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SITE INVESTIGATION FOR SITING A MUNICIPALLANDFILL SYSTEM IN MINNA, NORTH CENTRAL NIGERIAUSING ELECTRICAL RESISTIVITY METHOD

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ABSTRACT

Investigation of the proposed sites for sanitary landfill within Minna, North-Central Nigeria was carried out using electrical resistivity method. The MacOhms resistivity meter was used to obtain the field data for both 2-dimensional profiling (2D) and 1-dimensional vertical electrical sounding (VES). The investigation was used in the subsurface characterisation of the investigated site in orderto determine its suitability as potential site for sanitary landfill. 2D electrical subsurface imaging was used to determine the lateral and horizontal subsurface lithologic variation at the site. The vertical electrical sounding (VES) curve generated from the study area shows two curve types, which are H and HA with HA showing dominance. Geoelectric sections generated from the VES indicate four lithological layers: top/lateritic layer, clayey soil, the weathered/fractured zone and fresh basement rock. The results indicate the clay layer thickness ranged between2.0m to 5m while the depth to clay layer varied from 5.8m to 9m from the datum point. The findings indicate that the clay soil from the investigated site meets the geotechnical and hydrogeological conditions as barriers for impeding possible leachate migration from sanitary landfill.

Keywords: Subsurface, Electrical resistivity Method, Sanitary Landfill, Geoelectric section and Lithology

INTRODUCTION

Selection of site for sanitary landfill is the most critical aspect in the planning and design stage in establishing a municipal sanitary landfill system (Guyer, 2009).The concept of a well-engineered municipal sanitary landfill technology is aimed at mitigating soil and groundwater contamination and other environmental hazards (USEPA, 1979).Geophysical investigation viageo electrical technique is considered as a valuable tool in understanding the subsurface characteristics of proposed site for sanitary landfill. The resistivity investigation is used to determine the geological sequence and structural pattern of the subsurface lithology. It is primarily targeted at detecting the variations in subsurface conditions such as of thickness to bedrock, depth to lithologies, aquifer types and structural signatures (Olasehinde, 2009). An adequate and concise geophysical investigation of subsurface conditions of sites for solid waste sanitary landfill cannot be overemphasis. The assessment of the safety conditions of a proposed site for municipal sanitary landfill should be a prerequisite for the siting of such facilities in any proposed location (Ige and Ogunsanwo, 2009; Oyediran, and Iroegbuchu, 2013). There exists an infinite geological subsurface variation as you transverse from one location to the other. This gives rise to the need for a concise appraisal of all conditions that would guarantee the safety of the soil and groundwater resources (Amadi *et al.,* 2010; 2012).

The choice of sites for landfill construction is critical and cost effective and the consequences of a wrong choice could lead to environmental degradation and negative human health impact (Rowe, 2011). Hence, no effort should be spared in making accurate decisions that would lead to the choice of suitable sites for solid waste sanitary landfill (Amadi *et al*., 2015). The judgment on the safety of a site for municipal solid waste landfill should be based on the safety of the specific site. Till this day, waste disposal is carried out in an uncoordinated manner in open dumpsites within and around Minna metropolis, to this end a site have been specifically studied for sanitary landfill within Minna metropolis, North Central Nigeria. The area has an estimated population of about 350,287 covering a total area of 6,783 square kilometres (National Population Commission, 2009).

STUDY AREA

The investigated site is part of Minna sheet 164, it is located at the outskirt of Minna metropolis behind Talba Farms, accessible through Sauka-Kahuta to Gidan Kwano bypass also known as Mandela road. It lies within latitude 9°31′55.3″N and 9°32′11.0″N of the Equator and longitude 6°30′58.8″E and 6°31′08.3″E of the Greenwich meridian (Fig.1) with an average elevation of 230m above sea level. It covers a total area of about 8.9 km^2.The vegetation of the study area belongs to the savannah, which is a transitional type between the rain forest of southern Nigeria and the Guinea Savannah of northern Nigeria. The annual rainfall distribution pattern shows a maximum of 1300mm rainfall and minimum of 1000mm. The rainy season is between April and October covering a period of six months. (Federal Meteorological Agency, Minna, 2011). The topography of the study area is marked by high and flat terrain, with most of the highlands visible around the vicinity of the area. Some portions of the site is serving as a borrow pit for construction purposes. The area lies within the Nigerian Basement Complex rock, which is characterized by three lithofacies: the migmatite gneiss complex, the low schist belt and the older granites (Oyawoye, 1972; Rahaman, 1976). The rocks within study area are moderately deformed and as a result of the deformational activities, the basement in the area is overlain by in-situ overburden materials of different compositions.

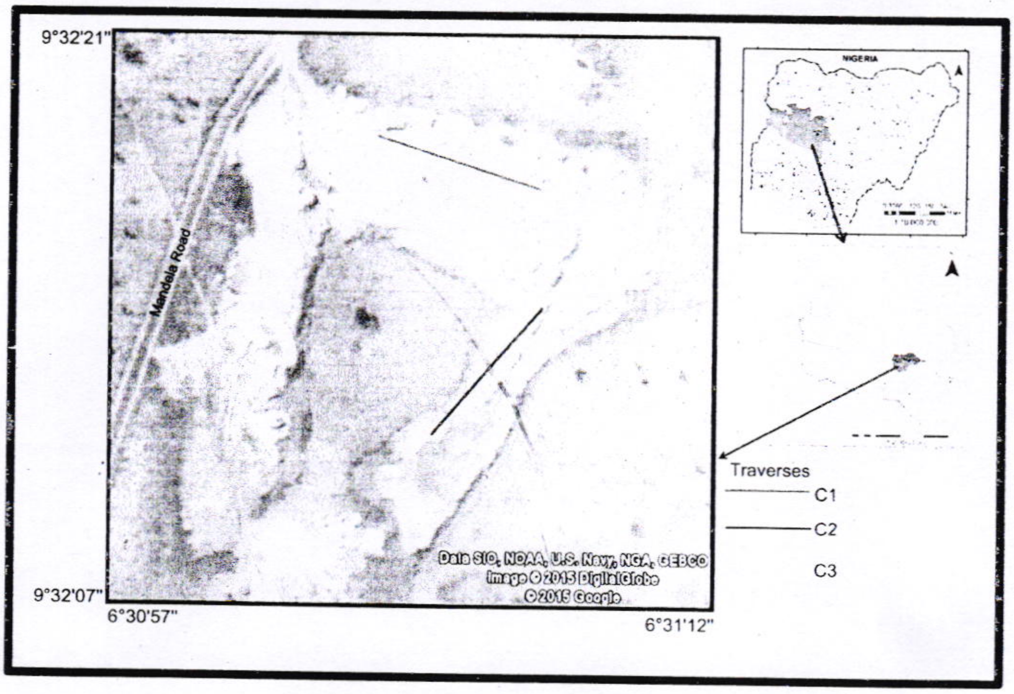

Fig.1: Study Area Showing Traverses

ATERIALS AND METHODS

Two geo-electrical resistivity methods vere employed for this investigation; the two imensional (2D) subsurface imaging echnique using the Wenner Alpha array and ıe one dimensional (1D) vertical electrical ounding (VES) using the Schlumberger onfiguration. The principle of electrical esistivity is generally based on Ohm's law. leasurements are normally made on the round by injecting current into the ground ırough pairs of current electrodes (C1 and 2). The resulting voltage difference is ıeasured between another pairs of potential ctrodes (P1 and P2) (Figure 2). The sistance (R) is derived from the current (I) and voltage (V) values using Ohm's law (R=V/I).Various geological and earth minerals respond to resistivity differently and this can be used to differentiate the variation in subsurface lithology's (Lowrie, 2007).The resistivity values of soil and rock are affected mainly by the mineralogy composition, moisture, porosity, amount and nature of dissolved salts.

For the 2D imaging the Wenner Alpha configuration as outlined by Loke, (1999) (Fig.2) was employed for the survey. The choice of the Wenner Alpha array was determined due to its strong signal strength as compared to Wenner Beta and Wenner Gamma arrays. A total of twenty one (21) electrodes were used for the survey, the traverse length was limited to a continuous intermittent break of 100m covering the entire area. The measurement is carried out in sequences along the traverse. For the first sequence of measurement the spacing between adjacent electrodes (a) at 1a was set at 5m. For the first measurement, electrodes numbers 1, 2, 3 and 4 served as C1, P1, P2 and C2 respectively (Figure 2). For the second measurement, electrodes numbers 2, 3, 4, and 5 servers as C1, P1, P2 and C2 respectively. This sequence was carried on until electrodes 18, 19, 20 and 21 served as C1, P1, P2 and C2 respectively. Eighteen mid-points were measured at the end of 1a sequence.

The next sequence of measurement with 2a was made. The adjacent spacing between electrodes was increased from 5m to 10m, but still maintaining the overlapping horizontal electrode movement of 5m. Electrodes 1, 3, 5 and 7 were used as C1, P1, P2 and C2 respectively for the first sets of measurement. Electrodes 2, 4, 6, and 8 were used for the second sets of measurement. This sequence was repeated down the traverse until electrodes 15, 17, 19 and 21last measurement in the 2a sequence.

The whole measurement procedure was repeated for 3a, 4a, 5a, and 6a spacing. From the first sequence of measurement 1a, a total of 18 mid-points were obtained, and the mid-point reduces by three in subsequently measured sequences. The inter electrode spacing ranges from 5m to 30m on the surface. The imaging traverse Azimuth orientations ranged from S-W to N-E directions. The data obtained were quantitatively interpreted by inversion using the RES2DINV software.

Three 1D VES stations were established at about 1m, 50m and 100m distances on each of the 2D traverse. The Schlumberger configuration of electrical resistivity method was employed for the VES with a maximum AB/2 of 30m. Quantitative interpretations of the obtained data were carried out. Visual inspection of the field curve, traditional curve matching were used for the manual interpretation. Computer iteration of the curve matched data was carried out using the Winresist software (Van der and Sporry, 1992) to generate sounding curves.

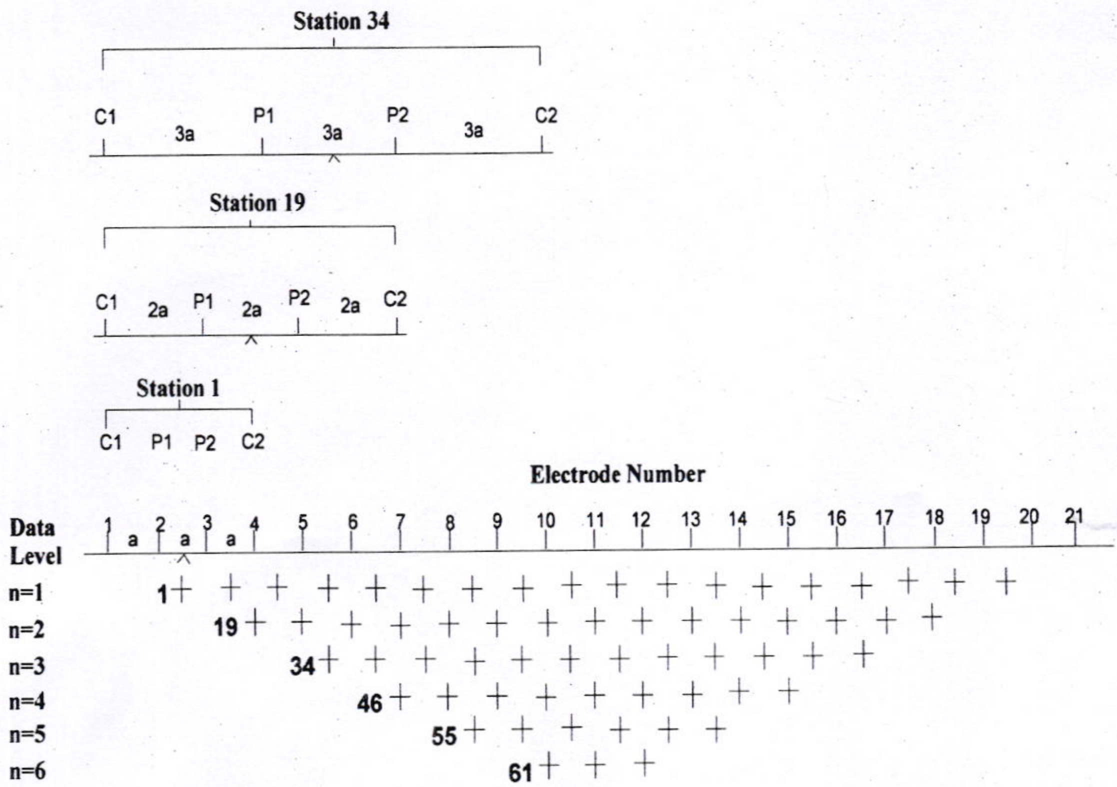

Fig.2: Sequence of 2D Wenner resistivity measurement to build a pseudosection (After Loke, 1999)

The Schlumberger array follows the general for electrode principle. The midpoint of the array remains fixed, with increase in electrode spacing between electrodes to obtain vertical information about the horizontal layering of the subsurface. In resolving the vertical resistivity layering, the potential electrodes MN are kept at close spaced and fix to the arrays midpoint while the current electrodes AB are increase outward. The increase in current electrodes measurement of MN is taking to interpolate the shift experienced in the sounding curve (Reinhard, 2006). AB connotes an increase in the depth of penetration of the subsurface (Reinhard, 2006). An increase in AB/2 leads to a rapid reduction in potential difference measured at electrodes MN/2. In this case the MN distance is also increased to get a better potential response. Due to near surface inhomogeneity, when the MN electrode spacing is increased a static shift in the sounding curve is observed. An overlapping

RESULTS AND DISCUSSION

The results of the 2-D profiles are displayed as cross sectional inverse models of the true resistivity distribution of the earth.

Profile C1

The inverse model resistivity section of profile C1 (Figure 3a) indicates a thick continues clayey layer as the dominant top layer. The layers resistivity ranges from about 60 Ωm to 117 Ωm, extending to a depth of about 9m to 11m. The second layer is composed of weathered basement rock with resistivity value ranging from 150 Ωm to 240 Ωm. The depth of the weathered basement ranges from about 12m at the SE to about 15m on the NW portions of the profile. The third layer is the fresh basement, which is indicated at 25m to 45m on the profile. The layers resistivity is above 250 Ωm.

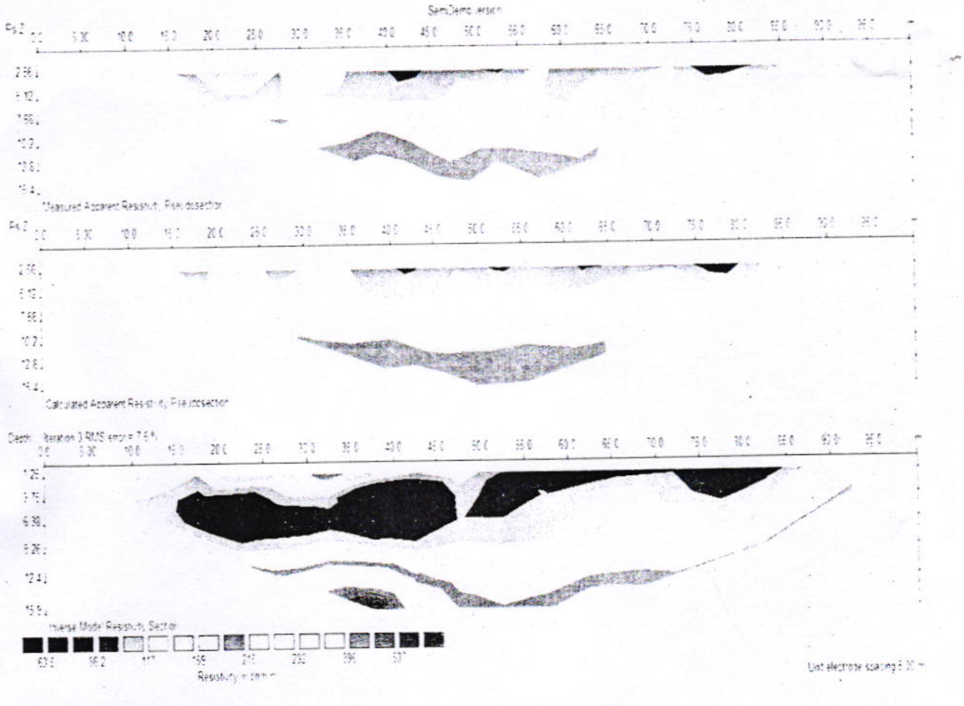

Fig.3a: 2D Inverse Model resistivity section for profile C1

Profile C2

From the inverse model section of imaging profile C2, three major layers were identified (Fig.3b). The first layer is of clay composition with resistivity value ranging from 12 Ωm to 45 Ωm. The depth of the clayey layer varies from about 2.5m at 5m profile to about 11m at 50m profile and 6m to 2.5m at 55-95m on the profile. The second layer is of weathered basement rock with alternating depth across profile ranging from 3.5m to 14m. The resistivity values of the weathered layer ranges from 72 Ωm to 214 Ωm. The third layer is the highly resistive fresh basement layer, it is more pronounced at 55m to 80m on the profile and its depth also varies from about 9m to 15m.

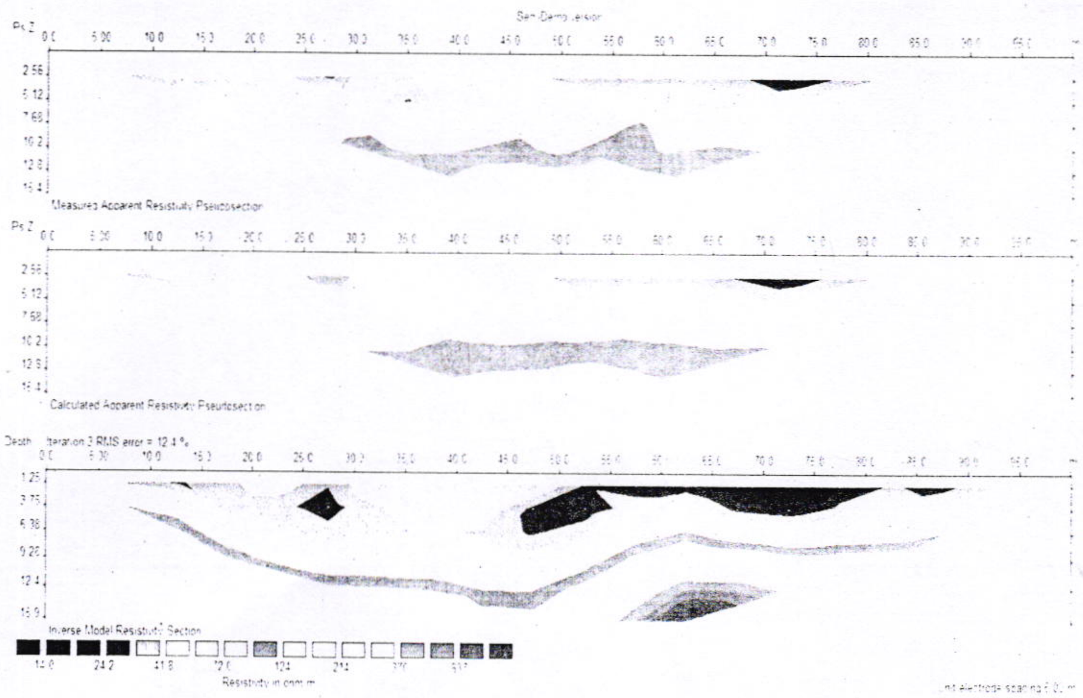

Fig.3b: 2D Inverse Model resistivity section for profile C2

Profile C3

From the C3 profile it is clearly indicated that the top layer is made up of highly conductive clay material (Fig.3c). The depth of the clay layer ranges from the surface to about 8m almost throughout the profile with resistivity value ranging from 76 Ωm to 141 Ωm. The second layer is the weathered basement rock unit, with resistivity range of about 195 Ωm to 400 Ωm and a depth range of about 9m to12m from 5m to 40m along the profile and 7m to 9m between 45m to 95m along the profile. The third layer which is only visible between 40m to 80m on the profile has a resistivity value above 400 Ωm.

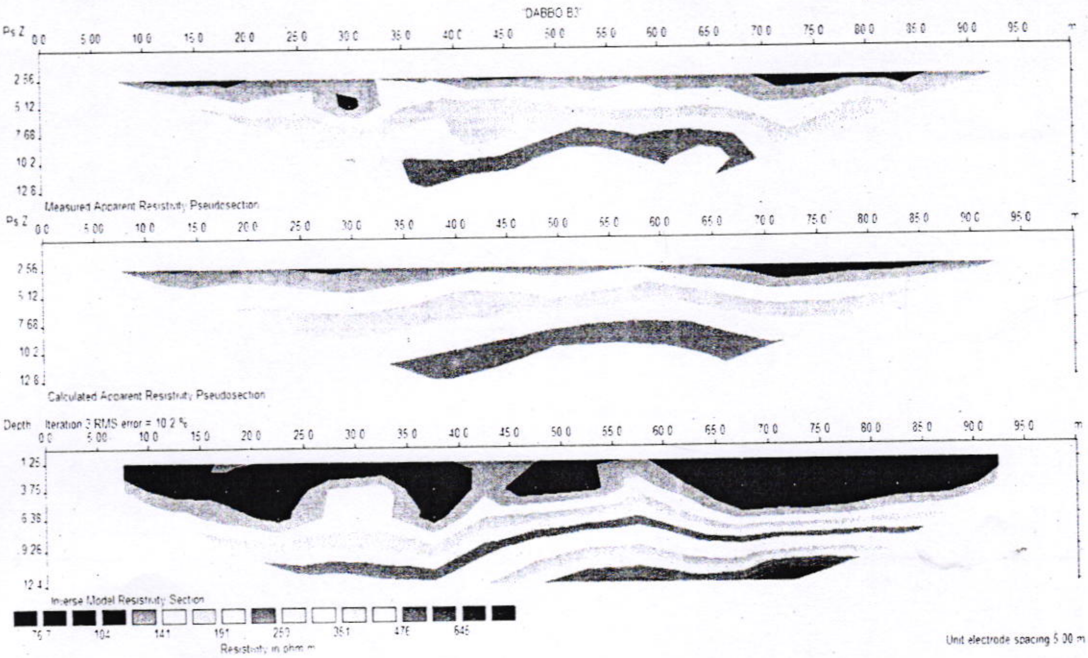

Fig.3c: 2D Inverse Model resistivity section for profile C3

The model sounding curves show three geo-electric layers which indicating four lithological units of lateritic soil, mottled zone, clayey soil and basement rocks at the different VES points along the established traverse. The mottled zone is a transitional layer that exists between the lateritic soil and clay soil. The curve types identified from the model sounding curves are H and HA types. The HA curve is the dominant curve type in the study area (Fig.4a to 4b).

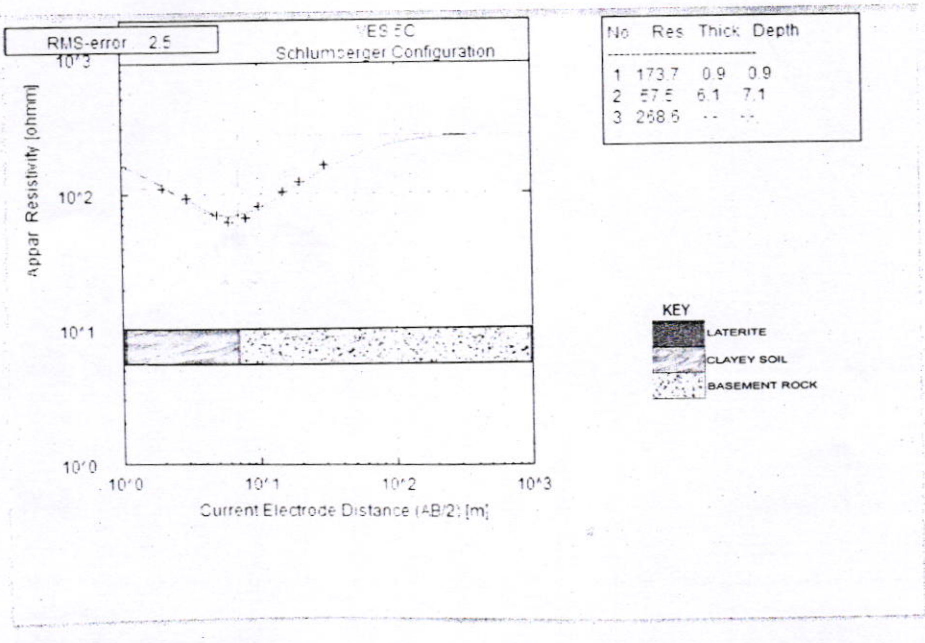

Fig. 4a: H Sounding Curve

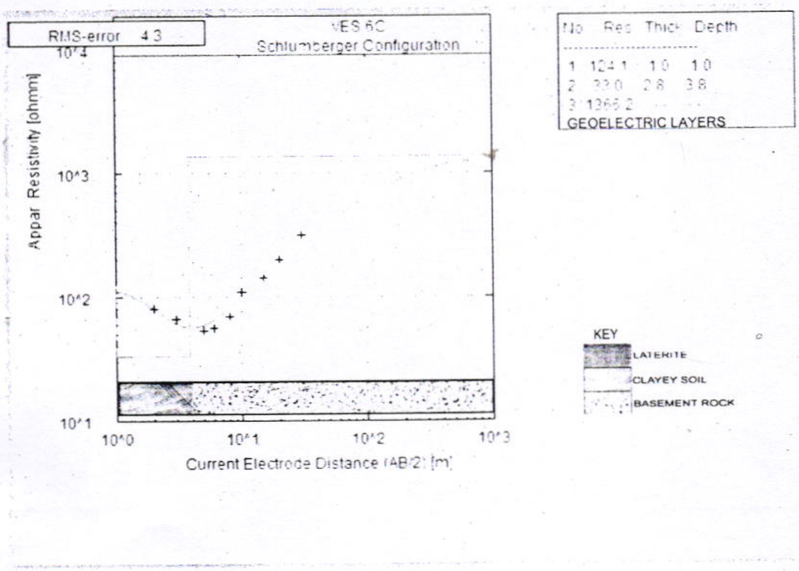

Fig.4b: HA Sounding Curve

The summary of the geelectric parameters are contained in Table 1. The geoelectric sections designed from the geoelectric parameters (Figs.5a to 5c), shows that the mottled zone and lateritic soil are the two formations that makes up the first layer at different VES points along the traverses. The resistivity of the mottled zone ranges between 74 Ωm to 96 Ωm to the depth of about 1.0m to 1.4m while that of laterite ranges between 120 Ωm to 174 Ωm to the depth of about 0.9m to 1.3m. The top layer is underlain by clayey soil characterized by low resistance. The resistivity value of this layer ranges between 18 Ωm to 86 Ωm with a thickness range of 2.8m to 8.0m to the depth of 3.8m to 9.0m. The ultimate layer is the basement rock unit with varying degree of weathering which has resistivity values above265Ωm to a fairly infinite depth. From the geoelectric sections the clay soil, show low resistivity values due to their charged surfaces and associated boundary layers of attracted ions, the resistivity value for clay is set at less than 100 Ωm.

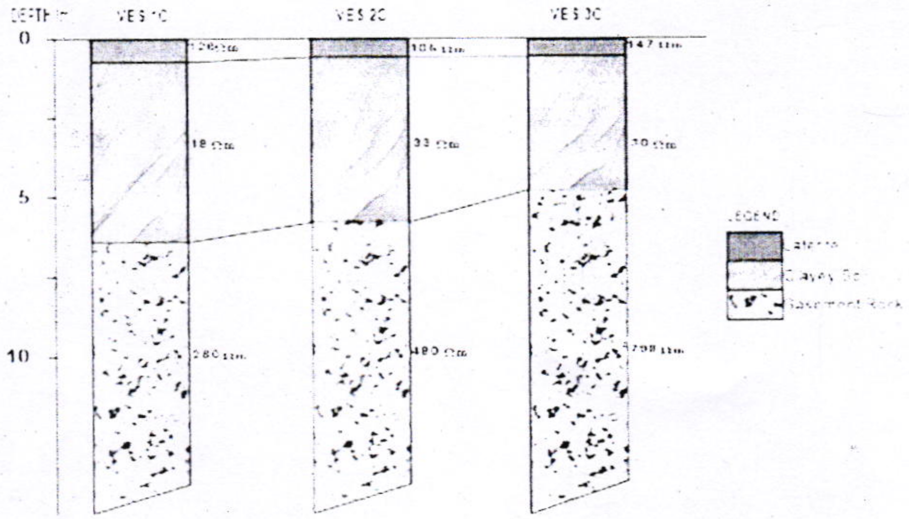

Fig.5aGeoelectric section 1C

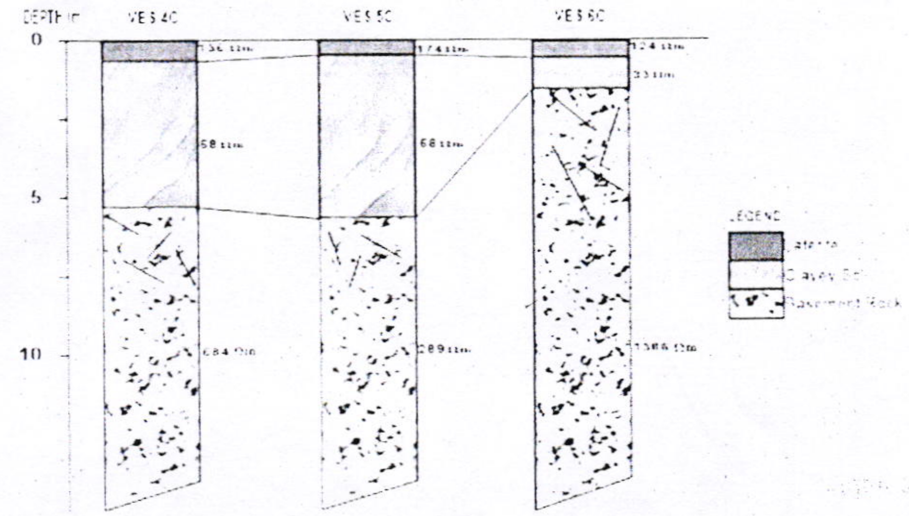

Fig. 5b Geoelectric section 2C

Table 1:Geoelectric parameters of the VES stations indicating Curve Types

LAYERS	Profile 1C			Profile 2C			Profile 3C		
	VES 1C	VES 2C	VES 3C	VES 4C	VES 5C	VES 6C	VES 7C	VES 8C	VES 9C
Layer1 ρ1/h1	141/0.9	93/1.4	380/0.7	64/O.8	130/1.0	100/1.1	89/1.5	118/1.3	99/1.3
Layer 2 ρ2/h2	71/7.2	113/7.4	112/6.0	22/4.4	68/5.7	60/7.3	86/5.2	83/6.3	72/8.0
Layer 3 ρ3/h3	300/∞	290/∞	863/∞	231/∞	245/∞	274/∞	504/∞	303/∞	265/∞
CURVE TYPE	HA	HA	HA	HA	H	HA	HA	HA	HA

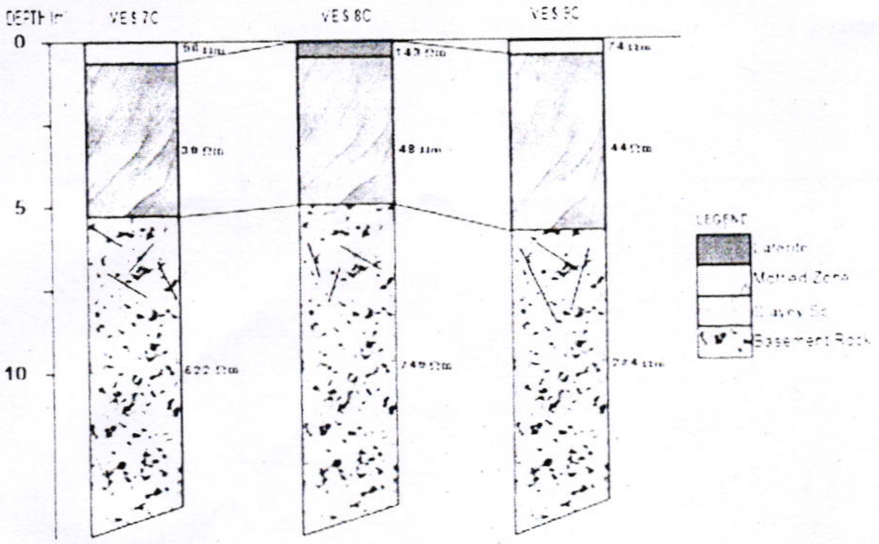

Fig. 5cGeoelectric section 3C

CONCLUSIONS

Subsurface electrical imaging has been successfully carried out within the basement complex of Minna north central Nigeria. All resistivity readings were taken within the excavated area of the investigated sites, with excavated depth ranged between 2m to 7m.The result of the 2D profiles and 1D VES are in agreement with each other. The 2D inverse model revealed three major lithologic layers, which includes the clay layer, the weathered basement rocks and the fresh basement rocks. Similarly the 1D VES indicates three to four lithologic layers, which include the top lateritic/mottled zone, underlain by the clayey layer which overlay weathered/fractured basement and finally the fresh basement rocks. The results indicate the clay layer thickness to be at the range of 2m to 5m while the depth to the layer ranges between 5.8m to 9m from the ground level. The findings from the interpreted results indicate that the clay soil within the study area is sufficient to serves as clay barriers for sanitary landfills.

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