AN INTEGRATION OF GEOPHYSICAL AND GEOCHEMICAL DATA IN EVALUATING GROUNDWATER RESOURCES IN SAPELE METROPOLIS, WESTERN NIGER DELTA

Aweto, K. E. and Ohwoghere-Asuma, O.

Geology Department, Delta State University, Abraka, Delta State, Nigeria
Email; kizaweto@yahoo.com

ABSTRACT

An integration of geoelectrical and geochemical data was used in Sapele metropolis to delineate the aquifer unit(s) and evaluated the geochemical parameters of the groundwater in the area. Ten (10) water samples were collected from hand-dug wells for geochemical analysis. The geochemical parameters showed average values of 6.20 pH; 156.0µs/cm EC; 7.60mg/l TH; 4.50mg/l, Ca^{2+}; 4.20mg/l Mg^{2+}; 0.95mg/I K^{+}; 1.00mg/l Na^{+}; 0.87mg/l ∑Fe; 0.03mg/I Cu^{2+}; 0.04mg/I Cr^{2+} ; 28.68mg/l Cl^{-} ; 5.40mg/I HCO_3^{-}; 2.41mg/l NO_3^{-}; 0.80mg/l SO_4^{2-} and average sodium absorption ratio (SAR) of 1.36. The relative abundance of cations using these concentrations is in the order of $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+} > \sum Fe > Cr^{2+} > Cu^{2+}$ while those of anions are in the order $Cl^{-} > HCO_3^{-} > NO_3^{-} > SO_4^{2+}$. Fifteen (15) vertical electrical soundings were carried out in the study area using Schumberger electrode configuration. The result of the interpretation of the VES curves showed that the area is made up of four and five geoelectric layer. The third and fourth layer made up of medium, coarse and gravelly sand constitutes the aquifer unit(s), the average depth to the aquifer is 35.2m. The concentration of the various parameters determined in the groundwater were relatively in accordance with WHO recommended standard for domestic and agricultural purposes except pH and ∑Fe in Okirighwre , Ajogodo and Ogorode. Cr^{2+} concentrations generally were below stipulated standard in most of Sapele metropolis, except at Ugbeyiyi and Ugberikoko where concentrations exceeded WHO maximum allowance limit of 0.05mg/l.

Keywords: Geoelectrical, infiltration, permissible, toxic, irrigation

INTRODUCTION

Domestic water supply in Sapele metropolis comes largely from groundwater found in large reservoirs called aquifers and it is accessed by wells (Price, 1985).

Water is ubiquitous in the natural environment but still there are some areas in which groundwater cannot be obtained in sufficient quantities due to factors like the porosity and permeability of the reservoirs (aquifers). Groundwater, even if present in sufficient quantities may be contaminated by dissolved natural chemical constituents which depends on the geochemical environment and source of groundwater. Thus proper precautions should be taken in such areas to reduce the risk of spending large sums of money in sinking abortive wells. A complete appraisal of available water resources is often best accomplished when the aspects of water quality are included. This is because in a planned water supply system, quality constraints and requirements dictate the source of water allocated to various stages. The quality of any water resources is its suitability for the intended uses. The quality of any water resources depends on the physical, chemical and biological characteristics of the water which in turns depends on the geology of the area and impacts of human activities.

The present study therefore intends to identify the aquifer unit(s) and also determine the quality of the groundwater in these aquifer unit(s) in order to assess their suitability for domestic and agricultural uses.

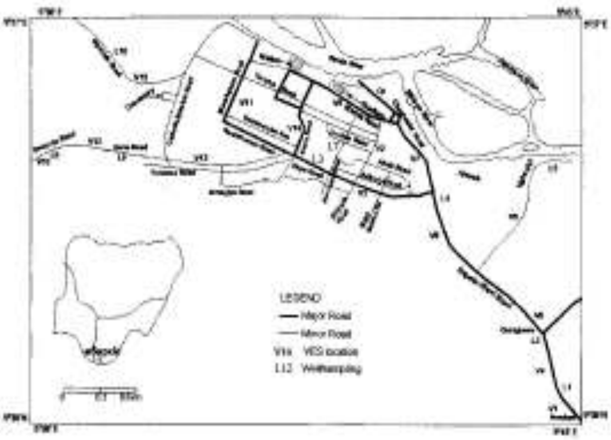
LOCATION, GEOLOGY AND HYDROGEOLOGY

Sapele lies on longitudes 5°38'E and 5° 45'E and latitudes 5° 30'N and 5° 37'N (Fig. 1) and covers an area of about 347km^2. The study area lies within the Tertiary Niger Delta, which is stratigraphically made up of three major formations: Akata Formation, Agbada Formation and Benin Formation. The three formations were laid down under marine, transitional and continental environments respectively (Short and Stauble, 1967).

The Akata Formation which is the lowermost unit is 4000ft thick and made up dark grey sand, silty shale and thin sandstone lenses. The Agbada Formation is made up of alternating sequences of sandstone and shale, this formation is about 1000ft thick. The Benin Formation (topmost unit) is made up of over 90% sandstone with shale intercalation. The thickness of this formation is variable but generally exceeds 6000ft.

Unconsolidated coarse and gravelly sands constitute the aquiferous units which are not confined. The hydraulic conductivity of the sand varies from 3.8 x 10^{-3}m/s to 9 x 10^{-3}m/s which indicates potentially productive aquifer (Akpoborie *et al*., 2000). The basic groundwater recharge of the study area are from direct infiltration of rainfall into the ground and infiltration through rivers beds such as the Ethiope river and Mayuku creek (Offodile,1992).

Fig. 1: *Map of Sapele metropolis showing*



sampling /sounding locations

MATERIALS AND METHODS

Geoelectrical Investigation

Fifteen (15) Schlumberger vertical electrical soundings (VES) were made in the study area using an ABEM tetrameter SAS 1000 with maximum current electrode spacing (AB/2) of 225m.

The apparent resistivity (ρ_a) obtained from the field were plotted on a log-log graph paper against half current electrode spacing (AB/2).

The initial interpretation of the VES data was carried out using the conventional partial curve matching techniques with two-layer master curves in conjunction with auxiliary point diagrams (Zhandov and Keller, 1994). The resistivities and thicknesses obtained from the partial curve matching were used as initial input to a computer programme that is based on optimization technique (Vander Velpen, 2004) which reduced errors to acceptable levels (Barker, 1989). Figure 2 shows examples of some sounding curves and their interpretation.

Geochemical Investigation

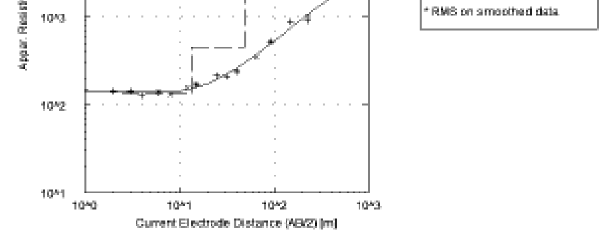
Groundwater samples were collected in sterilized polyethylene bottles from 10 locations (Fig.1). Parameters such as pH, electrical conductivity, total hardness, total iron (∑Fe) cations such as Ca^{2+}, Mg^{2+}, Na^{2+}, K^{+}, Pb^{2+}, Cr^{2+}, Zn^{2+}, and anions such as Cl^{-}, SO_4^{-}, HCO_3^{-} and NO_3^{-} were determined in the laboratory.

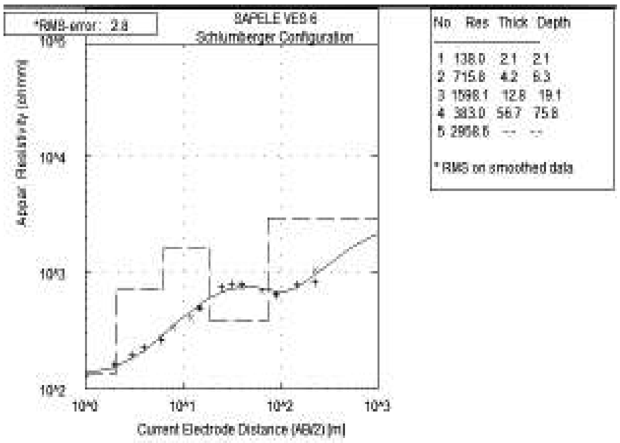
pH was measured with standard pH meter while electrical conductivity was measured with HACN conductivity meter. The Atomic Absorption Spectrophotometer methods were used to determine the concentrations of Ca^{2+}, Mg^{2+}, K^{+}, Na^{2+}, Pb^{2+}, Cu^{2+}, Fe^{2+}, Cr^{2+}, Zn^{2+}, SO_4^{2-}, HCO_3^{-}, NO_3^{-}, and Cl–.

RESULTS AND DISCUSSION

The result of the investigation showed that four to five subsurface layers were identified. The VES curves (Fig. 3) are the AK (20%), AA (33.4%), KH (13.3%), KQ(67%) and KHA (26.6%).

a





b

Fig. 2: Typical VES curves for Sapele

The first geoelectric layer with resistivity ranging from 138.2 – 148.6Ωm is the top soil. The second layer is fine sand with thickness ranging between 4.2 – 19.2m. The third layer consists of clayey sand and fine to medium grained sand. The fourth and fifth layer represents the aquifer units and consists entirely of medium, coarse and gravelly sands. The resistivity ranges from 383.0 – 5203.9Ωm with thickness varying between 12.6m (VES 12) and 29.8m (VES 4) as shown in (Figs. 3 and 4) to about 56.7m (VES 6) (Fig. 2).

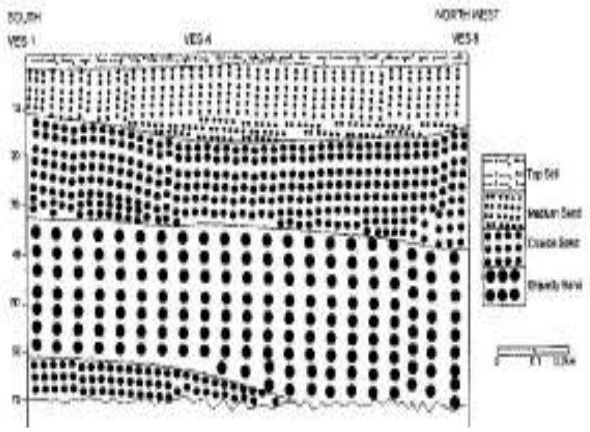


Fig. 3: Typical geoelectric section for Amukpe and Okirighwre

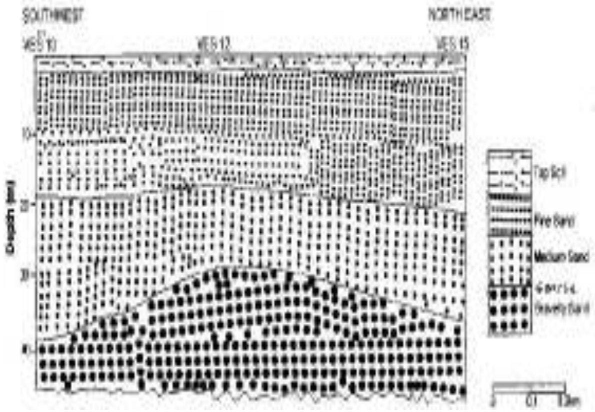


Fig. 4: Typical geoelectric section for Ugberikoko, Gana and Ogorode

The result from the geochemical analyses of groundwater samples are presented in Table 1.

The pH values ranged between 5.4 and 6.7. This indicates that the groundwater is acidic and that values of 50% of the sampled location fell below the minimum limit of 6.5 recommended by WHO (2004). On the basis of this, the groundwater can be regarded as quite acidic. Such acidity has usually been associated with acid rain resulting from crude oil station flares (Akpoborie *et al.* 2000).

Total hardness ranged from 2.32mg/l to 20mg/l and this indicates that the concentration is within the WHO limit for potability. According to Hem (1970), when the total hardness in water is less than 60mg/l (Table 2), it is classified as soft. Hence, the groundwater in Sapele metropolis is classified as acidic and soft.

The measured electrical conductivities of the investigated groundwater varied between 75µs/cm and 300µs/cm. The measured values of electrical conductivity were below the 1400µs/cm maximum permissible level stipulated by WHO (1984a).

For the major cations, Sodium (Na^+) concentration ranged from 8.53 - 11.22mg/l, Potassium (K^+) 0.20 - 1.54mg/l, Calcium

(Ca^{2+}) 1.42 -18.50mg/l and Magnesium (Mg^{2+}) 1.50 - 18.50mg/l. The concentrations of these cations in the investigated groundwater have been compared with the internationally recommended standard of WHO (2004) and were found to be below these standard limits for potability.

Heavy metals such as Lead (Pb^{2+}) and Zinc (Zn^{2+}) were not detected in the groundwater during the analytical work. High concentration of copper (Cu^{2+}) as well as the pH of water is regarded as toxic (Seim and Tischendorf, 1990). Copper (Cu^{2+}) was not detected in the groundwater at most sampled locations except at Okirighwre, Okpe road, Ajogodo and Ugbeyiyi, with concentrations ranging between 0.01mg/l and 0.05mg/l. These values were below WHO specification of 1.50mg/l. Concentrations of total iron (∑Fe) at the sample points ranged between 0.36 -1. 80mg/l, which are below WHO maximum allowance limit of 1.0mg/l except at Okirighwre, Ajogodo and Ogorode were concentration exceeded WHO limit for potability. Concentrations of chromium (Cr^{2+}) in groundwater sample varied between 0.01mg/l and 0.11mg/I and are generally below WHO maximum allowance limit of 0.05mg/l except at Amukpe, Ugbeyiyi and Ugberikoko where the concentration are above WHO standards.

The sources of iron and chromium in the groundwater has not been ascertained but it may be due to industrial activities, refuse dumps and metal scraps along the river courses which are also source of groundwater and those natural induced (i.e. from the geology of the area) as reported by FEPA (1991).

Table 1: Generalized results of the geochemical parameters of groundwater from Sapele Metropolis

Parameters /locations	Amukpe	Okirigwhre	Okpe Rd.	Ajogdo	Ugbeyiyi	Chechester Rd	Crudas Rd.	Gana	Ugberikoko	Ogorode	WHO Max allowance
Ph	5.90	6.40	6.70	6.00	6.30	5.80	5.70	5.40	6.80	6.60	6.5 – 8.5
Electrical Conductivity (µs/cm)	300	210	108	190	75	90	150	130	165	148	1400µs/cm
Total Hardness (mg/l)	4.62	3.96	14.60	30.00	4.32	5.00	2.30	2.77	2.85	6.00	500mg/l
Calcium (Ca^{2+}) (mg/l)	3.05	2.50	3.00	18.50	2.70	3.50	4.30	1.42	2.20	4.01	200mg/l
Magnesium (Mg^{2}) (mg/l)	4.27	3.40	1.62	5.00	2.30	1.50	18.50	1.86	2.00	3.70	150mg/l
Potassium (K^{+}) (mg/l)	1.54	0.20	0.48	1.52	0.92	0.64	0.84	1.25	1.05	1.06	
Zinc (Zn^{2+}) (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	15mg/l
Lead (Pb^{2+}) (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05mg/l
Copper (Cu^{2+}) (mg/l)	ND	0.03	0.05	0.01	0.02	ND	ND	ND	ND	ND	1.5mg/l
Chromium (Cr^{2+}) (mg/l)	0.11	0.04	0.05	0.03	0.06	0.02	0.01	0.01	0.06	0.01	0.05mg/l
Sodium (Na^{+}) (mg/l)	9.00	9.80	11.80	11.60	9.50	8.96	9.25	10.30	11.22	8.53	
Total Iron (∑Fe) (mg/l)	0.62	1.60	0.88	1.80	0.25	0.80	0.55	0.72	0.36	1.10	1.0mg/l
Chloride (Cl^{-}) (mg/l)	15.00	45.80	16.10	122.00	10.20	8.44	15.72	10.75	19.97	22.85	
Bicarbonate (HCO_3^{-}) (mg/l)	4.03	6.52	9.20	7.20	3.45	3.40	8.33	3.95	3.20	4.65	500mg/l
Nitrate (NO_3^{-}) (mg/l)	1.96	2.88	2.24	2.72	1.28	2.24	1.86	3.01	2.85	3.06	10mg/l
Sulphate (SO_4^{2+}) (mg/l)	1.34	1.28	0.22	0.45	0.30	0.50	0.78	1.56	0.25	1.40	400mg/l
SAR	1.10	1.34	1.94	0.87	1.45	1.43	0.61	1.90	1.86	1.05	

ND = No Detection

Table 2: Water class based on total hardness (After Hem, 1970)

Hardness mg/l	Water class
0-60	Soft
61-120	Moderately hard
121	Hard
>180	Very hard.

All the determined anions Cl^{-}, NO_3^{2-}, SO_4^{2-} and HCO_3- (Table 1) showed concentrations below those recommended by World Heath organization's guideline for drinking water quality (WHO, 1984a).

The suitability of groundwater in Sapele metropolis for irrigation purpose was determined using the Sodium Absorption Ratio (SAR). (Etu-Efeotor, 1981).

$$SAR = \frac{Na^{+}}{\sqrt{\frac{1}{2}\left(\left[Ca^{2+}\right]+\left[Mg^{2+}\right]\right)}}$$

Where, Na^{+}, Ca^{2+} and Mg^{2+} concentrations are in millimole/litre (mmol/l).

The value of Sodium Absorption Ratio (SAR) varied between 0.61 and 1.96 indicate that the groundwater in Sapele metropolis is excellent for irrigation purposes (Table 3). The SAR values also showed that the ground water will not pose any serious problem to the soil when used for irrigation purposes. When the SAR value rise above 12 to 15, serious physical soil problems arise and plants have difficulty absorbing water (Munshower, 1994).

Table 3: Water class based on SAR (After Etu-Efeotor, 1981)

SAR	Water Class
0	excellent
10-18	good
18-26	fair
>26	poor

CONCLUSION

The geoelectric sections revealed four and five geoelectric layers namely: the top soil, fine sand, medium sand and coarse/ gravelly sand. The fourth and fifth layer constitutes the main aquifer units and occurs at an average depth of 35.2m.

The results of the water qualities showed that the water is non toxic, soft and acidic. Most of water quality parameters analyzed were present in concentrations which were within the WHO permissible limit for drinking water.

Total iron ∑Fe and pH were the only parameters that were present in concentrations higher than WHO permissible limit for drinking water. However, high concentration of Cr^{2+} which exceeded WHO water quality standard was also observed at Ugbeyiyi and Ugberikoko. Comparing the geochemical parameters of the various water sample with WHO standards, the result showed that the groundwater in Sapele metropolis are chemically potable except for the locations where the total iron ∑Fe and chromium (Cr^{2+}) contents were found to be above the maximum permissible levels. Since pH and ∑Fe content of groundwater can be improved through adequate treatment, the water quality of the area can be described as generally good for domestic and irrigational purposes.

REFERENCES

Akpoborie, I. A., Ekakite, A. O. and Adaikpoh, E.O. (2000). The quality of groundwater from dug wells in parts of the western Niger Delta. *Journal of National Association for the Advancement of Knowledge.* **2:** 72-77.

Barker, R. D. (1989). Depths of investigations of collinear symmetrical four-electrode array. *Geophysics* **54:**1031-1037.

Etu-Efeotor, J. O. (1981). Preliminary hydrogeochemical investigation of the sub-surface waters in parts of The Niger Delta. *Journ. Min. and Geol.* 18(1); 103 -105.

Federal Environmental Protection Agency. (1991). National Guidelines and standards for industrial effluents, gaseous emission and hazardous waste management in Nigeria. pp. 178-179.

Hem, J. D. (1970). *Study and interpretation of chemical characteristics of natural waters.* Water supply paper, US Geological Survey, Washington DC.

Offodile, M. E. (1992). *An Approach to Groundwater Supply and Development in Nigeria* (1st edition), NECON Services Ltd, Jos.

Munshower, F. (1994). *Practical Handbook of Disturbed Land Revegetation.* Lewis Publishers, Boca Raton.

Price, M. (1985). *Introducing groundwater.* Allen and Unwin Publishers Limited, London.

Short, K. C. and Stauble, A. J. (1967). Outline Geology of Niger Delta. *A.A.P.G. Bulletin* **51:**145-172.

Siem, R. and Tischedorf, O. (1990). Grundtagen der Geochenije VEI3 Dentscher Verlag fir Grundstoff industries, Leipzig.

Vander Velpen, B. P. A. (2004). winResist Version 1.0. M.Sc Research project, ITC, Deft, The Netherlands.

World Health Organization (2004). *Guidelines for drinking water quality.* 3rd Edition, Vol. 1, World Health Organisation, Geneva.

Zhandov, M.S. and Keller, C. (1994). *The Geoelectrical Methods in Geochemistry and Geophysics.* 3rd edition. Elsevier Publishers, New York.