (PO₄³⁻)}, and heavy metals {lead (Pb²⁺), Zinc (Zn²⁺), Copper (Cu²⁺)}. Results were subjected to statistical evaluations using SPSS 18.0 for descriptive statistics and Analysis of Variance (ANOVA). It was observed that the elemental parameters in the boreholes sampled have mean values of the concentrations of Fe²⁺, Na⁺, Cl⁻, SO₄²⁻, Pb²⁺, Mn²⁺, Cu²⁺ and Zn²⁺ higher during the wet season relative to dry season. For the physico-chemical parameters, it was equally observed that parameters such as EC, TDS, TS, TSS were higher during the wet season than dry season while turbidity, temperature, pH and total hardness were higher during dry season than in the wet season. Water quality parameters such as Fe²⁺, Pb²⁺, NO₃⁻, and EC have mean values greater than World Health Organization and NESREA maximum permissible standards for drinking water. Elevated values of these parameters are of great concern to public health when the water from these boreholes is consumed without treatment by people. It is recommended that well and borehole waters in this area be adequately treated before consumption using advanced inorganic removal techniques such as Nano-filtration and Reverse Osmosis to safeguard human health in the study area.

Keywords: Boreholes, pollution, water quality, public health, physico-chemical parameters,

INTRODUCTION

Safe water has been described as water that meets the National Standard for Drinking Water Quality for Nigeria (Federal Ministry of Water Resources, 2004). Access to safe drinking water is a prerequisite to poverty reduction in that it prevents the spread of water-borne and sanitation-related diseases thereby reducing huge sums of family income that is often spent on disease treatment. However, in Nigeria, 52% of the population does not have access to safe, clean drinking water (UNICEF, 2005). Lack of access to safe water and adequate sanitation services especially in developing countries resulted in the death of about two million infants annually (UNICEF, 2005; Cosgrove and Rijsberman, 2000; Gomez and Nakat, 2002). As a result of rapid expansion of cities and subsequent population explosion, the development of groundwater resources for potable use has increased substantially over the last decade especially in developing countries.

Abeokuta, Southwestern Nigeria is continually growing in human population; this has resulted in continuous increase in water consumption demand. The current Abeokuta water scheme at Arakanga, Abeokuta, which supplies water to over six hundred thousand Abeokuta residents, has a designed and installed capacity of 163 million litres day⁻¹. Presently, the scheme produces 80 million litres day⁻¹ leaving a shortfall of about 40 million litres day⁻¹ in the domestic water demand of Abeokuta and environs which has been estimated to be 120 million litres day⁻¹ (Orebiyi *et al.*, 2010). This situation has led to persistent water shortage in the city and its environs. To meet this huge shortfall in the daily water demand, borehole drilling is being considered a complementary source. Groundwater is tapped for

domestic uses through the construction of hand dug wells and boreholes. However, while providing an alternative to the public water supply sources; most of the boreholes are often located too close to possible contamination sources. Close relationship exists between groundwater quality and land use. Various land use activities can result in ground water contamination. Potential sources of groundwater pollution include solid waste landfills, cemetery and animal wastes resulting from human activities, among others. In a solid waste landfill (open dumping or sanitary landfill), the organic and inorganic by-products resulting from the decomposition of wastes are leached out by the infiltration of rainfall. If leachate is released to the surrounding soil without proper collection and treatment, it could contaminate groundwater resources (Somjai and Suporn, 1993). Studies have shown that the leachate causes an increase in dissolved inorganic substances such as chloride, sulfate, bicarbonate, sodium and potassium into the groundwater system (Zanoni and Fungaroli, 1973; Kelly, 1976).

Groundwater contamination can originate on the surface of the ground, above the water table, or below the water table. Where a contamination originates is a factor that can affect its actual impact on groundwater quality. In comparison with rivers, groundwater tends to move very slowly and with very little turbulence. Therefore once the contamination reaches the groundwater, dilution or dispersion normally takes a long time. The contaminants usually form a concentrated plume that flows along the same path as the groundwater. Among the factors that determine the size, form and rate of movement of contaminant plume are the amount and type of contaminant, and the velocity of groundwater movement. Groundwater contami-

nants could be undetected for years until the supply is tapped for use. Substances that can contaminate groundwater can be divided into two basic categories: substances that occur naturally and substances produced by man's activities (USEPA, 1990). Naturally occurring substances include: minerals such as iron, calcium, magnesium, manganese, copper and selenium while those produced by man's activities (anthropogenic substances) are: Synthetic organic chemicals, hydrocarbons, pesticides, Polychlorinated Biphenyl (PCB), landfill leachates (liquids that have dipped through the landfill and carry dissolved substances like heavy metals, organic decomposition products), salts; bacteria and viruses.

This study was carried out to assess the pollution hazards of borehole water in selected locations in Abeokuta North Local Government Area, Southwestern Nigeria through determination of water quality parameters.

PHYSIOGRAPHY, GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

The study was carried out in Abeokuta North LGA of Ogun State, Nigeria (Fig. 1 and Fig. 2). Abeokuta is in the sub-humid tropical region of southwestern Nigeria; it lies between latitude 7°5'N-7°20'N and longitude 3°17'E-3°27'E with a population of 605,451 (Projected from 1991 Census of 374,043 at 3.5 of growth rate). Its geographical location makes it easily accessible from Lagos, the industrial capital of Nigeria and the nation's major seaport.

The study area is located within the southwestern part of the Basement Complex of Nigeria. These rocks are of Precambrian age to early Palaeozoic age and they extend from the north-eastern part of Ogun State

(to which study areas belong) running southwest and dipping towards the coast (Ako, 1979). They belong to the youngest of the three major provinces of the West African Craton recognized by (Hurley and Rank, 1976). The rocks were rejuvenated during the pan-African orogeny about six hundred million years ago. The sedimentary rocks segment of Ogun State is approximately three-quarters of the surface area of the state and the Basement Complex rocks make up the remaining one-quarter of the surface area of the State (Fig. 1).

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 NNE-SSW orientation which is particularly strong within the low grade metamorphic. The common metamorphic rocks encountered are gneiss, schist, quartzite and amphiboles. The study area is characterized by various rock types ranging from granite, granitic gneiss and pegmatite. The individual rock has various hydro-geologic characteristics and 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 characterized by pegmatite underlain by granite and therefore has good hydro-geological history. To the north east of Abeokuta North LGA lies Odeda study areas which comprises of folded gneiss, schist, quartzite, older granite, and amphibolites/mica schist (Jones and Hockey, 1964) with equally sound hydrogeologic history. The southern part like Ibara (made up of granitic gneiss) is characterized by fairly hydro-geological history. The western part is char-

acterised by granitic gneiss, granite and migmatites which is less porous, and various quartzite intrusions enters into the transition zone with the sedimentary basin (Key, 1992).

Ayoade (2003) described hydrogeology as the scientific study of groundwater with emphasis on the geology and its occurrence, movement and chemical characteristics of groundwater.

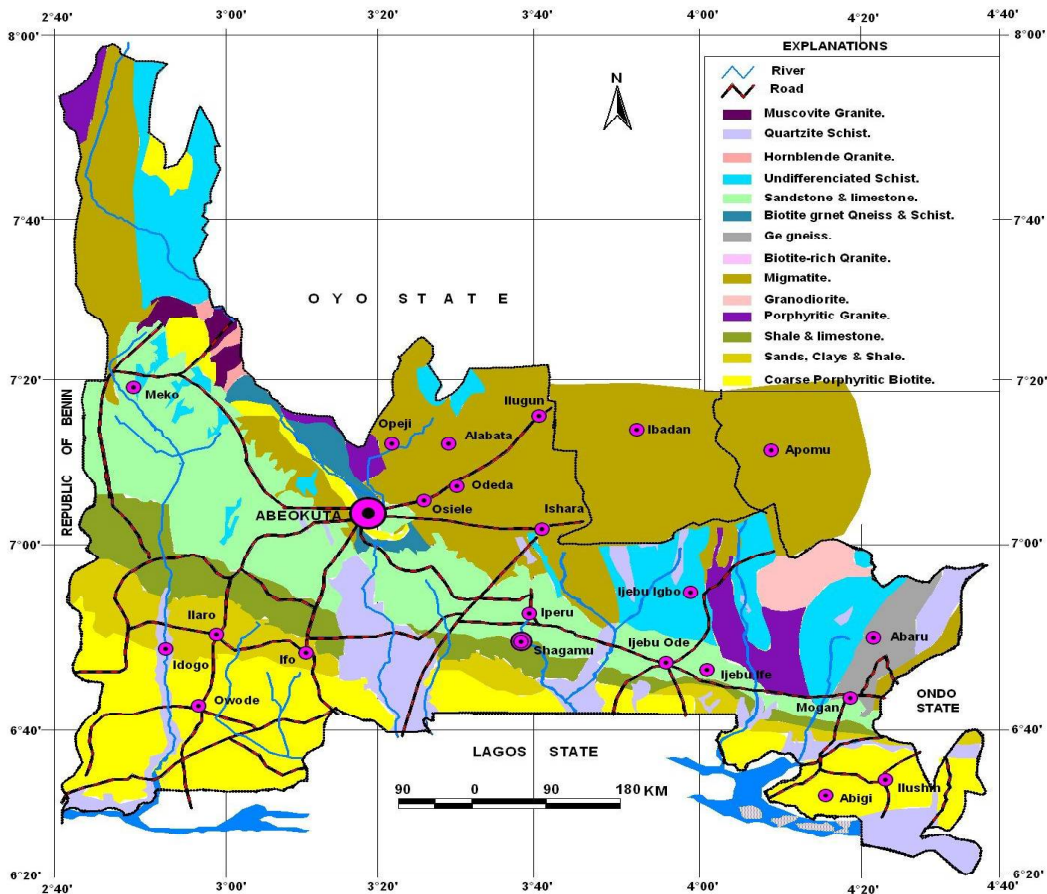


Figure 1: Geological Map of Ogun State showing the Study Area (Modified after Kehinde-Phillips, 1990; Obiora and Onwuka, 2005)

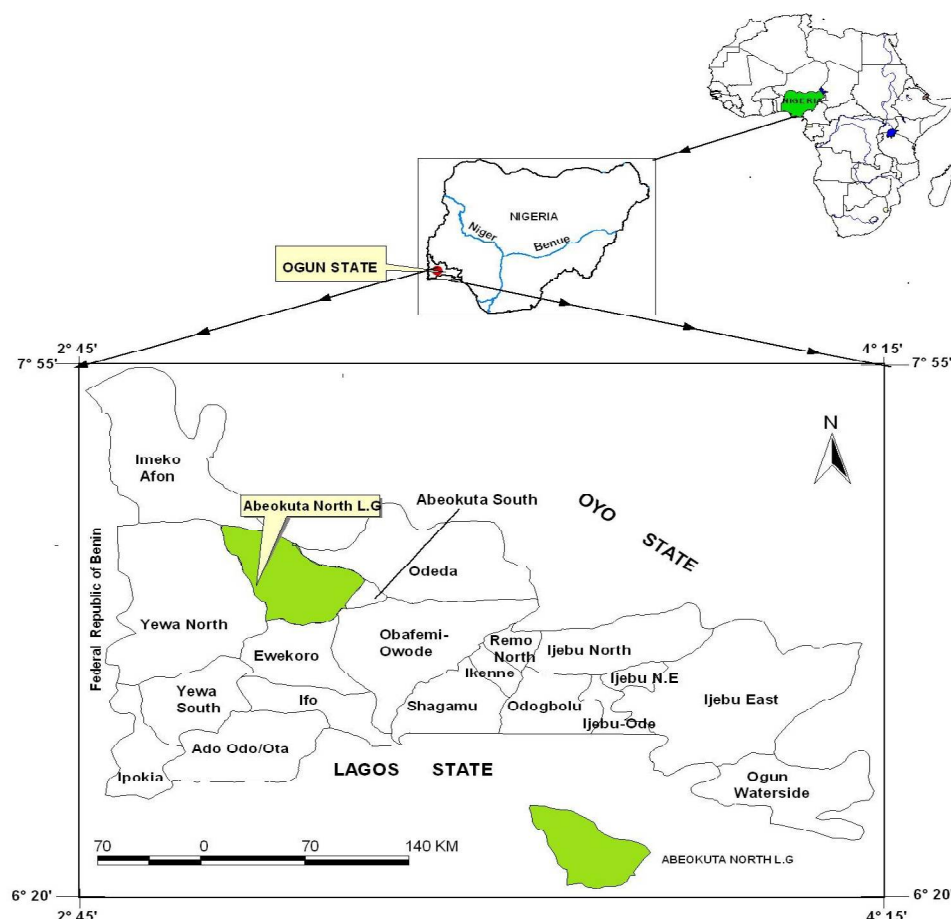


Figure 2: Political Map of Ogun State, Nigeria showing the location of Abeokuta North LGA {Inset: Map showing the location of Ogun State (using Esri Data/Nigeria Political Information in Arcview GIS 3.2A Environment)}

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 2m³/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 aquifers wholly within the fractured bedrock occur because of the typically low storativity 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 all groundwater can be said to originate as atmospheric or surface water; while 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 the study areas, as in many areas underlain by the basement complex rocks, the populace depends largely on the surface water, which is supplied from River Ogun by the water corporations. 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 the selected locations within the study area, 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 companies 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 which 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 the selected study areas.

MATHEMATICAL MODEL

The density function $f(y)$ indicates the relative frequency of occurrences of the ran-

dom variable y where y is the representation of the concentration of both the elemental and physico-chemical parameters of the aquifer system sampled in the respective borehole locations on the study area. If $f(y_1) > f(y_2)$, then points in the neighbour-

hood of y_1 are more likely to occur than

points in the neighbourhood of y_2 . The population mean of a random variable y is defined as the mean of all possible values of y and is denoted by μ . The mean is also referred to as the expected value of y , or $E(y)$. If the density function $f(y)$ is known, the mean can sometimes be found but if $f(y)$ is unknown, the populations mean μ will ordinarily remain unknown unless it has been established by past experience with a stable population. If a large random sample from the population represented by $f(y)$ is available, it is highly probable that the mean of the sample is close to μ . The sample mean of a

random sample of n observations y_1, y_2, \dots, y_n is given by the ordinary arithmetic average.

$$\bar{y} = \frac{1}{n} \sum_{i=1}^n y_i \quad (1)$$

Generally, \bar{y} will never be equal to μ ; by this we mean that the probability is zero that

a sample will ever arise in which \bar{y} is exact-

ly equal to μ . However, \bar{y} is considered a good estimation for μ because $E(y) = \mu$ and

$$\begin{aligned} \text{var}(\bar{y}) &= \mu \text{ and} \\ \text{var}(\bar{y}) &= \frac{\sigma^2}{n} \end{aligned} \quad (2)$$

where σ^2 is the variance of y . In other words is, \bar{y} is an unbiased estimator of μ and has a smaller variance than a single observation y . the notation $E(y)$ indicates the mean of all possible values of \bar{y} ; that is, conceptually, every sample concentration is obtained from the entire population of the formation or hydrogeological environment of the sampled location (Fig. 3), the mean of each is found, and the average of all these collected sample mean is calculated.

If every y in the entire population is multiplied by constant a , the expected value is also multiplied by a :

$$E(ay) = aE(y) = a\mu \quad (3)$$

The sample mean has a similar property. If

$$z_i = a y_i \text{ for } i=1, 2, \dots, n, \text{ then} \\ \hat{z} = a \bar{y} \quad (4)$$

The variance of the population is defined as

$$\text{var}(y) = \sigma^2 = E(y - \mu)^2 \quad (5)$$

Eqn(5) is the average squared deviation from the mean and is thus an indication of the extent to which the values of y (elemental and physico-chemical concentrations) are spread, distributed, dispersed and scattered in the groundwater formation of the study area. It can be shown that

$$\sigma^2 = E(y^2) - \mu^2 \quad (6)$$

The sample variance is defined as

$$S^2 = \frac{\sum_{i=1}^n (y_i - \bar{y})^2}{n-1} \quad (7)$$

Eqn(7) can be expressed further to be equal to

$$S^2 = \frac{\sum_{i=1}^n y_i^2 - n\bar{y}^2}{n-1} \quad (8)$$

The sample variance S^2 is generally never equal to the population variance σ^2 (the probability of such an occurrence is zero, but it is an unbiased estimator for σ^2 ; that is,

$E(S^2)$ indicates that the mean of all possible sample variances. The square root of either the population variance or sample variance is called the standard deviation (Rencher, 2002).

If each y is multiplied by a constant a , the population variance is multiplied by a^2 , that is,

$$\text{Var}(ay) = a^2 \sigma^2 \quad (9)$$

Similarly, if $z_i = a y_i$ where $i=1, 2, \dots, n$, then, the sample variance of z is therefore given by

$$S_z^2 = a^2 S^2 \quad (10)$$

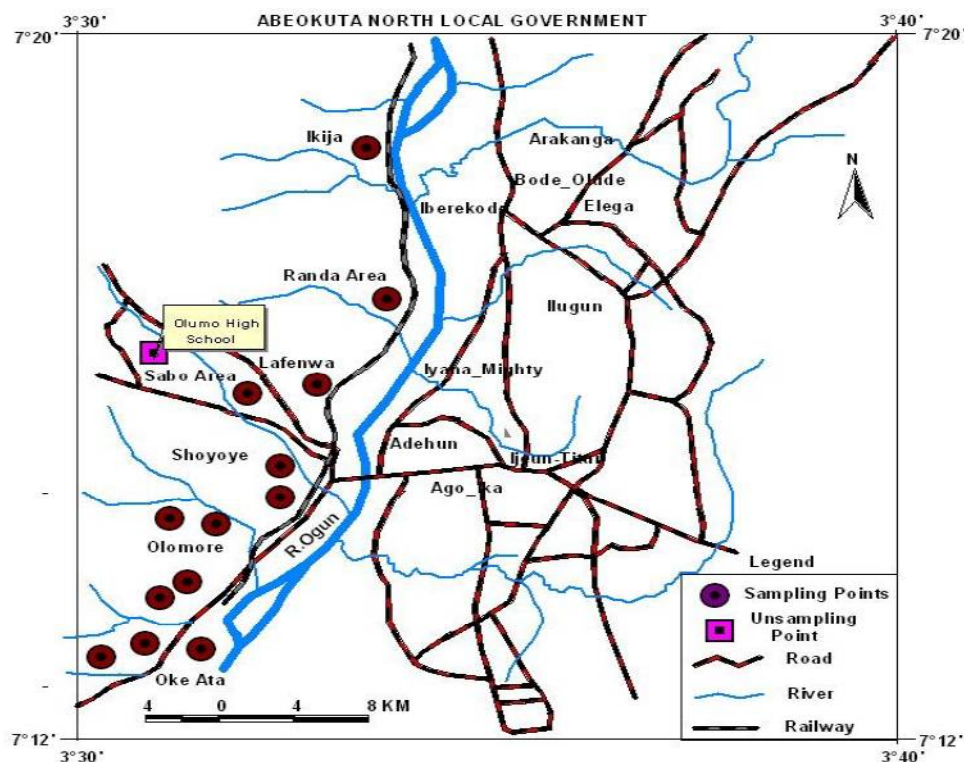


Figure 3: Map showing the sampled locations in Abeokuta North LGA Study Area

MATERIALS AND METHODS

A total number of thirty-one (31) boreholes were investigated in Abeokuta North LGA. The communities in Abeokuta North LGAs where water samples from their boreholes were collected included: Bode–Olude, Ita–Elegu, Iberekodo, Ikija , Ilugun Akomoje, Banjoko, Adehun, Bode–Olude, Oke Ata, Lafenwa, Sabo, Adehun, Soyoye and Randa , Lafenwa extensions, and Ita – Oshin. Majority of the people living in these parts of the city are farmers, traders, artisans and civil servants, with a few engaged in animal rearing on free-range system. Houses in these areas are densely populated with about six to twenty persons per house. Most of

the people who live in these areas are educated while few are not. The major activities in these areas are trading, textile making, artisans and transportation activities. The study covers both dry and wet seasons. Using standard laboratory procedures (Clesceri, 1989), the following parameters were analyzed: turbidity, temperature, electrical conductivity, pH, total dissolved solids, total suspended solids, total solids, total hardness, potassium, sodium, calcium, magnesium, manganese, iron, lead, zinc, copper, chloride, nitrate, sulphate, phosphate. pH, conductivity and total dissolved solids were measured with COMBO HI model 98130 pH/Conductivity/TDS meter. Total hardness

was determined by complexometric titration with standard EDTA as titrant in the presence of Eriochrome Black T indicator. Sodium and potassium were determined with flame photometer (Model PFP 7, JENWAY, UK). Other metals were analyzed by Atomic Absorption Spectrophotometric (AAS) method. TSS was determined gravimetrically while TS was determined by summing TDS and TSS together. Water temperature was measured by using mercury thermometer. Chloride was determined by using silver nitrate titration method while potassium chromate served as indicator (Vogel and Bassett, (1978). Turbidity was determined spectrophotometrically using UV/Visible spectrophotometer (HACH DR/4000, UK). Results were analyzed using SPSS version 18.0 package.

RESULTS

The mean values of elemental parameters obtained from water samples collected from boreholes in selected parts of Abeokuta North LGAs are shown in Table 1 while that of the physico-chemical parameters are depicted in table 2. The boreholes sampled in the study areas have concentrations of mean values of Fe^{2+} , Na^+ , Cl^- , SO_4^{2-} , Pb^{2+} , Mn^{2+} , Cu^{2+} higher during the wet season relative to dry season. For the physico-chemical parameters, it was observed that parameters such as EC, TDS, TS, TSS were higher during wet season than dry season. Results equally show the pattern of dominance of major cations based on the mean values to be $\text{Na}^+ > \text{K}^+ > \text{Ca}^{2+} > \text{Mg}^{2+}$ during wet season and $\text{Na}^+ > \text{Ca}^{2+} > \text{Mg}^{2+} > \text{K}^+$ during dry season in the study area.

Table 1: Seasonal Variation of Mean \pm SD Values of Elemental Parameters in Boreholes of Abeokuta North LGA (mgL⁻¹) (N=31)

ELEMENTAL PARAMETERS	MEAN \pm SD (DRY SEASON)	MEAN \pm SD (WET SEASON)	WHO	NESREA
Ca ²⁺ (mgL ⁻¹)	35.90 \pm 17.17	18.20 \pm 7.01	100-200	200
Fe ²⁺ (mgL ⁻¹)	0.10 \pm 0.09	0.40 \pm 0.91	0.30	0.30
Mg ²⁺ (mgL ⁻¹)	32.33 \pm 20.18	5.83 \pm 4.40	250	15
K ⁺ (mgL ⁻¹)	24.83 \pm 14.97	18.93 \pm 14.40	NA	3.9
Na ⁺ (mgL ⁻¹)	44.39 \pm 23.14	62.01 \pm 17.57	200	NA
Cl ⁻ (mgL ⁻¹)	80.62 \pm 71.23	92.30 \pm 53.35	250	200
NO ₃ ⁻ (mgL ⁻¹)	87.11 \pm 165.73	11.19 \pm 8.00	50	45
SO ₄ ²⁻ (mgL ⁻¹)	14.33 \pm 6.19	32.69 \pm 15.47	<250	500
PO ₄ ³⁻ (mgL ⁻¹)	12.89 \pm 17.69	0.13 \pm 0.17	NA	NA
Pb ²⁺ (mgL ⁻¹)	0.04 \pm 0.07	0.29 \pm 0.13	0.01	0.01
Mn ²⁺ (mgL ⁻¹)	0.01 \pm 0.02	0.02 \pm 0.04	0.5	0.2
Zn ²⁺ (mgL ⁻¹)	0.04 \pm 0.02	0.09 \pm 0.05	3.0	3.0
Cu ²⁺ (mgL ⁻¹)	0.03 \pm 0.02	0.07 \pm 0.13	2.0	1.0
Cd ²⁺ (mgL ⁻¹)	0.02 \pm 0.02	0.02 \pm 0.03	0.003	0.003
As ²⁺ (mgL ⁻¹)	0.00 \pm 0.01	0.01 \pm 0.02	0.01	0.01

Table 2: Seasonal Variation of Mean \pm SD Values of Physico-Chemical Parameters in Boreholes of Abeokuta North LGA (mgL^{-1}) (N=31)

PHYSICO-CHEMICAL PARAMETERS	MEAN \pm SD (DRY SEASON)	MEAN \pm SD (WET SEASON)	WHO	NESREA
TURBIDITY(NTU)	4.77 \pm 2.91	4.10 \pm 1.59	5.0	5.0
TEMP(OC)	28.17 \pm 0.65	25.33 \pm 0.55	NA	NA
EC (μScm^{-1})	602.50 \pm 320.78	764.70 \pm 185.58	250	NA
PH	7.15 \pm 0.43	6.88 \pm 0.31	6.50-8.50	7.00-8.50
TS(mgL^{-1})	283.25 \pm 220.98	571.27 \pm 130.54	2000	2000
TDS(mgL^{-1})	190.90 \pm 27.07	394.77 \pm 93.14	500	500
TSS(mgL^{-1})	96.52 \pm 15.54	181.50 \pm 66.43	NA	NA
TH(mgL^{-1})	63.80 \pm 6.15	23.28 \pm 8.83	NA	NA

Key: NA – not available in the guideline for drinking water.
NESREA – national environmental standard regulation enforcement agency
WHO – world health organization

DISCUSSION

The value of turbidity was relatively lower than WHO and NESREA standards as shown in Table 2 in both wet and dry season. Higher turbidity values in dry season relative to wet season are indications of high suspended materials and consequently may affect the appearance of the water in terms of colours (Orebiyi *et al.*, 2010). The water temperature which is generally less than 29°C, may affect the chemistry of the groundwater as well as metals toxicity (Awofolu *et al.*, 2007). PH values of the borehole samples are in the normal range of both WHO and NESREA permissible standard in drinking water. However, lower pH at wet season may result from deposition of CO₂ during precipitation. TDS and TS values fall below the international standard in drinking water (WHO, 2008; NESREA, 2010) but the high values of TSS in these wells is of health concern. As normally speculated, TS value in water should

be in the range of 25-80 mgL^{-1} (Robert, 1978). A positive significant correlation between TSS and Turbidity has been established (Bertram and Balance, 1998). Invariably, high TSS indicates high possible loads of both organic and inorganic materials in the aquifer system. Electrical conductivity is a measure of the ions or salinity. It has a mean value of 602.50 \pm 320.78 and 764.70 \pm 185.58 μScm^{-1} , Table 2, in both dry and wet season and is a reflection of high dissolved solids in groundwater system. Based on groundwater classification (Freeze and Cherry, 1979), the samples fall within brackish water. High conductivity indicates high Na and K salts, which was evident in the values obtained from these metals (Adediji and Ajibade, 2005). Hardness is a measure of how much calcium and Magnesium are present in water (Olajire and Imeokparia, 2001). In other words, the total hardness is dependent upon the amount of calcium or magnesium salts or both. Total hardness mean re-

sults are below 70mgL^{-1} in all the samples in both seasons (Table 1). Therefore the groundwater could be described as soft (Environment Canada, 1977). Calcium concentration is within the $10\text{-}100\text{mgL}^{-1}$ permissible in potable groundwater (Environment Canada, 1977; Walker, 1973). Calcium is usually present in water as the carbonate, bicarbonate and sulphate, although in water of high salinity, calcium, chloride or nitrate can also be found. In igneous and metamorphic rocks, weathering also releases calcium from such minerals as apatite, fluoride and various members of the feldspar, amphibole and pyroxene groups. Calcium contributes to the hardness of water within the bicarbonate, forming temporal carbonate hardness while sulphate, chloride and nitrate forming permanent or non-carbonate hardness (Twort and Dickson, 1994). Calcium has no health effects on human. Magnesium concentrations in sampled boreholes water also fall within 1.0 and 40 mgL^{-1} in both seasons which are normal range values in potable groundwater (Adediji and Ajibade, 2005). The value of Na is greater than that of K in both seasons, which was in line with the observation that concentration of K should normally be around one-tenth of sodium concentration and less than 10.0mgL^{-1} for portable groundwater (Orebiyi *et al.*, 2010). However the least value of potassium recorded in this study is found in wet season with a mean value of 18.93 ± 14.40 , Table 1. The mean value of iron fall below and later rise above the international permissible standards of 0.30mgL^{-1} in potable water in dry and wet seasons respectively. High iron concentration in water could impart taste, discolouration, deposits and turbidity (WHO, 1971; 1993). Pb concentrations of borehole water sampled in both seasons is greater than the international standards of

0.01mgL^{-1} , Pb has been classified as potentially toxic elements (PTEs) and hazardous to most forms of life (USEPA, 1986). It also causes a number of ailments in humans such as neurological disorders in fetuses and children. Manganese, Zinc, Copper, Cadmium and Arsenic mean concentrations are generally very low and are within the WHO and NESREA permissible limits in potable water. The higher values of most elemental parameters especially the metals in boreholes of the study areas could be attributed to the high urban run-off (USEPA, 1986) and the activities going on around the areas (transportation, motor mechanic and other vehicular and metallic activities like welding, Chloride and Sulphate mean concentrations are within the international standard limits of 250 and 500mgL^{-1} respectively. High chloride concentration groundwater may indicate pollutions by industrial waste inputs or saline water intrusions (Bertram and Balance, 1998). Both Chloride and Sulphate have no health implication on humans but at high correlations Chloride could impart taste in water while Sulphate could cause gastrointestinal irritation (WHO, 1971; 1993). Nitrate values were far higher than international standards in dry season and lower values were obtained in wet season, Table 1. This has a lot of health implications especially on growing infants and pregnant women (Adekunle *et al.* 2007). These elevated values of Nitrate in the aquifer sampled causes Methemoglobinemia especially in growing infants. The symptoms of Methemoglobinemia are paleness, bluish mucuous membranes, digestive and respiratory problems (McCasland *et al.*, 2007). Both WHO and NESREA have no standards for phosphate. However a save limit of phosphate concentrations in uncontaminated water in the range of $0.01\text{-}0.03\text{mgL}^{-1}$ has been established (Izonfuo and Bariweni, 2001). With this

range of values, the mean phosphate concentrations in the sampled boreholes of the study areas exceeded this limit (Table 1)

CONCLUSION

The high values of some physico-chemical and elemental (turbidity, nitrate, iron, lead, total suspended solids, phosphate) parameters in the sampled boreholes are higher than the recommended limits; it is an indication of pollution hazards. This however, in return has implications on human health as these boreholes are the main source of drinking water supply to the residents. Generally, the mean results of most parameters were higher at wet season than dry season.

RECOMMENDATION

Based on the results obtained from both seasons in the selected study area, the following recommendations are made:

- Wells (boreholes) owners should be well educated on site selection of wells, which should not be near to waste or dumpsites, landfills, septic tanks and industrial discharge or burial sites.
- There is need to evaluate and monitor groundwater quality on a regular basis.
- Installation of low cost modern water treatment devices should be provided by the government.
- Advanced inorganic removal treatment such as Nano-filtration and reverse Osmosis should be provided in the case of high chemical contamination.
- Every individual should endeavour to at least filter groundwater before consumption.
- Since most of the potential VES locations will derive their water from shallow aquifers within the regolith, the supervisory roles of the borehole client and contractor on the analysis of water samples becomes very important in order to know the

chemical composition of the formation water if they are within the allowable limit of WHO, NESREA and other set standards. This is for proper understanding of potential health hazards that might result from drinking such polluted water.

- Community effort should be harnessed toward leakages, control, security of treatment devices against theft and vandalization.
- NESREA should rise up to the challenges of groundwater pollution and intensify efforts in the area of enforcement.
- Further studies should be carried out on speciation of Pb^{2+} , Fe^{2+} , Cd^{2+} , As^{2+} , Mn^{2+} , NO_3^- and Fe^{2+} , in groundwater system to establish the forms available in drinking water of the study areas.
- Boreholes in these study areas should be well logged with the sediment or core samples analyzed in order to detect possible elemental discharges from the formation materials before casing.

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