INTEGRATED GEOPHYSICAL TECHNIQUES TO DELINEATE THE IMPACT OF DUMPSITE ON SOIL AND GROUNDWATER IN THE VICINITY OF IJAGUN OGUN STATE, SOUTHWESTERN NIGERIA

Supported by tetfund TERTIARY EDUCATION TRUST FUND

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Received: August 23, 2021 **Accepted:** September 30, 2021

Abstract: The impact of leachate produced from waste on the soil and groundwater was studied in this research. Geophysical methods involving very low frequency (VLF), vertical electrical sounding and 2D electrical resistivity tomography (2D ERT) was adopted to investigate the impact of leachate on the geologic materials. Five traverses of the VLF survey were carried out at the study area to locate possible conductive zones and vertical electrical sounding coupled with 2D ERT on the established conductive zones. The VLF field data were analyzed using the Karous Hjelt and Microsoft excel software, WinResist for the VES and Res2DInv was used to analyze the 2D ERT data. The VLF result of the study area shows that few conductive zones even though the method was adopted as a reconnaissance method. The lithological unit acquired from the electrical resistivity result revealed topsoil, leachate infiltrated stratum, wet sand/ dry sand and sandy clay. The topsoil has resistivity value ranging from 12-895 Ωm, leachate infiltrated stratum having resistivity value ranging from 8 – 79 Ωm, dry sand with resistivity value of 149 – 4058 Ωm and sandy clay with resistivity value ranging from 752-1316 Ωm. The result of the integrated methods shows that larger portion of the dumpsite is polluted as a result of the permeable materials. From the results obtained, it shows that the entire dumpsite is not polluted yet, but may get polluted in future.

Keywords: Leachate, groundwater, vertical electrical sounding, very low frequency, contaminant

Introduction

The hydrosphere is the part of a planet that is mainly composed of water. Rivers, lakes and oceans are also included in the hydrosphere. It is the watery part of the planet including vapour that float above the earth's surface and the underground water. However, groundwater constitutes little percent of the hydrosphere (Edward *et al*., 2014), yet it is an important source that serves as a vital source of freshwater fundamental to the continuous existence of life. There are many threats to groundwater resources in which landfills or dumpsites is not an exception (Carpenter *et al*., 1990). In a developing country like Nigeria, lack of portable water remains serious challenge. Over the years, there has been increased in environmental pollution which has affected human health especially those living close to the vicinity of the dumpsite as a result of polluted groundwater. When the waste is dumped after sometime, it gets decomposed and form a liquid called leachate. It is the leachate that percolates through the underlain materials to pollute the groundwater (Fig.1). Poor management of solid waste materials leads to possible disastrous environmental and health hazards such as periodic epidemic, infectious diseases and water borne diseases (Adewuyi *et al*., 2014; Adebayo *et al*., 2015). This contamination also gradually destroys the soil meant for agricultural purposes. Some micro-organisms for example protozoa, algae and fungi from the waste dumped can also serve as threat to the environment (Baldursson and Karanis, 2011).

Contributory factors of groundwater contamination can be classified as geological, climatic or anthropogenic. The geological factors include the composition, texture, the protective capacity and the petro-physical properties of the geological formation as well as proper proximity of the water table. In a situation where the available natural geologic underlain material is composed of permeable material, the formation allows the quick movement of leachate into the subsurface (Popoola and Adenuga, 2019) which contaminates the formation. The leachate becomes part of groundwater flow system as soon as it reaches the water table.

Generally, all waste generated by human activities if not properly collected and disposed pose risks to the environment and to the public (Zhu *et al*., 2008). Various geophysical methods have been applied for environmental purposes; which include electrical resistivity, seismic, electromagnetic, magnetic etc. Landfill or dumpsites characterization, determination of contaminant zones and extent of pollution have been applied using some of the geophysical methods or integrated methods for perfect delineation (Olayinka *et al*., 1991; Ehirim *et al*., 2009; Fajana, 2013; Porsani *et al*., 2004; Olagunju *et al*., 2017; Buselli and Lu, 2001). Integrated geophysical techniques are engaged because of their capability to combine speed with cost effectiveness in providing information on the subsurface, from extent of pollution to porosity of the materials etc.

The aim of this research is to study the extent of subsurface contamination both far and near the dumpsite, also its effect on the soil and groundwater around the dumpsite. This is achieved by adopting integrated geophysical methods.

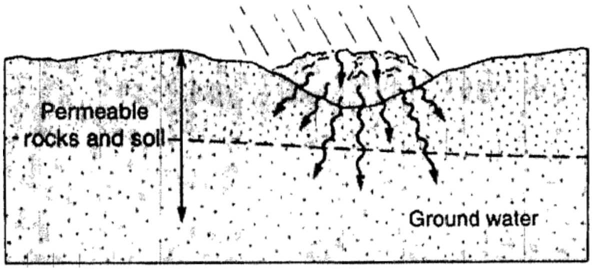


Fig. 1: Illustration of contaminant infiltration into the groundwater through the permeable materials (Osazuwa, 2008)

Geology of the study area

Thestudy area is located at Ijagun environs along Ijebu ode – Benin road, Ogun state Southwestern Nigeria. It lies within latitude $6^{0}78^{1}95^{11}$- $6^{0}79^{1}30^{11}$N and longitude $3^{0}93^{1}75^{11}$-$3^{0}94^{1}25^{11}$E. Generally, Ogun state comprises of basement complex terrain, sedimentary terrain and transition zones. This study area falls within the sedimentary terrain of southwestern Nigeria and it is classified under the sediments of Abeokuta group. The Abeokuta group consists of conglomerate, sandstones, siltstones, shales and limestone bands. It is considered to be Neocomian to Paleocene in age (Omatsola and Adegoke (1980) and it is the thickest single sedimentary unit in the basin. The most striking geographic feature in the area is the relief between the sloppy western ground with maximum relief of approximately 1/600 giving a nearly flat topography. Ariyo and Enikanoselu (2007) reported that landform such as relief, surface morphology and drainage systems depend to a large extent on the difference in the composition of rocks and the frequency of joints and fissures in rocks. The location is characterized by major settlement to secondary and minor road, also with footpath with heavy forest behind the dumpsite. The relief and location maps are presented in Figs. 2 and 3, while the geological map of the study area is presented in Fig. 4.

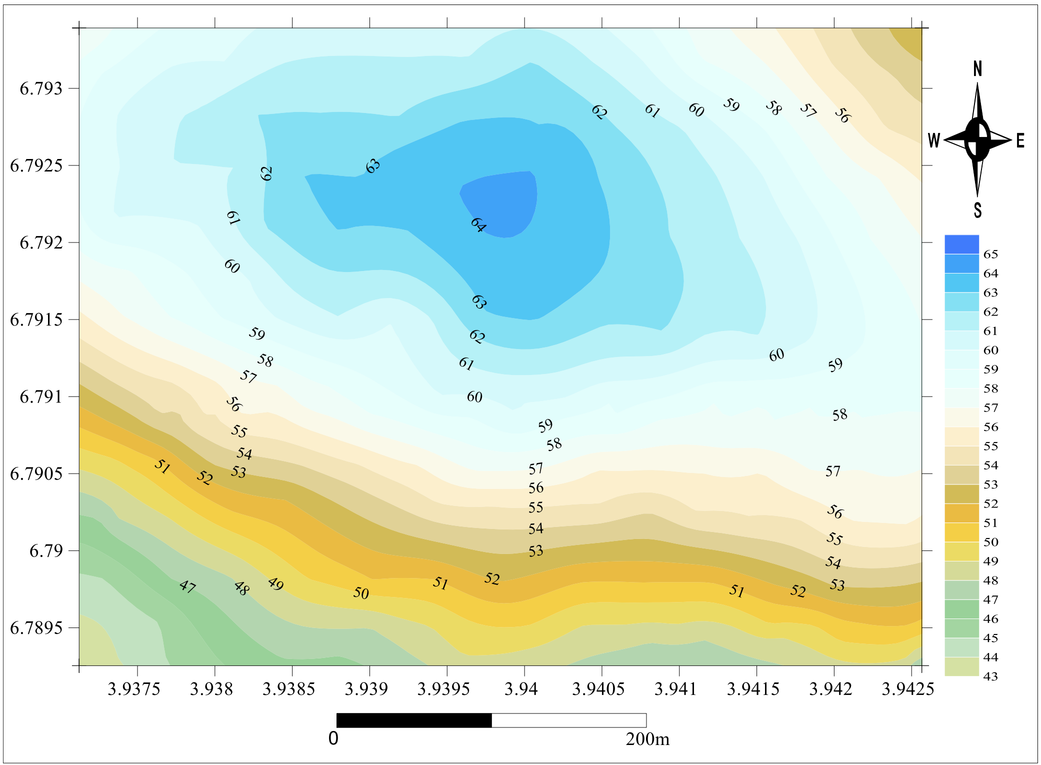


Fig. 2: Relief map of the study area

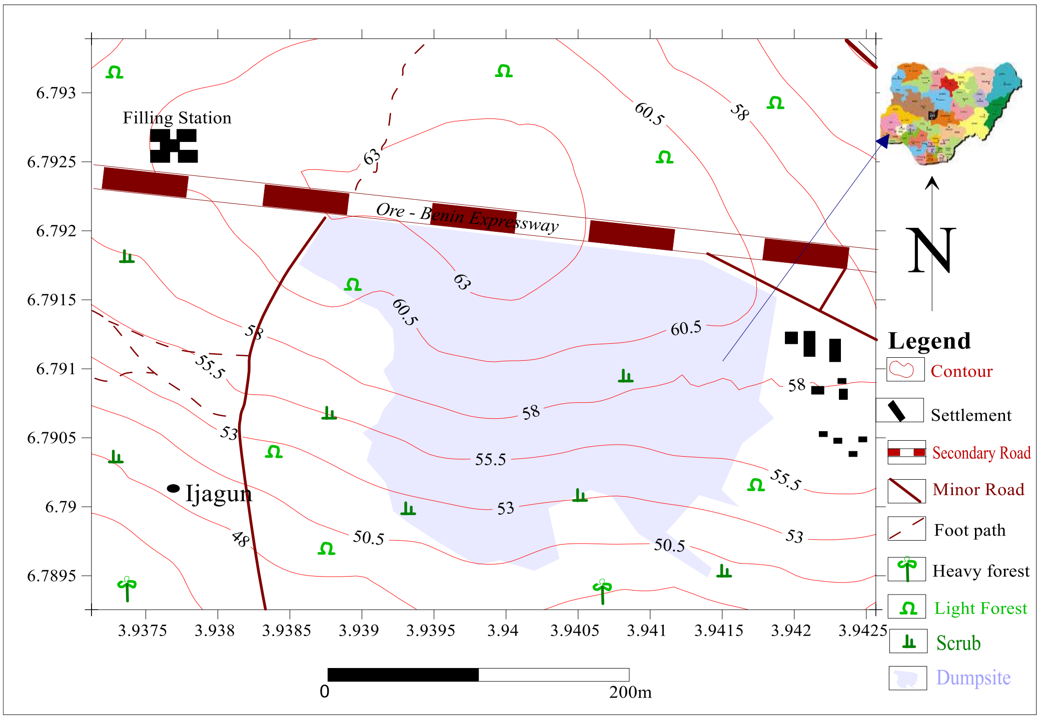


Fig. 3: Location map of the study area

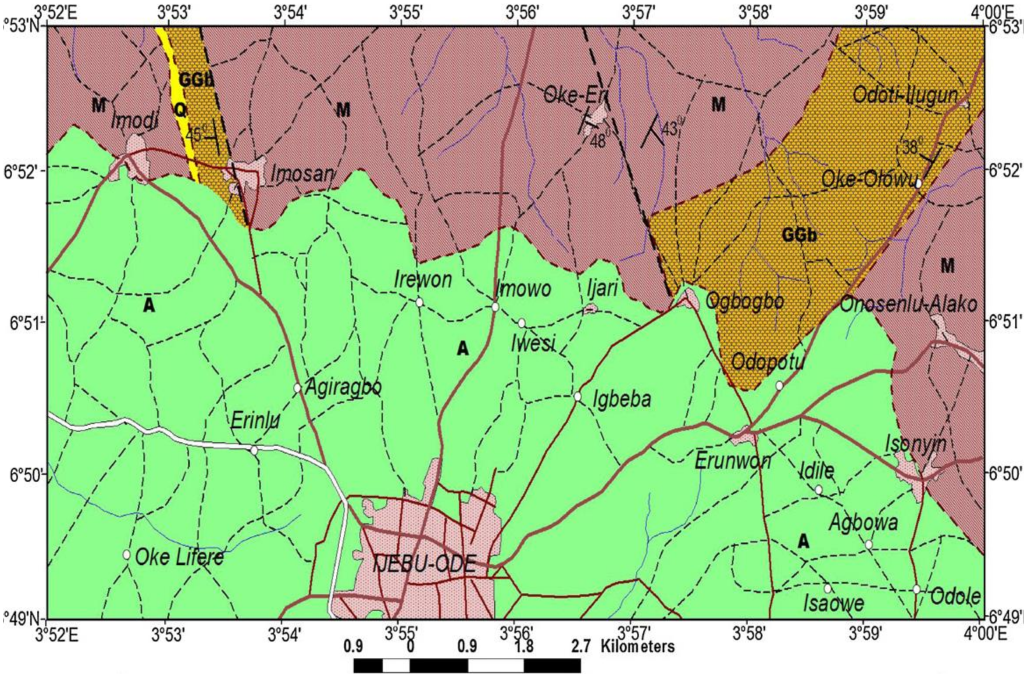


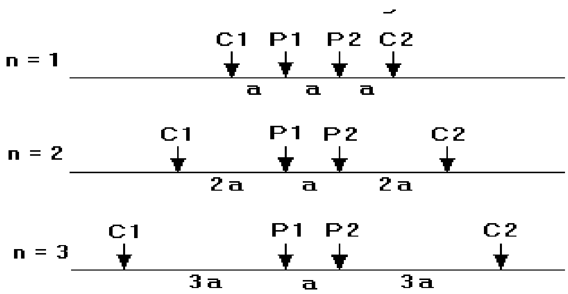
Fig. 4: Map showing the geology of Ijebu-Ode the study area and its environs (Modified after Osinowo *et al.*, 2012)

Materials and Methods

Electrical resistivity method comprising of Vertical Electrical Sounding (VES) and 2D Electrical Resistivity Tomography (2D -ERT) together with very low frequency electromagnetic method (VLE-Em) was adopted. Five traverses of the VLF survey were carried out on and around the dumpsite. The method was adopted as a reconnaissance tool to locate conductive zones that could serve as pathways for contaminant. After the VLF was done, the VES survey was also carried out at some VLF points and other location across the dumpsite and its environs. Lastly 2D ERT was carried out to give clearer information of the subsurface and the extent of pollution of the groundwater and the available soil. The map in figure 6 shows the data acquisition map of the study area in Ijebu ode.

Very low frequency

The VLF techniques of geophysics exploration makes use of very low frequency radio signals to establish the electrical properties of subsurface materials and shallow bedrock. Although, the VLF signals does not really travel far like other methods but still quite useful especially when considering integrated methods. It serves as good reconnaissance tools. The technique is capable of mapping sharply dipping structures like faults and fracture zones as well as areas of mineralization. Contaminant zones, overburden mapping, groundwater study and mineral exploration can be acquired using very low frequency technique. ABEM WADI equipment was used to take the measurement for both the vertical (HZ) and horizontal (Hy) magnetic components of the primary and secondary magnetic field, which is a definition of the quantity tipper B given as B = $\frac{Hz}{Hy}$. B is a complex quantity and a function of the electromagnetic induction phenomena (Karlik and Kaya, 2001; Reynolds, 1999; Mcneil and Labson, 1991). The data acquired was processed to obtain the filtered real, filtered imaginary, raw real and raw imaginary. The processed data later subjected to Karous- Hjelt software to produce the pseudo section and the Microsoft excel for the conductivity profiles. The Karous-Hjelt filter basically computes the corresponding current at a given depth called current density. The current density helps to interpret the width and dip of a fracture with its depth. The results were able to show few conductive zones in the study area.



a) Schlumberger array

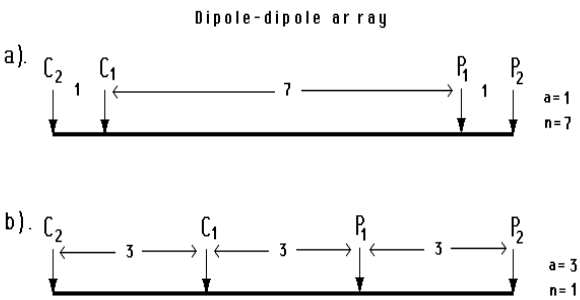


Fig. 5(a and b): sketch of schlumberger and dipole –dipole array (Keary and Brooks, 1991)

Vertical electrical sounding (VES)

Theelectrical resistivity also measures the resistivity of the medium so as electromagnetic method but differs in the way that electrical currents are being forced to flow in the subsurface. In this method, currents are injected into the ground using the positive and negative electrodes which is not applicable in electromagnetic method rather currents are induced using time varying magnetic fields. The VES technique of electrical resistivity method is said to be effective for its ability to determine the thickness of waste dumped, for mapping of contaminant plume, used in delineating the lithology of the study area and the extent of pollution. VES points were carried out on the dumpsites and meters away from the dumpsite at various traverses as space permits. The 2D electrical resistivity tomography was also adopted to show the clearer pictures of the subsurface in two dimensions which shows was interpreted to show the relative distribution of resistivity contour maps. The acquired data were processed using the manual curve matching and later subjected to DIPRO software to generate pseudo section which displays electrical picture of the probed area. The WinResist software was used to process the VES data, the layer parameters obtained from the curve's iteration were used to generate the geo electric sections of the established traverses. Schlumberger array was adopted for the VES data acquisition survey and dipole-dipole for the 2D Electrical resistivity tomography. The choice of electrode array selected for this research work is schematically presented in Fig. 5a and b.

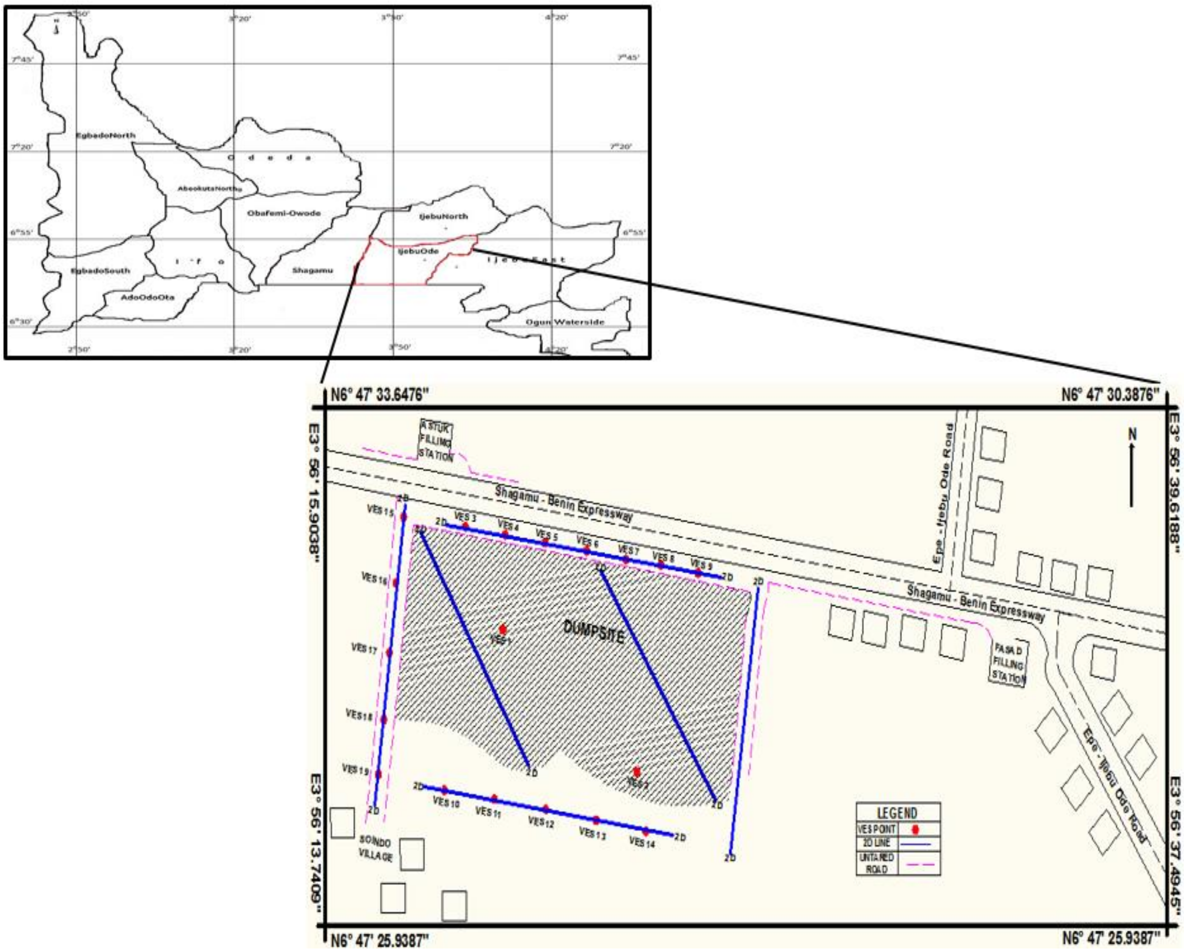


Fig. 6: Data Acquisition map of the study area and its environs showing the various points of VES and 2D

Results and Discussion

Very low frequency (VLF) results

The processed VLF data are presented in Figs. 7 – 10; showing the conductivity profiles and the corresponding Karous Hjelt pseudo sections. The areas with the high peak of the positive filtered real signatures corresponds to red coloration on the Karous Hjelt pseudo section, which are areas having high conductivity.

The Fig. 7 shows the conductivity profile one on the study area and the corresponding pseudo-section. The profile is 150 m long with the filtered real values ranging from 16.8 to 12.3 and the filtered imaginary values of -9.9 to 6.9. The profile depicts few points of the filtered real and filtered imaginary intersections at 100 – 120 m distance, which is an indication of possible conductive zones. Fig. 8 shows the conductivity profile two on the study area and the corresponding pseudo-section. The profile is 150 m long with the filtered real values ranging from – 46.0 to 45.9 and the filtered imaginary values of -31.9 to 18.9 with maximum peak of the filtered real at 8m which is the only point showing significant conductivity on the profile.

Figure 9 shows the conductivity profile three on the study area and the corresponding pseudo-section. The profile is 150 m long taken at the EW direction and taken kilometers away from the study area with the filtered real values ranging from – 35.5 to 17.4 and the filtered imaginary values of -16.8 to 10.4 with pronounced high peak of the maximum peak of the filtered real at 120 – 140 m distance which is showing significant conductivity on the profile. All the acquired possible conductive zones are indications of contaminants as the points were highly conductive. Electrical resistivity survey was later carried out to ascertain the electrical conductivity of the entire study area as it is an effective method.

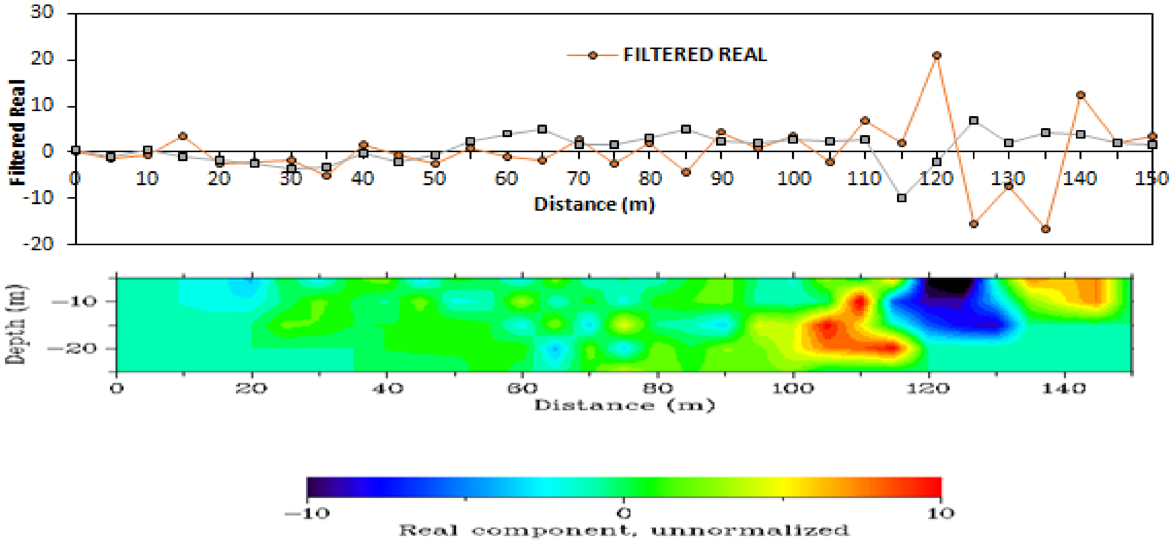


Fig. 7: The conductivity plot and Karous Hjelt pseudo section at Ijagun environs showing few available conductive zones in profile 1

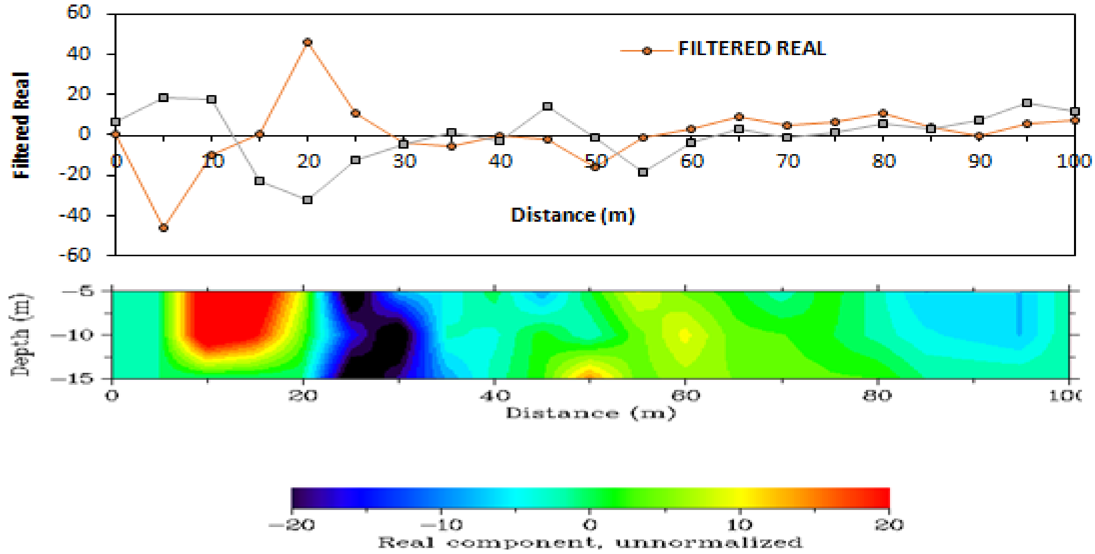


Fig. 8: The conductivity plot and Karous - Hjelt pseudo section at Ijagun environs showing few available conductive zones in profile 2

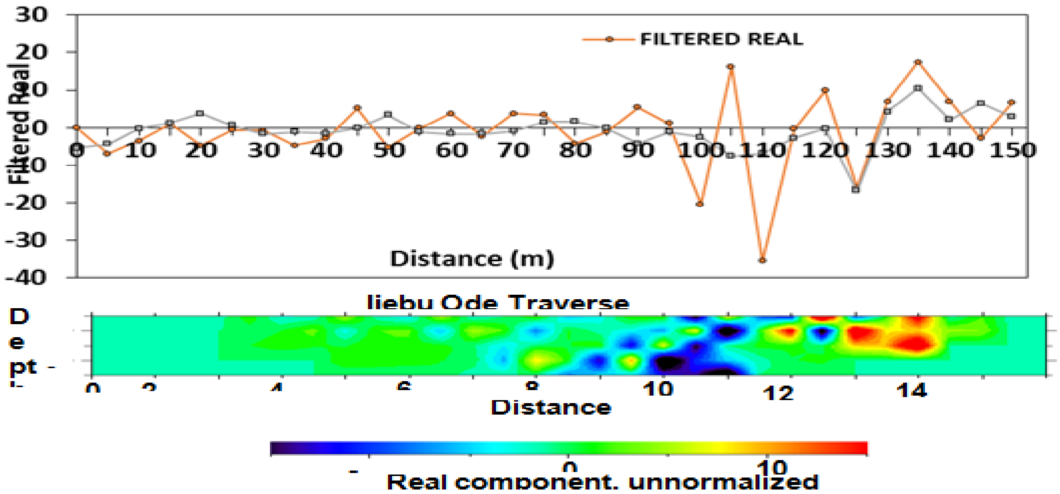


Fig. 9: The conductivity plot and Karous- Hjelt pseudo section at Ijagun environs showing few available conductive zones in profile 3

Electrical resistivity results

VES result

The acquired data were processed using manual curve matching and log –log graph before adopting the WINRESIST software for the generations of curve, and layer to layer parameters. From the interpretation of the results, three to four geoelectric layers were delineated on the study area which was presented in Figs. 10 and 11. Fig. 10 consists of 6 VES connected to produce the geoelectric section that revealed three layers inferred as topsoil with resistivity values 12 – 95 Ωm, the second layer which sand (leachate infiltrated stratum) with resistivity values ranging from 8 – 79 Ωm, the low resistivity value on this layer may be as a result of contamination from leachate as the underlain materials are loose to allow the percolation of leachate. The third layer is the sandy clay with resistivity values ranging from 149 – 196 Ωm. The permeable nature of the underlain materials of the study area can also be a factor to the contamination suspected in the area.

Traverse 2

The second traverse presented in Fig. 11, the geoelectric section which consists of four VES profiles. The geoelectric layers revealed topsoil which is the first layer with resistivity value of 222 – 895 Ωm, the second layer which is inferred to be sand has resistivity values ranging from 748-1600Ωm and the third layer which is dry sand with resistivity values 1983 – 4058 Ωm and the last layer with resistivity value ranging from 752 – 1316 Ωm is inferred to be wet sand. The portion of the VES that has high resistivity values shows the leachate had not migrated to such environment as it is a bit far off the dumpsite, but this doesn't mean it won't be contaminated with time; as the underlain geological material are not good for a seal against the percolation of leachate. The portion with the low resistivity is the northeastern part of the study area which is contaminated. The remaining portion may be contaminated with time.

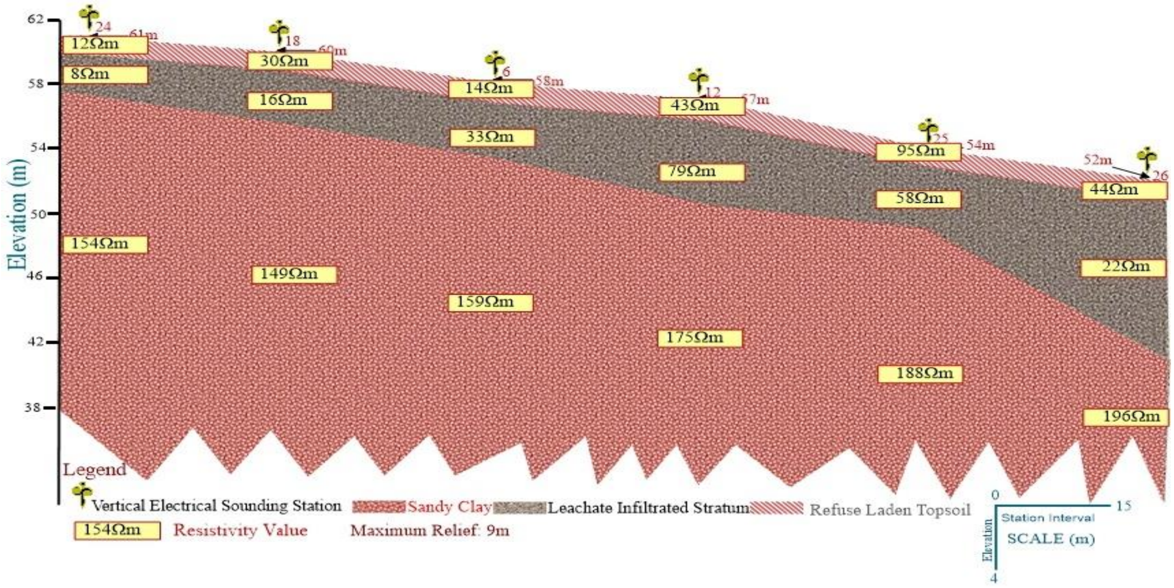


Fig. 10: Presentation of the geoelectric section of traverse 1 of the VES results acquired in the study area at Ijagun, Ijebu Ode environs

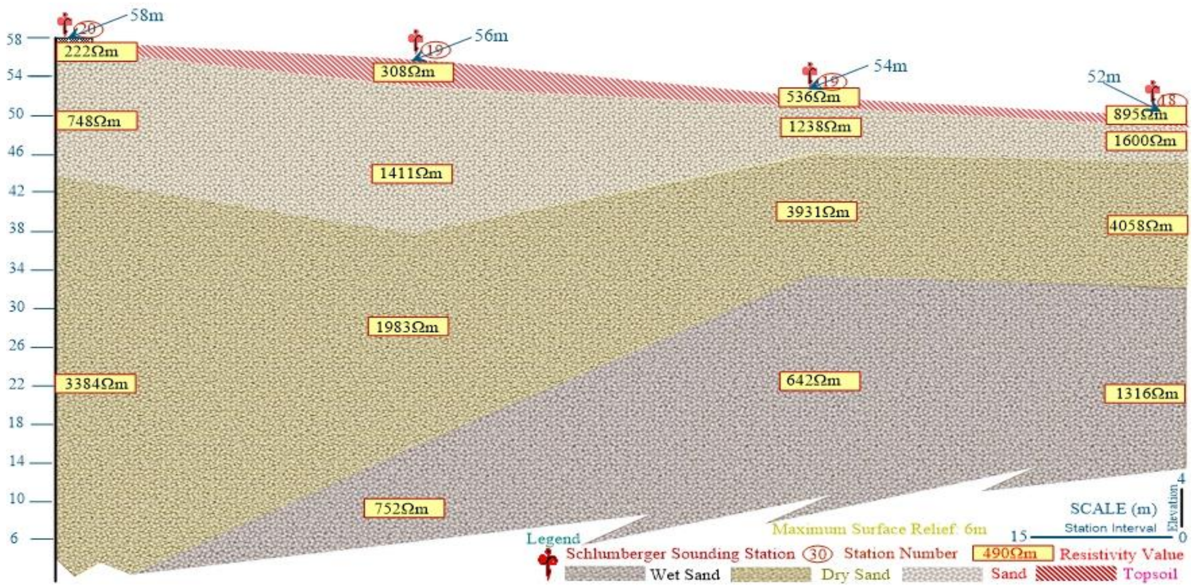


Fig. 11: Presentation of the geoelectric section of traverse 2 of the VES results acquired in the study area at Ijagun, Ijebu Ode environs

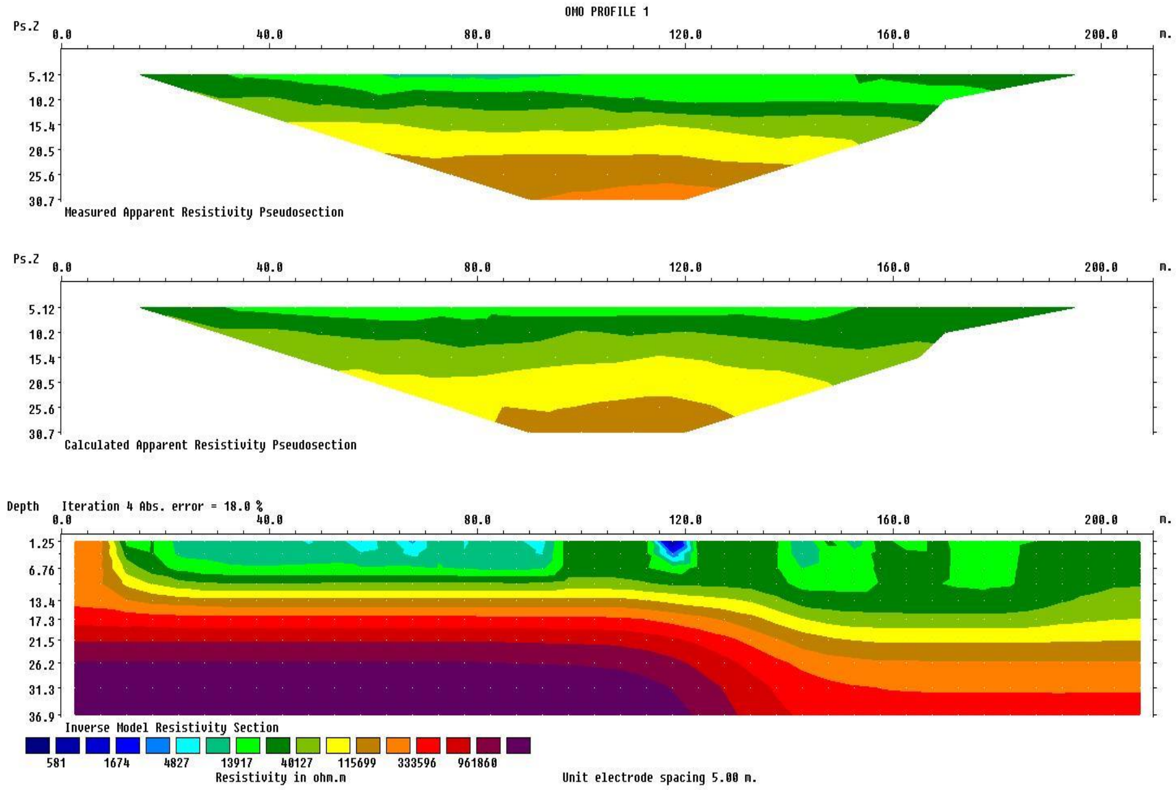


Fig. 12: Presentation of the 2-D electrical resistivity tomography result acquired in the study area at Ijagun, Ijebu Ode environs

2D ERT result

The result of the 2D resistivity is presented in Fig. 12. The inversed model resistivity section for the only traverse line in the study area shows an orientation that is approximately in the North-south direction with large and small pockets of moderate resistive material which is the topsoil. The apparent resistivity values of the topsoil ranges from 581 – 4827 Ωm with a vertical distance of 1.25 m to less than 6.76 m. The topsoil material is underlain by high resistive materials of apparent resistivity values between 4827 – 33596 Ωm (yellow to brown coloration) with the sand bearing horizon laterally continuous across the study area from the North-west (with vertical distance of 1.25 – 13.4 m) to the South-east with vertical distance of 10.08 – 31.3 m. This indicates the presence of sandy-clay clayey sand formation, which means that the available underlain materials are permeable materials that would have probably absorb leachate into the subsurface which would have contaminated the underground water and the soil available. At this point, it shows that the study area has been contaminated due to the underlain materials.

Conclusion

In this research work, three different geophysical methods were applied to delineate the impact of waste dumped on soil and groundwater at Ijagun dumpsite located in Ijebu Ode. The study reveals that the underlain materials comprise topsoil, leachate infiltrated stratum, sand/dry sand and sandy clay, which are indications that the soil and groundwater of Ijagun dumpsite is contaminated. The very low frequency (VLF) is the first method used to locate possible conductive zones and later the electrical resistivity methods. Results from the VLF shows few conductive zones which is as a result of leachate deposition in those areas. The results of the VES and 2D ERT shows the lithological units which are underlain by permeable materials which allows the free flow of leachate into the water table. The portion of the dumpsite with low resistivity values is an indication of contaminant plume and the extent of pollution. The study was able to map the contaminant zones even though the contaminant had not migrated to all parts of the dumpsite. There is every possibility that the remaining portion may be contaminated in future. It is therefore recommended that evacuation of the dumpsite to another well engineered dumpsite is recommended for such location.

References

Adebayo AS, Ariyibi EA, Awoyemi MO & Onyedim GC 2015. Delineation of contamination plumes at Olubonku dumpsite using geophysical and geochemical approach at Ede Town, Southwestern Nigeria. *Geosciences*, 5(1): 39-45.

Adewuyi RA & Abu M 2014. Investigating groundwater contamination using vertical Electrical Sounding andPhysio-Chemical Analysis around AngwanJukpa Municipal Solid Waste, Minna, North-central, Nigeria. *IOSR J. Appl. Geol. and Geophy.*, 2: 6-10.

Ariyo SO & Enikanoselu EM 2007. Integrated use of geoelectrical imaging and geochemical analysis in the environmental impact assessment of Egbe dumpsite in Ijebu- Igbo area, southwestern Nigeria. *Cont. J. Earth Sci.*, 1: 11 – 17.

Baldursson S & Karanis P 2011. Waterborne transmission of protozoan parasites: review of worldwide outbreaks - an update 2004–2010. *Water Res.*, 45(20): 6603-14.

Buselli G & Lu K 2001. Groundwater contamination monitoring with multichannel electrical and electromagnetic methods. *Journal of Applied Geophysics*, 48(1): 11 - 23.

Carpenter PJ, Kaufmann RS & Price B 1990. Use of resistivity soundings to determine landfill structure. *Groundwater*, 28(4): 569 - 575.

Edward JT, Frederick KL & Dennis GT 2014. *An Introduction to Physical Geology.* 11th edition 2014.

Ehirim CN, Ebeniro JO & Olanegan OP 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. *The Pacific J. Sci. and Tech*., 10(2).

Fajana AO 2013. Integrated geophysical characterization of subsurface conditions around Ilesha Dumpsite: Case of southwestern Nigeria. *Asian J. Appl. Sci. and Engr.*, 2.

Karlik G & Kaya AM 2001. Investigation of groundwater contamination using electric and electromagnetic methods. National Well Association, Dublin, OH, pp. 681-712.

Keary P & Brooks M 1991. An Introduction to Geophysical Exploration. 2nd edition Blackwell Scientific London Edinburgh, pp. 172 - 180.

McNeill JD & Labson V 1991. Geological mapping using VLF radio fields Electromagnetic Methods in Applied Geophysics Vol. 2 ed M N Nabighian (Tulsa, OK: Society of Exploration Geophysicists), pp 521–640.

Olagunju E, Ariyibi E, Awoyemi M, Adebayo A, Dasho O & Adenike C 2017. Application of geochemical and geophysical approach to environmental impact assessment: a case study of Emirin active open dumpsite, Ado-Ekiti Southwestern Nigeria. *Modeling Earth Systems and Environment*, 3(4): 1543 - 1555.

Osazuwa LB & Abdullahi NK 2008. Geophysics techniques for the study of groundwater pollution: A review. *Nigerian J. Physics*, 20(1): 163-174.

Osinowo OO & Olayinka AI 2012. Very low frequency and electrical resistivity investigation for groundwater potential evaluation in a complex geological terrain around the Ijebu-Ode transition zone, southwestern Nigeria, 9: 374-396.

Omatsola ME & Adegoke OS 1981. Tectonic evolution and Cretaceous stratigraphy of the Dahomey Basin. *J. Mining Geol.*, 18: 130–137.

Popoola OI & Adenuga OA 2019. Determination of leachate curtailment capacity of selected dumpsite in Ogun state Southwestern Nigeria using integrated geophysical methods. *Scientific African* 6: e00208.

Porsani JL, Filho WM, Elis Vagner R, Shimeles F, Dourado JC & Moura HP 2004. The use of GPR and VES in delineating a contamination plume in a landfill site: a case study in SE Brazil. *Journal of Applied Geophysics*, 55(3-4): 199-209.

Reynolds JM 1999. An introduction to applied and environmental geophysics. Wiley and Sons geoscience Ltd, UK.

Zhu D, Asnani PU, Zurbrugg C, Anapolsky S & Mani S 2008. Improving municipal solid waste management in India. The International bank for reconstruction and development/The World Bank.