Received: 13 Marchl 2023 | **Revised: 25 November 2023** | **Accepted: 27 November 2023**

Research Article
Journal of Research and Review in Science
27-40, Volume 10, December 2023.
DOI:

ORIGINAL RESEARCH

Investigation of the Effect of Electronic Waste on Groundwater of Olusosun Landfill Using Electrical Resistivity Methods

Ogungbe, Abiola[1], Saliu, Babatunde[1], Alabi, Aderemi[2], Whetode, James[1], Onori, Eugene[1], Solola, Gbenro[3], Atobatele, Olayinka[3], Atanley, Pauline[3]

[1]*Department of Physics, Lagos State University, Lagos, Nigeria*

[2]*Department of Physics, Federal University of Agriculture, Abeokuta, Nigeria.*

[3]*Department of Physics, Augustine University, Ilara, Epe, Lagos, Nigeria*

Correspondence
Olanrewaju Adigun Fagbohun, Department of Computer Science, Faculty of Science, Lagos State University, Nigeria.
Email:Olanrewaju.Fagbohun@lasu.edu.ng

Funding information
Grant sponsor and grant number: NUC Research Grant (nuc.edu.ng) (NUC1311/1)

Abstract:

Introduction/Aims: This paper is aimed at investigating and evaluating the effect of electronic waste on groundwater in Olusosun landfill, Ojota, Lagos State, Nigeria, using electrical resistivity surveys.
Materials and Methods: A total of twenty Vertical Electrical Sounding (VES) and six 2-D Constant Separation Traversing (CST) involving Schlumberger and Wenner arrays respectively were employed using PASI Terameter (model 16GL). The analysis of the VES data involved partial curve-matching technique, using WinResist (1.0) to create a model of perfect fit; indicating layer resistivity, thickness, and depth, while the 2-D data were processed using DIPROWIN software (4.0).
Results: Five geoelectric layers were delineated which are topsoil, clayey sand, clay, sand, and sandy clay with thickness range 0.6 to 0.9 m, 3.8 to 55.4, 1.4 to 17.1 m, 2.0 to 35.6 m, and 10.5 to 18.2 m. respectively. The resistivity values vary from 26 to 83 Ωm, 112 to 321 Ωm, 22 to 56 Ωm, 153 to 1032 Ωm and 54 to 90 Ωm respectively. Results of the resistivity values suggest that the contaminant plume has low resistivity zones (4 – 18 Ωm).
Conclusion: The results showed that Traverses B, C and E are predominantly contaminated with existence of clay/leachate layer while traverses A and D partially contaminated which is possible due to the effect of electronic waste disposal.
To Keywords: Electronic waste, Landfill, Groundwater, Vertical Electrical Sounding, Electrical Resistivity.

1. INTRODUCTION

Electronic waste (e-waste) is a combination of used or unwanted electronic products that have exceeded their shelf life (end-of-life). Electronic waste has been one of the fastest growing components of the municipal solid waste stream. This is as a result of people enhancing their mobile phones, computers, and audio. These are causing big issues as they are replaced most often [1].

Today, electrical, and electronic waste is a growing waste stream (about 4% growth a year). About 40 million tons of e-waste is created each year [2]. E-waste comprises electrical appliances such as fridges, air conditioners, washing machines, microwave ovens, and fluorescent light bulbs; and electronic products such as computers and accessories, mobile phones, television sets and stereo equipment. There is currently a high level of trans-boundary, often illegal, movement of e-waste into developing countries for cheaper recycling. Trans-boundary movement of e-waste is primarily profit driven. Recyclers and waste brokers are taking advantage of lower recycling costs in developing economies and at the same time avoiding disposal responsibilities at home. It is estimated that up to 80% of all e-waste sent for recycling in developed countries ends up in informal e-waste recycling sites in developing countries, primarily in Africa and Asia [3].

In receiving countries, crude and hazardous methods of recycling are used, jeopardizing people's health and the environment [4]. This raises an equity issue of developing countries receiving a disproportionate burden of a global problem, without having the technology to deal with it. Globalization of e-waste has adverse environmental and health implications as developing countries face economic challenges and lack the infrastructure for sound hazardous waste management, including recycling, or effective regulatory frameworks for hazardous waste management [5].

Indiscriminate e-waste disposal can have several adverse effects on groundwater. some specific ways in which indiscriminate e-waste disposal can affect groundwater are Leaching of toxic substances, Groundwater contamination, Persistent organic pollutants, Aquifer depletion, Bioaccumulation in the food chain. To mitigate these risks, proper e-waste management is essential. This includes recycling and proper disposal of electronic devices through authorized recycling facilities that follow environmentally responsible practices. Governments and organizations should implement regulations and educate the public about the importance of responsible e-waste disposal to minimize the impact on groundwater and overall environmental health [6].

Groundwater is of major importance to civilization since it is the largest reserve of potable water in regions where humans live. The health and well-being of the population depend on abundance and adequate supply of this natural resource. Water forms an indispensable resource in economic activities like commerce, tourism, industry, and for uses in domestic activities and agriculture. The result of some studies in Nigeria showed that water resources in many parts of the country especially the southern part are more than adequate to meet any demand and only need development [7;8]. Groundwater is less contaminated than surface water and pollution of this kind poses a threat to groundwater, and this has become an increasing concern in developed and developing nations due to contamination by toxic substances [9].

Waste metal dumps and other waste materials which are either surface or buried are known to produce leachates that penetrate the aquifer and contaminate the groundwater [10]. The electrical resistivity method is a unique geophysical tool used in groundwater and landfill studies [11]. The resistivity method is used for electrical sounding and imaging. The electrical sounding provides information about vertical changes in subsurface electrical properties and thus, it is useful in the determination of hydrogeologic conditions such as the depth to water table, depth to bedrock, and thickness of soil [12]. The electrical resistivity imaging maps ground water contaminant such as leachate plumes, contaminant source, migration paths, and depth [13].

This study is driven by the desire to investigate the effect of electronic waste on groundwater with a view to assessing the effect of electronic waste on groundwater in Olusosun landfill, Ojota area, Lagos State, Southwestern, Nigeria using Electrical Resistivity Techniques (ERT).

2.0 DESCRIPTION AND GEOLOGY OF STUDY AREA.

The Olusosun dumpsite is a controlled dumpsite located at Ojota, Lagos, within longitude 03.372E to 03.374E and latitude 06.588N to 06.595N as shown in figure 1. It is the largest government-owned dump facility in Nigeria, and it is managed by the Lagos Waste Management Authority (LAWMA). It is about 18 meters deep and covers close to 42 hectares of land. Olusosun refuse dump was established in 1991 with a lifespan of 35 years. The dump is surrounded by Oregun industrial layout, Olusosun residential compound, Shangisha residential areas and commercial neighbourhood. It receives an average of 1.2 million tons of assorted wastes annually and is presently serving as a pilot project for biogas production in Nigeria [14].

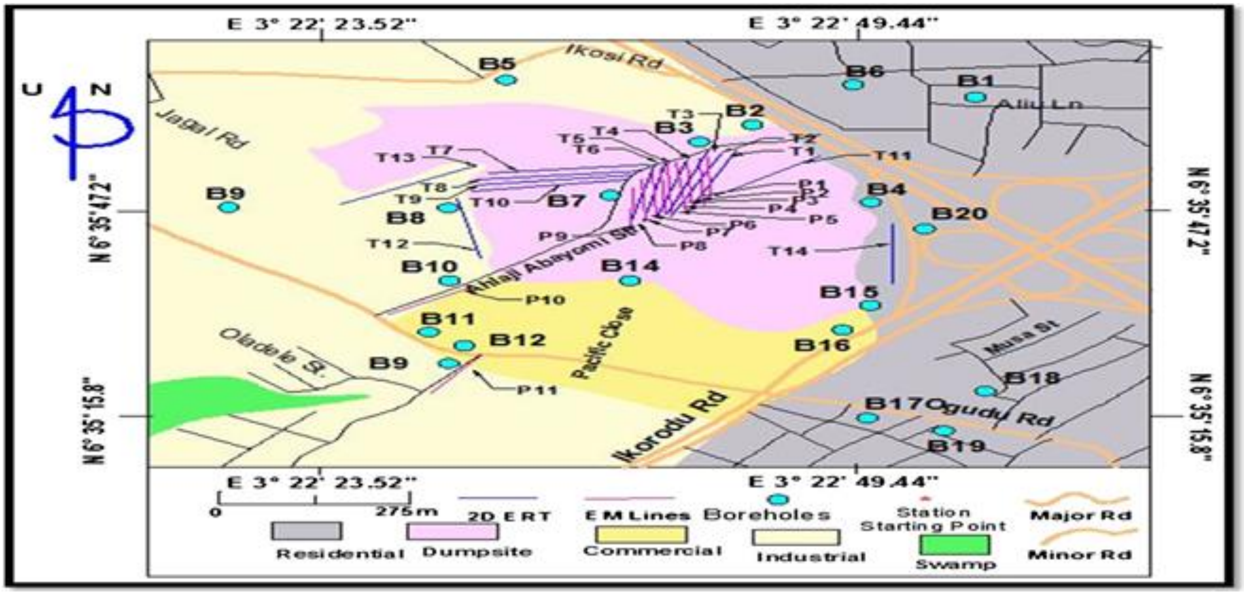

Figure 1: Base Map of Olusosun Lanfill in Ojota

The geology of Olusosun area is generally characterized by coastal plain sands. It forms low lying, gently sloping topography with extensive red earths and loose poorly sorted sands that are mixed with an abundance of clays. The elevation generally ranges from 18 to 52 m above the mean sea level.

3.0 MATERIAL AND METHODS

The electrical resistivity survey was carried out along five traverses using 2D and vertical electrical sounding electrical imaging method.

3.1 Materials

The survey was conducted using the PASI Terameter Model 16 GL and battery, metallic electrodes, measuring tape, reels of cables, Garmin Global positioning system (GPS), crocodile clips and hammer.

3.2 Data Acquisition

The Wenner array electrode configuration was used for the 2D resistivity imaging. Five (5) profiles were run at 10 m interval. The Schlumberger configuration was used to acquire twenty (20) Vertical Electrical Sounding Stations at different points along the five profiles. The Schlumberger current electrode spacing (AB) was varied from a minimum of 2.0 m to a maximum of 700.0 m at the VES locations. The directions of the VES points were in the “North-South and East-West directions. The geodetic system of coordinates was obtained using the GPS.

3.3 Data Processing/Interpretation

The DIPRO software was used. The field data pseudo section and the 2D resistivity structure were produced after running the inversion of the raw data to filter out noise. The quantitative interpretation of the depth sounding curves was carried out by adopting the partial curve matching technique. The partial curve matching technique involved the use of a standard two (2) layer master curve and four (4) auxiliary type curves (H, K, A, and Q). The results of the VES curves obtained from the partial curve matching were then used to constrain the interpretation by the computer iteration using Winresist software.

3.4 Generation of Geoelectric Sections

The geoelectric sections were generated with the AutoCad software. This involved the combination of two or more interpreted VES results along each profile.

4.0 RESULTS AND DISCUSSION

4.1 Results

The 2D electrical resistivity structures are shown in Figures 3(a-e) while the geoelectric sections are displayed in Figures 4(a – e). The resistivity curves and the summary of the interpreted VES results are presented in Table 1.

Table 1: Summary of interpreted VES results with inferred Lithology

VES NO	RESISTIVITY (ohm-m)	THICKNESS (m)	DEPTH (m)	LITHOLOGY	CURVE TYPE
VES 1	54	0.8	0.8	Topsoil	HK
	36	2.7	3.5	Clay	
	184	55.4	58.9	Clayey sand	
	54	--------	---------	Sandy clay	
VES 2	83	0.9	0.9	Topsoil	HK
	37	2.2	3.1	Clay	
	286	37.4	40.5	Sand	
	82	--------	---------	Sandy clay	
VES 3	57	0.7	0.7	Topsoil	KH
	363	2.0	2.7	Sand	
	65	18.2	20.9	Sandy clay	
	257	--------	---------	Sand	
VES 4	79	0.6	0.6	Topsoil	HK
	22	1.7	2.2	Clay	
	594	12.3	14.5	Sand	
	90	--------	---------	Sandy clay	
VES 5	60	0.8	0.8	Topsoil	HK
	25	1.9	2.6	Clay	
	526	14.7	17.3	Sand	
	112	--------	---------	Clayey sand	
	49	0.8	0.8	Topsoil	
	25	2.1	2.8	Clay	

VES 6	321	3.8	6.7	Clayey sand	HAK
	1032	22.6	29.2	Sand	
	56	-------	--------	Clay	
VES 7	37	0.7	0.7	Topsoil	HK
	26	2.4	3.0	Clay	
	973	23.0	26.1	Sand	
	131	--------	---------	Clayey sand	
VES 8	41	0.9	0.9	Topsoil	HK
	32	2.9	3.8	Clay	
	619	35.6	39.3	Sand	
	174	--------	--------	Clayey sand	
VES 9	61	0.8	0.8	Topsoil	H
	29	2.5	3.4	Clay	
	153	---------	---------	Sand	
VES 10	55	0.9	0.9	Topsoil	QH
	18	3.0	3.9	Leachate	
	4	5.5	9.5	Leachate	
	22	---------	---------	Clay	
VES 11	57	1.1	1.1	Topsoil	H
	7	11.5	12.6	Leachate	
	33	---------	---------	Clay	
VES 12	54	0.7	0.7	Topsoil	HKH
	32	0.9	1.6	Clay	
	42	8.3	10.0	Clay	
	21	8.6	18.6	Clay	
	718	--------	---------	Laterite	
VES 13	16	0.8	0.8	Leachate	HKH
	4	3.5	4.3	Leachate	
	13	8.9	13.2	Leachate	
	4	11.4	24.5	Leachate	
	56	--------	---------	Clay	

VES 14	40	0.8	0.8	Topsoil	QHA
	8	15.8	16.6	Leachate	
	17	17.1	33.7	Leachate	
	5	33.2	66.9	Leachate	
	73	--------	---------	Sandy clay	
VES 15	29	0.9	0.9	Topsoil	AKH
	41	4.2	5.1	Clay	
	76	10.5	15.6	Sandy clay	
	23	15.8	31.4	Clay	
	786	--------	---------	Laterite	
VES 16	65	0.9	0.9	Topsoil	HA
	35	1.4	2.3	Clay	
	52	9.0	11.4	Clay	
	130	--------	---------	Clayey sand	
VES 17	62	0.9	0.9	Topsoil	HKH
	24	0.7	1.6	Clay	
	42	10.0	11.5	Clay	
	25	8.0	19.5	Clay	
	140	---------	--------	Clayey sand	
VES 18	48	0.7	0.7	Topsoil	HKH
	36	4.5	5.1	Clay	
	55	5.4	10.6	Clay	
	28	16.5	27.1	Clay	
	173	--------	---------	Clayey sand	
VES 19	15	0.8	0.8	Leachate	QH
	7	2.1	2.9	Leachate	
	6	24.8	27.6	Leachate	
	49	---------	--------	Clay	
VES 20	26	0.7	0.7	Topsoil	H
	7	35.0	35.7	Leachate	
	30	---------	---------	Clay	

Figure 3a shows the 2D resistivity structure along traverse one. From 6 m up to a spread of 17 m along the profile is a zone of low resistivity, ranging between 64 to about 80 Ωm and to a depth of 3 m which indicates topsoil mixed with possible leachate (Blue color). Underlying this, to a depth of about 10 m from the surface, to about 22 m spread, is a zone of moderate resistivity, varying from 85 to 150 Ωm. This could be as a result of clayey s and. At a depth below 20 m, up to 30 m depth, is a zone of relatively high resistivity ranging from 257 to 619 Ωm across the profile, up to a lateral distance of 22 m which is an indication of sand formation (Purple color).

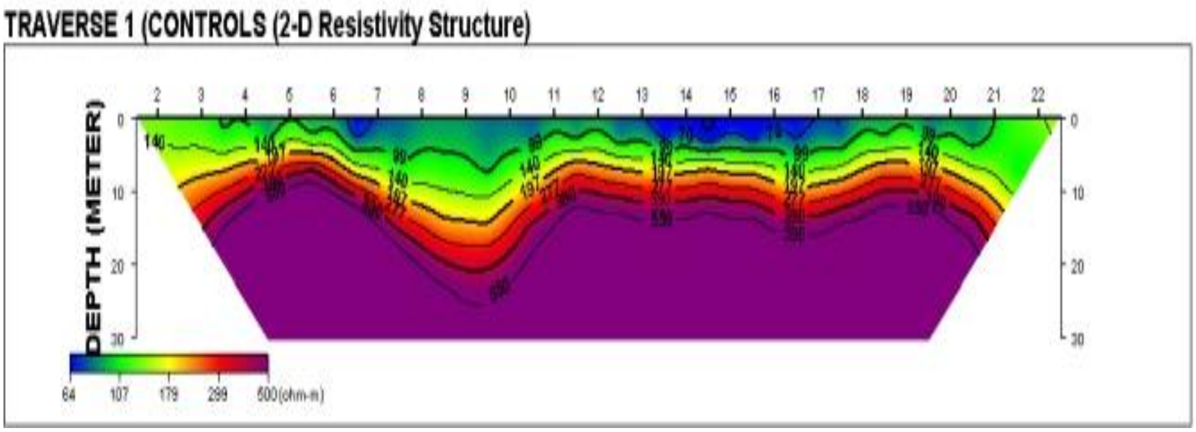

Figure 3a: 2D Resistivity Section along Traverse one

2D Resistivity Section along Traverse Two

Figure 3b shows the 2D resistivity structure along traverse two. From the surface, up to a spread of 22 m depicts sections of very low to moderate resistivity values, ranging between 4 to about 68 Ωm and to a depth of 15 m. This indicates zones of leachate and clay with resistivity values varying from 4 to 7 Ωm and from 18 to 68 Ωm respectively. The leachate is pronounced at lateral distance between 15 to 17 m and depth up to 3 m along the profile and has percolated into the subsurface up to 15 m depth at lateral distance between 11 to 15 m along the surface.

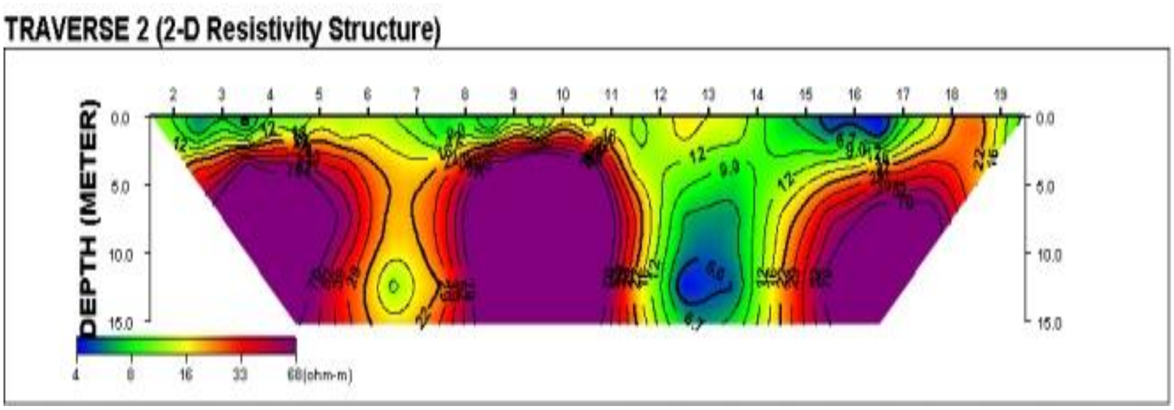

Figure 3b: 2D Resistivity Section along Traverse two

2D Resistivity Section along Traverse Three

The 2D resistivity structure along traverse three is shown in Figure 3c. From 6 m spread up to 16 m is a zone of low resistivity, ranging between 2 to 8 Ωm and to a depth of 5 m. This zone of highly low resistivity is an indication of leachate and has percolated to a depth of 5 m into the subsurface. Underlying this, is a zone of moderate resistivity, varying from 34 to 86 Ωm. This could be as a result of clay formation. This is from 5 m to 15 m depth and across the profile up to 17 m spread. The high resistivity zone with lateral distance of 22 m and depth from 8m is indicative of sand.

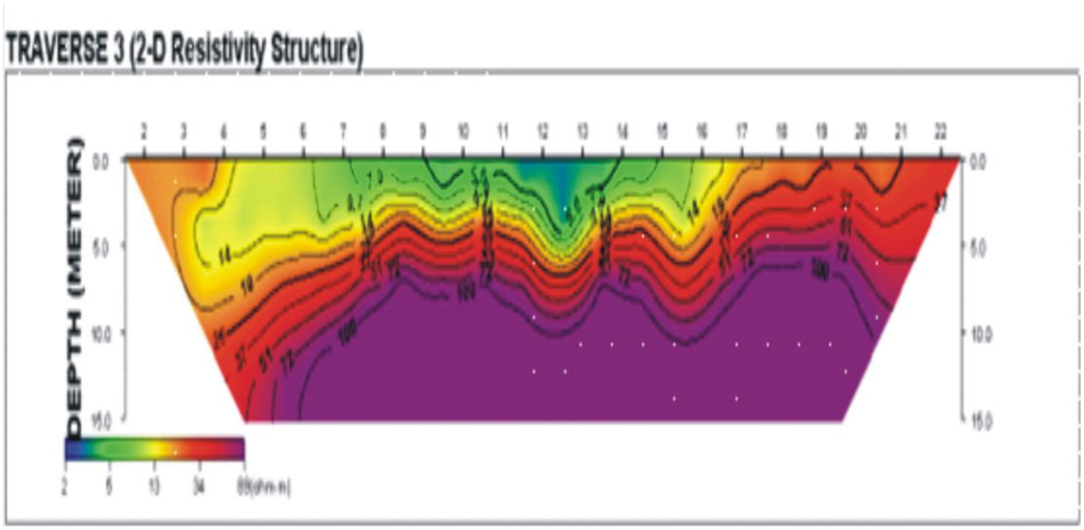

Figure 3c: 2D Resistivity Section along Traverse Three

2D Resistivity Section along Traverse Four

Figure 3d shows the 2D resistivity structure along traverse four. Most part of this profile is characterized by zones of low to moderate resistivity, ranging from 4 to 171 Ωm. Up to a spread of 22 m, and to a depth of 15 m, characterized by resistivity ranging from 66 to 171 Ωm. This is an indication of clayey sand formation. Within this zone, at a depth of 3 to 15 m and lateral spread of 14 to 16 m along the profile, is a localized zone of low resistivity, ranging from 10 to 20 Ωm. This is an indication of leachate. This is also observed at a spread of 22 m to 29 m along the profile, from a depth of 2 m to 15 m and with relatively low resistivity value.

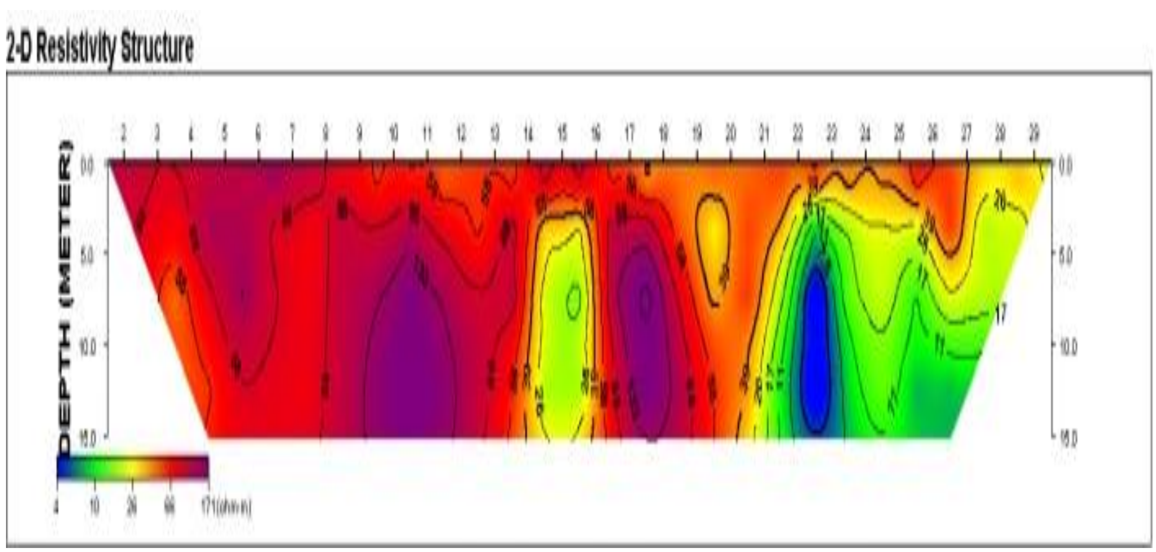

Figure 3d: 2D Resistivity Section along Traverse Four

2D Resistivity Section along Traverse Five

The 2D resistivity profile along traverse five is shown in Figure 3e. From 10 m up to a spread of 19 m along the profile is a zone of low resistivity, ranging between 2 to about 8 Ωm and to a depth of 15 m from the surface. This is an indication of leachate zone. Within this zone is a localized zone of relatively moderate resistivity, ranging from 15 to 39 Ωm, and depth from the surface up to 10 m at a lateral spread of 13.5 to 18 m along the profile. This indicates topsoil mixed with clay. This is also observed from the surface up to 15 m depth at a lateral spread up to 10 m and from 19.5 to 22 m along the profile.

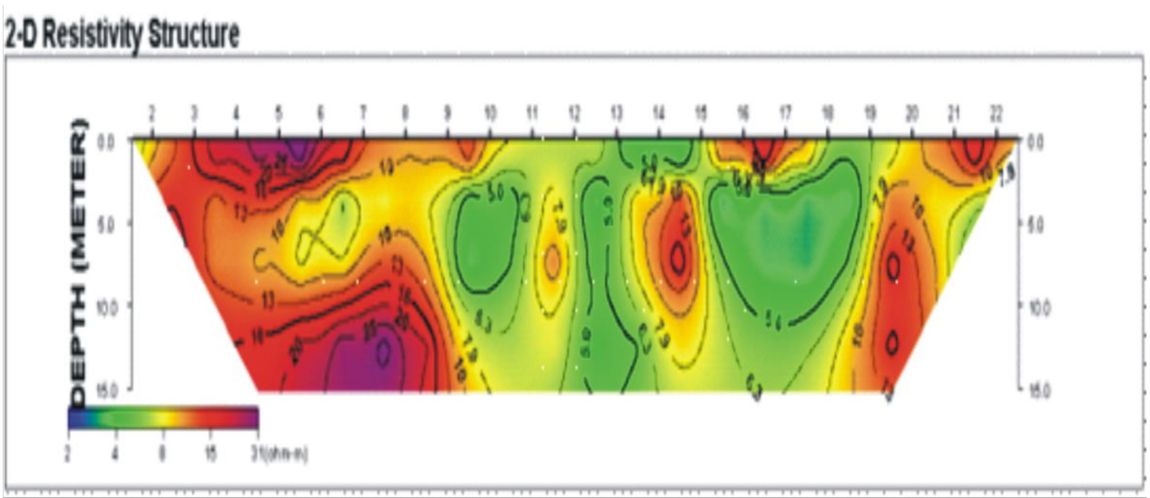

Figure 3e: 2-D Resistivity Section along Traverse Five

4.3. Discussion on Geoelectric Section

Geoelectric Section along Traverse one

Figure 4a consists of VES 1 to 8. The section revealed five to six subsurface layers namely, topsoil, clay/leachate, clayey sand, sandy clay, sand. The topsoil is characterized by resistivity values ranging from 37.0 to 83.0 Ωm and layer thickness of 0.7 to 0.9 m. The second layer in VES 1 to 8 denotes clay/leachate with resistivity and layer thickness values that range between 22.0 to 37.0 Ωm and 1.7 to 2.2 m respectively, while the second layer in VES 7 depicts sand with resistivity and layer thickness values of 619 Ωm and 35.6 m respectively.

The third layer connotes sand with resistivity and layer thickness that vary between 1032 to 286.0 Ωm and 22.6 to 37.4 m respectively.

The fourth horizon beneath VES 1, 2, 4, 5, and 6 signifies clayey sand with resistivity values ranging from 321.0 to 112.0 m. The layer thickness in VES 1 and 6 ranges from 3.8 to 55.4 m while the layer thickness in VES 4 and 5 could not be determined due to the fact that the current terminated within this region, while the fourth layer in VES 3 is a representative of sand with resistivity value of 257 Ωm. The sand in this zone represents an aquifer where ground water could be tapped. In VES 7 and 8, the fourth geoelectric layer revealed sand with resistivity value of 973 Ωm and layer thickness of 23.0 m.

The fifth geological layer in VES 1 depicts sandy clay with resistivity value of 54 Ωm, while the fifth geoelectric layer in VES 2 and 4 depicts sandy clay with resistivity values ranging from 82.0 to 90.0 Ωm. But in VES 7 and 8, the fifth and sixth layer connote sand with resistivity value of 619 m to 973 Ωm and the layer thickness between 23.0 to 35.6 m. The sand in these zones represents an aquifer where ground water could be tapped.

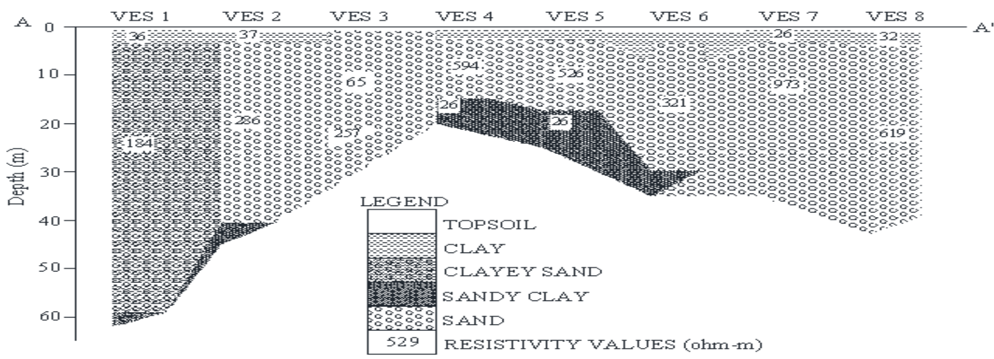

Figure 4a: Geoelectric Section for VES 1,2,3,4,5,6,7 and 8

Geoelectric Section along Traverse two

Figure 4b consists of VES 9 to 12. The section revealed four subsurface layers namely, topsoil, clay/leachate, clay and clayey sand. The topsoil is characterized by resistivity values ranging from 16.0 to 61.0 Ωm and layer thickness of 0.7 to 0.8 m. The second horizon beneath VES 9 and 10 signifies clay with resistivity values ranging from 18 to 29 Ωm with layer thickness of 2.5 m to 3.0 m, while in VES 11, the second horizon depicts clay/leachate with resistivity of 4 Ωm to 7 Ωm. In VES 12, the second horizon connotes clay with resistivity value of 32.0 Ωm with layer thickness of 0.9 m. The third geologic layer in VES 10 to 11 connotes clay with resistivity values that range between 22.0 to 33.0 Ωm and the layer thickness could not be determined due to the fact that the current terminated within this horizon. The third layer in VES 10, 11 and 12 is clayey sand with resistivity ranging from 22.0 Ωm to 42.0 Ωm and the layer thickness of 0.0 m to 0.9 m.

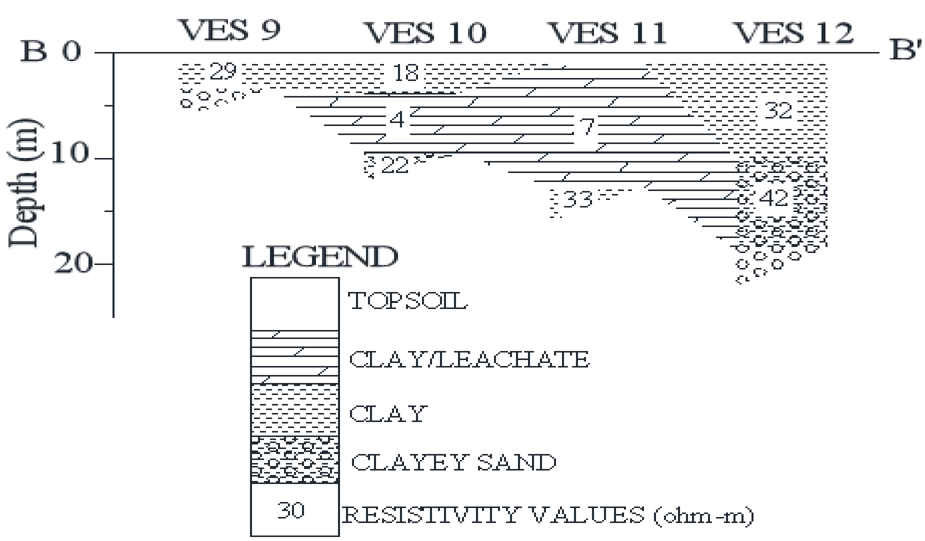

Figure 4b: Geoelectric Section for VES 9, 10, 11 and 12.

Geoelectric Section along Traverse three

Figure 4c consists of VES 13 and 14. The section revealed four to five subsurface layers namely, topsoil, clayey/leachate, clay, and clayey sand. The topsoil is characterized by resistivity value of 29.0 Ωm and layer thickness of 0.9 m. The second layer beneath VES 13 and 14 denotes clay/leachate with resistivity and thickness values that range between 4.0 Ωm to 8.0 Ωm and 11.4 m to 15.8 m respectively. The third identified layer depicts clay with resistivity values ranging from 13.0 Ωm to 17.0 Ωm and layer thickness of 8.9 m to 17.1 m. The fourth layer is indicative of clay/leachate with resistivity values ranging from 4.0 Ωm to 5.0 Ωm and layer thickness of 11.4 m to 33.2 m, while the fifth layer connotes clayey sand with resistivity value ranging between 56 Ωm and 73 Ωm but the layer thickness could not be determined due to the fact that the current terminated within this region.

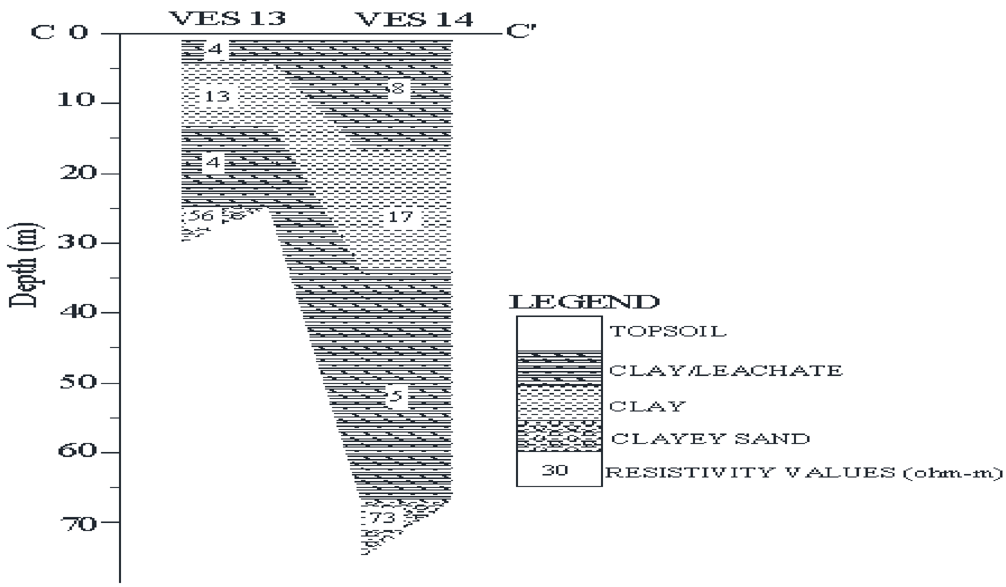

Figure 4c: Geoelectric Section for VES 13 and 14

Geoelectric Section along traverse four

Figure 4d consists of VES 15 to 18. The section revealed four to five subsurface layers namely topsoil, sand, clay, and clayey sand. The topsoil is characterized by resistivity values ranging from 29.0 to 65.0 Ωm and layer thickness of 0.7 m to 0.9 m. The second layer beneath the VES 15 denotes clayey sand with resistivity value of 41 Ωm and thickness of 4.2 m, while the second layer beneath VES 16, 17 and 18 depicts clay with resistivity and layer thickness values of 35.0 to 36.0 Ωm and 1.4 to 4.5 m respectively. The third substratum layer in VES 15, 16, 17 and 18 connotes clay with resistivity values ranging from 55.0 to 76 Ωm and layer thickness of 5.4 to 10.5 m. But in VES 16, the fourth layer represents clayey sand with resistivity value of 130 Ωm and the layer thickness could not be determined due to the fact that the current terminated within this region, while in the fourth layer in VES 15, 17, and 18 revealed clay with resistivity values ranging from 23.0 to 28.0 Ωm and layer thickness of 15.8 to 16.5 m. The fifth horizon signifies clayey sand with resistivity values ranging from 140 to 786 Ωm but the layer thickness could not be determined due to current terminated within this region.

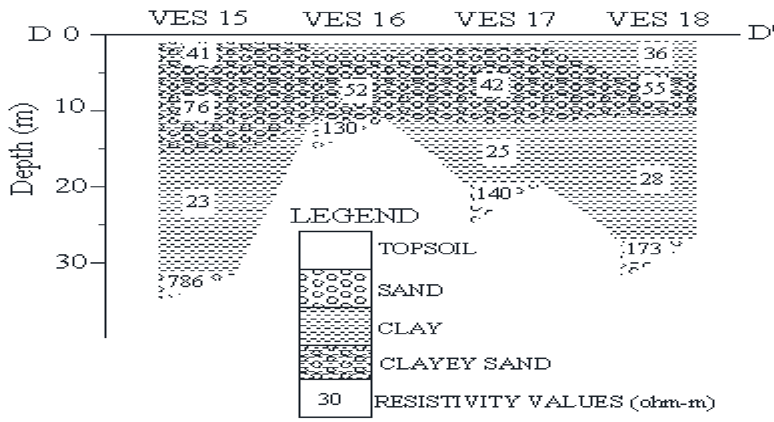

Figure 4d: Geoelectric Section for VES 15, 16, 17 and 18

Geoelectric Section along Traverse five

Figure 4e consists of VES 19 and 20. The section revealed three subsurface layers namely topsoil, clay/leachate, and clayey sand. The topsoil is characterized by resistivity values ranging from 15 to 26 Ωm and thickness of 0.7 to 0.8 m. The second layer in VES 19 denotes clay/leachate with resistivity and thickness value of 7 Ωm and 2.1 m respectively. The third identified geoelectric layer of VES 19 and 20 is indicative of clay with resistivity and layer thickness values of 6.0 to 7.0 Ωm and 24.8 to 35.0 m respectively. The fourth geoelectric layer connotes clayey sand with resistivity values ranging between 30 to 49 Ωm but the layer thickness could not be determined due to the fact that the current terminated within the region.

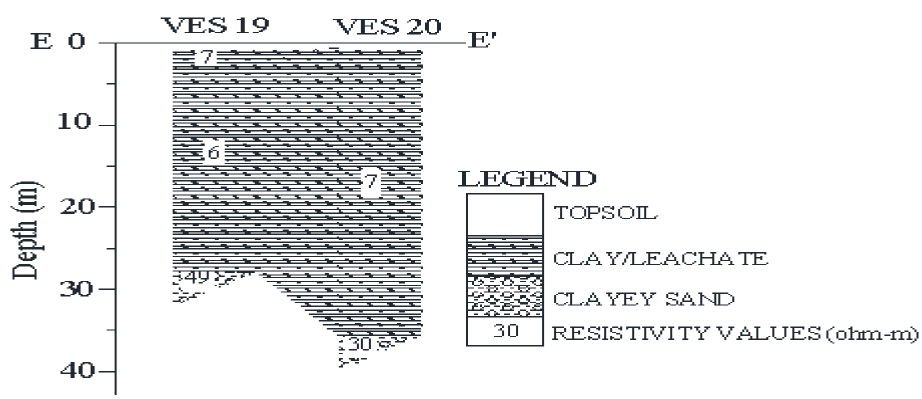

Figure 4e: Geoelectric Section for VES 19 and 20

5. CONCLUSION

Effect of Electronic Waste on Groundwater using Electrical Resistivity Technique (ERT) has been conducted. Five to six geoelectric layers were delineated namely, topsoil, clayey sand, sand, sandy clay and clay/leachate. The 2-D resistivity structures also revealed resistivity values ranging from 4 to 1032 Ωm. Traverses B, C and E are predominantly contaminated with leachate from the electronic dumpsite while traverses A and D partially contaminated with leachate. Traverse A shows to be the best for borehole drilling with depth to aquifer ranging from 10.0 to 40.0 m but due to its proximity to leachate, it is highly vulnerable to contamination.

ACKNOWLEDGEMENTS

A brief acknowledgement section may be given after the conclusion section just before the references. The acknowledgments of people who provided assistance in manuscript preparation, funding for research, etc. should be listed in this section. All sources of funding should be declared as an acknowledgement. Authors should declare the role of funding agency, if any, in the study design, collection, analysis and interpretation of data; in the writing of the manuscript. If the study sponsors had no such involvement, the authors should so state.

COMPETING INTERESTS

Authors have declared no conflict of interest.

AUTHORS' CONTRIBUTIONS

Author A' designed the study. 'Author B' and 'Author E' performed field work and acquired the data. 'Author C' interpreted the data. 'Author E' processed the data. All authors read and approved the final manuscript."

REFERENCES

1. Herat and Agatha (2012). Municipal Solid Waste Generation, Recycling and Disposal, United States, pp 1-14.
2. Rolia, E and Sutjiningsih, D (2018). Application of geoelectric method for groundwater exploration from surface (A literature study). In AIP Conference Proceedings 1977(1), p. 020018
3. Perkins DN, Drisse MN, Nxele T and Sly PD (2014). E-waste: a global hazard. Annals of global health. 80(4) pp.286-95.
4. Smith B and Edger E (2006). Environmental Science: A study of interrelationships (10th edition). New York: McGraw-Hill Higher Education, 3-5.
5. Kofoworola OF (2007). Recovery and Recycling Practices in Municipal Solid Waste Management in Lagos, Nigeria. Waste Management Vol. 27 (9) pg 1139-1143.
6. Wath, S.B., Vaidya, A.N., Dutt, P.S. and Chakrabarti, T (2010). A roadmap for development of sustainable E-waste management system in India. Science of the Total Environment, 409(1), pp.19-32.
7. Egereonu UU, Ibe KM (2003). Investigation of nitrate Pollution in Groundwater of Owerri and Environs, South Eastern Nigeria. J. Assoc. Adv. Model. Simul. Techn. Enterprises., 65(1): 59-76.
8. Alile OM, Jegede SI, Emekeme RE (2009). Subsurface Probe and Hydrochemical Analysis for the Purpose of Siting Waste Landfill. Afr. J. Environ. Sci. Technol., 4(1):472-476.
9. Li, P., Karunanidhi, D., Subramani, T. and Srinivasamoorthy, K (2021). Sources and consequences of groundwater contamination. Archives of environmental contamination and toxicology, 80, pp.1-10.
10. Becker CJ (2001). Hydrogeology and leachate plume delineation at a closed municipal landfill, Norman, Oklahoma. Water Resources Investigations Report 01-4168. U.S. Geological Survey.
11. Dahlin T, Zhou B (2002). Gradient and Mid-point referred measurements for multichannel 2-D resistivity imaging, Procs. 8th meeting of the environmental and engineering geophysics, Aveiro, Portugal. pp 157-160.
12. Rolia, E and Sutjiningsih, D (2018). Application of geoelectric method for groundwater exploration from surface (A literature study). In AIP Conference Proceedings 1977(1), p. 020018
13. Maurya, P.K., Rønde, V.K., Fiandaca, G., Balbarini, N., Auken, E., Bjerg, P.L. and Christiansen, A.V (2017). Detailed landfill leachate plume mapping using 2D and 3D electrical resistivity tomography-with correlation to ionic strength measured in screens. Journal of Applied Geophysics, 138, pp.1-8.
14. LAWMA (2004) Landfill gates records. Ijora Head office, Ijora, Lagos.