Journal of the Nigerian Association of Mathematical Physics
Volume **24 (July, 2013), pp 499 – 504**
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Geoelectric Investigation of Groundwater Quality in Four Communities in Esan North East LGA of Edo State, Nigeria.

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Abstract

Geoelectric investigation was carried out in four locations namely Obeidu, Eror, Arue and Eguare all in Esan North East Local Government Area of Edo State, Nigeria. The SAS 300B ABEM terrameter was utilized for data acquisition and schlumberger electrode configuration was employed, IP2WIN computer iteration programme for data interpretation was adopted. The test parameters include pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Conductivity, Hardness, Turbidity, Colour, Alkalinity, Iron, Zinc, Manganese, Copper and Nitrogen Oxides. Water samples were collected from hand dug wells spread across the locations and used in delineating the geoelectric sections. The experimental setup was conducted over depths of 87.67m, 15.12m, 144.47m and 76.08m in the respective locations. At a maximum depth of 76.08m, perched aquifer was discovered in Eguare. Groundwater samples were collected from the wells and subjected to physical and chemical analysis. Empirical analysis showed evidence of pollution from chemical sources with evidences of high levels of nitrite in Arue (3.22mg/L) and Eguare (4.44mg/L). For each parameter studied, there were five (5) replicates and data were analysed using simple ANOVA. The observed values were above the ecological benchmarks of 3.0mg/L recommended by World Health Organisation (WHO) drinking water standards. It was further established that wells closer to the farms were more polluted than the others located far away from the farms. Nitrite (NO_2^-) in drinking water has the potentials to cause serious health abnormalities especially the Blue Baby Syndrome (BBS).

Keywords: Blue Baby Syndrome (BBS), Aquifer, Borehole, Hand dug well.

1.0 Introduction

The City of Uromi lies North – Eastern Esan in Edo State , Nigeria, located on longitude 3^0 24'E and latitude 6^0 27'N and occupy a land mass covering about 2987.52 square kilometres [1]. Uromi stands topmost on the plateau sitting at about 304800mm above sea level, with the people of Ivue occupying the highest point on the Ishan plateau with about 454152mm above sea level [2]. The advent of technology has made the quest for water for all purpose in life to drift from ordinary search for water to prospecting for steady and reliable subsurface or groundwater from boreholes [3]. Groundwater exploration aids the general economy by prospecting and locating shallow aquifer that will never dry up [4]. This will however provide adequate groundwater that would serve the need of the communities domestically, agriculturally and industrially. Besides, man settles where water is available right from the time immemorial [5]. Human activities during the last century have polluted most of the groundwater in Nigeria [6]. Water on the earth can be said to be enormous in quantity when it is considered that more than two-thirds of the earth surface is covered by water [7]. But UNEP and WHO [8] argued that it is not sufficient merely to have access to water in adequate quantities, the water also needs to be of adequate quality to maintain health and it must be free from harmful biological and chemical contamination. Dauda observed that as surface water becomes increasingly polluted, people turn to groundwater for alternative supplies [9]. Therefore the development and efficient management of groundwater resources is of particular concern. Access to clean and safe drinking water has been a major problem in Uromi and it has therefore been and continues to be a focus of considerable research efforts over time. This work aims at evaluating the groundwater quality and defines zones of potential groundwater contamination in the study area.

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2.0 Methodology

In the research work, the schlumberger array electrode configuration was adopted. The basic field equipment for this study is the ABEM Terrameter SAS 300B which displays apparent resistivity values digitally as computed from ohm's law. It is powered by a 12.5V DC power source other accessories to the terrameter include cables, electrodes, booster, measuring tape, cutlass and hammer for driving the electrodes into the ground [10].

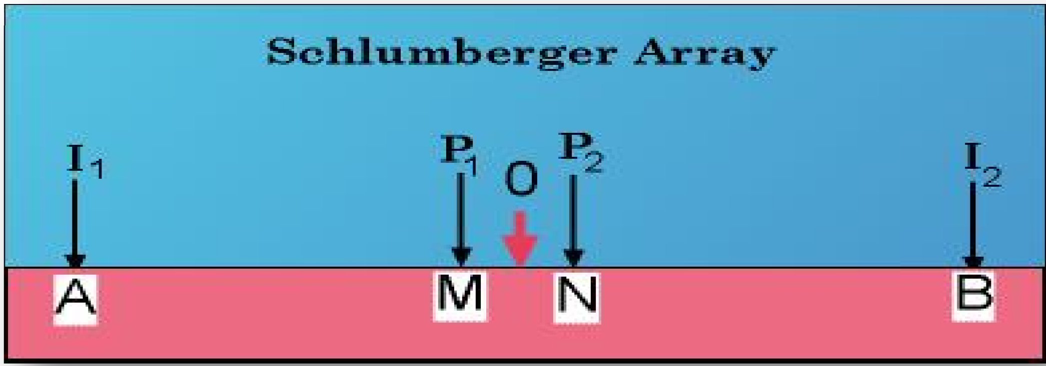

Figure 1: Schlumberger array

The electrodes consist of two types namely current electrodes generally denoted by C and potential electrode denoted by P. The four electrodes are made of galvanised iron or stainless steel provided with heads and is pointed for easy driving into the ground. They are equipped with probes for cable connection. The four terminals, the potential terminals P_1, P_2 and current terminals C_1 and C_2 are connected to the potential electrodes M, N and current electrode A, B respectively of the ABEM Terrameter [11]. In this setup, the potential electrodes are placed in between the current electrodes. It is required that MN, the distance between potential electrodes must never exceed 2/5 of AB/2 where AB is the distance between current electrodes, that is

$$MN \leq \frac{AB}{5}$$

For the potential at M

$$V_M = \frac{I\rho}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \qquad (1.0)$$

And potential at N:

$$V_N = \frac{I\rho}{2\pi}\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \qquad (2.0)$$

The potential difference between M and N is given by:

$$V = V_M - V_N = \left(\frac{I\rho}{2\pi}\right)\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{R_1} + \frac{1}{R_2}\right) \qquad (3.0)$$

The resistivity is given by the equation:

$$\rho = \left(\frac{2\pi a \Delta V}{I}\right)\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} \qquad (4.0)$$

If in equation (4.0) above the geometric factor K is represented by

$$K = 2\pi\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} \qquad (5.0)$$

Substituting $L - \frac{MN}{2}$ for r_1 , $\frac{AB}{2} + \frac{MN}{2}$ for r_2, r_2 for R_1 and r_1 for R_2, we have

$$K = (\pi MN) \quad \left(\left(\frac{L}{MN}\right)^2 - 0.25\right) \qquad (6.0)$$

and apparent resistivity is given by

$$\rho_a = \frac{KV}{I} = \left(\frac{\pi MNV}{I}\right)\left(\left(\frac{L}{MN}\right)^2 - 0.25\right) \qquad (7.0)$$

For the purpose of this survey, a maximum spread of AB/2 equals 316.00meters was used. The cables were run in parallel adjacent to the Terrameter and arranged symmetrically with respect to the potential electrode. These cables and electrode arrangement were meticulously done to avoid current leakage and creep which could substantially reduce the attainable accuracy and sensitivity and depth penetration [12]. The etrex Legend H of the global positioning system (GPS) was used to map out various vertical electrical sounding (VES) stations in the 4 communities of the study area where electrical resistivity survey was carried out.

Groundwater was sampled at accessible hand dug wells from four (4) rural communities in Uromi. The laboratory analysis of the sampled water was used to reveal the chemical composition of water. The ground water samples were analysed in Edo Environmental Consults and Laboratory, Ministry of Environment and Public Utilities, Palm House Annex, Sapele Road, Benin City and the data obtained were compared with the WHO standards of drinking water [13]. The parameters evaluated were pH, Total Dissolved solid (TDS), Conductivity, Total suspended solid (TSS), Hardness, Turbidity, Colour, Alkalinity, Iron, (Fe), Zinc (Zn), Manganese (Mn), Copper (Cu), Nitrogen Oxide (NO_2^-) based on the procedures outlined by [14]. Their concentrations were established using standard laboratory procedures; pH meter, EC meter, TDS meter, Turbidity meter, Titrometric method, Atomic Absorption spectrophotometer, UV spectrophotometer.

3.0 Results and Discussion

The results of the geophysical survey employing the techniques of vertical electrical sounding (VES) are presented as field/computer iterated curves shown in figures 2 – 5 and their corresponding subsurface lithological tables shown in tables 2 – 5. The results of each location are presented below with a view of determining the presence of aquifer, soil lithology, total depth of penetration of current and evaluation of water quality.

Table 1: Test Results of Physicochemical Properties

Survey sites	pH	(EC) (µs/cm)	TDS (Mg/l)	TSS (Mg/l)	Hardness (Mg/l $CaCO_3$)	Turbidity (FAU)	Colour (ptCo)	Alkalinity (Mg/l $CaCO_3$)	(Fe) (Mg/l)	Zn (Mg/l)	Mn (Mg/l)	Cu (Mg/l)	NO_2 (Mg/l)
Obiedu	6.95	76.5	40.6	Nil	1.42	1	1	43	BDL	0.13	BDL	BDL	Nil
Eror	6.50	104.6	71.6	Nil	2.76	3	1	66	BDL	0.18	BDL	BDL	Nil
Arue	5.59	18.4	14.7	Nil	2.70	2	1	86	BDL	0.07	0.04	BDL	3.22
Eguare	6.80	80.5	57.1	Nil	2.69	2	2	73	BDL	0.21	0.02	BDL	4.44
WHO Standards.	6.5-8.5	1000	1000	N/A	100-500	5	15	500	1	5	200	0.03	3.0

FAU = Formazin Attenuation Units, $\mu s/cm$ = Micro second per centimetre, **Mg/l** = Milligram per litre, **ptCO** = Platinum-Cobalt Scale BDL = Below Detectable limit

Computed values of apparent resistivities were plotted (as ordinates) against current electrodes spacing AB/2 (as abscissa) using double logarithmic graphs for necessary qualitative interpretations.

Table 2: VES at Obeidu Secondary school, Uromi

Layer	Apparent Resistivity ρ_a (Ohm-m)	Thickness h (m)	Soil Lithology
1.	8624	1.07	Top Soil
2.	2481	24.70	Sandy soil
3.	10511	61.9	Sandy soil
4.	927	∞	Clayey soil

Total Depth = 87.67 meters

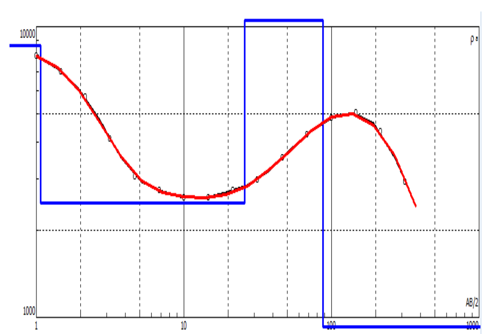

Fig 2: VES Curves for Obeidu Secondary School. Uromi

The survey was carried out within the premises of Obeidu Secondary School, Uromi, with a GPS Co-ordinate of N06^0 43.715'E006^0 15.763'. The result shows a HKH type geoelectric structure with a top layer of resistivity 8624 ohm-m followed by a less resistive layer of resistivity 2481 ohm-m. The third and last layers have resistivity values of 10511 ohm-m and 927 ohm-m respectively. The first layer of thickness 1.07m is probably top soil, the second and third layer of thickness

24.7m and 61.9m are probably sandy soil respectively, while the last layer is probably clayey soil. The maximum depth of penetration is 87.67 meters. Water was not encountered in this location. The physiochemical analysis of well water sample carried out in Obeidu, Uromi, shows that all the parameters analysed for groundwater were within the desirable limits of the WHO standards of potable drinking water.

Table 3: Lithology for Eror Primary School, Uromi

Layer	Apparent Resistivity ρ_a (Ohm-m)	Thickness h (m)	Soil Lithology
1.	6777	1.17	Top Soil
2.	1748	5.4	Sand stone
3.	320	8.55	Clayey soil
4.	8532	∞	Dry Sand

Total Depth = 15.12 meters

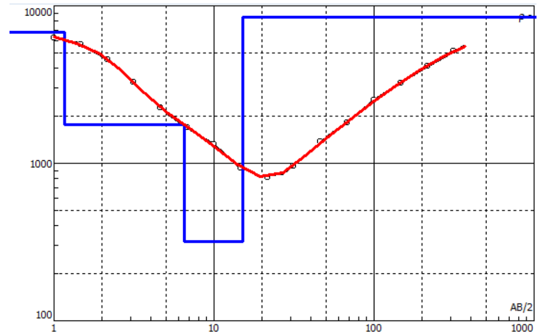

Fig 3: VES Curves for Eror Primary School, Uromi

The survey was carried out in Eror Primary School, Uromi, with a GPS Co-ordinate of N06^0 44.020' E006^0 17.208'. The result shows a four-layer HK-type geoelectric structure. Layers 1, 2, 3 and 4 have resistivity values of 6777 ohm-m, 1748 ohm-m, 320 ohm-m and 8532 ohm-m respectively. The four layers have thickness of 1.17m, 5.4m and 8.55m respectively. Layers 1 have top soil, layer 2 contains sand stone, and layer 3 has clayey soil while the last layer contains dry sand. The total depth of penetration is 15.12 meters. Water table was not encountered in this location. The physiochemical analysis of well water sample carried out in Eror, Uromi shows that all the parameters analysed for groundwater were within the desirable limits of the WHO standards of drinking water.

Table 4: Lithology for Arue Primary School, Uromi

Layer	Apparent Resistivity ρ_a (Ohm-m)	Thickness h (m)	Soil Lithology
1.	1461	0.5	Top soil
2.	1100	6.2	Sand stone
3.	4157	9.77	Sand stone
4.	546	128	Sandy clay
5.	26162	∞	Dry sand

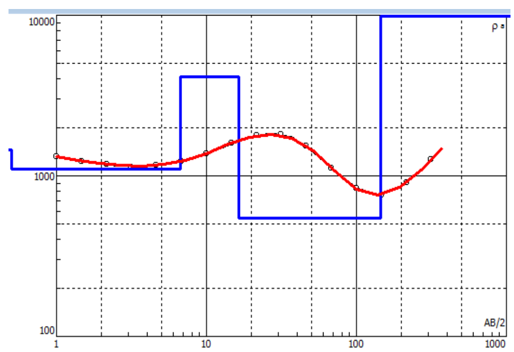

Fig 4: VES Curves for Arue Primary School, Uromi

Total Depth = 144.47 meters

The survey was done in Arue Primary School, Uromi, with a GPS Co-ordinate of N06^0 44.087' E006^0 17.875'. The result indicates a five-layer HAK-type curve. Layers 1-5 have resistivity values of 1461 ohm-m, 1100 ohm-m, 4157 ohm-m, 546 ohm-m and 26162 ohm-m respectively. Layers 1-4 have thickness 0.5m, 6.2m, 9.77m and 128m respectively. The top most layer is composed of top soil, layer two and three have probably sand stone respectively, layer four have probably clay while the fifth layer has dry sand. The total depth of the survey area is 144.47 meters. Water was not struck in this station.

The physiochemical analysis of well water samples carried out in Arue, Uromi, shows that the parameters analysed for groundwater were within the WHO drinking water standards apart from NO_2^- (nitrite) 3.22mg/L which was above the desirable limits of WHO standards of 3.0mg/L . It was observed that the location where the well water samples were collected were close to farmlands in which nitrogen based fertilizers were used due to intense farming in the area, thereby leading to high NO_2^- concentration in groundwater. When there is excessive rainfall, nitrite will be leached below the plants roots zone and may eventually contaminate groundwater. Nitrite is highly leachable and readily moves with water through the soil profile. NO_2- in drinking water can be hazardous to health especially for infants (blue baby syndrome). Symptoms include shortness of breath and blueness of the skin.

Table 5: Lithology for Eguare Primary School, Uromi

Layer	Apparent Resistivity ρ_a (Ohm-m)	Thickness h (m)	Soil Lithology
1.	448	0.877	Top soil
2.	1772	13.2	Sand
3.	340	21.8	Clay
4.	5471	40.2	Sandy clay
5.	585	∞	Water bearing sand

Total Depth = 76.08 meters

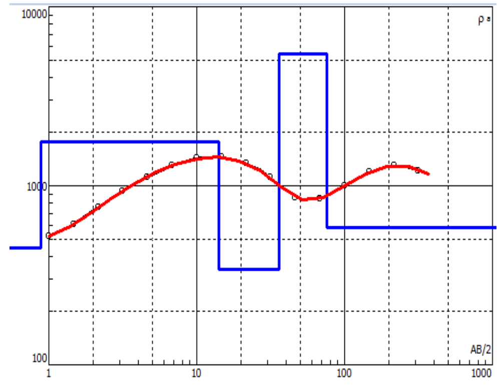

Fig 5: VES Curves for Eguare Primary School, Uromi

The survey was done in Eguare Primary School, Uromi, with a GPS Co-ordinate of N06^0 43.194' E006^0 19.685'. The result shows a five-layer KAH-type curve with layer 1 – 5 having resistivity values of 448 ohm-m, 1772 ohm-m, 340 ohm-m, 5471 ohm-m and 585 ohm-m respectively. The thickness of layer 1 – 4 is 0.877m, 13.2m, 21.8m and 40.2m respectively. The top most layers is made up of top soil, the second layer is probably sand, third and fourth layers have probably clay and sandy clay respectively while the fifth layer is probably composed of water bearing sand. The maximum depth of current penetration is 76.08m. There was presence of aquifer in this station.

The physiochemical analysis of well water sample carried out in Eguare, Uromi, shows that the parameters analysed for the groundwater collected were within the desirable limits of the WHO standards of drinking water except for NO_2^- nitrite (4.44mg/L) which was above the WHO potable drinking water standards of (3.0mg/L). It was observed that the location where the well water samples was collected was close to farmlands in which nitrogen based fertilizers were used due to intense farming in the area, thereby leading to high NO_2 concentration in groundwater. NO_2^- in drinking water can be hazardous to health especially for infants (blue baby syndrome).

4.0 Conclusion

This paper has provided information on the depth to groundwater, thickness of the aquifer unit and the evaluation of groundwater quality in the study area. This information is going to be relevant in the development of an effective water scheme for the area and possibly beyond other areas underlain by the formation. The vertical electrical sounding (VES) has proven to be reliable for groundwater studies and therefore the method can excellently be used for shallow and deep underground water geophysical investigation. The result obtained therefore showed that Eguare with a maximum depth of 76.08 meters had the presence of a perched aquifer, while aquifer was not encountered in Obeidu, Eror and Arue. However, these areas may hold good prospects for groundwater when very long current electrode spacing is used thus going through a great depth to reach the water level or table. It was also observed that the groundwater sampled in Obeidu and Eror were within the drinking water limits of the WHO standard as at time of assessment while Arue and Eguare had high values of nitrite concentrations of (3.22mg/L) and (4.44mg/L) respectively which was above the WHO standards of 3.0mg/L. The high values of nitrite concentration are due to the use of nitrogen based fertilizers in the area due to intense farming. Therefore in order to improve the quality of groundwater in the study area to be used for domestic purposes hand dug well/ boreholes should *not* be sited along the flow path of potential pollution sources such as farm lands were nitrogen based fertilizers are used and also the provision of water treatment plant should be provided for the people in the study area, this will help to mitigate the high concentration of NO_2^- thereby bringing the values to fall within the acceptable WHO standards.

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