ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 6 , June 2018

Structural Foundation Safety Assessment of Closed Solid Waste Dumpsite at AMINGO Junction, NNAMDI AZIKIWE Bypass, KADUNA, NIGERIA Using Geoelectric Resistivity Properties

SHOLADOYE MuniruOyewale, OYELEKE Raifu Brown, JIMOH Y. A,
TOMORI Abdulfatai Adeyinka

ABSTRACT: The results of 2-D DC resistivity imaging compares favorably well with those of the VES measurements, with regard to geotechnical-geophysical assessment of the contaminated soils within the dumpsite. The results of the combined investigation of leachate plume contamination of the ground water aquifer system and soil using 2-D resistivity and VES data is quite revealing. It shows that the surrounding soil and groundwater around the landfill may have been contaminated to depth exceeding 5 and 8m. Subsurface foundation geo-materials engineering competence for structural use can be qualitatively evaluated from layer resistivity: the higher the value of a layer resistivity, the higher the competence. The 2-D resistivity tomograms and the 1-D VES results of investigations for all the sites, revealed very low resistivity and IP of the dumpsite geo-materials generally, up to all the achievable depths (varying from 5 - 8m). Thus, it is diagnostic of a weak structural competence, capable of precipitating unsafe differential settlement and unfit to accommodate safely any structural foundation of civil engineering hardware or infrastructures. The delineated total thickness/depth of both the 2-D resistivity tomograms and the 1-D VES results are respectively 0.47 – 6.82 m and < 1.0 – 8 m (generally except in about few profiles that threw up 5 and 6 meters reachable depth) respectively. Thus, a signpost that geotechnical borings is required to further the depth of site investigation for possible deep structural foundation. Consequent upon the above, driven pile foundation is recommended for further geotechnical structural safety assessment. Meanwhile, a coat of bitumen round a driven pile foundation to be designed could insulate the pile material against the geo-environmental hazards that could arise from site corrosives and deleterious geochemical.

KEYWORDS: Closed Solid Waste Dumpsite, Geophysical characterization, Structural Foundation, Resistivity, Induced Polarization

I. INTRODUCTION

Population explosion with its attendant infrastructural expansion and shelter development especially in the urban cities is increasingly placing excessive pressure on the demand for good and usable land within the built environment. Thus, economic value of land accordingly jerks up, such that consideration for building structures on closed solid waste dumpsites or other previously abandoned structurally feeble ground becomes potently a necessity (Bouazza and KavazanjianJr, 2001).

The solid waste of closed dump site contains various complex characteristics; biodegradable and non-biodegradable (Pauzi, Omar, Huat and Misran, 2014; Rai and Mishra, 2016). Time dependent decomposition and onsite burning of solid waste reduces the materials to soil and non-soil. However, the geotechnical challenges such as substantial settlement potential and unconvincing structural bearing capacity associated with building on closed dumpsites require proper and critical evaluation of the subsurface foundation materials upon which the structure will be built.

Soil supporting a structure must have satisfactory load-carrying capacity (bearing capacity) and not droop (settle) unduly. Such conditions could scarely be attributed whatsoever to solid waste soil at dumpsites. In addition to the organic soils which mortify the geotechnical capacity of the soil matter, there are other environmental and soil contaminants inherently associated with solid waste sites. These are leachate and gaseous elements such as methane (CH4) and carbon dioxide (CO2) produced during the decomposition and degradation process of the waste transformation (Bouazza and KavazanjianJr, 2001; Rai and Mishra, 2016).The migration of these gases into buildings or confined spaces is possible and may have accumulated within the site materials to explosive concentrations. Methane gas at concentrations of between 5 to 15 % by volume in air can explode, whereas, concentrations greater than 15% is not explosive (Bouazza and KavazanjianJr, 2001).

Overwhelming factors such as heterogeneous composition and moisture content of solid waste, as well as evaluation of waste settlement is makes structural sustainability properties very complex and precarious. Also, High differential movement characteristic potential of dumpsite soil could pose a serious problems tostructural foundations leading unto failure manifestations in cracks, jamming of doors and windows, ruptured pipe lines and roads if not duly considered (Nehal, Chandresh andAtuk2011; Rai and Mishra, 2016).

Construction on closed solid waste dumpsite is a challenging task as the behavior of waste is complex and difficult to characterize. Heightened level of research and technology, leading unto successive and successful construction of buildings atop of brown field sites, such as closed solid waste dumpsites has greatly reduced the skepticism and fear over building of structures on them (Nicole, 2016).

The scenario painted above is typified in Kaduna south local government of Kaduna city. Civil engineering infrastructural development is gradually turning Kaduna conurbation into a megacity,Dogara and Auwal (2016).This is somewhat evidenced by the increased in traffic volume along NnamdiAzikiwe express road, the boost in economic activities and kind and class of structures built along this route. Ugwuanyi, (2016) indicated that the road was gradually constructed and used as bypass but has metaphorsized into a metropolitan road. Accordingly, several illegal and privately owned dumpsites along that road were closed; developed and utilized as carwash, motor technician sites etcetera, Dogara and Auwal (2016). The tendency for redevelopment into highly loaded building sites is gradually becoming manifest.

Construction on this site requires the provision of apposite foundation or a befitting ground improvement technique (Nehal et al, 2011) as suggested by site investigation. In other to ascertain these and ensure a safe design of structures on this site, if it must be used, proper site investigation, characterization and analysis is crucial.

The use of geoelectric resistivity survey (GRS) is increasingly gaining ground in geotechnical engineering (Ehirim et al, 2009, Nwokoma, Chukwu, and Amos-Uhegbu., 2015; Innocent, Christopher and Austin 2017)). This is on account of its aptness in revealing the subsurface characteristics and constituents of the underlying materials at a relatively reduced cost and time required in site investigation. Thus, it can serve as a non-destructive spot-on precursor appraisal of a candidate site to accommodate safely, a structural foundation. Normally, dumpsites are characterized by waste soil and other non- soil dump materials of various state and form. This work is therefore an attempt to investigate the geotechnical competence and safe foundation impression apposite for a chosen closed dumpsite at Amingojunction,NnamdiAzikiwe bye pass, Kaduna, Nigeria, using its geoelectric properties and environmentally corrosives chemical elements constituents.

II. LOCATION, CHOICE AND DESCRIPTION OF THE STUDY AREA:

Kaduna South Local Government (KSLG) area (Fig 1) was chosen for this study, because of its strategic location and features within Kaduna city, Kaduna state. The state is known as a relatively ancient city and the political and administrative capital of the defunct northern Nigeria. KSLG features many viable dumpsites.

This study was carried out at Amingojunction, between Abakwa and Nasarawa and along NnamdiAzikiwe bypasses (Fig 2). Geographically, the study site is located at a very close proximity to the bypass and is within 10°27'43" N and 7°25'38" E (10.4619^{0}N and 7.42722E). It served as disposal site for the two major municipal dweller's settlement patterns; Squatter and formal (Dogara and Auwal, 2016). The area coverage of the dumpsite is about 27 Sqm^2 and a waste fill height of about 8.5 m at his highest point(see Fig 2 and 3).

Geologically, the area under study falls within the Basement Complex of North Central Nigeria, which are mostly migmatite, granite gneiss, undifferentiated schists and porphyritic biotitegrantite (Aboh, 2009). The rocks of the area are mostly Precambrian in age and have been subjected to progressive stages of transformation; the older been metamorphosed sedimentary type, consisting of quartzite, muscovite schist, muscovite biotite schist, biotite gneiss, migmatite and marble while the younger is of igneous origin comprising of biotite granite, phorphyritic granite and few plugs of diorite, gabbro and syenite (Abdullahi, Ugbade, Abdullahi 2016). The Migmatic-Gneiss Complex which underlies most of the study area and hence characterized by spectacular exposure of well-defined Migmatite (Aboh, 2009), The study area lies within the Guinea Savannah belt, which experiences the tropical Savannah climate with two distinct seasons. The dry season normally begins in October/ November to March/April, while the wet season occurs between April/May to October/November (Aboh, 2009:Abdullahi, Ugbade, Abdullahi 2016)

Enquiries from residents around, revealed that the sites were previously low land ravines or old mine gully, resulting from their use as borrow pits for construction materials for the road and the other roads linking the bypass during the development. Thereafter, they were been filled up with refuse and subsequently closed with soil (controlled for reclamation).

The surrounding area of the non-engineered closed dumpsite is currently well developed particularly for housing and commercial purposes; multistoried buildings, factories and other heavy weight structures. And so there is a high propensity of highly loaded structures coming atop of the closed dumpsite with time.

III. METHODOLOGY

The Methodology of study is mainly hinged on 1D (One-Dimensional) Vertical Electrical Sounding (VES) as well as 2D (Two-Dimensional) Horizontal Resistivity Profiling (HRP) techniques. The HRP involves Electrical Resistivity (ER) Imaging and Induced Polarization (IP) Tomography, obtained from Res2Dinv computer software processed data, simultaneously generated from the sites

A. Field work/ Method of study:

The field work was accomplished in the month of February, 2017, which falls at the dry season. At this period, the probable interference by rain which could slow down the work is eschewed and also a good ground-electrode contact is guaranteed. The instruments used in the geoelectrical survey include resistivity meter (SA1000/ SA4000 ABEM Terrameter equipment), Geographic Positioning System (GPS), 12 Volts heavy duty motor battery with two connecting wires with crocodile clips, four hammers and four electrodes with rolls of wire, two rolls of 100 m rope each, Three rods for ropes (one central and two end ones), One big umbrella for shade, Data sheets and writing pen.

B. VES Techniques

The sounding was used to delineate the various lithologic units and depths of the waste soils and the corresponding geo-electric properties along the vertical sections of the dumpsites. Three (3) Vertical Electrical Sounding (VES) stations were occupied along the traverses established on each site as indicated in table 4, using the Schlumberger electrode array. The Schlumberger array (fig 5) is mostly used for VES surveys because of its logistic simplicity (Adagunodo et al,2014)

The VES interpretation results were used to generate geoelectric sections. Figure 4 shows the typical VES curves and the interpretation models generated by the use of Res2Dinv computer software.

C. TYPES OF VES CURVE

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 6 below:

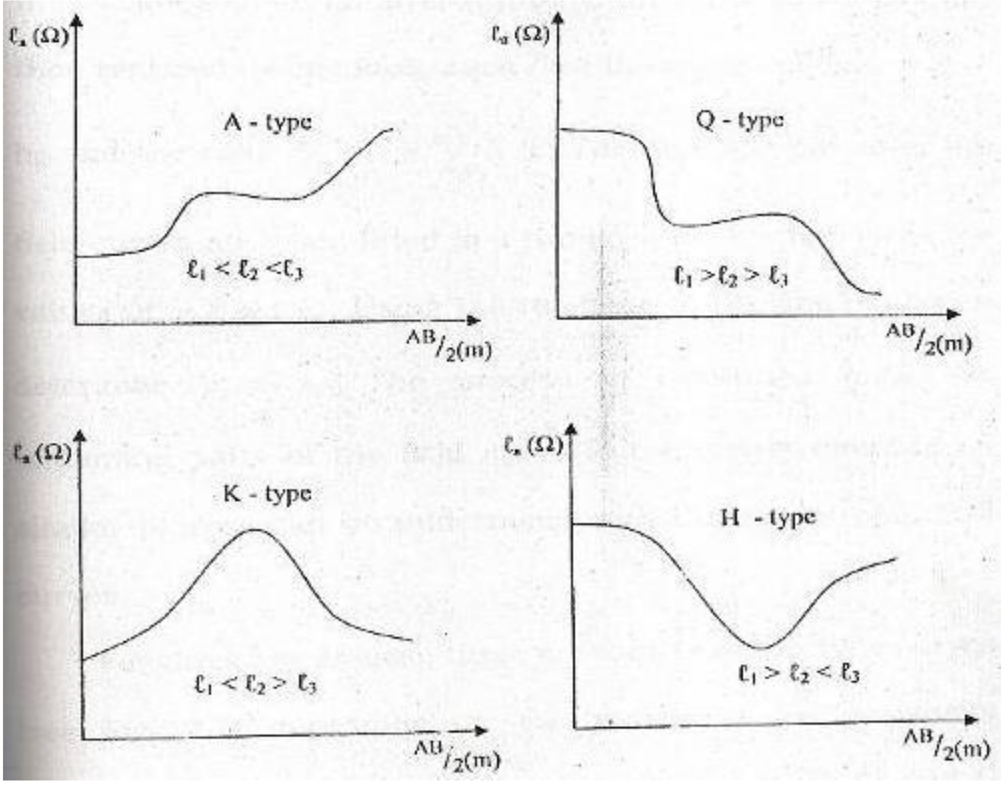


Figure 6: Typical Curves of Electrical Resistivity (VES) (Source: Ekeocha et al, 2012)

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. (Ekeocha, Ikoro&Okonkwo, 2012)
According to Ekeocha et al, (2012); Type H Curve shows that a low resistivity layer is sandwiched between two high resistivity layers typical of a three layer case (ρ1> ρ2< ρ3). Type A Curve shows that the resistivity of the layers is increasing. (ρ1<2 ρ< ρ3). Type K Curve shows that a high resistivity layer was sandwiched between two low resistivity layers. (ρ1< ρ2> ρ3). Type Q Curve shows that resistivity is decreasing with depth. (ρ1> ρ2> ρ3),

IV. ERI TECHNIQUES:

Also, the Electrical Resistivity Imaging (ERI) substantiates the result of the sounding as well as to determine the presence of leachate contaminants, spatial distributions of the waste soils and the corresponding geo-electric properties. Three (3) parallel traverses at 20m intervals, along the N-S axis, trending approximately in the W-E direction were, established on the study sites, starting from the beginning of the dumpsites. A Wenner electrode configuration at 2m inter-electrode spacing was used, employing the roll-along method. Combined resistivity- IP data were collected as 2D geoelectrical imaging with the ABEM Lund Imaging System. Also, the 2D (ER & IP-chargeability) data generated was inverted using the software package RES2DINV (Loke, 1997; Oyedele, Adeoti, Lukman, and Kamil, 2014).That, gave the production of the 2-D ER and IP tomogram in fig.8. The traverses length varies according to what the stretch allowed, as a result of developments of existing structures in around the site.A 2 m inter-electrode spacing wenner array electrodes configuration was used, owing to its high sensitivity to lateral in homogeneity, to provide a good idea of variation of materials in a continuum within the site of interest.

V. PRESENTATION AND DISCUSSION OF RESULTS

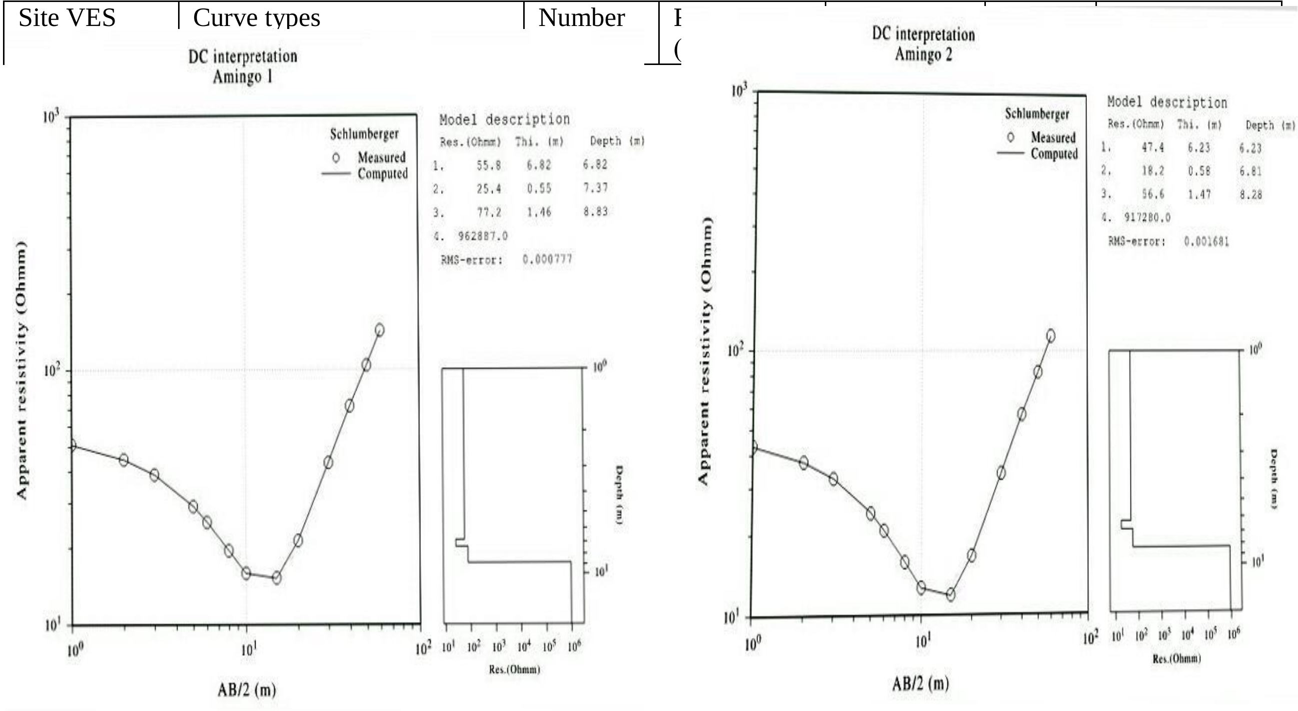
The field results, images and curves and the interpreted models (geo-electric sections) are presented in tables and figures below:

A. Vertical Electrical Sounding (VES)

The VES field results of the study are presented in both qualitative (curve shapes) and quantitative interpretations (in terms of layer resistivity, thickness and depth) as shown in Table 4.1 and fig 4.1 respectively.
The resistivity type curves identified include HA and QH. The numbers of subsurface layers delineated from the VES ranges are 4. Table 4 gives a summary of the interpretation results of the VES curves at the studied Site/locality.

Fig 4:Schlumberger Field curve

Table4. Quantitative interpretation of VES showing geo-electric layers parameters obtained from the deactivated dumpsites



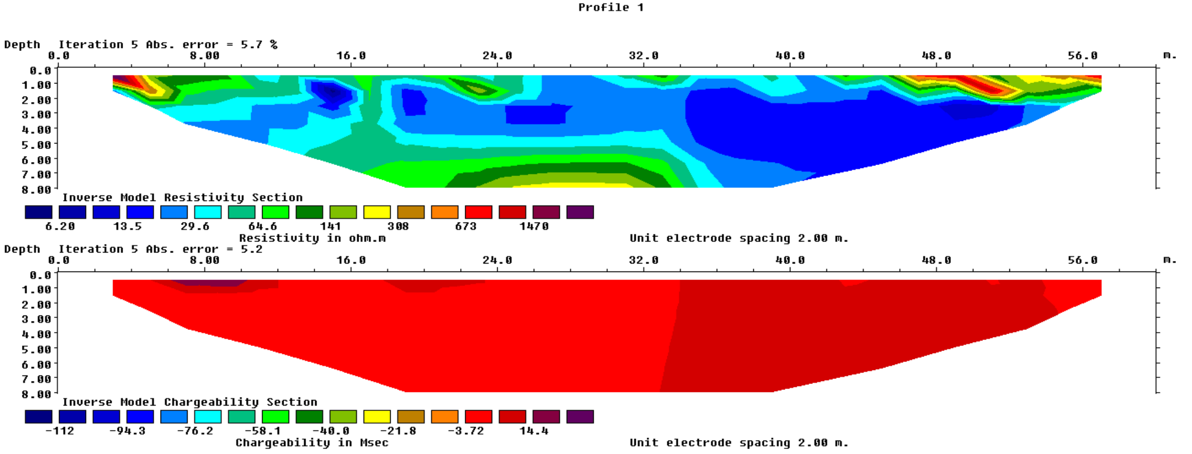
Site VES	Curve types	Number	I (			
AMINGO	HA	$P_1>P_2<P_3<P_4$	4	55.8 25.4 77.2	6.82 0.55 1.46	6.82 7.37 8.83	Silty Sand ClayeySand Fine sand
VES 1							
				962887			Below 8.83
VES 2	HA	$P_1>P_2<P_3<P_4$	4	47.4 18.2 56.6	6.23 0.58 1.47	6.23 6.81 8.28	Silty Sand Clayeysand Fine sand
				917280			Below 8.28

B. 2-D resistivity Imaging/Tomographs

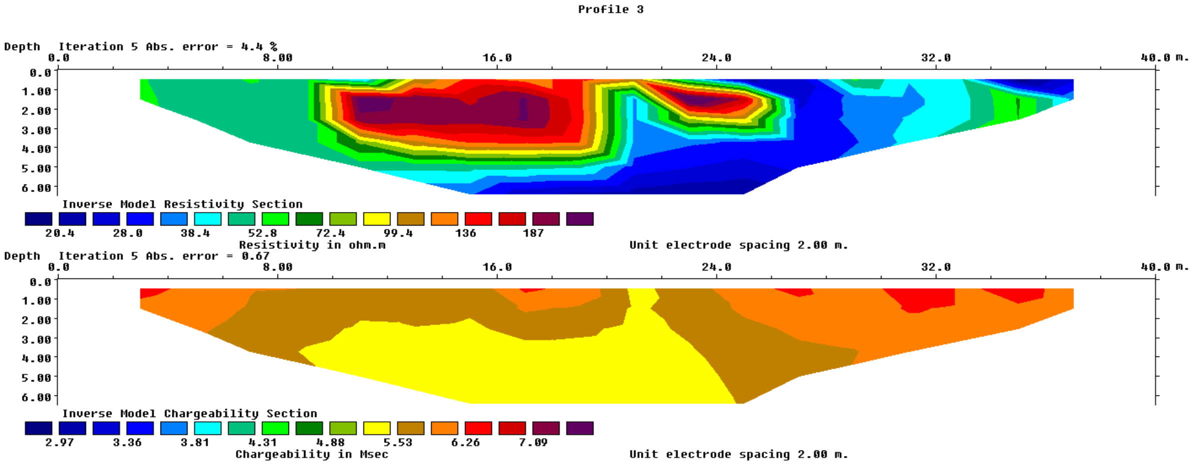
The geoelectric sections of the ERI for both resistivity and chargeability (2D-Models) are as shown in figs below;

AMINGO JUNCTION DUMPSITE 2D TOMOGRAPHS (PROFILE 1- 3)

Profile 1(One)



Profile 2 (Two)



Profile 3 (Three)

C. Discussion: VES and 2D geo-electric sections of Amingo Dumpsite:

The field curves and the interpreted models are presented in Figure 4. The interpreted geo-electric sections are shown in Table 4 and their results are presented in terms of resistivity, thickness and depth. Each VES station shows four (4) layer geo-electric sections and HA curve type. The 1st layer in both stations is a corroded waste soil diagnostic of silty sand with resistivity values of 55.8 and 47.4.3, thicknesses of 6.82 and 6.23 and up to the depth of 6.82 and 6.23 respectively. The 2nd layer in both stations is diagnostic of corroded waste soil clayey silt with resistivity values of

25.8Ωm and 18.2, thicknesses of 0.55 and 0.58 and up to a depth of 7.37 and 6.81 respectively. Third layer has a high resistivity value of 77.2 and 56.6 Ωm, thicknesses of 1.46 and 1.47 at the depth of 2.5m.The fourth layer in both stations whose depth could not be reached has an anomalous high resistivity values of 962887 and 917280Ωm respectively.These are zones of anomalously high resistivity, probably of gaseous nature containing methane (CH4), ammonia (NH4), carbon dioxide (CO2), and hydrogen sulphide (H2S) resulting from the biodegration of organic waste and leachate plumes of anomalously low resistivity containing organic matter, dangerous pathogens, and dissolved solids.

The resistivity values predominantly ranges between 10 and 100 ohmm, which is indicative of silty clay, silty sand and sand. And an indication of leachate plume accumulation in the overburden. The corrositivity of the site area is slight to moderate in view of the predominating resistivity value of 10 and 180 as indicated in table 2.5.The low chargeability or IP in fig 1 (b) is an indication of unsaturated condition of the dumpsite and as well confirming the sand, silt description of the waste soil and the variation of the chargeability points to a measurable concentration of metallic elements in the soil

In Profile one : some patches of dump material of resistivity value ranging between 150 and 1500 appearing at the left and right side atop of the dump area is revealed. The blue portion suggests a contaminated unsaturated dump material plume of resistivity value range of between 10 and 30.This is however surrounded by material of resistivity value of about 30, beneath which is a material of resistivity value of between 50 and 300,thus signalling an unsaturated silty sandy material.

In Profile two : A small portion at a central region of the study area, within the length of 10-20m and depth of about 3.5m having a resistivity value of between 100 and 200 signpost a leachate contaminated dump material of silty sand classification. This, however, flow through the dump at a depth of 1.5m and up to length of 25.5m. At the right hand side of the area between length of 0 and 9m up to a depth of about 5m. Thus, signaling an unsaturated clayey sand material of resistivity between 50 and 80.

In Profile Three : The left hand side portion of the section shows predominant resistivity values of between 150- 450 with some patches of dump material of resistivity value ranging between 950 and 5050 appearing at the left side atop of the dump area

VI. CONCLUSION

The results of 2-D DC resistivity imaging compares favourably well with those of the VES measurements, with regard to geotechnical-geophysical assessment of the contaminated soils within the dumpsite. The results of the combined investigation of leachate plume contamination of the ground water aquifer system and soil using 2-D resistivity and VES data is quite revealing. It shows that the surrounding soil and groundwater around the landfill may have been contaminated to depth exceeding 5 and 8m. Subsurface foundation geo-materials engineering competence for structural use can be qualitatively evaluated from layer resistivity: the higher the value of a layer resistivity, the higher the competence. The 2-D resistivity tomograms and the 1-D VES results of investigations for all the sites, revealed very low resistivity and IP of the dumpsite geo-materials generally, up to all the achievable depths (varying from 5 - 8m). Thus, it is diagnostic of a weak structural competence, capable of precipitating unsafe differential settlement and unfit to accommodate safely any structural foundation of civil engineering hardware or infrastructures.

The delineated total thickness/depth of both the 2-D resistivity tomograms and the 1-D VES results are respectively 0.47 – 6.82 m and < 1.0 – 8 m (generally except in about few profiles that threw up 5 and 6 meters reachable depth) respectively. Thus, a signpost that geotechnical borings is required to further the depth of site investigation for possible deep structural foundation. Even though some portion of the sites surveyed implied non corrosiveness, the predominantly low resistivity value ranges of 10 to of 100 ohm suggests Moderately Corrosive (MC) to Slightly Corrosive (SC) sites, up to the depth of investigation. Consequent upon the above, driven pile foundation is recommended for further geotechnical structural safety assessment. Meanwhile, a coat of bitumen round a driven pile foundation to be designed could insulate the pile material against the geo-environmental hazards that could arise from site corrosives and deleterious geochemical. Conducting geophysical surveys for every major brownfield redevelopment project in which the likelihood of past environmental impacts is possible allows for the rapid characterization of subsurface foundation materials. Thus, can help to guide site investigations through the advancement of soil borings or test pits. Anomalous areas as defined by the results of the surveys can be sampled to determine the presence of any environmental impacts, and allow for the calibration of various site materials to the geophysical signatures observed.

REFERENCES

[1]Joseph Olakunle Coker (2015),Integration of Geophysical and Geotechnical Methods to Site Characterization for Construction Work at the School of Management Area, Lagos State Polytechnic, Ikorodu, Lagos, Nigeria, International Journal of Energy Science and Engineering,Public Science Framework, American Institute of Science, Vol. 1, No. 2, pp. 40-48

[2]OyedeleKayode Festus, Adeoti, Lukman, Oladele Sunday and KamilAkintunde,(2014), Investigation of a Proposed Four Storey Building Sites Using Geophysical and Laboratory Engineering Testing Methods in Lagos, Nigeria, International Journal of Scientific Research in Knowledge, 2(2), pp. 83-91

[3]Wallace R.B (2011) Landfill redevelopment: Beneficial use and aftercare, URS Corporation, Seattle, Washington

[4]DogaraSandaTah and Auwal F. Abdussalam (2016), GIS Analysis in the Siting of Incinerators as a Panacea for Solid Waste Management in Kaduna State, Science World Journal (11)3,pp17-22

[5]RaiAjai Kumar, Mishra Brajesh, (2016), Geotechnical Properties Based Characterization of Closed Dumpsite: A Case Study of Lucknow City of Uttar Pradesh,International Journal of Innovative Research in Science, Engineering and Technology,2958-2963

[6]Ugwuanyi S. (2016), Kaduna Government thanks FG for handover of NnamdiAzikiwe,Ahmadu Bello roads.Daily Post(online)

[7]Pauzi NIM, Omar H, Huat BBK, and Misran H, (2014),Characterizations of Waste Soil of Open Dumping Area, Electronic Journal of Geotechnical Engineering “EJGE”

[8]Nehal G.D, Chandresh H.S and Atuk K.D. (2001). Cement Grouting: An Alternative Ground improvement, World applied Sciences Journal 12(8), IDOSIPublication, 1240-1244.

[9]Nicole Li, GIPENZ (2016), Design and construction of a commercial building on a closed municipal solid waste landfill in Takapuna, Auckland,Proceedings of the 11th ANZ Young Geotechnical Professionals Conference Queenstown, New Zealand, 25 – 28

[10]ICRCL-Interdepartmental Committee on the Redevelopment of Contaminated Land-, (1990), Notes on the development of and after-use of landfill sites, ICRCL Guidance Note 17/78,8thEdn

[11]Bouazza and KavazanjianJr, (2001), Construction on Former Landfills,.USA.Retrieved from faculty.engineering.asu.edu/kavazanjian/wp.../32_Construction-on-Old-Landfills, 1-18

[12]Jatau B. S., Fadele S.I. and Agelaga A. G.(2013), Groundwater Investigation in Parts of Kaduna South and Environs using Wenner Offset Method of Electrical Resistivity Sounding, Journal of Earth Sciences and Geotechnical Engineering, vol. 3, no. 1, Scienpress Ltd, 41-54

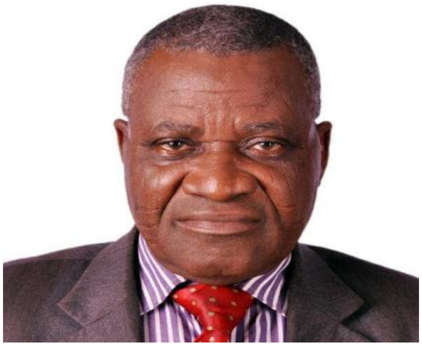
[13]Abdullahi N.K, Ugbade S.F., Abdullahi M.A.(2016), Engineering Geophysical Study of the Convocation Square, Kaduna State University,Science World Journal Vol 11 (3)

[14]Aboh, H.O. (2009), Assessment of the Aquifers in some selected villages in Chikun local Government Area, Kaduna State, Nigeria. Science World Journal Vol 4 (2)

AUTHOR’S BIOGRAPHY

1. Sholadoye Muniru Oyewale (PhD in view,MNSE,MNGA) is a Nigerian Chattered Civil Engineer and a chief lecturer in Kaduna Polytechnic,Kaduna, Nigeria. His research interest is in the area of geotechnical engineering dealing with foundation geo materials safety analysis.

2. Oyeleke Raifu Brown (PhD, MNSE, MNICE) is a Nigerian chattered civil engineer and a chief lecturer in Kaduna Polytechnic, Kaduna,Nigeria.His research interest is in environmental geotechnics with specialisation in landfill liner.



3. Jimoh Yunusa Alaro (FNSE, FNICE, FNGA) is a Nigerian Chattered Civil Engineer and a Professor of highway and geotechnical engineering in University of Ilorin, Kwara State,Nigeria.

4. Tomori AbdulFatai Adeyinka (MSc) is a chartered economist and chartered researcher. He is a research development expert at Biohistoculture Research Center, a premier research and communications consultancy. He also work as a part time Lecturer at the Offa Metropolitan College of Management and Technology