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Investigation of subsurface contaminants leachate within Ansaru-Islam Secondary School, Ilorin, Nigeria

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Abstract. This study adopts the use of Vertical Electrical Sounding (VES) and 2-D resistivity imaging (employing Schlumberger and Wenner array configurations) to investigate and map the extent of leachate's migration and its possible impacts on groundwater within Abata Asunkere dumpsite, Ilorin, Kwara State. This study was inspired by the unrestrained manner of garbage dumping in the area over time, which poses great threat to the availability of clean water for the increasing populace. To delineate the subsurface, 2-D resistivity imaging data were acquired along two traverses, while the VES data were randomly acquired along the established traverses. The 2-D resistivity imaging and VES data were processed using Res2D and IPI2Win software respectively. The results of the 2-D and VES revealed five (5) geoelectric sections, which correspond to the topsoil, clayey sand, weathered basement, fractured basement and fresh basement rocks with H, QH and KH sounding signature curve types. The topsoil has layer thickness of 0.5 - 1.7 m and resistivity values ranging from 11.9 - 165 Ωm. The clayey sand has layer thicknesses between 0.7 - 2.8 m and resistivity values ranging from 20.1 - 56 Ωm. The weathered basement has thickness of 0.9 - 16.3 m and resistivity values ranging from 2.09 - 5.25 Ωm. The fractured to fresh basement has resistivity values ranging from 26.8 - 3000 Ωm with thickness ranging from 5.3 m to infinity. The third layer with low resistivity values of 2.09 - 3.52 Ωm at depth range 0.9 - 10 m is suggestive of leachate contamination. The outcome of this study indicates that some regions around the dumpsite are susceptible to leachate's contamination, which has tendencies to permeate the unconfined aquifers in the study area if not properly monitored and controlled.

Keywords: Leachate, Fracture, Aquifer, Traverse, Psuedo-section, Geo-resistivity

1. Introduction

Some of the most severe disputes among the populace of the global community have revolved around discussions surrounding waste management and disposal, particularly, with the ever-increasing addition of refuse annually [1-4]. There are various reasons for the intense arguments that surround the issue of waste management and disposal. One of the major disputes rallies around the existence of landfills, the condoning of landfills around habitable homes and the lack of will to live near one [5]. The landfill contains municipal solid waste or variety of everyday wastes such as nylon wrappers, grasses and weeds, damaged furniture, clothing, food leftovers and scraps, old newspapers and magazines [6-8]. The landfill constituents are predominantly household waste. As the wastes become decomposed or biodegraded, they contain toxic substances, which wax into a composite with water infiltrate to form an organic liquid known as leachate.

The physical, chemical and biological processes act upon one another concurrently to result in total putrefaction of the garbage. One of the several consequences of this process is leachate, a terminology widely used in environmental sciences. It refers to a contaminated liquid often generated from the infiltration of water through a solid waste disposal and contains environmentally toxic constituents, which may then pollute the surrounding water sources and contaminate the soil surface and other subsurface entities. Leachates from landfills vary broadly in its constituents, subject to how long such dumpsite has existed [9-11]. Dump site leachate constitute majorly of percolated rain water based solution. This water then seeps into the subsurface producing a dark coloured liquid with a pungent smell, caused by waste decomposition and the intrinsic liquid in the waste [12]. One of its characteristics features is that it constitutes four categoriesof hazardous wastes which are; water solubleorganic matter (DOM), macro components of inorganic nature, heavy metals and organic compounds of xenobiotic nature [13-18]. Areas with close proximity to landfill, possess the tendency of groundwater pollution, due to the possible pollution source and toxicity of leachate seeping into the aquifer from the dumpsite.The pollution of groundwater creates a considerable danger to local users and presents potential threats to the surrounding habitat and ecosystem [19-21]. This represents a genuine contamination danger to the groundwater source, surface water and soil, prompting an antagonistic effect on the earth, general wellbeing and property [22]. Occasionally, when the climax of the raining season is reached, the landfills are swamped up by flood water, which is a factor that aids the seeping of leachate into the aquifer through the landfill [23].

As a result of the leachate present in the subsurface, it is necessary to investigate the aquifer protective capacity, so as to know if the aquifer is strong enough to prevent the leachate from seeping through it and thereby contaminate it. The extreme efficacy and effectiveness of geophysical methods have been confirmed in areas such as groundwater probing, engineering site investigation, delineating subsurface components, archeological survey, evaluation of topsoil hydrological characteristics and foundation stability evaluation [24-36]. However, in this context the combined use of geophysical techniques provides an indispensable device in the profiling and assessment of leachate pollutants caused by urban landfills (domestic and/or industrial) [37-43]. Of all the geophysical methods, electrical resistivity tomography (ERT) has been established most appropriate for such type of environmental analyses, because of the conductive tendency of mostpollutants. The study is aimed at understanding subsurface material characteristics especially, to know if solid wastes are producing contaminants leachate in the subsurface and to determine the definite aquifer protective capacity within the project site.

2. Materials and methods

2.1 Site Description and Geological Setting

Geological formations in Kwara state ranged in Age, from Precambrian to quaternary. About 90 percent of the state is covered by Precambrian rock (Basement complex) and the remainder by cretaceous and quaternary formations (sedimentary an alluvia). Figure 1, indicates where the study area is situated, Ansarul-Islam secondary school, along Okekere Alore Ilorin, Kwara State. The area of study, is situated on the latitude 8° 30’ 16 .76’’ North and longitude 4°31’ 55.72’’ East. The area was used as a dumpsite for about 10 years ago. The thickness of the contamination of the area when it was excavated was 8 m. The area covered 400 m by 200 m in terms of length and breadth.

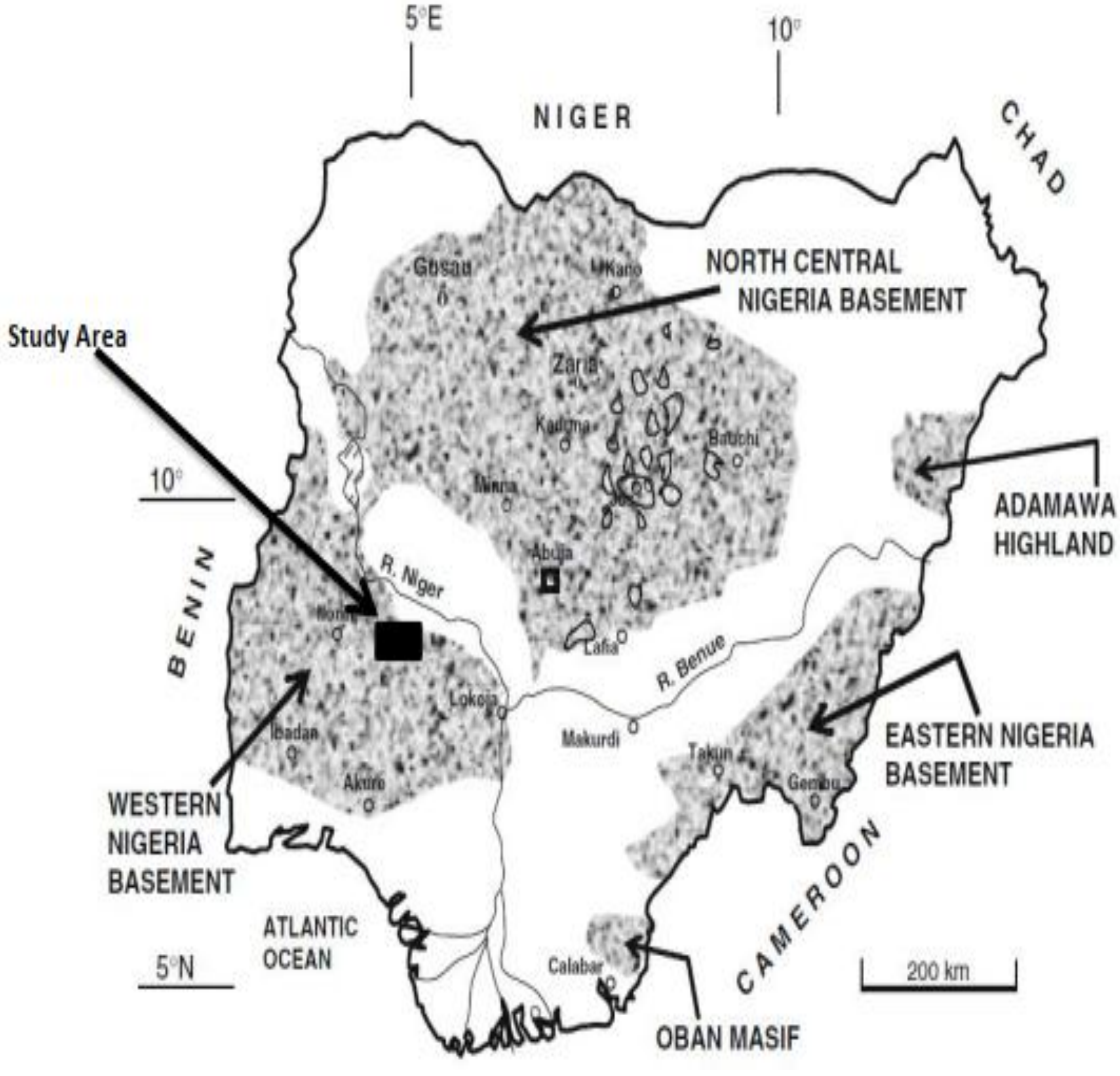


Figure 1: Geology Map of Nigeria revealing the study area, Ilorin, Kwara state

2.2 Field Survey

In this study, in order to ascertain the deepness to the groundwater table, thickness of the aquifer and subsurface geological makeup for the distribution of groundwater alongside its potential as an alternative to the surface water reserves, the Vertical Electrical Sounding (VES) was employed. Four (4) VES points as shown in Figure 2, were sounded near Ansaru-Islam Secondary School Abata Asunkere, Alore area of Ilorin. The Schlumberger electrode arrangement was adopted with a set maximum (AB/2) of 80 m.

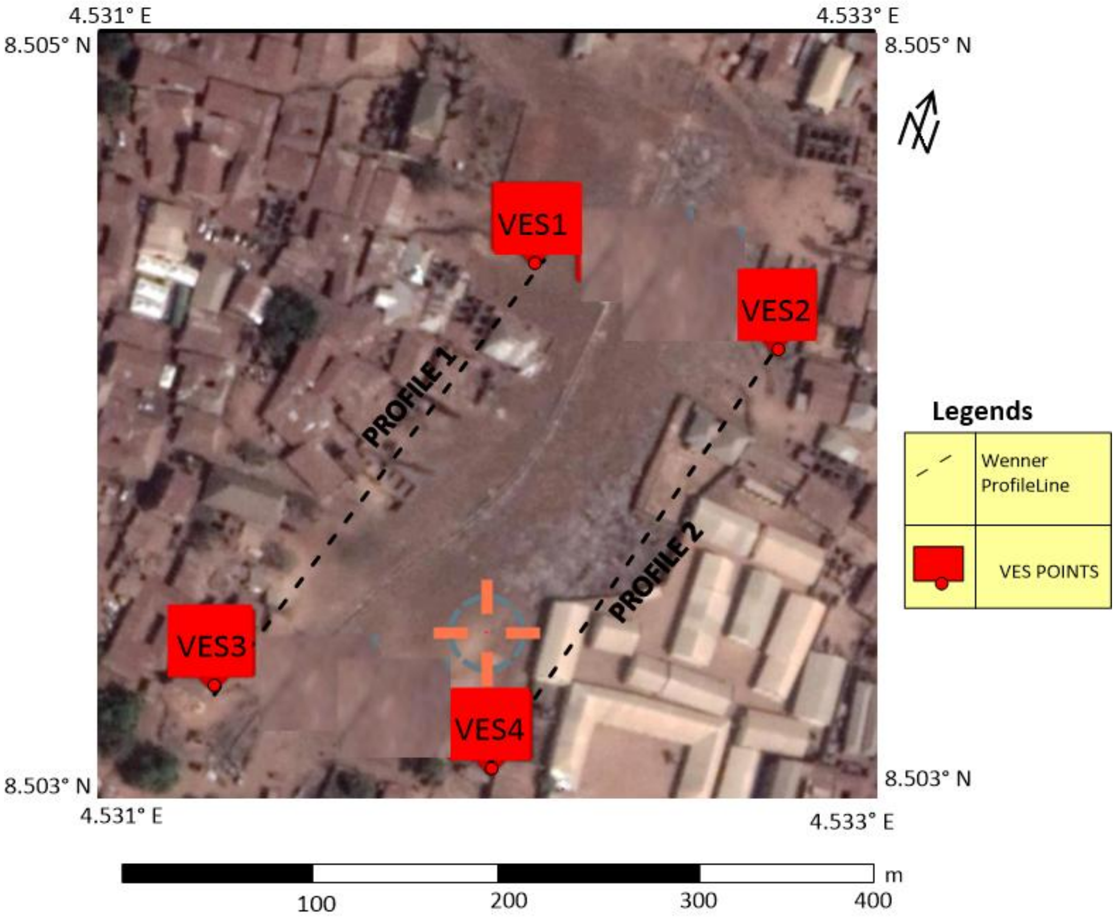


Figure 2: Base map of the study area

2.3 Data Acquisition

Though, it is procedural to test several electrical resistivity Imaging (ERI) arrays when starting a survey so as to ascertain the array that is fitting for the desired survey target because eachERI|has its merits and demerits. For this study however, the Wenner and the Schlumberger arrays were preferred because of their sensitivity to vertical variations in subsurface resistivity, and less sensitive to horizontal variations, which was considered beneficial for this survey location since semi lateral continuity of the geologic structure of the aquifer was expected. The Wenner and Schlumberger arrays were generally known to have good signal strength, because the electric potential measurement electrodes were located between the current injection electrodes.

2.4 Field Method

This study employed the Vertical Electrical Sounding (VES) using the Schlumberger and Wenner electrode configurations. The ABEM SAS 300C Terameter was used for the field measurements. A total of four (4) VES points along two profiles, uniformly distributed on the waste were marked and sounded. The field data were plotted on a log resistivity graph for a rough interpretation. Further analyses and interpretations were done using the IPI2Win and RES2DINV software. The pseudosections obtained from RES2DINV geo-electrical software consists of measured apparent resistivity data, calculated apparent resistivity data and resistivity contour-section.

3. Results and discussion

3.1 2D electrical resistivity imaging results

The geosounding images obtained in this study are presented in Figures 3 – 6. The results of the interpreted 2D Electrical resistivity data are presented in a colour coded format comprising the Inverted 2D Resistivity image. The horizontal scale represents the lateral distance while the vertical scale connotes the depths (in metres). For traverse one (Figure 3), the 2D resistivity image reveal a thick conductive body buried under the subsurface at a depth extent of about 10 m. A slightly resistive top layer of resistivity values less than 100 to 400 Ωm typically of clayey sand to sandy clay was observed all through Figure 3 - 6. Next to this, is a layer of moderate to low resistivity values (<100Ωm) which has composition similar to weathered basement rock. Beneath this is resistive zones represented by yellow to purple colour, which represent fractured to fresh basement rock zones.

3.2. 1D VES geo-resistivity sections

3.2.1 VES Profile 1

Figure 7, which represents VES 1 shows geo-electric section for three profiles. The sandy topsoil which is the first layer has a resistivity and thickness of 56.4 Ωm and of 2 m, respectively. The clayey sand which occupies the second layer has a resistivity ranging from 3.52 Ωm to 3.77 Ωm with the thickness that ranges between 2 m to 6 m. Due to the accretion of leachates or the attraction of ions at the charged surface of associated boundary, there is high conductivity in the second layer. The decreasing threads of resistivity is an indication of contamination.The third layer shows increasing thread in the resistivity point.

3.2.2 VES Profile 2

Figure 8, which represents VES 2 shows geo electric section for four profiles. The sandy topsoil which is the first layer has a resistivity and thickness of 61.1 Ωm and 1m, respectively. The clayey sand which occupies the second layer has a resistivity ranging from 20.1to 25.2 Ωm with thickness that ranges between 1to 3 m. The weathered basement which occupies the third layer has resistivity ranging from 5to 8 Ωm while the thickness ranges between 3to 10 m. Due to the accretion of leachates or the attraction of ions at the charged surface of associated boundary, there is high conductivity in the weathered basement. The decreasing thread of resistivity is an indication of contamination.The bedrock layer (Fractured or Fresh Basement) which occupies the fourth section has a resistivity range of 2500 and 2589Ωm. The low resistivity values at the basement level could also be because of contamination.

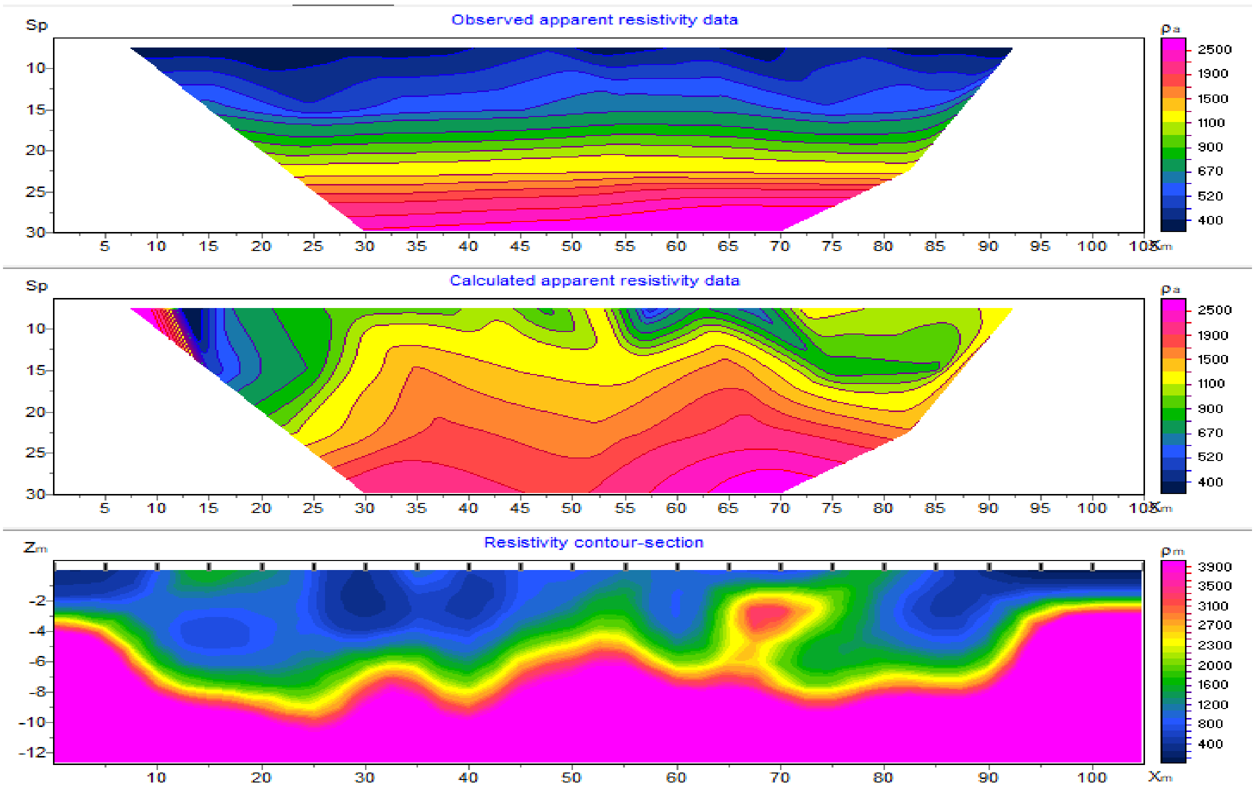


Figure 3: 2D Resistivity Pseudo-Section along Traverse one

3.2.3VES Profile 3

Figure 9, which represents VES 3 shows geo electric section for four profiles. The sandy topsoil which is the first layer has a resistivity and thickness of 12 Ωm and 1m, respectively. The clayey sand which occupies the second layer has a resistivity which ranges from 56.1to 58.5 Ωm with thickness that ranges between 1to 3 m. The weathered basement which occupies the third layer has a resistivity ranging from 5to 8 Ωm and a thickness ranging between 3to 17 m. Due to the accretion of leachates or the attraction of ions at the charged surface of associated boundary, there is high conductivity in the weathered basement. The decreasing threads of resistivity is an indication of contamination. The bedrock layer (Fractured or Fresh Basement) which occupies the fourth section has a resistivity range of 2656 and 3021 Ωm. The low resistivity values at the basement level could also be as a result of contamination.

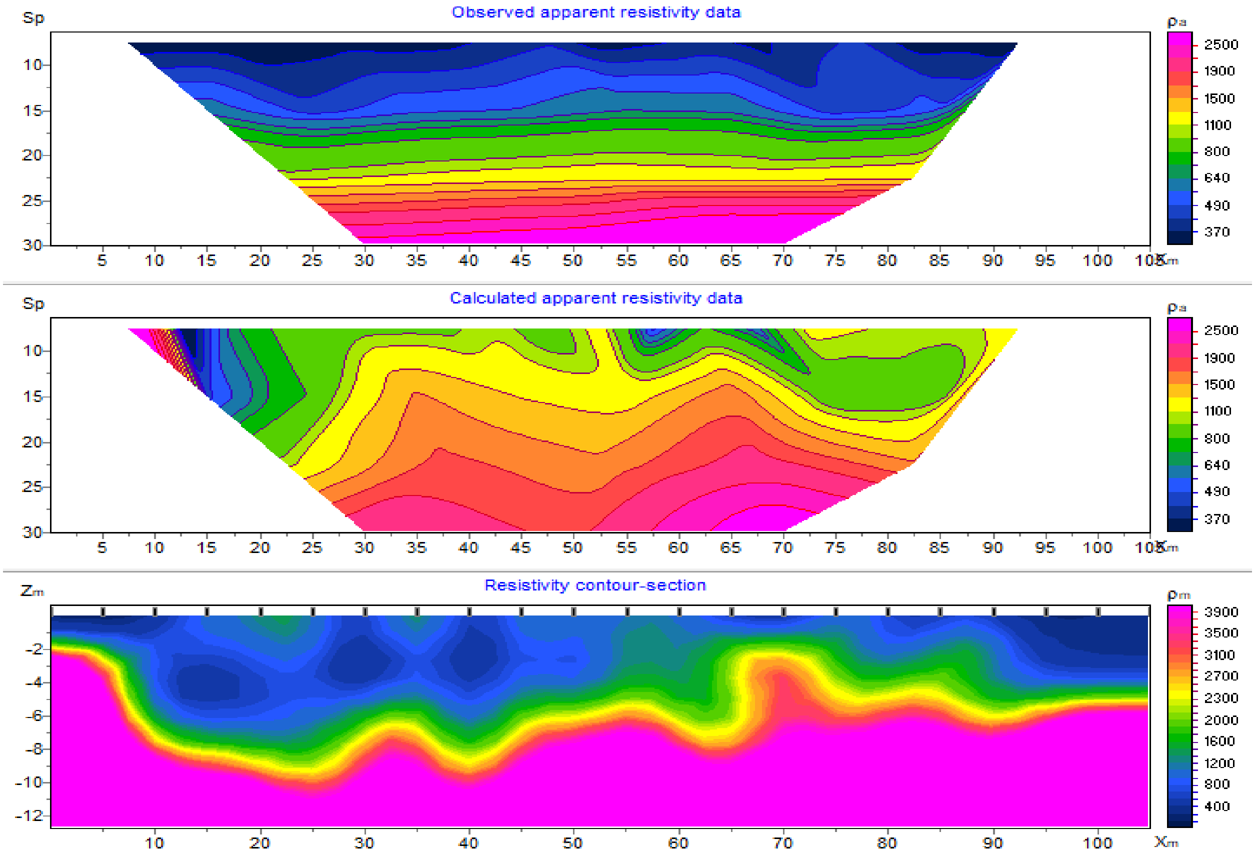


Figure 4: 2D Resistivity Pseudo-Section Along Traverse two

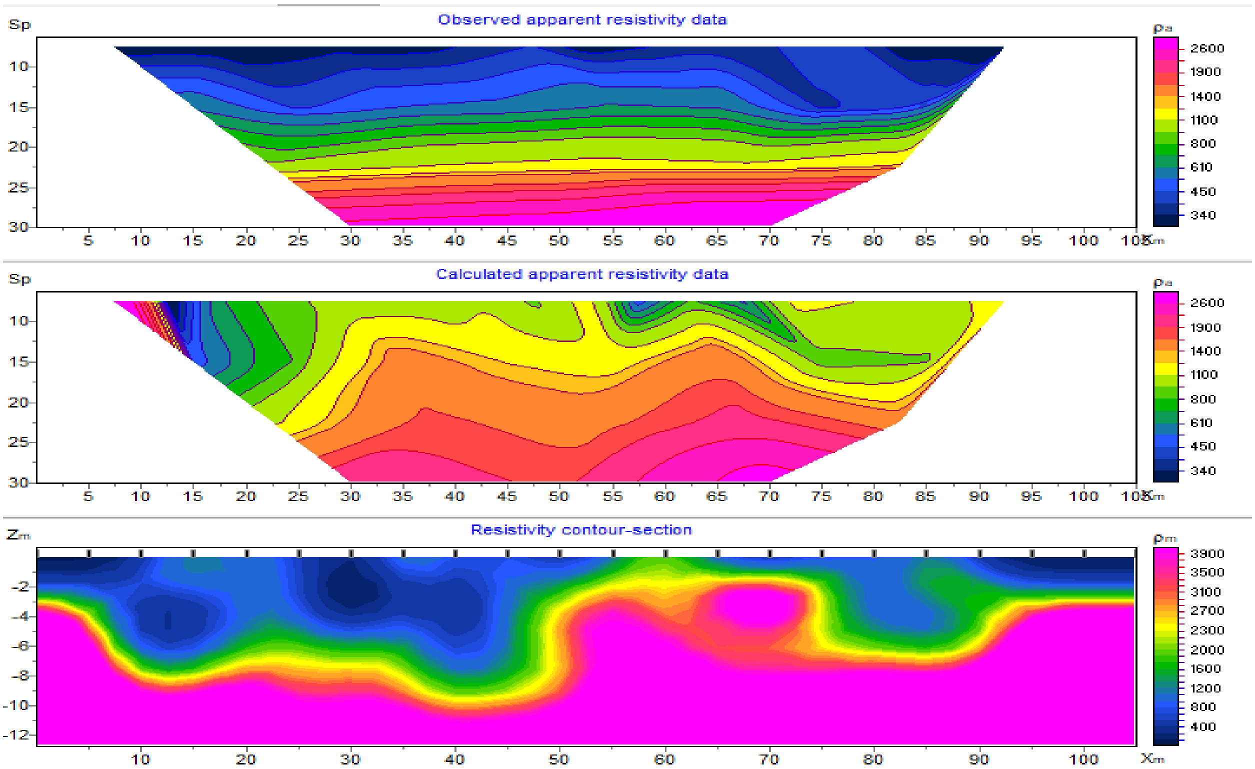


Figure 5:2D Resistivity Pseudo-Section along Traverse three

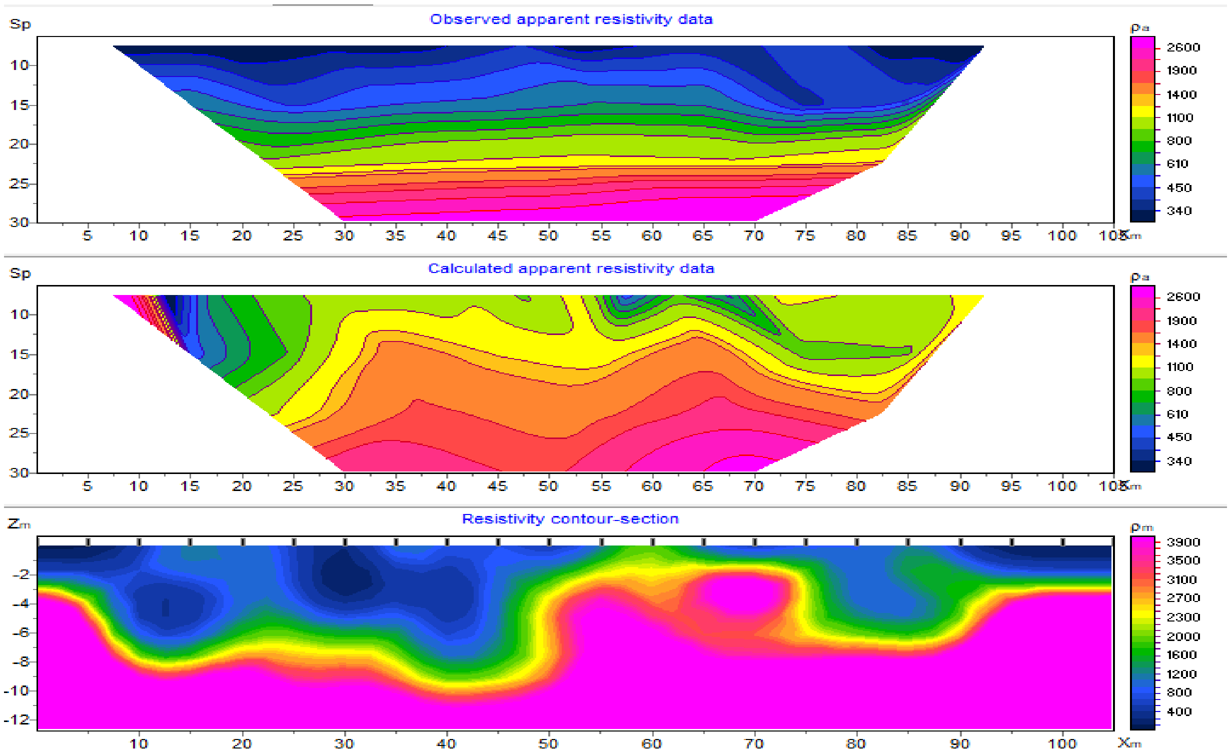


Figure 6: 2D Resistivity Pseudo-Section along Traverse four

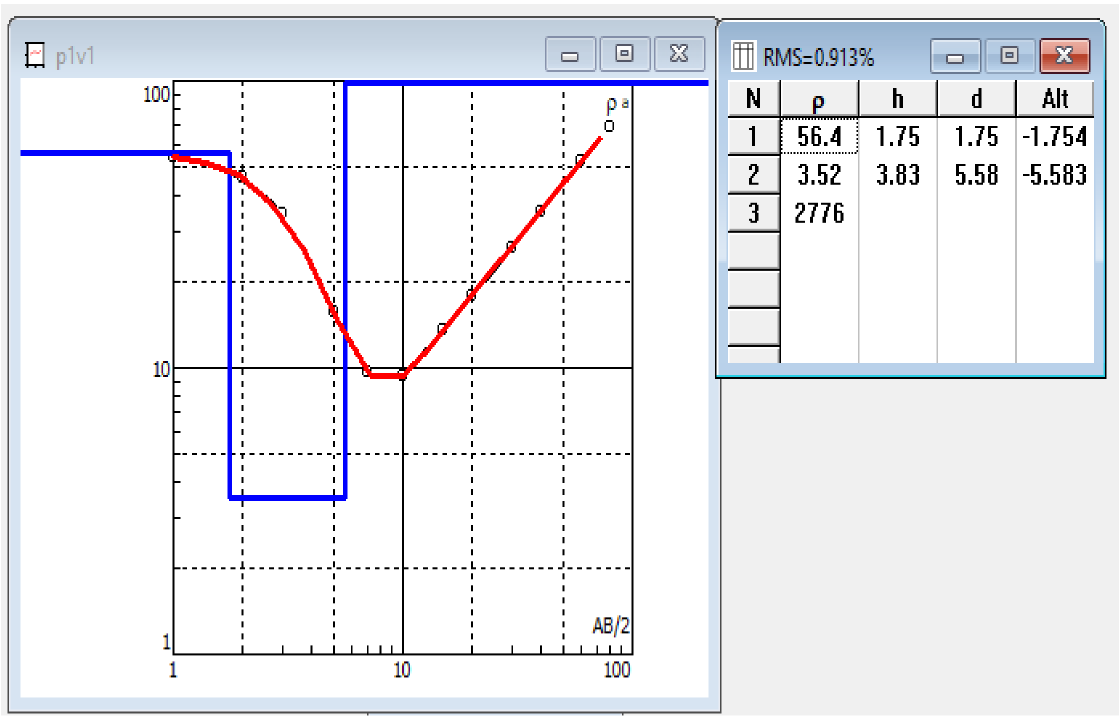
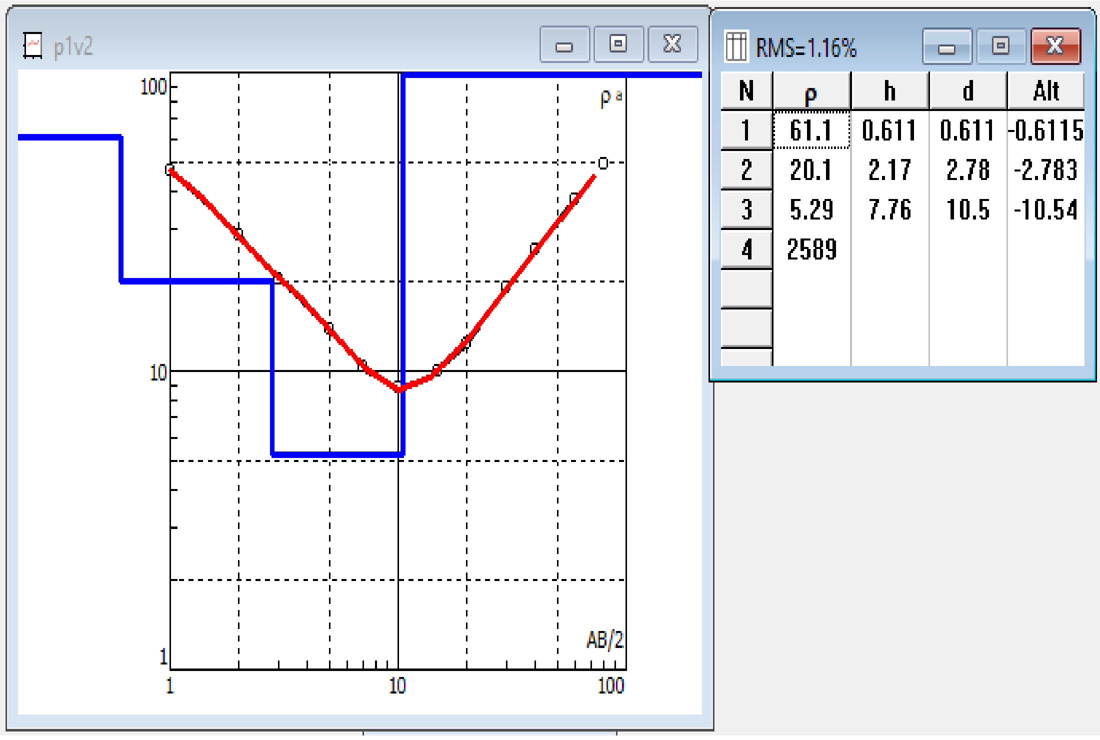
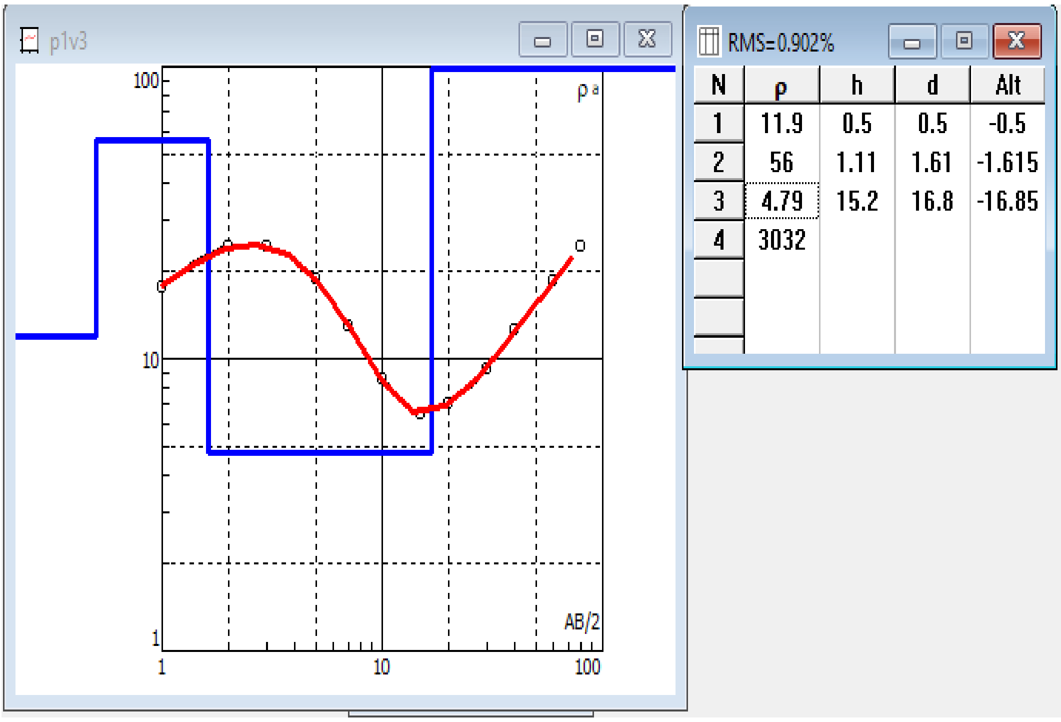


Figure 7: Sounding curve for VES 1



N	ρ	h	d	Alt
1	61.1	0.611	0.611	-0.6115
2	20.1	2.17	2.78	-2.783
3	5.29	7.76	10.5	-10.54
4	2589			

Figure 8: Sounding curve for VES 2



N	ρ	h	d	Alt
1	11.9	0.5	0.5	-0.5
2	56	1.11	1.61	-1.615
3	4.79	15.2	16.8	-16.85
4	3032			

Figure 9: Sounding curve for VES 3

3.2.4 VES Profile 4

Figure 10, which represents VES 4 shows geo electric section for three profiles. The first layer consists of sandy topsoil, with resistivity and thickness of 165 Ωm and 2 m, respectively. The second layer, which consists of clayey sand has resistivity ranging from 2 to 2.89 Ωm while the thickness ranges between 2to 9 m. This low resistivity value was attributed to either the accretion of leachates or the attraction of ions at the charged surface of associated boundary layers. The third layer shows increasing thread in the resistivity point. The decreasing thread of resistivity is an indication of contamination.

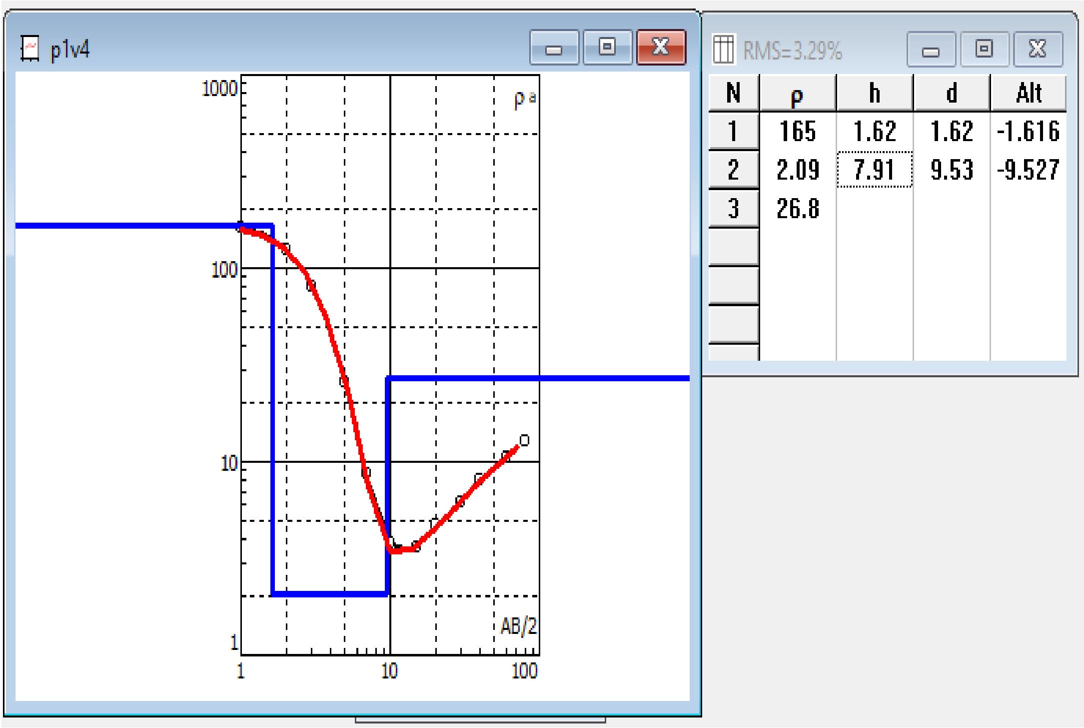


Figure 10: Sounding curve for VES 4

3.3 Geo-electric section

Figure 11, shows the Geo-electric section of Abatasunkere revealing the horizontal diagrammatic section of layers which is deduced from the electrical resistivity depth probing, in which the layers are identified by their apparent resistivities. The figure showed that VES 1 has three layers (3), VES 2 has four layers (2), VES 3 has four layers (4) and VES 4 has three layers (3) culminating into a total of five lithologies in the area which are topsoil, clayey sand, weathered basement, fractured basement and fresh basement rocks.

The subsurface lithology according to the VES survey shows that the study area comprises of the top soil, clayey sand, weathered basement, fractured basement and fresh basement rocks with H, QH and KH sounding signature curve type. The top soil consists of sandy clay materials having resistivity range of 11.9 to 165 Ωm with thickness ranging between 0.5 to 1.7 m. The clay percentage is higher in some VES stations such as VES 1 to VES 3. Also, VES 4 has a slightly higher resistivity (165 Ωm) with results from the higher sand content.

The weathered basement which is the third layer has resistivity ranges from 2 to 5 Ωm with a thickness variation of 0.9 to 16.3 m which is the highest layer in terms of thickness. The low resistivity values might as a result of landfill discharges be one of the aquiferous layer within the study area. The fractured to fresh basement has resistivity ranges from 26 to 3000 Ωm with an infinite depth.Consequently, it was revealed that the soil surface and subsurface encompassing the landfill section have drifted into the aquifer zone, adulterating it 10 m deep.

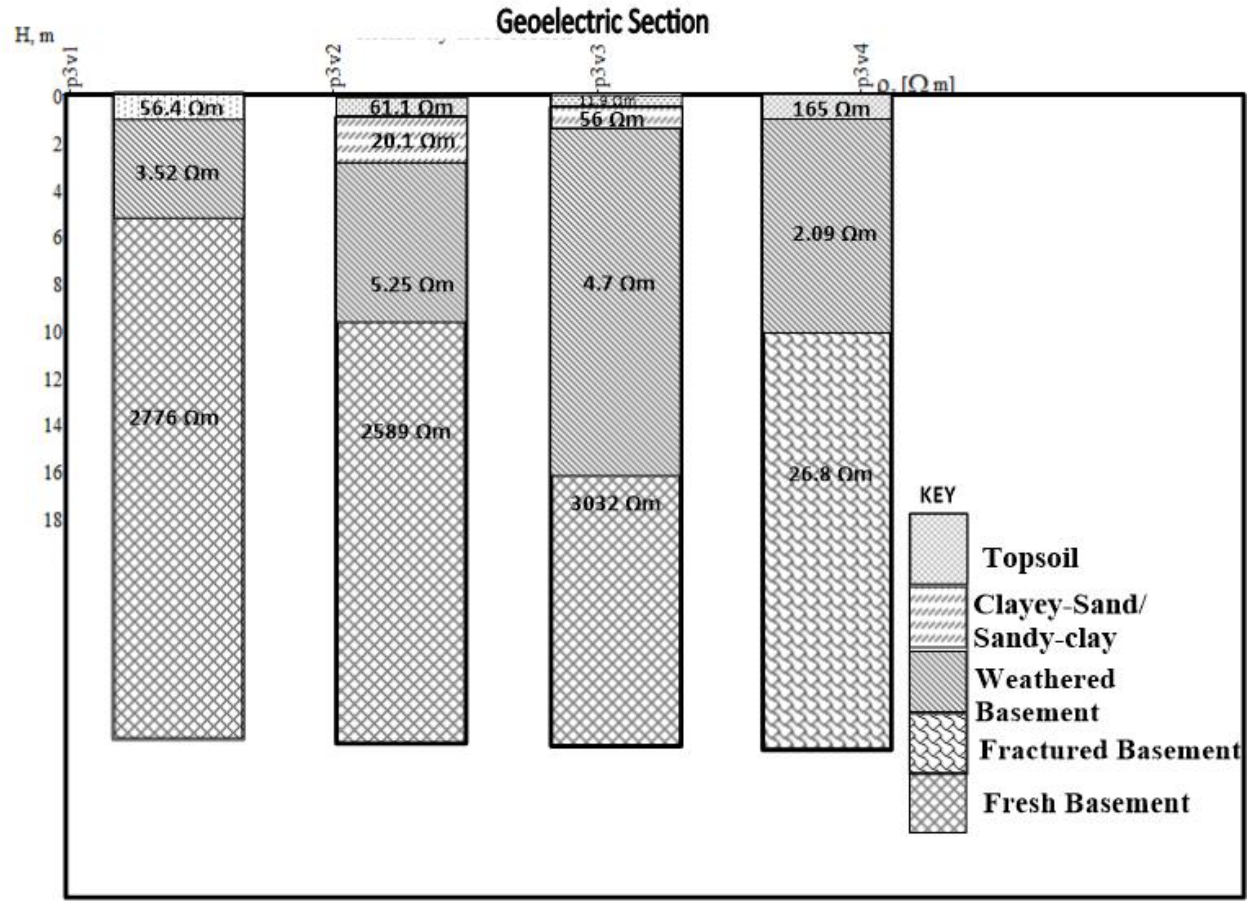


Figure 11: Horizontal geo-electric section of layers in the study area.

For all VES stations, geo-electric sectioning revealed top layers that are mostly clayey and clayey sand, while the second layer is occupied by sandy clay/weathered basement. This result was also confirmed with the aid of Wenner pseudo-section, along traverse two. The Wenner resistivity pseudo section reveals conductive zones, that is the areas with blue colours which are seen up to 10 m depth along horizontal distances starting from 0 m tothe end of the profile. This also shows some signs of discontinuities around 65 to 75 m. This indicates a fractured structurein the aquifer zone through which fluids leaks towards or into the aquiferous layer. The fractured structures also aid as channels for the inflow of leachate plume to groundwater, which reveal areas of contamination in the study area.

4. Conclusion and Recommendation

The lateral and vertical extents of contaminants within Abata Asunkere area of Ilorin have been delineated using the Schlumberger and Wenner arrays. The outcome of the VES survey has been able to delineate subsurface leachate plume as high conductivity zones. Via 2D resistivity imaging, the extent of contamination in the study area was characterized in terms of the landfill geometry, leachate plumes and disposal trenches. The study revealed that some regions around the dumpsite may have been contaminated by leachates with tendency to infiltrate the unconfined aquifers in the area if not properly monitored and regulated.

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References

[1] Ozbay G.,Jones M.,Gadde M.,Isah S. and Attarwala T. (2021). Design and Operation of Effective Landfills with Minimal Effects on the Environment and Human Health. Journal of Environmental and Public Health,2021: 1 - 13. https://doi.org/10.1155/2021/6921607.

[2] Ma K. and John Taylor W. (2020). A Comparative Study of Solid Waste Management in the United States, Europe and Asia. Annals of Civil and Environmental Engineering,4(1):3 - 11. https://doi.org/10.29328/journal.acee.1001019.

[3] Kumar S.,Singh S., andBanerjee S. (2020). Solid Waste Management in Developing Countries. Journal of Critical Reviews,7(10): https://doi.org/10.31838/jcr.07.10.252.

[4] Akpan V.E. andOlukanni D.O. (2020). Hazardous Waste Management: An African Overview. Recycling,5(3): https://doi.org/10.3390/recycling5030015.

[5] Banda H.M.N. (2016). Landfilling and Environmental Problems in Sri Lanka(with reference to Gampaha District). Felicitation Volume of Professor G.W. Indrani, 187–194.http://repository.kln.ac.lk/handle/123456789/12036.

[6] He P.,Chen L.,Shao L.,Zhang H. and Lü F. (2019). Municipal Solid Waste (MSW) Landfill: A Source of Microplastics? -Evidence of Microplastics in Landfill Leachate. Journal of Water Research,159: 38 - 45. https://doi.org/10.1016/j.watres.2019.04.060.

[7] Ma S., Zhou C., Pan J., Yang G., Sun C., Liu Y., Chen X., Zhao Z. (2022). Leachate from Municipal Solid Waste Landfills in a Global Perspective: Characteristics, Influential Factors and Environmental Risks. Journal of Cleaner Production,333. https://doi.org/ 10.1016/j.jclepro.2021.130234.

[8] Aromolaran O.,Fagade O.E.,Aromolaran O.K.,Faleye E.T. andFaerber H. (2019). Assessment of Groundwater Pollution Near Aba-Eku Municipal Solid Waste Dumpsite. Environmental Monitoring and Assessment,191(12): 1 - 25. https://doi.org/10.1007/s10661-019-7886-1.

[9] Agbozu I.,Oghama O. andOdhikori J. (2015). Physico-Chemical Characterization and Pollution Index Determination of Leachates from Warri Waste Dumpsite, Southern Nigeria. Journal of Applied Sciences and Environmental Management, 19(3): 361 - 372. https://doi.org/10.4314/jasem.v19i3.4.

[10] Mojiri A., Zhou L., Ratnaweera H., Ohashi A., Ozaki N., Kindaichi T., Asakura H. (2021). Treatment of Landfill Leachate with Different Techniques: An Overview. Journal of Water Reuse and Desalination,11(1): 1 - 30. https://doi.org/10.2166/wrd.2020.079.

[11] Zamri M.F.M.A.,Kamaruddin M.A.,Yusoff M.S.,Aziz H.A. andFoo K.Y. (2017). Semi-aerobic Stabilized Landfill Leachate Treatment by Ion Exchange Resin: Isotherm and Kinetic Study. Applied Water Science,7(2): 1 - 10. https://doi.org/10.1007/s13201-015-0266-2.
[12] Peng Y. (2017). Perspectives on Technology for Landfill Leachate Treatment. Arabian Journal of Chemistry,10: 1 -8. https://doi.org/10.1016/j.arabjc.2013.09.031.
[13] Christensen G.A.,Waddell K.L.,Stanton S.M. andKuegler O. (2016). California's Forest Resources: Forest Inventory and Analysis, 2001–2010.USDA Forest Service-General Technical Report Pacific Northwest Research Station-GTR, 2016(GTR-913).
[14] Pivato A. and Gaspari L. (2006). Acute Toxicity Test of Leachates from Traditional and Sustainable Landfills using Luminescent Bacteria. Waste Management,26(10): 1 - 8. https://doi.org/10.1016/j.wasman.2005.10.008.
[15] Liu Z.P.,Wu W.H.,Shi P.,Guo J.S. andCheng J. (2015). Characterization of Dissolved Organic Matter in Landfill Leachate During the Combined Treatment Process of Air Stripping, Fenton, SBR and Coagulation. Waste Management,41: 1 - 8.https://doi.org/10.1016/j.wasman.2015.03.044.
[16] Teng C.,Zhou K.,Peng C., andChen W.(2021). Characterization and Treatment of Landfill Leachate: A review. Water Research,203: 1 - 13. https://doi.org/10.1016/j.watres.2021.117525.
[17] Mojiri A.,Aziz H.A.,Zaman N.Q.,Aziz S.Q. andZahed M.A. (2016). Metals Removal from Municipal Landfill Leachate and Wastewater using Adsorbents Combined with Biological Method.Desalination and Water Treatment,57(6): 1 - 16. https://doi.org/10.1080/19443994.2014.983180.
[18] Torabian A.,Hassani A.H. andMoshirvaziri S. (2004). Physicochemical and Biological Treatability Studies of Urban Solid Waste Leachate. International Journal of Environmental Science and Technology,1(2): 103 - 107.https://doi.org/10.1007/bf03325822.
[19] Baderna D.,Caloni F. andBenfenati E. (2019). Investigating Landfill Leachate Toxicity In-vitro: A Review of Cell Models and Endpoints.Environment International,122: 1 - 10. https://doi.org/ 10.1016/j.envint.2018.11.024.
[20] Njoku P.O.,Edokpayi J.N. andOdiyo J.O.(2019). Health and Environmental Risks of Residents Living Close to a Landfill: A Case Study of Thohoyandou Landfill, Limpopo Province, South Africa. International Journal of Environmental Research and Public Health,16(12): 1 - 27. https://doi.org/10.3390/ijerph16122125.
[21] Vaverková M.D.(2019). Landfill Impacts on the Environment - Review. Geosciences (Switzerland),9(10): 1 - 16. https://doi.org/10.3390/geosciences9100431.
[22] Wemegah D.D.,Fiandaca G.,Auken E.,Menyeh A. andDanuor S.K.(2014). Time-domain Spectral Induced Polarization and Magnetics for Mapping Municipal Solid Waste Deposits in Ghana. Near Surface Geoscience, 20th European Meeting of Environmental and Engineering Geophysics. https://doi.org/10.3997/2214-4609.20142084.
[23] Loke M.H.,Acworth I. andDahlin T. (2003). A Comparison of Smooth and Blocky Inversion Methods in 2D Electrical Imaging Surveys. Exploration Geophysics,34(3): 182 - 187.https://doi.org/10.1071/EG03182.
[24] Aizebeokhai A.P.,Ogungbade O. andOyeyemi K.D. (2018). Geoelectrical Resistivity Data Set for Characterising Crystalline Basement Aquifers in Basiri, Ado-Ekiti, Southwestern Nigeria. Data in Brief,19: 810 - 816. https://doi.org/10.1016/j.dib.2018.05.091.

[25] Oyeyemi K.D., Olofinnade O.M., Aizebeokhai A.P., Sanuade O.A., Oladunjoye M.A., Ede A.N., Adagunodo T..A., Ayara W.A. (2020). Geoengineering Site Characterization for Foundation Integrity Assessment. Cogent Engineering, 7(1): 1 - 15.https://doi.org/10.1080/23311916.2020.1711684.

[26] Oladunjoye M.A.,Salami A.J.,Aizebeokhai A.P.,Sanuade O.A. andKaka S.L.I. (2017). Preliminary Geotechnical Characterization of a Site in Southwest Nigeria Using Integrated Electrical and Seismic Methods. Journal Geological Society of India,89(2): 209 - 215. https://doi.org/10.1007/s12594-017-0585-z.

[27] Aizebeokhai A.P.,Olayinka A.I. and Singh V.S. (2010). Application of 2D and 3D Geoelectrical Resistivity Imaging for Engineering Site Investigation in a Crystalline Basement Terrain, Southwestern Nigeria. Environmental Earth Sciences, 61(7): 1481 - 1492. https://doi.org/10.1007/s12665-010-0464-z.

[28] Oyeyemi K.D.,Oladunjoye M.A.,Aizebeokhai A.P.,Ajekigbe P.G. andOgunfolakan B.A.(2015). Integrated Geophysical Investigations for Imaging Archaeological Structures in Ancient Town of Ile-Ife, Nigeria. Asian Journal of Information and Technology, 14(7): 246 - 252. https://doi.org/10.3923/ajit.2015.246.252.

[29] Ewusi A. and Seidu J.(2020). Efficacy of Geophysical Techniques for Groundwater Exploration in the Volta Basin, Northern Region of Ghana. Ghana Mining Journal, 20(1): 10 - 19. https://doi.org/10.4314/gm.v20i1.2.

[30] Adagunodo T.A., Sunmonu L.A., Oladejo O.P., Olanrewaju A.M. (2019). Characterization of Soil Stability to withstand Erection of High-Rise Structure using Electrical Resistivity Tomography. In: Kallel A. et al. (eds.). Recent Advances in Geo-Environmental Engineering, Geomechanics and Geotechnics, and Geohazards. Advances in Science, Technology and Innovation (IEREK Interdisciplinary Series for Sustainable Development). https://doi.org/10.1007/978-3-030-01665-4_38 © Springer Nature Switzerland AG 2019. Print ISBN 978-3-030-01664-7, Online ISBN 978-3-030-01665-4.

[31] Adagunodo T.A., Bayowa O.G., Ojoawo A.I., Adewoyin O.O., Isibor P.O., Jephthah E.A., Anie N.O. (2022). Investigation of foundation bed's characteristics and environmental safety assessment in some parts of Bayelsa State, south-south Nigeria. Cogent Engineering, 9: 2119533. https://doi.org/10.1080/23311916.2022.2119533.

[32] Bayowa O.G., Adagunodo T.A., Akinluyi F.O. and Hamzat W.A. (2022). Geoelectrical exploration of the Coastal Plain Sands of Okitipupa area, southwestern Nigeria. International Journal of Environmental Science and Technology, https://doi.org/10.1007/s13762-022-04393-4.

[33] Adewoyin O.O., Joshua E.O., Akinyemi M.L., Omeje M., Adagunodo T.A. (2021). Evaluation of Geotechnical Parameters of Reclaimed Land from Near-surface Seismic Refraction Method. Heliyon, 7: e06765. https://doi.org/10.1016/j.heliyon.2021.e06765.

[34] Adagunodo T.A. and Oladejo O.P. (2020). Geoelectrical Variations in Residential Area of Ojongbodu, Oyo, Southwestern Nigeria. Nature Environment and Pollution Technology, 19(4): 1771 – 1774.

[35] Bayowa O.G., Adagunodo T.A., Olaleye O.A., Adeleke A.E., Usikalu M.R., Akinwumi S.A. (2020). Hydrolithological Investigation for near Surface Aquifers within Lekki Peninsula, Lagos, Southwestern Nigeria. Nature Environment and Pollution Technology, 19(2): 511 – 520.

[36] Adagunodo T.A., Akinloye M.K., Sunmonu L.A., Aizebeokhai A.P., Oyeyemi K.D., Abodunrin F.O. (2018). Groundwater Exploration in Aaba Residential Area of Akure, Nigeria. Frontiers in Earth Science, 6: 66. https://doi.org/10.3389/feart.2018.00066.
[37] Green A.,Lanz E.,Maurer H. andBoerner D. (1999). A Template for Geophysical Investigations of Small Landfills. The Leading Edge,18(2): 248 - 254. https://doi.org/10.1190/1.1438264.
[38] Chibueze Okpoli C.(2013). Application of 2D Electrical Resistivity Tomography in Landfill Site: A Case Study of Iku, Ikare Akoko, Southwestern Nigeria. Journal of Geological Research,2013: 1–8. https://doi.org/10.1155/2013/895160.
[39] Orlando L. andMarchesi E. (2001). Georadar as a Tool to Identify and Characterise Solid Waste Dump Deposits. Journal of Applied Geophysics, 48(3): 163 - 174. https://doi.org/10.1016/S0926-9851(01)00088-X.
[40] Osinowo O.O.,Agbaje M.A. andAriyo S.O. (2020). Integrated Geophysical Investigation Techniques for Mapping Cassava Effluent Leachate Contamination Plume, at a Dumpsite in Ilero, Southwestern Nigeria. Scientific African,8: 1 - 12. https://doi.org/10.1016/j.sciaf.2020.e00374.
[41] Lopes D.D.,Silva S.M.C.P,Fernandes F.,Teixeira R.S.,Celligoi A., andDall'Antônia L.H. (2012). Geophysical Technique and Groundwater Monitoring to Detect Leachate Contamination in the Surrounding Area of a Landfill - Londrina (PR - Brazil). Journal of Environmental Management, 113: 481 - 487. https://doi.org/10.1016/j.jenvman.2012.05.028.
[42] Osabuohien I.,Monday A.O. andJohn A.O. (2020). The Application of Geophysical Techniques in Tracking Leachate Plumes Migration in a Typical Cemetery within the Sandy Formation in Benin City, Nigeria. Journal of Geological Research, 2(1): 20 - 25. https://doi.org/10.30564/jgr.v2i1.1970.
[43] Hung Y.C.,Lin C.P.,Lee C.T. andWeng K.W. (2019). 33D and Boundary Effects on 2D Electrical Resistivity Tomography. Applied Sciences, 9(15): 1 - 19. https://doi.org/10.3390/app9152963.