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THE USE OF VERTICAL ELECTRICAL SOUNDING (VES) TO INVESTIGATE THE EXTENT OF GROUNDWATER CONTAMINATION AND LITHOLOGY DELINEATION AT A DUMPSITE IN ALUU COMMUNITY, RIVERS STATE.

*** R. Bello, G. O. Emujakporue, U. U. Mkpese and B. G. Gladman**

Department of Physics, University of Port Harcourt, Port Harcourt, Nigeria

**Corresponding Author: E-mail – rasaq.bello@uniport.edu.ng, Tel. - +234(0)8036684498*

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ABSTRACT
Vertical electrical sounding (VES), an electrical method of geophysical exploration, using the Schlumberger array has been applied in an attempt to check the vertical extent of penetration of contaminated leachate from a waste dumpsite in Aluu community of Rivers State. Lithology delineation has also been interpreted from the VES result. Data were acquired in a single VES run with AB extending 100 m and maximum MN = 6 m. The acquisition was done using Ohmega Resistivity Meter (Series No. 0138), a product of Allied Association Geophysical Ltd. The result of the survey interpreted by IP2win software shows a characteristic KH curve type. Four layers of known thicknesses 0.43 m, 0.55 m, 2.7 m and 14.9 m were identified; a fifth layer which is suspected to be an onset of clean aquifer at a depth of 18.6m was also identified. The chemical make-up of leachate from waste dumps generally increases hardness and conductivity of groundwater. The VES result shows a sharp drop of resistivity value from 115 Ωm and 405 Ωm for the first two thin layers to resistivity values of 119 Ωm and 182 Ωm for layer three and four respectively, being an indication of an aquiferous zone with different levels of contamination. According to our results from this geophysical survey (VES), one must drill to about a depth of 20 m to be sure of a getting a portable drinking water in the area of study. However, from the result, there is no clear evidence of thick clay inter-beds to act as seal; hence, the aquifer zone of the area is still at risk of further contaminant penetration.

Key words: Vertical Electrical Sounding, Aquifer, Groundwater, Resistivity, Lithology

INTRODUCTION
The earth's subsurface information and its physical properties are readily made available with the use of various Geophysical methods. The various methods, either active or passive, include seismic methods based on earth's response to seismic energy; electrical method based on electrical conductivity/resistivity of the earth; magnetic method based on the variance of earth's magnetic properties from place to place; Radiometric methods based on the radioactivity of certain formation rocks. Several other methods not mentioned here do exist and others are still evolving.

The electrical resistivity method used in this work is routinely used in many engineering and hydrogeological investigations usually aimed at revealing certain shallow subsurface geologic make up. Several researchers have used this method to confirmed the detection ofcontaminated substrate of sandstone, investigate groundwater pollution, investigate causes of road failure, etc. (Barker, 1990; Emujaporue, 2012; and Egai and Douglas, 2015). Subsurface inhomogeneities are usually reflected from the variation in the values of resistivity or conductivity which will directly or indirectly infer the various lithologies and fluid content, and most practically, both combined.

In the Niger Delta, water is one of the abundant resources available. However due to industrialization and other human activities these ground waters are often polluted. The studied area located in Aluu Community, Obia/Akpor Local government Area of Rivers State has the problem of high iron concentration prevalence in the available boreholes in the area. Iron stains laundry, show brownish colouration in containers, objectionable taste, impair and corrodes pipes, castings, plumbing fixtures and cooking (Vincent and Vincent, 2015).

Akpokodje (1999) noted that a staggering amount of solid waste is generated in the Port Harcourt metropolis each year; a situation which has worsened in recent years. Some component of these wastes including food, paper etc consume oxygen including increased oxygen demand and due to contamination thereby changing the redox potential of the liquid present. Percolating groundwater provides a medium through which wastes particularly organics can undergo degradation into simpler substances through biochemical reactions involving dissolution, hydrolysis, oxidation and reduction processes. This leachate, the liquid drains from the dump, mainly organic carbon largely in the form of fulvic acids (Taylor and Allen, 2001) migrate downward and contaminate the groundwater.

Additionally, groundwater as the only source of potable water supply for domestic, industrial and agricultural uses is under intense pressure of degradation and contamination due to indiscriminate waste disposal, indiscriminate location of petroleum products storage tanks and the leakage of these facilities, sinking and leakage of septic tanks of various households. Unfortunately, the water table and depth to the aquiferous units are very close to the surface (Okiongbo and Ogobiri, 2011). However, this work is particularly concerned with investigating the extent of leachate penetration into the aquiferous zone from waste dump on the surface, and will possibly also discuss the lithological variations in the study area.

Location and Summary of the Geology of the Study Area

The study area is located between the boundary of Choba and Aluu communities of Rivers State, and less than 3km from the University of Port Harcourt'sDelta Park, and the survey point has a GPS readings of longitude 006°55'10.4"E and latitude 04°55'12.6"N. A Google map view of the study area is presented figure 1. It lies within the coastal sedimentary lowlands hydro-geological province.

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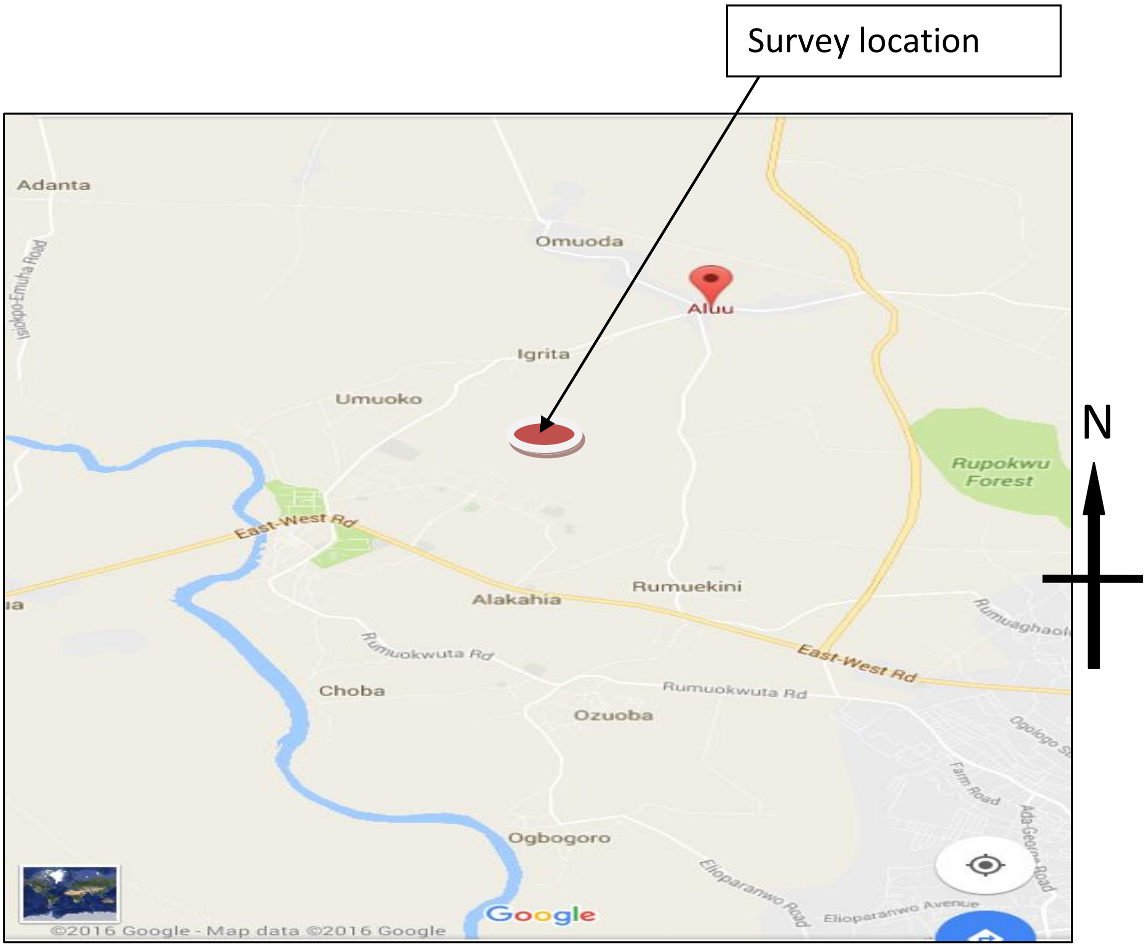

Fig 1: Location of Study Area from Google maps

The area is characterized by two seasonal patterns which are the Wet and Dry seasons (Egai and Imasuen, 2013). The wet season begins from the month of April to the month of October when there is usually a rise in water table and the dry season begins by November to the month of March. Within the rainy season a short break is observed in the month of August commonly referred to as “August break’’.

The Niger Delta basin generally has been identified with three lithostratigraphic units (Akata, Agbada and Benin Formations) which consist primarily of regressive Tertiary age sediments. The Benin Formation has been classified as the uppermost limit of the Delta with thickness up to 3,000m and consist of fluvial sands and sandstones. The sands and sandstones range from coarse to fine grain and are poorly sorted showing a little lateral continuity. The Benin Formation constitutes the major aquiferous layer and the study area is within this formation (Udom and Esu, 2004). The uppermost section of the Benin Formation is the Quaternary deposits of about 40 - 150 m thick and comprises of rapidly alternating sequences of sand and silt/clay with the later becoming increasingly more prominent seawards.

The quality of the groundwater is generally good. The occurrence of iron rich water in the Niger Delta is a well-known problem.

Although the iron problem is more prevalent in the freshwater and saltwater mangrove swamps, it can sometimes constitute a major problem in some isolated localities in the dry deltaic plains. Unfortunately, the major factors controlling the lateral and vertical occurrence and distribution of high iron content groundwater in the Niger Delta have not been confirmed (PHWC, 2014).

MATERIALS AND METHODS

Vertical Electrical Sounding (VES) adopting the Schlumberger Configuration was the technique used for the data acquisition by applying current to the ground through two electrodes (A and B) and then measuring the resultant potential difference (V) between the potentials M and N. The centre point of the electrode array remains fixed but the spacing of the electrodes was increased so as to obtain the information about the stratification of the subsurface. The schlumberger array data were taken in overlapping segment because at each step of AB spacing, the signals of the resistivity meter become weaker. The data acquisition was design in such a way that the MN spacing was enlarged once values for the AB/2 measured gets weaker. The schlumberger configuration was employed not only because it is faster and less likely to be influenced by lateral model but also require a fewer number of field personnel as the only the current electrode A and B requires frequent changes. Figure 2 is the schematic diagram of the Schlumberger (VES) acquisition plan.

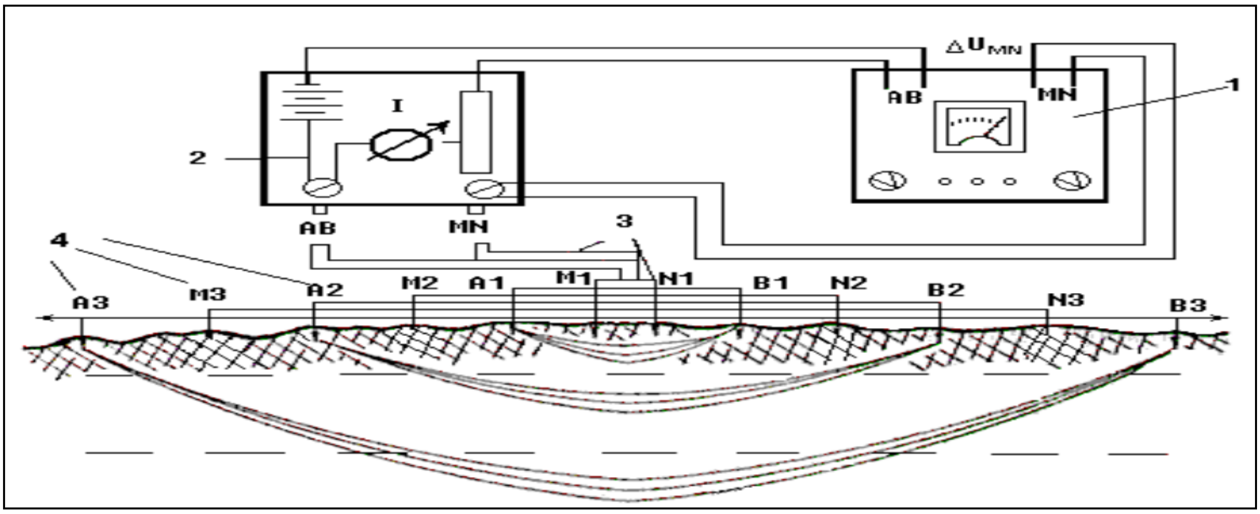

Fig 2: Schematic diagram of the Vertical Electrical Sounding (VES) device: (1) autocanceller, (2) commutator for electrodes AB and MN, (3) netted wires for different distances among electrodes AB and MN, and (4) electrodes (After Koefoed, 1979)

A single VES run was acquired with AB extending 100m and maximum MN = 6m. The acquisition was done using Ohmega Resistivity Meter (Series No. 0138), a product of Allied Association Geophysical Ltd. This acquisition range could probe at least a depth below the first aquifer zone of the study area.

The relationship between the electrical resistivity, current and the electrical potential is governed by Ohm's law (voltage = resistance x current). The basic data from a resistivity survey are the positions of the

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current and potential electrodes, the current (I) injected into the ground and the resulting voltage difference (ΔV) between the potential electrodes. The current and voltage measurements are then converted into an apparent resistivity (ρ_a) value derived from:

$$\rho_a = K \, {}^{\Delta V}/_{I} \quad (\Omega \mathrm{m}) \qquad 1$$

Where

ΔV = Potential difference

I= Electric current

K = Geometric factor

ρ_a = Apparent resistivity

The field data were first inputted into Microsoft Excel for computation of geometric factor and apparent resistivity using equations (Telford *et al.*, 1990).

$$K = \pi \frac{[({}^{AB}/_2)-({}^{MN}/_2)]}{MN} \qquad 2$$

And based on Ohm's law,

$$R = \frac{\Delta V}{I} \qquad 3$$

Where

K = Geometric factor

AB/2 = Half of current electrodes spacing

MN/2 = Half of potential electrodes spacing

ρ_a = Apparent resistivity

R = Measured resultant Resistance

Therefore, equation 1 can be rewritten as

$$\rho_a = KR \qquad 4$$

These were finally exported to IP2win resistivity software for layer analysis and interpretation. The generated sounding curves were interpreted to obtained the true resistivities and thicknesses of the subsurface layers.

RESULTS

The one dimensional inversion of the field curve is shown in figure 3. The inversion result gives a KH curve type ($\rho_1 < \rho_2 < \rho_3 < \rho_4$) with apparent resistivity values 115Ωm, 405 Ωm, 119 Ωm, 182 Ωm and 528Ωm. Five layers were identified within the maximum depth probed. A model interpretation of these results is shown in Table 1 and can further be visualized in an interpreted resistivity cross-section presented in figure (4). A statistical distribution of the apparent resistivity values is presented in figure (5)

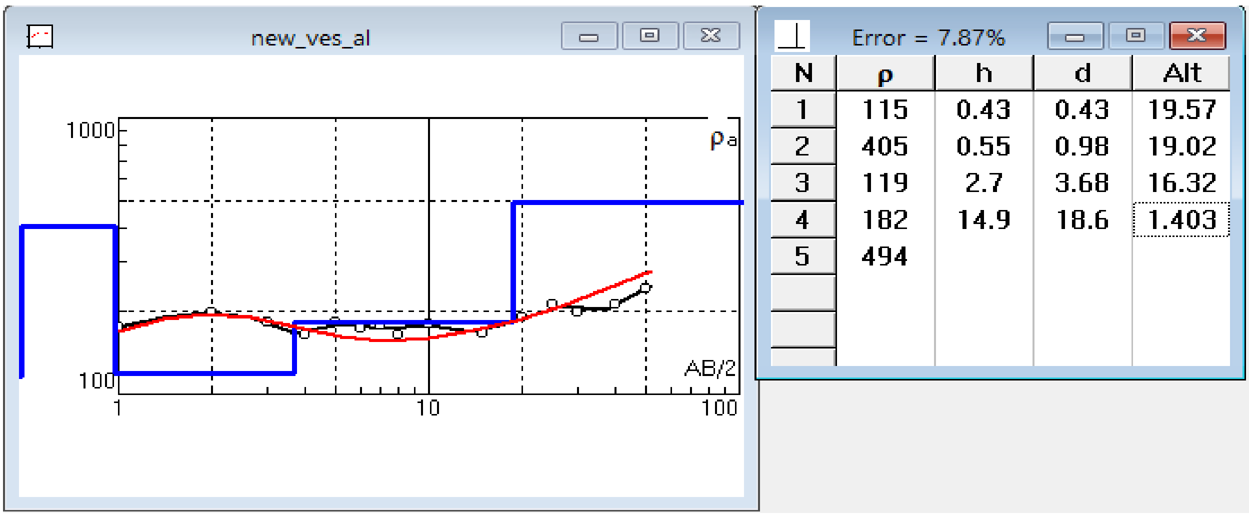

Fig 3: The model Schlumberger array representing a KH curve type.

Table 1: Inferred lithologies and layer thicknesses

No. of Layers	Resistivity Values (Ωm)	Layer thickness (m)	Depth (m)	Lithology
1	115	0.43	0.43	Topsoil
2	405	0.55	0.98	Lateritic soil
3	119	2.7	3.68	Sandy clay
4	182	14.9	18.6	Moist clayey sand
5	528	-	-	sand

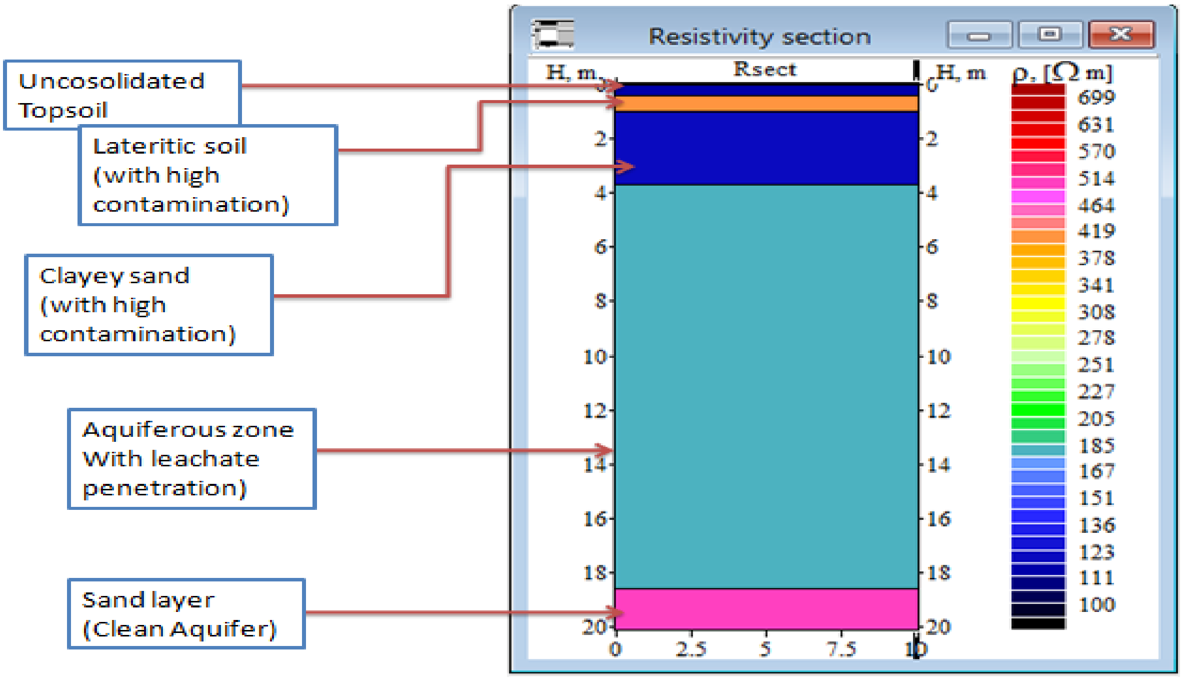

Fig 4: Interpreted Resistivity Cross-section showing clean aquifer units and contaminated aquifer unit.

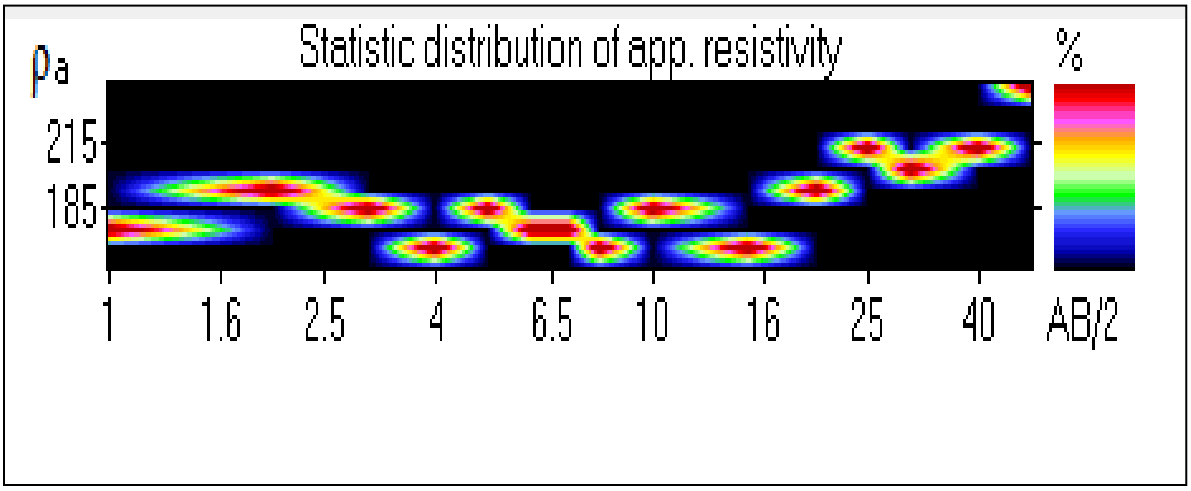

Fig 5: Statistical distribution of field curve.

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Table 2 shows the raw field data while figure 6 shows the field equipment used for this work.

Table 2: Raw field data

AB/2 (m)	MN/2 (m)	Geometric Factor, K	Res (Ω)	Apparent Res (Ωm)
1.00	0.30	4.76	36.35	173.20
2.00	0.30	20.47	9.56	195.62
3.00	0.30	46.65	3.84	179.05
4.00	0.30	83.30	1.95	162.36
4.00	0.50	49.48	3.59	177.83
5.00	0.50	77.75	2.32	180.00
6.00	0.50	112.31	1.52	171.05
7.00	0.50	153.15	1.15	175.67
8.00	0.50	200.28	0.81	161.68
8.00	1.00	98.96	1.59	157.74
10.00	1.00	155.51	1.16	179.92
15.00	1.00	351.86	0.47	165.41
15.00	1.50	233.26	0.74	173.38
20.00	1.50	416.52	0.46	190.31
25.00	1.50	652.14	0.32	211.82
30.00	1.50	940.12	0.27	251.48
30.00	2.50	561.56	0.35	198.40
40.00	2.50	1001.38	0.21	209.39
50.00	2.50	1566.87	0.15	241.77

Fig 6: Field equipment set-up

DISCUSSION

The inferred lithologies and contaminated zone are made based on standard resistivity values presented by a number of authors and researchers (Reynold, 1997; Telford *et al*, 1990; Osemudiamen, 2013).

From the values in Table (1), the first and second layers were identified as unconsolidated topsoil and lateritic soil. The average resistivity of the first and second layers are 115 Ωm, 405 Ωm respectively. The third and fourth layers with average resistivity values of 119 Ωm and 182 Ωm. The low resistivity values obtained for layer three and four may be attributed to the presence of leachate and contaminant from the dumpsitearea (Reynolds, 1997).The lithologies of the third and fourth layers are sandy clay and and clayey sand. Theleachates from the open dumps containbiological and chemical constituents. Organic matterdecomposing under aerobic conditions produces carbon IV oxide which reacts with the leaching waterto form carbonic acid.

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

This in turn acts upon metals in the refuse and other calcareous material in the soils and rocks resulting in increasing hardness and conductivity of contaminated water.We inferred that the groundwater in the third and fourth layer which depth extends from 1.41 to 18.6m at the dumpsite is polluted because of its high conductivity value. The breakdown of excess organic matters in waste dump does not only consume energy but also release a variety of compounds such as nitrate, phosphates, and sulphates into groundwater and this is known as euthrophication (Carla, 2000).

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Older dumps generate leachate plumes which can possibly travel kilometers in more permeable environment like in the Niger Delta. This can be detected with a combination of VES survey and Wenner array (horizontal profiling). The fifth layer has a high resistivity value of 528Ωm. The high resistivity may be attributed to due to freshwater which has not be contaminated with the leachate from the dumpsite. This is possible because of the forth clayey sand layer which act as a seal to the leachate migration downward.This work however had only concentrated on investigating the vertical extent of contamination at a new dumpsite.

The result also suggests the lithology of the fifth layer is sand and it is an aquifer zone. beginning from a. It is hereby suggested that if a water well was to be drilled in the surveyed area, then the drilling must be above the depth of 18.6m in order to access a portable water that is not contaminated and harmful to human health.

Results obtained here are strong enough to discourage indecent and incessant dumping of waste materials in residential environments. A possible contamination down to about depth of 18m has been detected and yet boreholes drilled in the area are mostly shallower than that depth Considering the nature and geology of the Niger Delta, always reclaiming and filling, and the permeability of the top formation – the Benin sand, dumpsites must be regulated and located on a geologically impermeable ground like clay. Clay which is known for its relatively impermeability to water is used when natural seals are needed such as in the cores of dams or as a barrier in landfills against seepage. Variable amount of water can be trapped in clay by polar action and clay adsorption removes heavy metals from waste water. The VES survey could only reveal sandy clay soil type overlying the aquifer zone and no clear evidence of thick clay inter-beds in the area, hence, the aquifer units in the area are vulnerable to major contamination from leachates.

Electrical resistivity technique (VES) has been helpful in detecting and/or delineating depth to aquifer units and vertical extent of contaminant penetration in the study area. Five layers were delineated from the interpretation and it was discovered that the third and fourth layers are highly contaminated while the fifth layer which is the aquifer was not contaminated. It is hereby suggested that other geophysical techniques be used as comparativetechniques and for detecting lateral extent of the contaminant. We also suggest that government make such legislations that will enforce preliminary investigations of groundwater contamination before any drilling of boreholes for groundwater in the area.

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