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GEOPHYSICAL ASSESSMENT OF LEACHATE PLUME AROUND SELECTED DUMPSITES IN BENIN CITY, EDO STATE, NIGERIA

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ABSTRACT

This paper is focused on the geophysical assessment of leachate plume around selected dumpsites in Benin municipality. The basis of this investigation was centered on the envisaged impact of solid waste dumping on its recipient soils which could be evident from its delineated leachate plumes. Actual measurements were carried out by transmitting electric current into geological layers of located soils in and around the dumpsites. The measurements obtained were transmitted into several two dimensions (2-D) imagery of electrical resistivity tomogram with the aid of proprietary software (RES2DINV). The analysis of these tomograms revealed evidence of pollutants leached into the soil geological strata for all the dumpsites studied. They were characterized by different colored portions from which bluish colored zones implied regions of low resistivity and leachate plume indicating groundwater contamination. Other suspected contaminants in the tomograms were landfill gases and chemical waste. The chemical constituents of these identified polluted regions could not be ascertained from the electrical resistivity tomograms. Further geochemical investigations of the dumpsites will be required in this regards.

1. INTRODUCTION

Benin City, the capital city of Edo State, Nigeria is highly urban centre with a population of over five million people. The economic main stay of the inhabitants is farming (Imasuen and Omorogieva, 2013). Also, commercial activities are predominant while industrial and manufacturing are diminutive. Although, there are no engineered landfills, solid waste generated within the city are usually dumped at excavated earth sites called local dumpsites

(Azeez et al., 2011). These dumpsites are spread across the city but mainly located at the city gateways; Important examples include Asoro dumpsite, Ikhuen (or Lagos-Benin by-pass) dumpsite, Sokponba dumpsite and Iriri-Ogba dumpsite. Wastes that are often found in these dumpsites are normally in solid forms which range from natural products to synthetic materials. Broader categories of these solid wastes are biodegradable and non-biodegradable materials. The former includes food materials, fruits, garden wastes etc, and the latter consists of metals, plastics, electronics glass wares etc (Butu and Mshelia, 2014).

Solid waste is an unused, non liquid (or non gaseous) materials generated from combined residential, industrial, agricultural and commercial activities (Hoornweg and Bhada-Tata, 2012 and Pillai et al., 2014). The reports of Schueler and Mahler (2007) and Kaushal et al. (2012) noted with one accord that the characteristics of solid waste produced differ for different countries, with more organic components being evident in the waste streams of developing countries than developed ones. The studies further opined that the waste characteristics changes slightly with geographical region and season. The general composition of solid waste generated in Nigeria is reported to be about 70% organic and 30% inorganic matter (Ejidare, 2014). In addition, factors that can influence the type and volume of waste generated in a region have been identified as population size, technological advancement, state of national economy and socio-economic status of the populace (Banar et al., 2009).

An indicator for measuring environmental performance is an appropriate and sustainable waste management policy which must be implemented in accordance with best practices (Tchobanoglous et al., 1993; Bhalla et al., 2013). In the absence of proper environment policies, the consequences will be indiscriminate dumping of wastes, unscientific management of such wastes, exposure of the populace to health hazards and serious ecological problems (Ogbuene et al., 2013). Evidences abound that support the fact that open dumping of solid wastes into excavated soils (or dumpsites) without proper regulation can be harmful to the environment (Aderemi et al., 2011 and, Ramaiah and Krishnaiah, 2014). Toxic substances such as heavy metals, recalcitrant organics and salts can fluidize and migrate by seepage within the top and sub-soil geologies to form leachate plumes (Olayinka et al., 2014). There may be other evidences of sub-soil contamination which could include natural gas and chemical waste (Buteh et al., 2013). These are strong evidences of pollution which can affect groundwater purity, soil fertility, aquatic lives and green vegetation (Abdus-Salam, 2009).

Therefore, the focus of this paper is on the application of geophysical technique for the preliminary assessment of the level of contamination of soils around the Benin City dumpsites. This method will give theoretical insight into the level of contamination these dumpsites had impacted on its surrounding soils from both vertical and horizontal orientations. The generated results will be in the form of tomograms showing resistivity measurements for the geological strata; which can be used to predict the degree of dumpsite soil contamination and also to differentiate one dumpsite from another.

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2. MATERIALS AND METHODS

2.1. Materials

The main material used for this geophysical study is an assembly of the ABEM Terremetre SAS 2000B apparatus (resistivity meter). Other components of the assembly are DC power source (12 V battery), cables (potential and transmission), metal electrodes, industrial tape (30m), geologic hammers, RES2DINV special software (in MS environment) and a printer.

2.2. Study Area

The locations of the two dumpsites selected on the basis of central government and community involvement in waste management are presented in Figure 1.

2.2.1. Ikuen dumpsite

Ikuen dumpsite is situated in Ikuen community, along Lagos-Benin by-pass, Uhunmwonde Local Government Area of Edo State. It occupies an approximate twelve hectares of land. The site is bounded by Lagos-Benin by-pass expressway (East), residential buildings (South and West) and block industry (North). The site is fenced with a representative of Edo State waste management agency on ground. According to residents around the facility, the dumpsite is about thirteen years old and its origin is attributed to site excavation for the construction of the Lagos – Benin By-Pass. Waste dumping started with community dumping before the government took over and then fenced it. However, organized waste segregation/sorting is absent except those by local waste scavengers.

2.2.2. Asoro dumpsite

Asoro community dumpsite is situated in Uzebu community, Asoro, Oredo Local Government Area of Edo State. The site is a product of gulley erosion and bounded by residential houses, churches and water stream. This dumpsite is owned and operated by the community. It serves as both refuse and sewage dumps. The dump is completely open, without any form of access control. Again, like every conventional open dumpsite, all kinds of domestic waste (including sewage) are housed there. Activities of local scavengers seeking plastics and other recyclable materials are higher in this site.

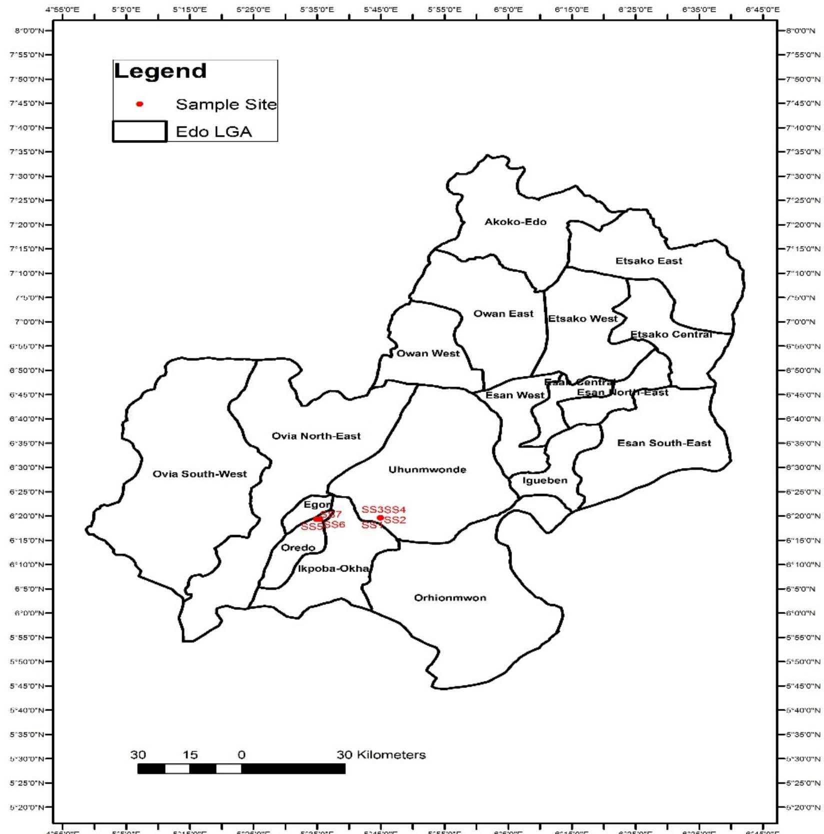

Figure 1: Map of the study area

2.3. Methods

The measurements were carried out in the dumpsite using an array of four electrodes. Two of the electrodes aided the potential difference (ΔV) distribution that arose when electric current was transmitted into geological layers through two other electrodes. The industrial cable was used to mark the intervals of 5 m along a 100 m total distance to be covered around the dumpsite, while pegs were inserted as guides. The electrodes were planted at 0, 5, 10 and 15 m marks, and electric current was then injected through the outer pair electrodes (0 and 15 m marks). The resulting potential difference was recorded from the screen of the measuring device. This procedure was repeated with the electrodes planted at 5, 10, 15 and 20 m marks etc until the entire length was covered.

Figure 2: ERT data acquisition

The electrodes were moved from one end of the line to the other in a systematic manner depending on the prevailing spacing to achieve continuous horizontal resolution of the subsurface. The measured resistances R (Ω) along each traverse were converted to apparent resistivity ρ_a (Ωm) using the Ohms law derivation ($R=\Delta V/I$) (Dahlin, 2001). The measured data were processed using proprietary software (RES2DINV) to plot resistivity measurements against soil depth, thereby given tomography information on estimated resistivity for subsurface formations penetration in both vertical and horizontal orientation.

3. RESULTS AND DISCUSSION

The results obtained are presented in Figures 3 to 7 and these represent electrical resistivity tomogram (ERT) for the investigated dumpsites as well as that of the control profiles (conducted 1 km away from the dumpsite). Figures 3 and 4 are the ERT for Lagos-by-pass: N-S and E-W, Figures 5 and 6 for Asoro community and Figure 6 is the control ERT. The electrical resistivity tomography (ERT) results (Figures 3 to 7) for the dumpsites under study were generated based on the parameters of soil depth, horizontal distance and soil resistivity. The bluish portion of the tomogram showed zone of low resistivity (i.e. probable leachate plume), while purple to brownish portion showed zone of high resistivity (i.e. probable landfill gas or chemical waste) while the yellow portions showed zone of water bearing sands. Evidences of seepage of leachates into soil formation change its pH thereby resulting in metal dissolution and reduction in resistivity of the soil media. Low values of resistivity in soils are strong indication of ground water contamination.

The ERT Profile 1 for N-S direction (Figure 3) for the Lagos–Benin By-Pass dumpsite showed low resistivity zones (<287 - 689 Ωm), indicated by bluish scheme near the surface with depths between 1.28 to 9.0m. Evidence of these low resistivity zones are predominantly prevalent in horizontal sections between 0 -30m, 50m and in transverse sections between 43 –

100 m with corresponding depths of 1.28m to 6.45, 9.0 and 1.28 m to 6m respectively. These bluish sections are interpreted to be possible contamination by leachate plume mixed with decomposing waste, which is an indication of pollution of surrounding soil.

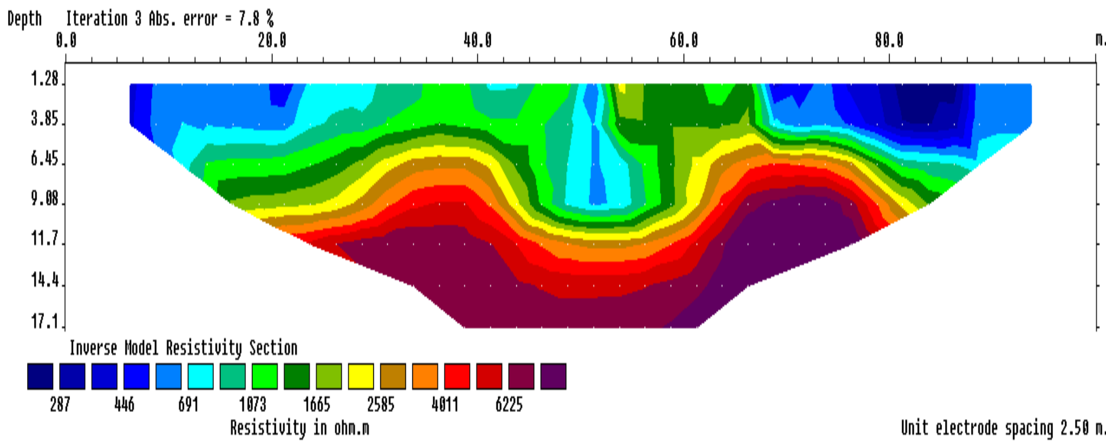

Figure 3: Lagos by-pass dumpsite Tomogram (N-S)

The next underlying zones are isolated zones with mixed and sandwich spectrum of moderate resistivity's (<1879 – 2385 Ωm) existing at depths between 6.45 m to 11.7 m. Soil materials in these zones are interpreted as sands of varying sizes, thicknesses and moisture and delineated as water bearing sand (Samouelian et al., 2005, Ehirim and Ebenro, 2013). Below the water bearing sand zone are another isolated zones of high resistivity's (≥6225 Ωm and above) at depths 11.7m downward. These zones are interpreted to have high resistivity indicated by evidence of gaseous chemical compounds such as methane (CH_4), ammonia (NH_4), carbon dioxide (CO_2), and hydrogen sulphide (H_2S) or landfill gases and other by products (Ehirim et al., 2009).

The ERT profile 2 in the E-W direction (Figure 4), showed low resistivity zones (<284 - 689 Ωm) predominantly bluish spectrum isolated near the surface with depths between 1.28 to 6.45 m. These zones are predominant horizontally between 58 m to > 90 m traverse due east. Similar inference of Figure 3 can also be drawn for this case i.e. contaminant leachate plume mixed with decomposing waste. Next to this zone are lateral sections (18 m to 45 m) with predominantly orange colored portion zones of resistivity (< 3135 Ωm) between depth 7.0 to 17.1 m making a V-shape projection at 50 m of the transverse and continued making an oval shape about 2m thickness. Also, along the transverse between 62 to 80 m and depths 13 m, a very high resistivity zones (≥9351 Ωm) suspected to be endowed with chemical compounds of gaseous nature similar to profile 1 (N-S): methane, ammonia, carbon dioxide and hydrogen sulphide (H_2S) or landfill gases and other byproducts.

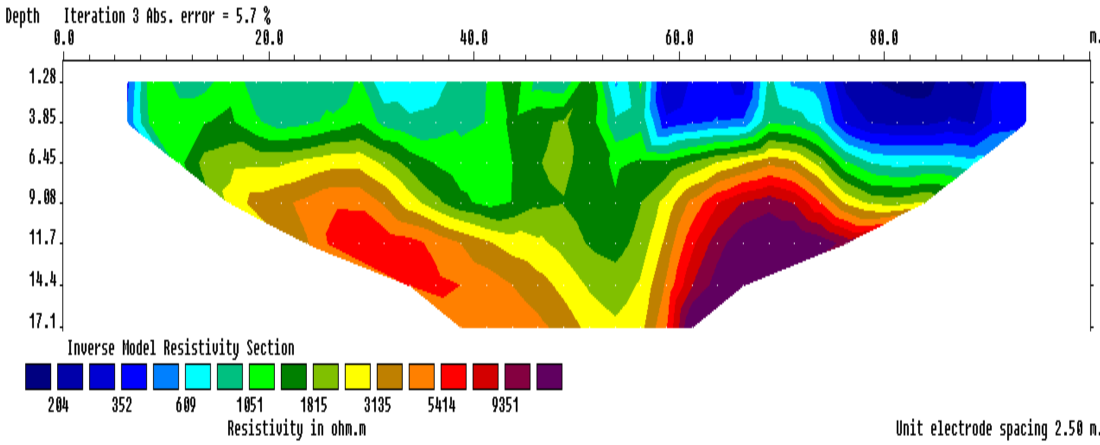

Figure 4: Lagos by-pass dumpsite tomogram (E-W)

Asoro community dumpsite is located Westward of the Ogba river and along the Southwest axis of Gelegele river. From the ERT profile 1 (Figure 5), the transverse is about 6 m from the edge of the dumpsite. Evident are isolated zones of moderate resistivity structures (>886 Ωm) with bluish-green portion having depth between 1.28 to 17.14 m which are delineated along the length of the entire section. The most prominent of these structures occur to the south of the section. These structures are interpreted to be the same high resistive chemical compounds already delineated in the other previous profiles. They might have been displaced to the topmost part of the entire section, probably by the more dense fluids below (Sudha et al., 2009, Samouelian et al., 2005) However, an oval shaped of very low resistivity zone (<1.38 Ωm) with depth between 11.7 to 17.1 m along the horizontal length 50 to 81 m was also observed. These structures are indications of possible leachate plume plunges into the soil, and a confirmation of possible interaction of the leachate plume with the ground water aquifer (Samouelian et al., 2005)

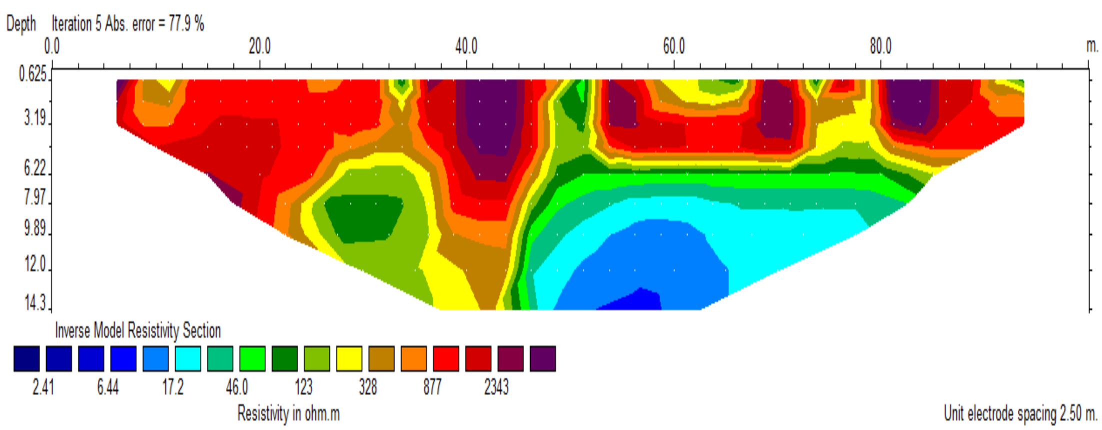

Figure 5: Asoro dumpsite tomogram 1

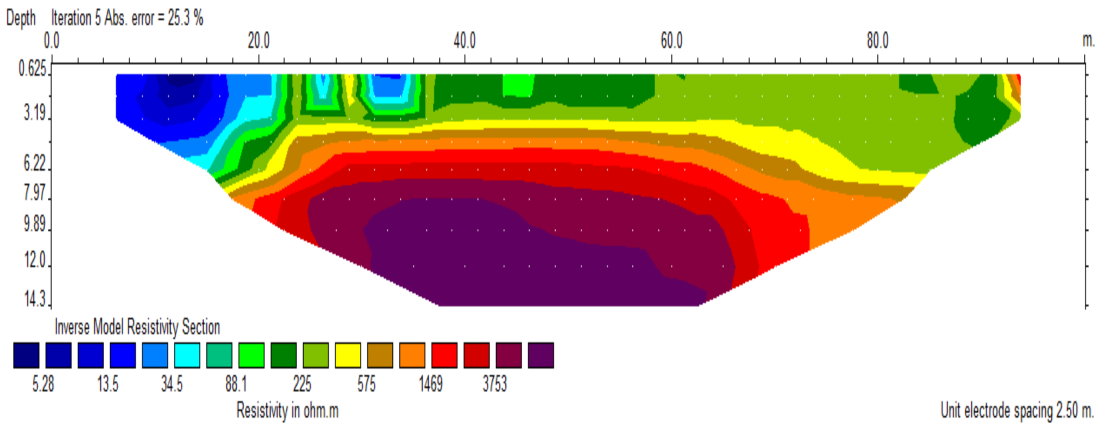

Figure 6: Asoro dumpsite tomogram 2

The ERT profile 2 for Asoro dumpsite transverse about 4 m from the edge of the dumpsite (Figure 6). Isolated zones of low resistivity structures (<34.5 Ωm) with depth between 0.625 to 6.22 m were delineated along the length 7 to 21 m of the section. These bluish portions stretches to indicate probable contaminant leachate plume mixed with decomposing waste. Adjacent to this bluish section is an oval shaped of purple - reddish portion of very high resistivity (>3753 Ωm), interpreted as chemical compounds containing natural gases similar to that of Lagos–Benin By- pass profiles. They have been displaced to the bottom part between the depth 6.22 m downward and length 22 to 63m of the section which evidence of probable landfill contaminated materials in contact with the water is bearing aquifers, also an indication of possible ground water contamination (Grellier et al., 2005).

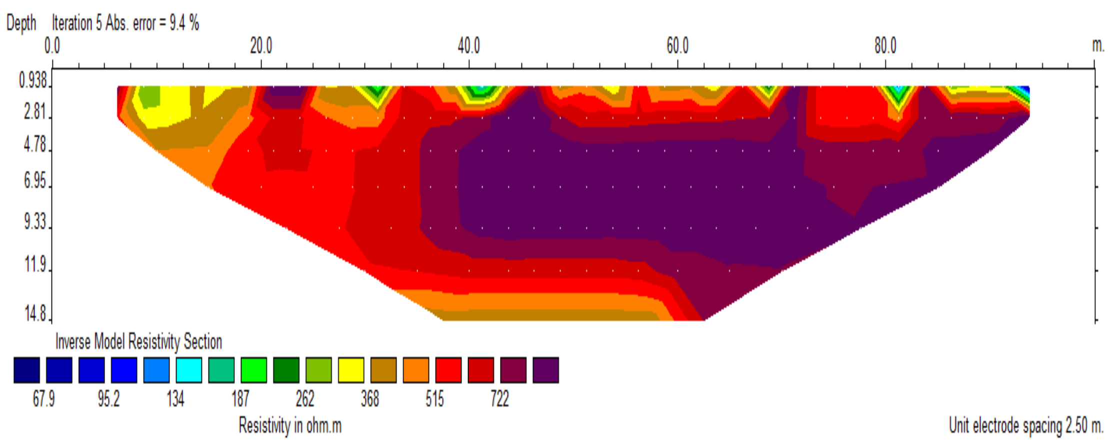

Figure 7: Control tomogram

Figure 7 is a tomogram measured at 1 km away from Asoro community dumpsite. It showed isolated zones of moderate resistivity structures (>722 Ωm) with depth between 2.81 to 11.9 m were delineated along the length 39 m to the end of the entire section. These structures are interpreted to be probable landfill gases which are suspected to have migrated to the area. Evidence of groundwater contamination due to the presence of water bearing structure of low resistivity is observed at the bottom of the profile. The residence around the profile had orally complained of foul odor in their borehole water which is evidence of contamination.

4. CONCLUSION

The results of the geophysical investigation of the selected dumpsites in Benin City using 2 D resistivity imaging of ERT analysis showed evidence of probable leachate plume contamination of soil and groundwater in the study areas as well as in the control point. These leachate contaminants are products of digested solid wastes that have accumulated in the soil strata because of proximity to dumpsite location. These findings corroborate the works of Ehirim et al. (2009) which reported that MSW leachates are characterized by high ion concentrations and low resistivity. However, the chemical constituents of the pollutants identified in the dumpsites and its environs cannot be evaluated from the ERT reports, but geochemical analytical methods can provide detailed insight into their chemical nature.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Abdus-Salam, N. (2009). Assessment of Heavy Metals Pollution in Dumpsites in Ilorin Metropolis. *Ethiopian Journal of Environmental Studies and Management,* 2(2), pp. 334-339

Azeez, J.O., Hassan, O.A. and Egunjobi, P.O. (2011). Soil Contamination at Dumpsites: Implication of Soil Heavy Metals Distribution in Municipal Solid Waste Disposal System: A Case Study of Abeokuta, Southwestern Nigeria. *Soil and Sediment Contamination: An International Journal*, 20, pp. 370–386.

Banar, M., Ozkan, A. and Altan, M (2009): Modelling of Heavy Metal Pollution in an Unregulated Solid Waste Dumping Site with GIS. *Research Journal of Environmental and Earth Sciences*, 1(2), pp. 99-110.

Bhalla, B., Saini, M.S. and Jha, M.K. (2013). Effect of age and seasonal variations on leachate characteristics of municipal solid waste landfill. *International Journal of Research in Engineering and Technology*, 2(8), pp. 223-232.

Buteh, D.S., Chindo, I.Y., Ekanem, E.O. and Williams, E.M. (2013). Impact Assessment of Contamination Pattern of Solid Waste Dumpsites Soil: A Comparative Study of Bauchi Metropolis. *World Journal of Analytical Chemistry*, 1(4), pp. 59-62.

Butu, A.W. and Mshelia, S.S. (2014). Municipal Solid Waste Disposal and Environmental Issues in Kano Metropolis, Nigeria. *British Journal of Environmental Sciences,* 2(2), pp.10-26.

Dahlin, C. (2001). The development of DC resistivity imaging techniques. *Computer and Geoscience*, 27(9), pp. 1019 – 1029.

Ehirim, C.N and Ebenro J.O. (2013). 2-D Electrical resistivity monitoring of a municipal solid waste dumpsite in Port Harcourt, Nigeria. IOSR *International Journal of Environment Science and* Technology, 2(5), pp. 29-34.

Ehirim, C.N. Ebeniro, J.O. and Olanegan, O.P (2009). A Geophysical Investigation of Solid Waste Landfill Using 2-D Resistivity Imaging and Vertical Electrical Sounding Methods in Port Harcourt Municipality, Rivers State, Nigeria. *Pacific Journal of Science and Technology*, 10(2), pp. 604 - 613

Ejidare, E.O. (2014). Methane Emission from Municipal Solid Waste in PortHarcourt, M.Eng Thesis, University of Port Harcourt, Nigeria.

Grellier, S., Bouye, J.M., Guerin, R., Robain, H. and Skhiri, N. (2005). Electrical resistivity tomography (ERT) applied to moisture measurements in bioreactor: principles in situ measurements and results International workshop 'Hydro-physico mechanics of landfills' Grenoble 1 University, France.

Hoornweg, D and Bhada, T.P (2012). 'What a Waste: A Global Review of Solid Waste Management' World Bank's Urban Development and Local Government Unit of the Sustainable Development Network.

Imasuen, O.I. and Omorogieva, O.M. (2013). Comparative study of heavy metals distribution in a mechanic workshop and a refuse dumpsite in Oluku and Otofure Benin City, Edo State, Southwestern Nigeria. *Journal of Applied Science and Environmental Management*, 7(3), pp. 425-430.

Kaushal, R. K., Varghese, G. K. and Chabukdhara, M. (2012). Municipal Solid Waste Management in India-Current State and Future Challenges: A Review. *International Journal of Engineering Science and Technology*, 4(4), pp. 203-209.

Samouelian, A., Cousin, I., Tabbagh, A., Bruand, A., Richard, G. (2005). Electrical resistivity survey in soil science: a review. *Soil & Tillage Research* 83, pp. 173–193.

Schueler, A.S. and Mahler, C.F. (2007). Soil Contamination Caused By Urban Solid Waste Leachate , Proceedings Sardinia 2007, Eleventh International Waste Management and Landfill Symposium, S. Margherita di Pula, Cagliari, Italy; 1 - 5 October 2007, CISA, Environmental Sanitary Engineering Centre, Italy

Sudha, K., Israil, M., Mittal, S. and Rai, J. (2009). Soil characterization using electrical resistivity tomography and geotechnical investigations. *Journal of Applied Geophysics*, 67(1), pp. 74-79.

Pillai, S., Anju, E. P., Sunil B.M. and Shrihari S. (2014): Soil Pollution near a Municipal Solid Waste Disposal Site in India. International Conference on Biological, Civil and Environmental Engineering (BCEE-2014) March 17-18, Dubai (UAE)

Tchobanoglous, G., Theisen, H. and Virgil, S. (1993). Integrated Solid Waste Management. McGraw-Hill, New York.