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Electrical Resistivity Investigation of Solid Waste Dumpsite at Rumuekpolu in Obio Akpor L.G.A., Rivers State, Nigeria

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ABSTRACT

A geophysical investigation using electrical resistivity method was conducted around a solid waste dumpsite at Rumuekpolu in Obio Akpor L.G.A of Rivers State, Nigeria to investigate the effect of waste dump on soil and groundwater resources. Vertical Electrical Sounding (VES) and 2-D resistivity imaging were used with a digital read out resistivity meter (Mc Ohm model 2115) to acquire data in the area. A contaminant leachate plume was delineated in both the VES and 2-D resistivity sections as low resistivity zones. The results were presented in terms of resistivity, thickness and depth. The 2-D were identified as bluish zones of low resistivity (less than 33.9Ωm) with the depth ranging from 39.0m to 49.8m in the entire inverse model sections. The result of the electrical resistivity survey also showed eight (8) layer geo-electric sections and an H type sounding curve. The result indicated that 6th layer VES, has low resistivity value of 55Ωm at the depth of 65.0m and thickness of 49.0m. The 8th layer VES whose depth and thickness could not be reached has a low resistivity value of 35Ωm and revealed that the groundwater around the dumpsite has been contaminated to depth exceeding 65.0m.

Keywords: *Vertical electrical sounding, leachate, resistivity, contaminant, plume.*

1. INTRODUCTION

Wastes, which are described here as materials that result from an activity or process but have no immediate economic value or demand and must be discarded, have been managed in a manner that has made the quest of the government to positively actualize the mega city status a difficult task. In the area, like in most other areas and cities, wastes are generated daily and most of the wastes are discarded in improperly situated and dumping sites that are not engineered. Most of the dumping sites are located within residential areas, markets, farms, roadsides, and others. This threatens the groundwater and road facilities, not sparing the aesthetics of such affected areas. Unarguably, uncontrolled citing of boreholes as the source of potable water in most of our urban and rural communities as the government seemingly no longer provides the populace with water has become a serious challenge. However, maintaining a portable ground water supply that is free from microbial and chemical contaminants is far from reality in most of our urban centers, and in particular Port Harcourt municipality, due to poor waste disposal and management practices. The challenge is worsened by the fact that there are inadequately trained waste disposal personnel and equipment, poor waste collection, sorting and disposal methods, and indiscriminate location of disposal sites without regards to the local geology and hydrogeology of the area. All these contribute significantly to the contamination of soil and ground water. Recent industrial development and increased urbanization in the municipality have resulted to enormous generation of all kinds of waste ranging from municipal to industrial. The type of waste generated varies widely with many human activities located close to dumpsites. Industrial wastes are generated from industrial activities such as chemicals, pesticides, paints, grease, inorganic materials, oil sludge, etc. while domestic wastes are those generated from commercial establishments and household activities. They occur in different forms, water – borne waste from households, including sewage, human and animal remains as well as chemical and laboratory waste. The release of these materials into the environment sometimes causes serious health problems. The level of wastes produced by dense human and domestic animal population often exceeds the local ecosystem's biodegradability, resulting in serious environmental pollution and epidemic outbreaks of diseases (Ronald, 1988). During the peak of the rainy season, the dumpsite is covered by flood water and this contributes to the formation of leachate. It is this contaminated liquid that enters into the soil and also eventually into the underlying groundwater at such dumpsites. The manner of disposal points to the fact that solid waste management is one of the greatest challenges facing state and local government environmental protection agencies in Nigeria. In view of the foregoing, this study was embarked upon to establish the adverse effect potentials of the wastes at the dumpsite to the groundwater systems of the area.

The major source of ground water contamination in the municipality is the solid waste landfill. Others are improperly functioning septic tank systems, hydrocarbons, and industrial chemicals. Solid waste landfills (SWL) have become a popular waste management system for the disposal of all manner of waste materials in the municipality. They are usually abandoned or disused exhumed pits used for road construction, and are therefore, not engineered for the containment of landfill emissions into the environment. As a result of the imminent impact of solid waste landfills, it has become necessary to investigate the potential for the contamination of soil and ground water around a municipal solid waste landfill. In this work, electrical resistivity method was used in line with Benson *et. al.* (1983), Mathias *et. al.* (1994) and kayabali *et. al.* (1998) to investigate the effect of the waste on the soil and groundwater in the dumpsite area.

2. LOCATION AND DESCRIPTION OF STUDY AREA

The dumpsite is located in Rumuekpolu in Obio Akpor L.G.A., Rivers State. It is delineated between Latitude 4^o 30' and 4 ^{o} 55'N and longitudes 6 ^{o} 55' and 7 ^{o} 00'E (Figure 1) within the Niger Delta region of Nigeria. The Niger Delta area has a tropical rainforest climate, with a distinct wet (April – October) and dry (November – March) seasons. The mean annual rainfall ranges from 2000mm (inland) to over 4000mm at the coast and the area is characterized by five major geomorphic units namely dry flatland & plains, Sombreiro-Warri deltaic plains with abundant freshwater back swamps, freshwater swamps, meander belts & alluvial swamps, saltwater or mangrove swamp and active/abandoned coastal ridges (Akpokodje, 2001). The proximity of the aquifers to the surface, flat topography, high annual rainfall, and permeable soil media contributes to insignificant runoffs in the site, and implies that the total precipitation goes into storage. This enhances decomposition activities by bacteria and fungi and leaching of contaminants into the aquifer

The area is geologically composed of various Quaternary deposits that overlie the three main stratigraphic units of Benin, Agbada and Akata. The Benin Formation (Oligocene to Recent) is the aquiferous formation in the study area and is exploited for groundwater supplies (Akpokodje, 2001). Although a depth of 100m is most exploited, about 300m depth has been exploited for water (Ngah, 1990). The Benin Formation consists essentially of massive and highly porous sands and gravels with a few thin clay intercalations. The uppermost section of the Benin Formation is the Quaternary deposits of about 40-150m thick and comprises of rapidly alternating sequences of sand and silt / clay with the later becoming increasingly more prominent seawards (Etu-Efeotor and Akpokodje, 1990).

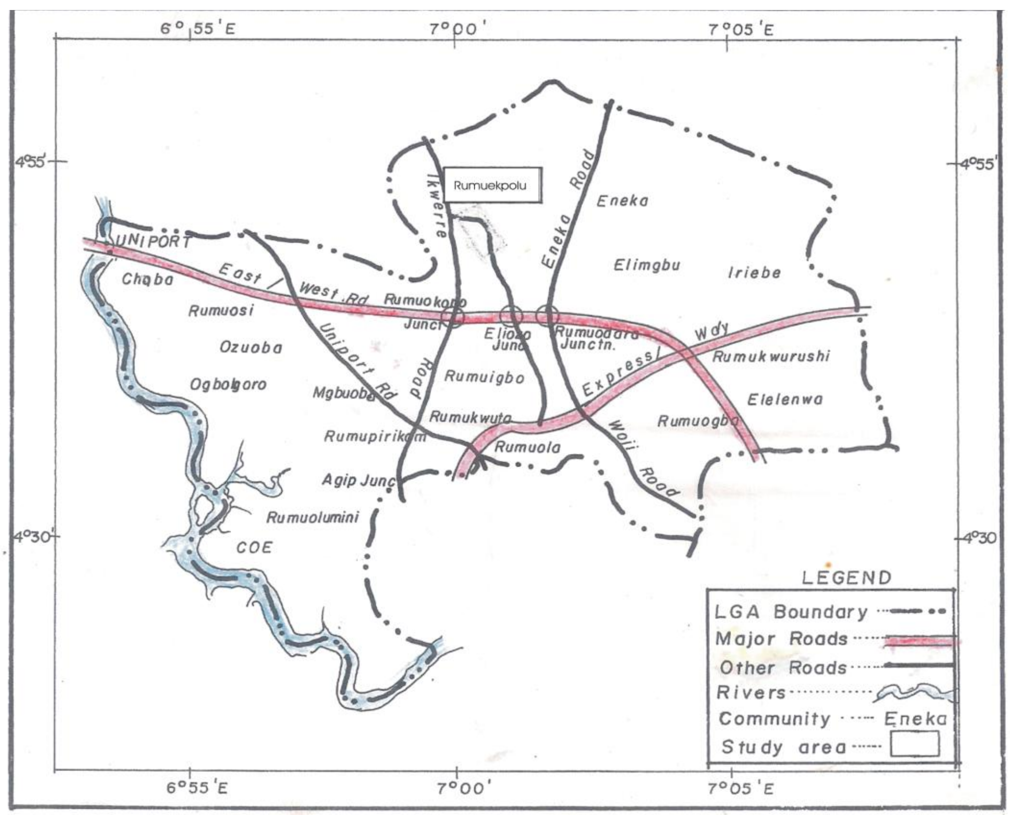


Figure 1: Map of Obio Akpor L.G.A showing the study area

3. LITERATURE REVIEW

Etu-Efeotor and Odigi (1983), Amadi and Amadi (1990) and Ugwu and Nwosu (2009) carried out studies in various parts of Rivers State. Ehirim *et. al.* (2009) carried a geophysical and hydro-physiochemical study of the contaminant impact of a solid waste landfill (SWL) in Port Harcourt municipality, Nigeria and concluded that the contamination of ground water and soil is dominantly by landfill gases, while the excessive amount of micro-organisms is an indication of leachate contamination. Landfill related studies have been carried out using the 2-D resistivity imaging method by various authors (Olayinka and Olayiwole, 2001, Samsudeen *et. al.*, 2006, and Esmail *et. al.*, 2008). This is because of its inherent ability to detect vertical as well as lateral resistivity changes related to variations in fluid content, chemical composition, and contaminant migration.

4. METHOD OF STUDY

The survey involved the use of electrical resistivity techniques. These techniques adopted Vertical Electrical Sounding (VES) in combination with resistivity imaging. The sounding was used to characterize the various lithologic units and to determine the depth to water table while the resistivity imaging was used to substantiate the result of the sounding as well as to determine the presence of leachate contaminants, direction of flow of contaminant and the direction of groundwater flow.

A Mc Ohm model 2115 resistivity meter with a Signal Averaging System which gives the average of different readings taken consecutively, giving more reliable result than those obtained from single-short systems was used for the resistivity measurement using the Schlumberger and Wenner electrode configurations. The VES field data were processed using the Schlumberger automatic IP12 WIN analysis software, which generates model curves using initial layer parameters. The VES data are presented as sounding curves, which are obtained by plotting graphs of apparent resistivity verses half electrode spacing. The 2-D resistivity field data were processed using the RES2DINV inversion software, which subdivides the subsurface into blocks and uses the least square inversion to determine the values of each block. Electrode spacing of 20m, 40m, 60m, and 80m was used with a total distance of spread of 380 meters in East-West direction (Figure 2). One parallel profile was run with inter profile spacing of 20m from the beginning of the dumpsite with total distance spread of 380 meters in East-West direction. Electrodes were moved from one end of the line to the other in order to achieve a horizontal setting of the subsurface.

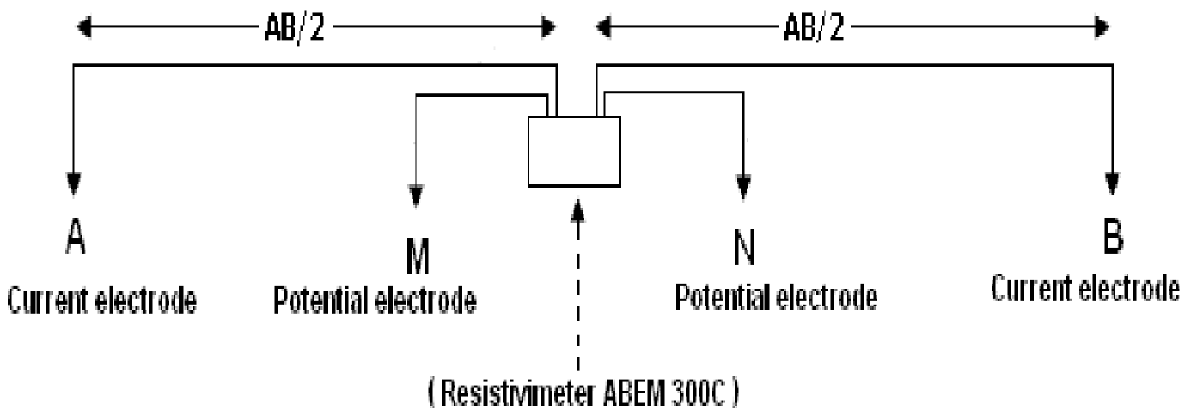


Figure 2: Schlumberger electrode array

The apparent resistivity is given as,

$$pa = \pi \left\{ \frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right\} \Delta \frac{V}{1} \quad (1)$$

Where AB = Distance between the current electrodes meters,

MN = Distance between the potential electrodes (meters),

ΔV = Potential difference measured between the potential electrodes (Volts)

I = applied current strength (Ampere).

The geometric factor for Schlumberger array is;

$$k = \pi \left\{ \frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right\} \quad (2)$$

5. TYPES OF VES CURVE

The data analysis was done by plotting the values of the apparent resistivity (determined from eqn. 1) against the values of the half electrode spacing (Figure 2) on a logarithm scale. Field curves are generated and the number of inflections on the curve was used for the estimation of layer resistivity and thicknesses. The typical curve types for different layers in electrical resistivity data deduction are given in Figure 3 below.

These shapes are known as Q-type (or DA. descending Hummel) H-type (Hummel type with minimum), A-type (ascending) and the K-type (or DA, displaced anisotropic). The K curve rises to a maximum level, and then falls, indicating that the middle layer has the highest resistivity compared to the top and bottom layers. The type H curve shows the opposite effect; it falls to the minimum then increases again due to an intermediate layer that is a better conductor than the top and bottom layers. The type A curve may show some changes but the apparent resistivity generally increases continuously along with increased electrode space separation, indicating the true resistivity increases with depth from layer to layer. The type Q curve exhibits the opposite effect; it decreases continuously along with a progressive increase of resistivity with depth.

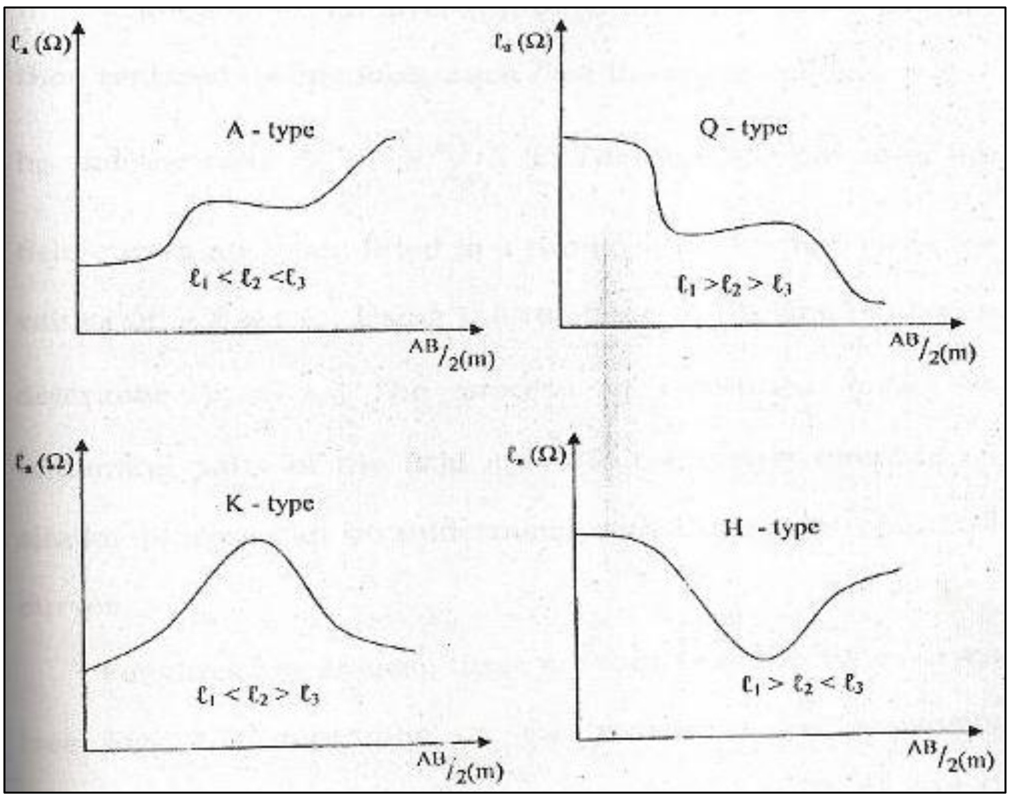


Figure 3: Typical Curves of Electrical Resistivity (VES)

Type H Curve shows that a low resistivity layer is sandwiched between two high resistivity layers typical of a three layer case $(\rho 1 > \rho_2 < \rho_3)$

Type A Curve shows that the resistivity of the layers is increasing. $(\rho_1 <_2 \rho < \rho_3)$

Type K Curve shows that a high resistivity layer was sandwiched between two low resistivity layers.
$(\rho_1 < \rho_2 > \rho_3)$

Type Q Curve shows that resistivity is decreasing with depth. $(\rho_1 > \rho_2 > \rho_3)$

6. WENNER ELECTRODE CONFIGURATION

The Wenner array uses four electrodes equidistant from each other. It is useful in separating the different layers of the subsurface according to their resistivity values, in a vertical pattern from the sounding point. The depth of penetration is increased by increasing the common distance of separation between the electrodes and maintaining the location of the center of the array (Figure 4).

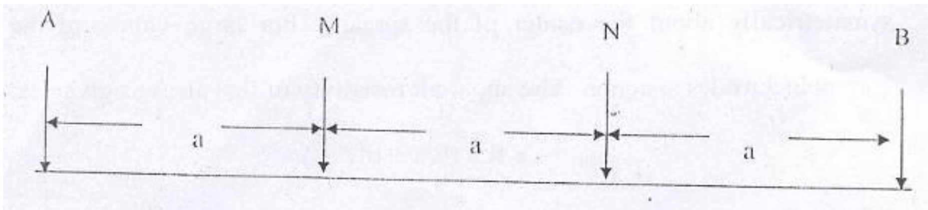
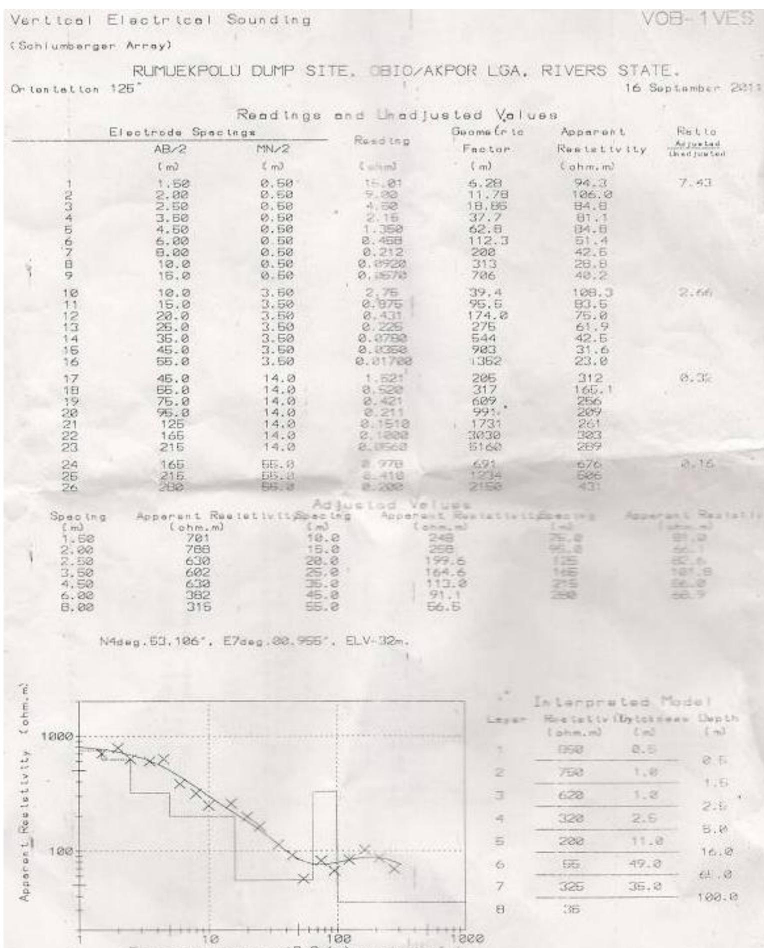


Figure 4: Wenner electrode array

7. PRESENTATION AND DISCUSSION OF RESULTS

7.1 Vertical Electrical Sounding (VES)

The field curves and the interpreted models are presented in Figure 5. The interpreted geo-electric sections are shown in Table 2 and their results are presented in terms of resistivity, thickness and depth. The VES shows eight (8) layer geo-electric sections and a type H curve. The 1st layer is the top soil with underlying sands of varying sizes and thickness. The 2nd layer has a high resistivity value of 750Ωm at the depth of 1.5m. This layer was interpreted to be high resistive chemical compounds. Third layer has a high resistivity value of 620Ωm at the depth of 2.5m. It was also interpreted to be high resistive chemical compound. Fourth layer has a resistivity value of 320Ωm at the depth of 5.0m. The 5th layer has a resistivity value of 200Ωm at depth of 16.0m. The 6th layer has a low resistivity value of 55Ωm at the depth of 65.0m; it was interpreted as the contaminant leachate plume indicating contamination of the groundwater in the study area. The 7th layer has a resistivity value of 325Ωm at the depth of 100.0m. The 8th layer whose depth could not be reached has a low resistivity value of 35Ωm.



Vertical Electrical Sounding VOB- 1VES
(Schlumberger Array)

RUMUEKPOLU DUMP SITE, OBIO/AKPOR LGA, RIVERS STATE.

Orientation 125° 16 September 2011

Readings and Unadjusted Values

	Electrode Spacings AB/2 (m)	MN/2 (m)	Reading (ohm)	Geometric Factor (m)	Apparent Resistivity (ohm.m)	Ratio Adjusted/Unadjusted
1	1.50	0.50	15.01	6.28	94.3	7.43
2	2.00	0.50	9.00	11.78	106.0	
3	2.50	0.50	4.50	18.86	84.8	
4	3.50	0.50	2.15	37.7	81.1	
5	4.50	0.50	1.350	62.8	84.8	
6	6.00	0.50	0.458	112.3	51.4	
7	8.00	0.50	0.212	200	42.5	
8	10.0	0.50	0.0920	313	28.8	
9	15.0	0.50	0.0570	706	40.2	
10	10.0	3.50	2.75	39.4	108.3	2.66
11	15.0	3.50	0.875	95.5	83.5	
12	20.0	3.50	0.431	174.0	75.0	
13	25.0	3.50	0.225	275	61.9	
14	35.0	3.50	0.0780	544	42.5	
15	45.0	3.50	0.0350	903	31.6	
16	55.0	3.50	0.01700	1352	23.0	
17	45.0	14.0	1.521	205	312	0.3k
18	55.0	14.0	0.520	317	165.1	
19	75.0	14.0	0.421	609	256	
20	95.0	14.0	0.211	991	209	
21	125	14.0	0.1510	1731	261	
22	165	14.0	0.1000	3030	303	
23	215	14.0	0.0560	5160	289	
24	165	55.0	0.978	691	676	0.16
25	215	55.0	0.410	1234	506	
26	280	55.0	0.200	2150	431	

Adjusted Values

Spacing (m)	Apparent Resistivity (ohm.m)	Spacing (m)	Apparent Resistivity (ohm.m)	Spacing (m)	Apparent Resistivity (ohm.m)
1.50	701	10.0	248	75.0	81.0
2.00	788	15.0	258	95.0	56.1
2.50	630	20.0	199.6	125	82.6
3.50	602	25.0	164.6	165	101.8
4.50	630	35.0	113.0	215	56.0
6.00	382	45.0	91.1	280	58.9
8.00	315	55.0	56.5		

N4deg.53.106', E7deg.00.955', ELV-32m.

Apparent Resistivity (ohm.m)
1000
100
1 10 100 1000
Electrode spacing AB/2 (m) or depth (m)

Interpreted Model

Layer	Resistivity (ohm.m)	Thickness (m)	Depth (m)
1	850	0.5	0.5
2	750	1.0	1.5
3	620	1.0	2.5
4	320	2.5	5.0
5	200	11.0	16.0
6	55	49.0	65.0
7	325	35.0	100.0
8	35		

(Type H curve ($\rho 1 > \rho 2 < \rho 3$))

Figure 5: Schlumberger Field curve

Table 1: Layer parameters of the geo-electric section (VES)

	LAYER NO.	RESISTIVITY Ωm	THICKNESS	DEPTH	SOIL DESCRIPTION
VES	1	850	0.5	0.5	Top soil
	2	750	1.0	1.5	Laterite Sand
	3	620	1.0	2.5	Sand
	4	320	2.5	5.0	Sand
	5	200	11.0	16.0	Sand
	6	55	49.0	65.0	Sand
	7	325	35.0	100	Sand
	8	35	-	-	Sand

7.2 2-D Pseudo Section Analysis

The 2-D pseudo section obtained from the constant separation traversing (CST) survey is shown in Figure 6. In the pseudo section, high resistivity zone (greater than 404Ωm) existed near the surface with depth ranging from 5.00m to 37.0m to the North and South of the section. This zone was interpreted as high resistive chemical compounds and its migration to near the surface is an indication that it is less dense. Underlying the zone of high resistive chemical compound is the zone of low resistivity (less than 33.9 Ohm meter) with the depth ranging from 39.0m to 49.8m.

Between the high resistive chemical compound and the low resistive zone are sands of varying sizes and thickness. The bluish portion shows zone of low resistivity (contaminant leachate plume), purple to brownish portion shows zone of high resistivity (chemical waste) and the yellow portion shows zone of water bearing (sands). The migration of the contaminant leachate plume to the bottom is an indication that it is denser. The result of the geophysical resistivity survey using Vertical Electrical Sounding and 2-D resistivity imaging has shown that soil and groundwater around the dump area are contaminated. The interpretation of the sounding curve shows a characteristic curve type namely type H curve at the dumpsite. The observed contamination is consistent with Ehirim *et.al.* (2009).

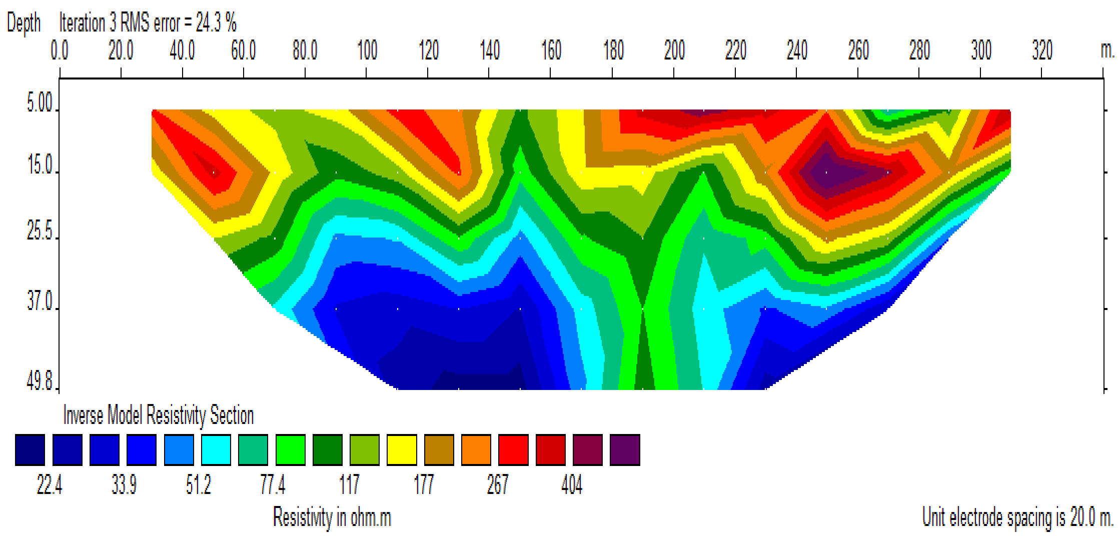


Figure 6: Wenner interpreted 2-D pseudo section

Two zones were identified; they are the zones of high and low resistivity. Zone of high resistive chemical compound was shown in both VES and 2-D resistivity sections. Contaminant leachate plume was identified in both the 2-D resistivity and the VES data as the section of low resistivity zone.

8. CONCLUSION

The results of the electrical resistivity investigation of solid waste using VES and 2-D resistivity imaging at Rumuekpolu in Obio-Akpor Local Government of Rivers State, Nigeria has enabled us establish contamination of the subsurface environment. Contaminants occur at depths exceeding 65.0m with low resistivity reading of 55.0 Ωm and as such proper scientific approach is therefore necessary towards the utilization of resources within the interval

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