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Effects of Leaking Septic Tanks on Underground Water Quality in Owerri Municipal, Imo State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors NNV and HO designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors IOP and CIG performed the statistical analysis. Authors NNV, PCN, AOS and IOP managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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Method Article

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ABSTRACT

Aim: To determine the effects of leaking septic tanks on underground water quality in Owerri Municipal.
Place and Duration of the Study: Department of Geosciences, Federal University of Technology Owerri, and Department of Chemistry, Alvan Ikoku University of Education, Owerri, Imo State, Nigeria, between January 2013 to May 2014.
Methodology: Geophysical and geochemical analysis was carried out using chemical and geophysical analyses. Owerri Municipal is located within Longitudes 6º59'E to 7º06'E and Latitudes 5º33'N. It falls within the coastal plains sands. The quality of groundwater was determined by taking samples from three locations namely Amakohia, Naze and Nekede and carrying out physiochemical

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analysis on each to ascertain the nature of dissolved substances in the groundwater. Also, physiochemical parameters like bulk density, porosity and permeability of the samples were determined. Description of the lithology and aquifer parameters were obtained using vertical electrical sounding method.

Results: The density of the samples ranged from 1.49 to 1.98 mg/L, the porosity values are from 0.20 to 0.38 while the permeability varies from 0.51 mg/L to 0.67 mg/L.

The chemical analysis revealed that some heavy metals have concentrations above the amount acceptable by WHO standards. Iron 18.6 to 63.9 mg/L, Nickel 7.5 mg/L and Manganese, 0.46 mg/L. The resistivity of the topsoil ranges from 618 Ωm to 3800 Ωm. An average resistivity range of 7500 Ωm exist up to 30 m while a layer of low resistivity indicating clay and clayey sand extends to 60 m at Naze, 60 m at Nekede and 50 m at Amakohia. Beyond these depths, the resistivity is high on the average of 3500 Ωm.

Conclusion: The results showed that the subsurface is permeable which implies that traces of heavy metals present in the samples are contained in the leachets from surrounding environments either from septic tanks or from industrial activities on the surface. Groundwater quality can be improved within this environment by recommending boreholes drilled from 70 m where leachet permeability is negligible.

Keywords: Resistivity; concentration; permeability; subsurface; chemical and septic wastes; ground water; pollution.

1. INTRODUCTION

Hardly will life be sustained without water. Good water ensures healthy living. Due to urbanization and industrialization the commonest source of water, surface water and rain water have been polluted with waste products from industries and contaminations from individuals and households. The only safe haven is the groundwater. This has been gradually polluted over the years due to many sources of contamination [1]. Pollution can be in the form of solid waste or in the liquid or gaseous forms. The most common is the liquid that can easily penetrate or permeate the solid, [2-3] it flows down into the aquifer system. Pollution of ground water depends on many factors; the rock units that form the lithology of the subsurface, the porosity, and the permeability of the subsurface within the given environment [4]. Septic refers to the anaerobic bacteria environment that develops in the tank which decomposes the waste discharged into the tank.

All over the world, waste and particularly sewage disposal are deposited in the ground. In Africa pits are dug and slabs built over it in a small house a little removed from the main house, defecation is done there until it is filled and eventually be closed and a new one will be made. ln this pattern the waste is directly in contact with the ground and pollution rate is high. But modern life introduced septic tanks [5-6] whereby chambers are built with cement walls. These walls are subject to degradation with time. Chemical wastes, biological or organic wastes in form of feaces and other contaminants fill these tanks. These contents stay there for a long time. They decompose and also reduce the strength of the cement walls. This degradation deteriorates into leakage of the septic tanks. The leachets seep down into the aquifer system and the surrounding environment and thereby causing groundwater pollution and subsequently reduce the ground water quality. Another consequence of this is reduction in strength of the rock units around the septic tanks. In this regard the effects of leaking septic tanks on groundwater quality in Owerri Municipal is necessary since it is sitting on a highly porous and permeable geologic setting with the highest transmissivity coefficient. It is necessary to investigate these effects by employing some geo-chemical analysis, carrying out vertical electrical sounding to ascertain the geoelectric sections of the rock units [7-12]. This will give insight of the effects of leaking septic tanks within the Owerri Municipal which is the purpose of this study.

The study area is located between latitudes 5º25’ N to 5º33’N and longitudes 6º59’E to 7º06’E. Fig. 1. The area is basically underlain by the Benin Formation. It has an extensive stratigraphic unit in southern Nigeria sedimentary basins [6-8], it has been earlier referred to as coastal plains sands. It lies within the Northern depobelt of the Niger Delta Basin [13]. The Benin Formation is underlain by Oligocene –Miocene Ogwashi-Asaba Formation and overlain by the quaternary alluvium. The age is from Miocen to Recent.

The study area (Owerri Municipal Imo State, South Eastern Nigeria)

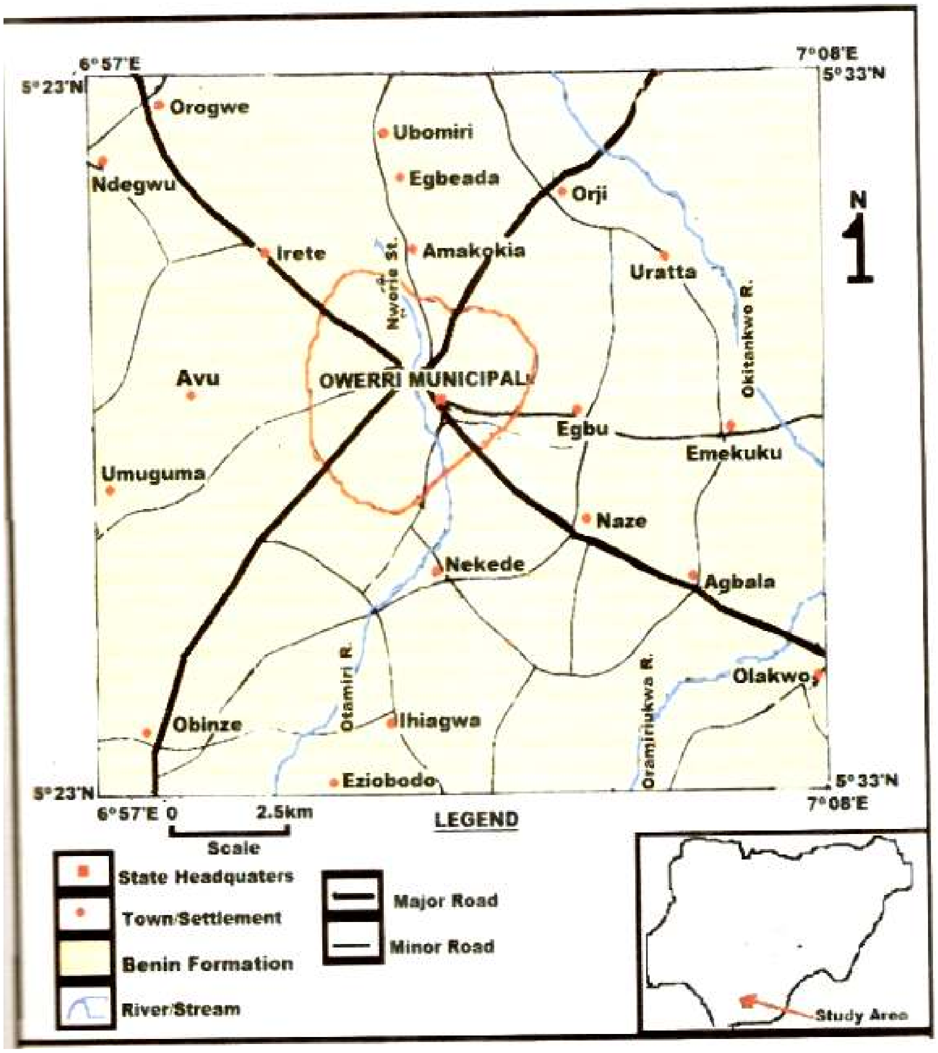

Fig. 1. Geology and physiography of the study area

It is mainly characterized by sands and sandstones with alternations of clay and shales strata [8]. The study area is within tropical rainforest belt of Nigeria and covered by thick vegetation, but it has been degradated due to population density and use of wood for local cooking fuel. The climatic conditions are affected by mean annual temperature of 27℃, a relative humidity of 60 – 80% at maximum during rainy season. The annual rainfall ranges from 200 cm^3 to 300 cm^3 mainly from April to November [13] and bimodal in July and September and a break in August. The Formation is of late Tertiary age. It is rather deep, porous, infertile and highly leached. The area is low lying being generally about 100 m above sea level (Fig. 1). The main stream draining the study area is the Otamiri river. It has a dendritic drainage pattern undulations are found between Egbu and Naze with ridges running East to West.

2. MATERIALS AND METHODS

This study aims at determining the extent of contribution of pollution through septic tanks to ground water quality. The objective is to determine the characteristics of the subsurface rock units by conducting geophysical survey using vertical electrical sounding method to determine the lithology and possible depth to water level of each location. Analyses of water and soil samples were done to determine the chemical constituents, porosity and permeability of the host rocks around the various environments of Naze, Amakohia and Nekede.

2.1 Vertical Electrical Sounding (VES) and Soil Test Analyses

A vertical electrical sounding using the schlumberger arry [14-16] was carried out in each of the locations at a spread of AB/2 = 350 m using ABEM Terrameter SAS 4000 m. Garmin GPS 76CSX was used to determine the coordinates and elevation of the sample and VES points. The apparent resistivity data collected were plotted on a log-log graph sheet and smoothed. Then a 2D-inversion computer software was used to model to give the actual resistivities of the various interpreted geoelectric layers (Tables 2-3, Figs. 2-4).

2.2 Water Samples Analyses

Three water samples were collected from each of the three locations and analysed for physio-chemical complete water analysis. Soil samples were collected at 2 m from each location and analyzed for soil porosity and permeability. The measurement of the water conductivity and total dissolved solids with WPACMD 400 m with capability of measuring conductivity over the range of 10^{-2} to 10^{-6} N Siemens/cm^2 with an accuracy of 0.1 NS/cm^2 and the TDS meter respectively. The physio-chemical properties and water quality analysis on the samples were determined using HACH DR 2800 spectro-photometer. All samples were preserved in a refrigerator to avoid microbial activity and unwanted chemical reactions and all analysis were completed within two days of collection.

3. RESULTS AND DISCUSION

The results of the analyses for chemical analyses, physiochemical parameters and the geophysical vertical electrical soundings, including the porosity and permeability are presented in Tables 1 and 2. The presented data are a means of triplicate determinations, with standard deviation ranging from 0 to 0.00051.

Table 1. Samples analyses, physical and chemical parameters and their concentrations

Parameter/ Units	Amakohia	Nekede	Naze
Bulk density determination (mg/cm^3)	1.98	1.73	1.49
Natural moisture content/Dry density determination (%)	10.3/1.8	6.6/1.83	3.6/1.99
Porosity (%)	0.38	0.30	0.20
Permeability (k(cm/S))	0.51	0.59	0.67

Sample No / Units	Amakohia	Nekede	Naze	WHO (2006)
Odour	Colourless	Odourless	Colourless	
PH	6.5	6.0	6.5	
Colour/Tubidity	5 Hazen	5 Hazen	5 Hazen	
Conductivity chemical parameters	800 µS/cm^3	750 µS/cm^3	120 µS/cm^3	
Acidity (mg/L)	50	50	50	
Alkalinity PH at 24℃	800	650	500	30 – 500
Total solids (mg/L)	0.4	0.4	0.5	500
Dissolved solids (mg/L)	0.37	0.38	0.35	0.1
Suspended solids (mg/L)	0.03	0.2	0.15	0.5
Copper (C_u) (mg/L)	2.0	1.8	1.2	1.3
Iron (F_e) (mg/L)	63.9	21.8	18.6	0.3
Lead (P_b) (mg/L)	Nil	Nil	Nil	6.01
Manganese (M_n) (mg/L)	0.16	0.46	0.05	0.05
Nickel (N_i) (mg/L)	7.5	3.16	1.70	1.41
Zinc (Z_u) (mg/L)	0.99	1.74	2.38	5.0
Chloride (Cl) (mg/L)	10.38	125	102.4	250
Nitrate NO_2 (mg/L)	1.1	1.0	0.92	5.0

Table 2. Interpretation of vertical electrical sounding results

Layer	Resistivity Ωm	Depth (m)	Probable lithology	Resistivity Ωm	Depth (m)	Probable lithology	Resistivity Ωm	Depth (m)	Probable lithology
1	619.0	0.8	Topsoil	1990.0	0.6	Topsoil	3800.0	0.6	Topsoil
2	1640.0	2.8	CLSD	980.0	4.3	CL	14500.0	3.1	SD
3	405.0	8.3	CL	3170.0	9.5	SD	3170.0	10.8	SD
4	1380.0	20.3	SDCL	6660.0	21.3	SD	7500.0	30.8	SD
5	290.0	49.2	CL	1620.0	47.3	CLSD	810.0	69.6	CL
6	732.0	75.3	SLCL	4710.0	66.3	SD	3370.0	90.7	SD
7	1660.0	106.0	CLSD	4190.0	97.6	SD	6300.0	113.0	SD
8	2280.0	141.0	SL	1450.0	126.0	SDCL	9900.0	141.0	SD
9	2390.0	178.0	SL	890.0	159.0	CL	63800.0	>141.0	SD
10	7520.0	>178.0	SD	311.0	>159.0	CL			

3.1 Physical Parameters

From the results in Table 1, the total dissolved solids (TDS) for the three samples ranged from 0.35 to 0.38 mg/L. The alkalinity varies from 500 at Naze to 800 at Amakohia. Suspended solids at Amakohia is 0.03, Nekede, 0.2 and Naze, 0.15. The concentration and presence of heavy metals measures are: Copper content ranged from 1.2 to 2.0 mg/L, Iron, F_e; 18.6 to 63.9 mg/L; Manganese (M_n), 0.05 to 0.46 mg/L; Nickel (N_i), 1.7 to 7.15 mg/L; Zinc (Z_n), 0.99 to 2.38 mg/L; Lead (P_b) has zero readings while the chloride (Cl) ranges from 102.4 to 125 mg/L and the Nitrate (NO_3), is from 0.92 to 1.1 mg/L. The highest concentration is from chloride which does not have any direct link with the components of pure water [17]. The presence of Nitrate is low and falls within the accepted limit by WHO (2006) Standard. The concentration of copper is between 1.2 to 2.0 mg/L is slightly higher than the standard acceptable. This could be due to the presence of the Hospitals located within the environment and as well as the population density. High concentration could be hazardous to health. Other concentrations that pose high risk to health are Iron (F_e) with value of 18.6 to 63.9 mg/L, Nikel (N_i), 7.5 mg/L and Manganese (M_n), 0.46 mg/L.

The measurable parameters like bulk density of samples, porosity, permeability of the soil samples as well as vertical electrical soundings from the three locations revealed that the soil samples have bulk and dry density in the range of 1.49 to 1.98 mg/cm^3 and Natural moisture content/dry density determination of 10.3/1.8 at Amakohia to 3.6/1.99 mg/cm^3 at Naze. The porosity ranges from 0.2 at Naze to 0.38 at Amakohia while the permeability increases from 0.053 to 2.49 in the same area. In Table 3, The resistivity values of the lithologic units of the topsoil ranges from 619 Ωm to 3800 Ωm. The resistivity of the 4th layers of the locations range from 1380 Ωm to 7500 Ωm and for depths between 20 m and 30 m. The 6th layers have resistivity values of 732 Ωm and is interpreted as clayey sand at Amakohia, 4710 Ωm as sands at Nekede and 3370 Ωm as sands at Naze. This zone is referred to as the aquiferous zone or water bearing zone. Though the 5th layer of the three curves have low resistivities in the range of 290 Ωm to 1620 Ωm at Nekede, other layers have high resistivities which have high correlation with the permeability of the soil samples analyzed. The high permeability of the sub-surface top soil samples and the sand units is revealed by high resistivity values of about 3500 Ωm at greater depths. Some deductions

Table 3. Density, moisture content, porosity and permeability determination

Sample no	Amakohia	Nekede	Naze
Weight of ring and sample (g)	124.1	125.5	129.3
Weight of ring (g)	60.3	60.3	60.3
Weight of sample	63.8	65.2	69.0
Sample (cm^3)	32.2	37.7	46.3
Bulk density (mg/cm^3)	1.98	1.73	1.49
Moisture content			
Weight of wet soil (g)+ container	97.4	86.0	05.6
Weight of container + dry soil (g)	90.1	81.9	102.6
Weight of container (g)	19.5	19.6	18.9
Weight of wet soil	77.9	66.4	86.7
Weight of dry Soil	70.6	62.3	83.7
Weight of water	7.3	4.1	3.0
Moisture content	10.3	6.6	3.6
Dry density	1.80	1.83	1.99
Porosity computation			
Dry density	1.80	1.83	1.99
Surface gravity	2.89	2.63	2.49
Volume of solid sample (vs)	0.62	0.70	0.80
Volume of voids (vv)	0.38	0.30	0.20
Void ratio (e)	0.61	0.43	0.25
Porosity (u)	0.38	0.30	0.20
Permeability using	$K = 100 \times D10^2$		
K	0.51	0.59	0.67

could be arrived by the high presence of some of the heavy metals (Table 1) and possible pollution of groundwater by leakages from septic tanks as a result of the dominance of sand units (Figs. 2-5) which are permeable to these solutes and constituents from human and industrial activities on the surface within these locations. The pollution index [18-23] show that the samples of water at shallow depths between 30 m and 76 m have vulnerability to these contaminants than samples from greater depths 75 m. The suspected thick impermeable clayey layer between 30 m and 50 m within the study area serves as seal or proof from the leachets for the surface and shallow depth pollutions [24-26]. Good aquifer devoid of these contaminants is advisable to be drawn from depths beyond 70 m.

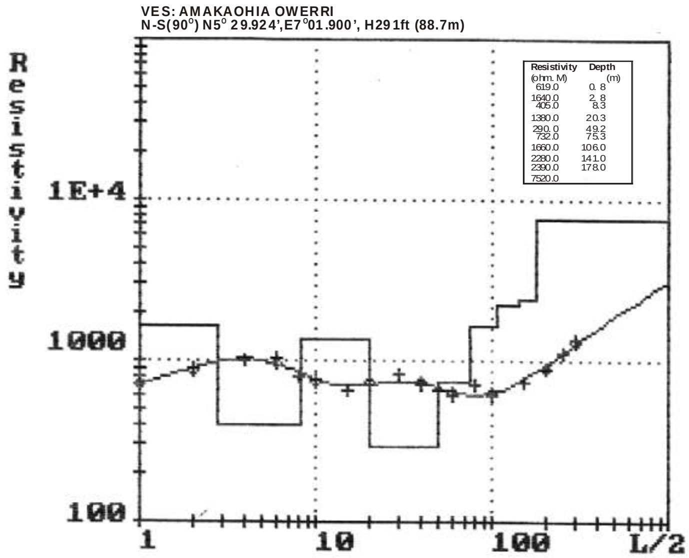

Fig. 2. Computer modelled curve of resistivity (Ωm) against depth (m) of Amakohia Owerri, Imo State, Nigeria

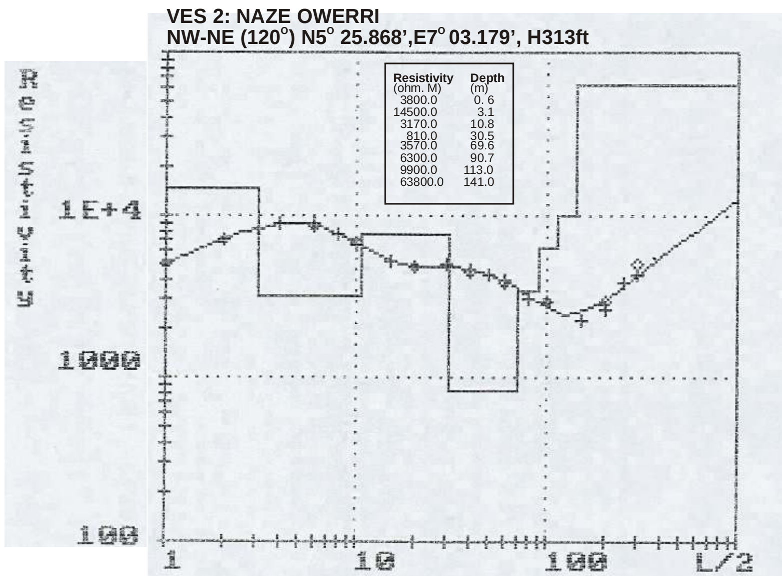

Fig. 3. Computer modelled curve of resistivity (Ωm) against depth (m) of Naze Owerri, Imo State, Nigeria

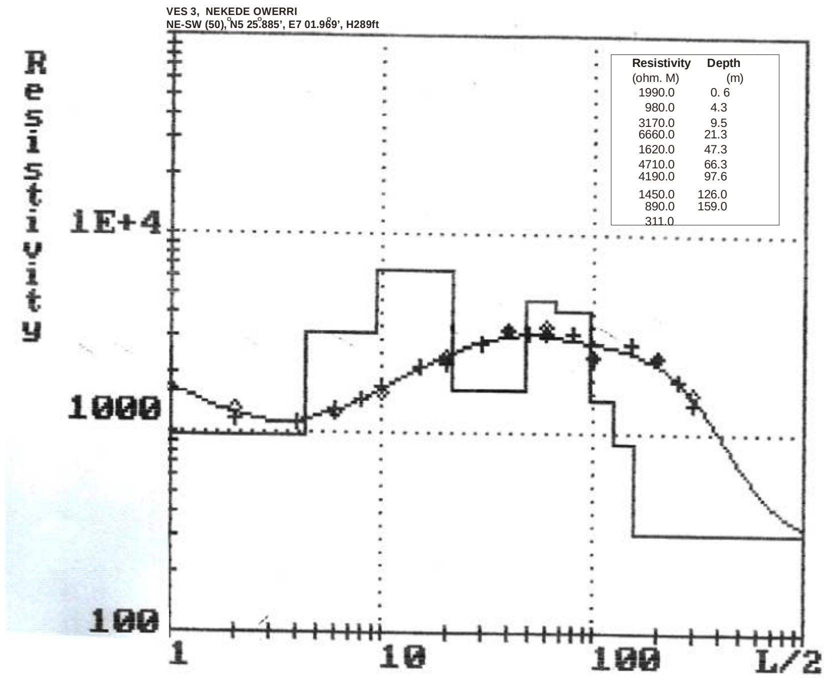

Fig. 4. Computer modelled curve of resistivity (Ωm) against depth (m) of Nekede Owerri, Imo State, Nigeria

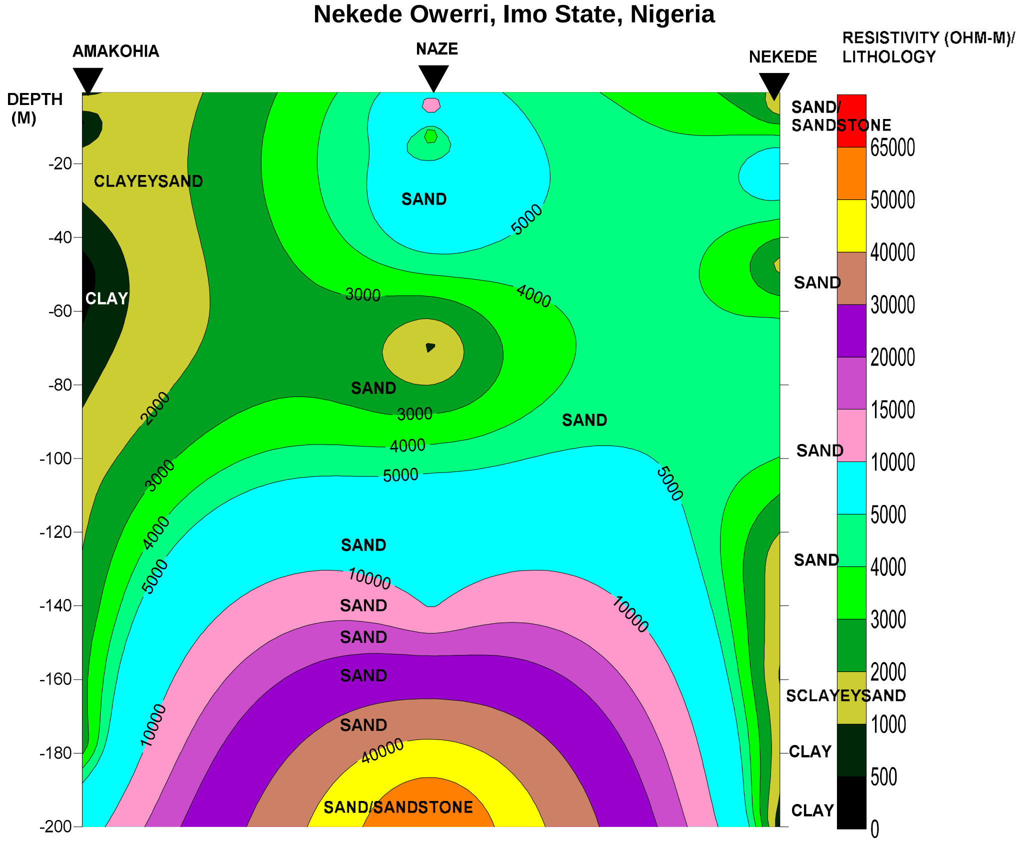

Fig. 5. Profile of the resistivity and lithology of the subsurface of Amakohia, Naze and Nekede in Owerri, Imo State, Nigeria

4. CONCLUSION

All the chemical, physio-chemical and geophysical parameters measured conform with the standard set for acceptable presence of these elements in groundwater. The density measurements are in the range of 1.49 to 1.98 mg/L, the porosity ranges from 0.20 to 0.38 mg/L while the permeability is from 0.51 to 0.67 mg/L. This high permeability correlates well with high resistivity value of average of 1990 Ωm for the topsoil and gradual increase in value to the 4^{th} layer extending to 20 m which is the assumed water level of the ground water within the study area. The resistivity value revealed that the leachets can be stopped by a thick layer of clayey / sandy clay units at about 25 – 30 m. The high concentration of some of the heavy metals is suspected to be present in the leachets which could have infiltrated as a result of human deposits and industrial activities within the environment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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