DISCOVERY

Geo-electrical mapping of contaminant plume in some open dumpsites using electrical resistivity tomography in Maiduguri metropolis, Northeastern Nigeria

Shuwa ZA, Kamale HI*, Ibrahim Y

To Cite:
Shuwa ZA, Kamale HI, Ibrahim Y. Geo-electrical mapping of contaminant plume in some open dumpsites using electrical resistivity tomography in Maiduguri metropolis, Northeastern Nigeria. *Discovery* 2023; 59: e45d1049

Author Affiliation:
Department of Geology, University of Maiduguri, Nigeria

***Corresponding author**
Department of Geology, University of Maiduguri
Nigeria
Email: hikamale@unimaid.edu.ng

Peer-Review History
Received: 15 March 2023
Reviewed & Revised: 18/March/2023 to 28/March/2023
Accepted: 31 March 2023
Published: April 2023

Peer-Review Model
External peer-review was done through double-blind method.

Discovery
pISSN 2278–5469; eISSN 2278–5450

DISCOVERY SCIENTIFIC SOCIETY

ABSTRACT
Groundwater has been the main source of water for domestic and other uses, these uses are under threat as a result of anthropogenic activities that is poor waste disposal practice. Contamination of groundwater under and near waste disposal sites happens as a result of infiltration of contaminants through the soil. Pollutants are aqueous liquid called leachate. Leachates are formed when rain falls on dump, sinks into the waste and picks up contaminants as it seeps downwards. Some wastes dumped at the dumpsite over the years are expected to have biodegraded and generated leachate which could have become a point source of pollutant into the soil and groundwater. 2D resistivity imaging survey (tomography survey) was used in the 8 dumpsites to map out the leachate plumes. Three zones of varying resistivity contrast were delineated, the zone of low resistivity interpreted as leachate plumes and decaying waste materials, the zone of moderate resistivity interpreted as sand and clay and high resistivity zone representing dry sand.

Keywords: Geo-electric, Dumpsite, Leachate, Tomography, Resistivity, contaminant.

1. INTRODUCTION
The problem of environmental contamination and waste management is one of the major threats to the environment. Fast industrial development and the uncontrolled growth of the urban population result in the production of toxic solid wastes. Groundwater water quality is an important factor in the context of sustainable water management. The integrity of underlying aquifers is mainly affected by pollution from above ground sources (Kumar et al., 2013) particularly solid waste disposal. Uncontrolled urbanization results in generation of huge amount of waste, hence generation of leachate especially in developing countries like Nigeria and can adversely affect the quality of underlying groundwater

water if not properly controlled (Foster et al., 1998). Once groundwater is contaminated its quality cannot be easily restored and it is very expensive and difficult to clean it up when contaminated (Krishiiah et al., 2009).

It is recognized that the quality of water is just as important as its quantity. The usability of water depends on it quality either for drinking water, industrial water and irrigation water vary widely (Ehirim et al., 2013; Ugwu and Ogubazghi, 2014). Therefore, the need to investigate the contamination is important. Urban waste materials, mainly domestic garbage is usually disposed of inappropriately in waste disposal sites posing a high risk to the groundwater resources, the environmental pollution and the community health. Moreover, older waste sites often lack reliable geological or artificial barriers as such leaching of pollutants into the groundwater is a concern. The evaluation of groundwater quality has become increasingly important as more industrial waste and solid domestic refuse come into contact with groundwater (Dahlin and Berstone, 1997). One method of detecting contaminated groundwater is by noting the electrical resistivity of the contaminated soil.

Poor dumpsite will create a number of environmental impacts including wind-blown litter attraction of mice and pollutants such as leachate which can pollute groundwater. In recent times the impact of leachates on groundwater and other water sources has attracted a lot of attention because of the high quantity of waste production and poor management system of the produced waste, which pose a serious threat to groundwater and other water sources attracted a lot of attention because of the high quantity of waste production and poor management system of the produced waste which pose a serious threat to ground water resources (Telford et al., 1976; Ikem et al., 2002). It is therefore important that the aquifer vulnerability capacity of the layers underlying the dumpsite on groundwater in the area is investigated. Electrical resistivity tomography (ERT) is a geophysical method used to image the groundwater using difference in measured electrical resistivity at the surface. These differences in resistivity can be tied to the porosity, fluid content and degree of water content in the groundwater (Dahlin and Loke, 1998; Loke, 2004). The data collected in these surveys is then inverted to give an image of the groundwater electrical characteristics. The map of Maiduguri metropolis with the location of the Dumpsites is presented in Figure 1.

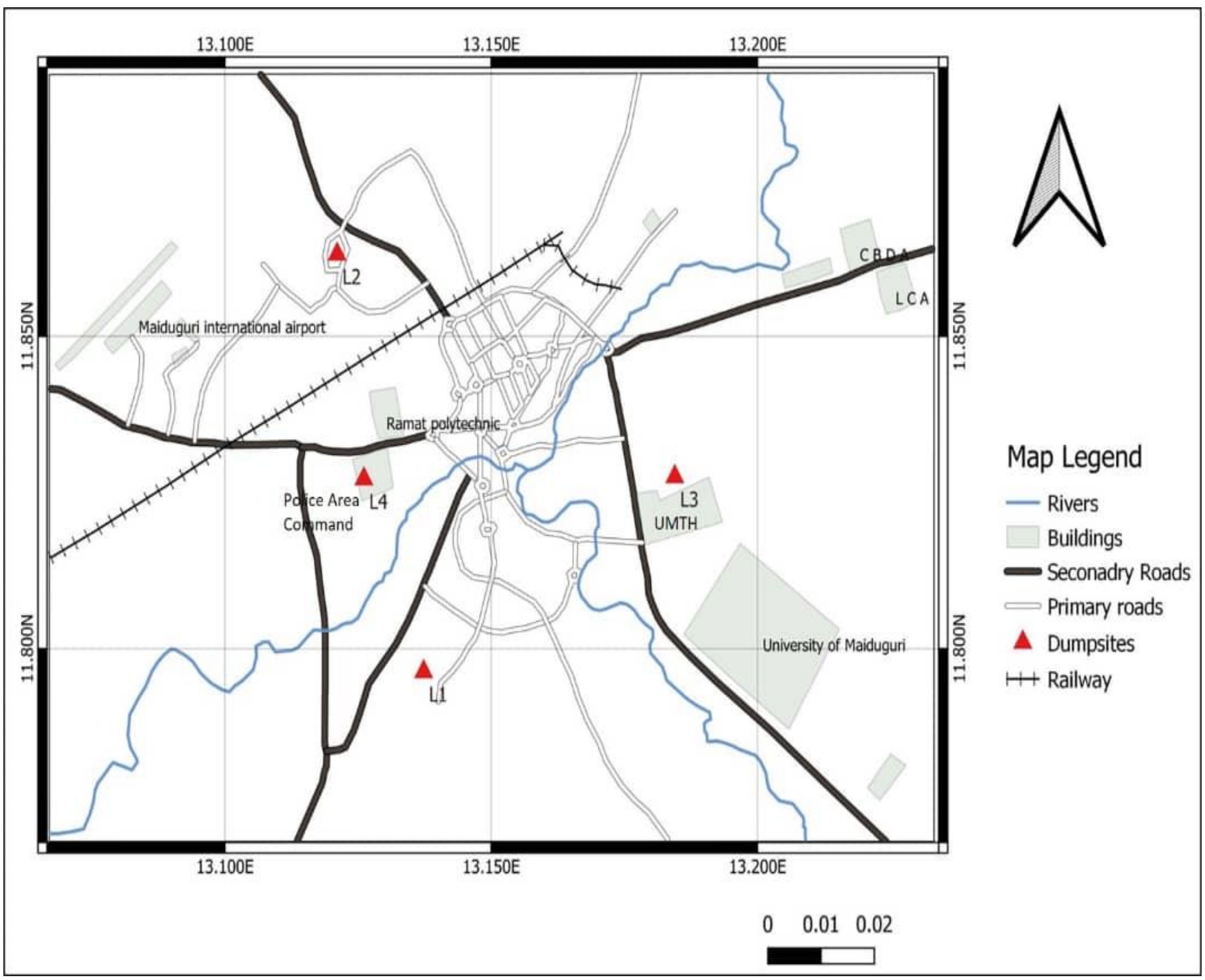

Figure 1 Map of Maiduguri Metropolis showing study areas (Dumpsites).

2. METHODOLOGY

The geo-electrical resistivity field data was acquired using the earth resistivity meter commonly referred to as Terra meter. The equipment is portable, light weight and relatively cost effective when compared with other geophysical data acquisition systems. A conventional setup of the earth resistivity meter basically consist of the following: A constant current source, commonly a battery pack connected to a commutated DC circuit to change polarity of the current source; an ammeter which measures the injecting current; a very sensitive voltmeter that measures the response signal; twenty (20) metal stake electrodes made of steel, which ensures low impedance characteristic; and four cable reels used in connecting the electrodes to the current source and voltmeter, hammer, crocodile clips, measuring tapes, note book and pen. The internal impedance of the ammeter, connected in series with the current source should be low so as to minimize its effect on the measuring circuit. Similarly, the voltmeter connected in parallel with the ammeter should have high input impedance so as to suppress any effect arising from the ammeter (Figure 2). In general, the current source and both meters are usually housed in a single box. 2D pictorial view of the groundwater in the sub-surface was obtained using Wenner electrode array as given in Dahlin and Loke, (1998) and Ugbor et al., (2021) and the electrode spacing is shown in Figure 3.

Figure 2 Some equipment used during field data acquisition

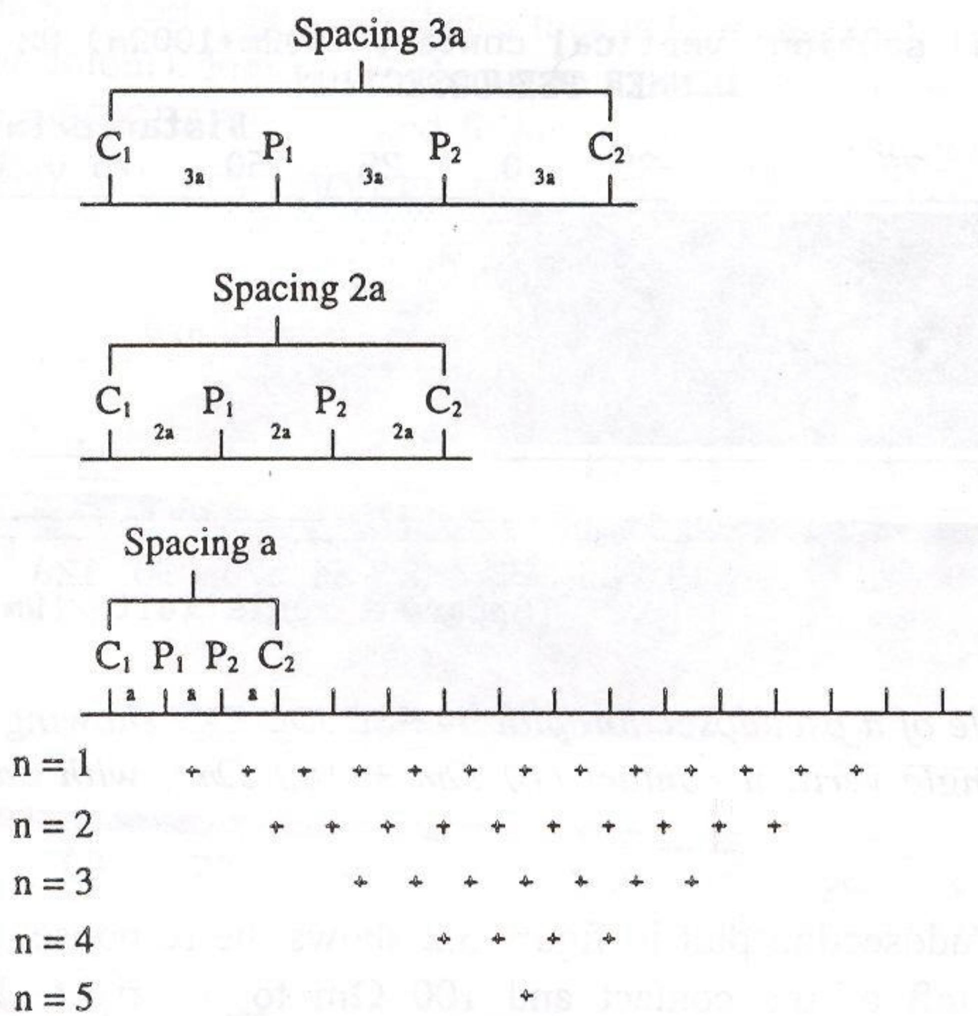

Figure 3 Principle for building up of a pseudo-section (Loke, 2001).

3. RESULT

The 2D electrical images along the profiles and their interpretations are discussed. Eight profiles were taken for this survey, 2-profiles on each dumpsite. The inversion result for each profile shows the images of the pseudo-sections (geo-electric sections) obtained from the processed data (Figures 4–11). The results show three distinct images for each profile. The upper image is a plot of the measured (observed) apparent resistivity pseudo-section. The middle image is the calculated apparent resistivity pseudo-section and the lower image is the true resistivity model obtained after a definite number of iterations of the inversion programme.

Profile 1 Saltimari, Polo

The tomographic images for Salimari profile are presented in Figure 4 thus, indicating that good fit between the measured and calculated apparent resistivity data were achieved. The Apparent resistivity is plotted against pseudo-depth. The Profile is located at the middle of the dumpsite, running E - W direction for a distance of 180m long. Pockets of low resistivity zones (< 18Ωm) were identified as vertical length of 5-15m, 110 – 120m, 130 – 137m along the profile (Dark Blue-light Blue) with maximum depth of penetration of 8m. A more pronounced and very low resistive section was seen at depth between 9m – 17.3m which may have exceeded the depth of the profile marked (Figure 4). Pockets of low resistivity zones were identified at vertical length of 41-55m, 63-75m and 80 – 85m along the profile (Dark Blue-light Blue) (Figure 5). This indicates a possible zone of contamination and composed of leachate and decaying materials within the formation. The green to yellow colouration indicates the moderate resistivity being the major part of the profile with no possible contamination and most likely composed of sand to little clay. The brownish to purple colouration indicates high resistivity zone implying zone of no contamination with possible dry sand.

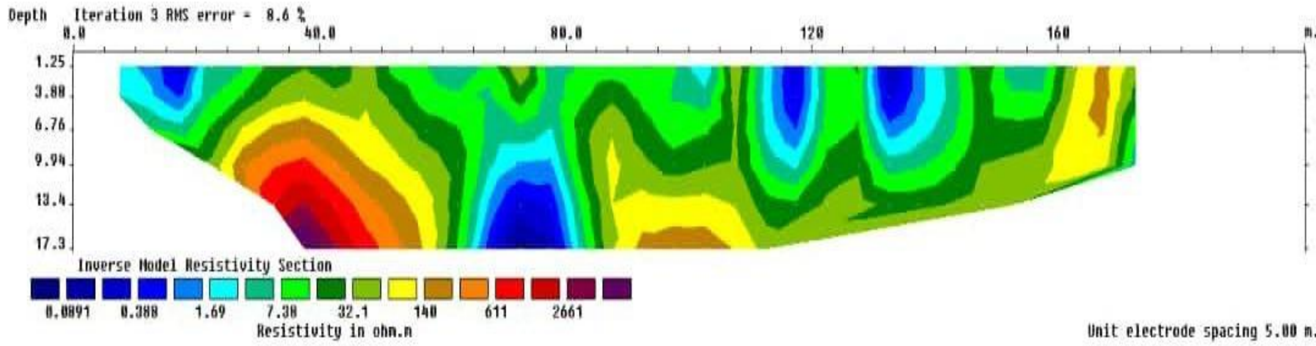

Figure 4 ERT obtained over profile 1 at Saltimari, Polo

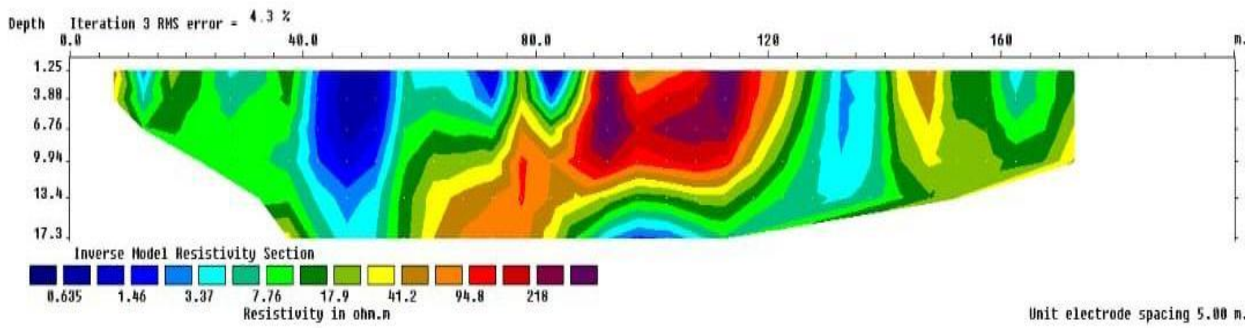

Figure 5 ERT obtained over profile 2 at Saltimari, Polo

Profile 3 Baga Road

The tomographic images for Baga road dumpsite profile are shown in Figure 6. Thus, indicating that good fit between the measured and calculated apparent resistivity data were achieved. The Apparent resistivity is plotted against pseudo-depth. The Profile is located within the dumpsite running from NW - SE direction and it is 180m long. Pockets of low resistivity zones (< 15Ωm) were identified at the vertical length of 0 – 20m, 50 – 70 m, 95 – 10m, 112 – 130m and 140 – 150m along the profile (Dark Blue-light Blue). This indicates a possible zone of contamination and composed of leachate and decaying materials within the formation (Figure 6). Pockets of low resistivity zones (< 10Ωm) were identified at the tail end of the profile 140 – 170m (dark blue-light blue). This indicates a possible zone of contamination and composed of leachate and decaying materials within the formation (Figure 7). The green to yellow colouration indicates the moderate resistivity zone having no possible contamination, with most likely composed of sand to little clay. From the brownish to purple colours indicates high resistivity at the bottom of the profile between the depths of 9.94 – 17.3m. This is zone of no contamination with possible dry sand.

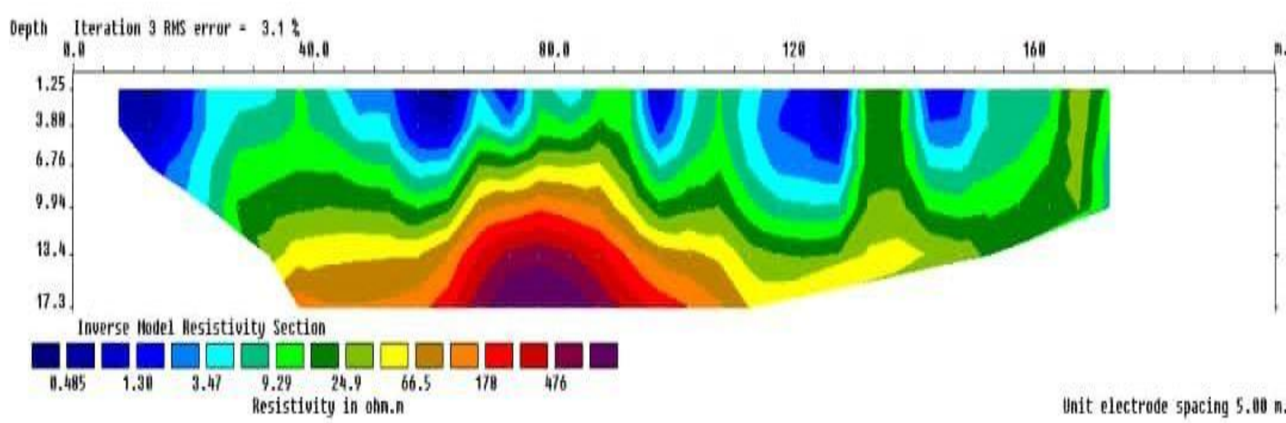

Figure 6 ERT obtained over profile 1 at Baga Road

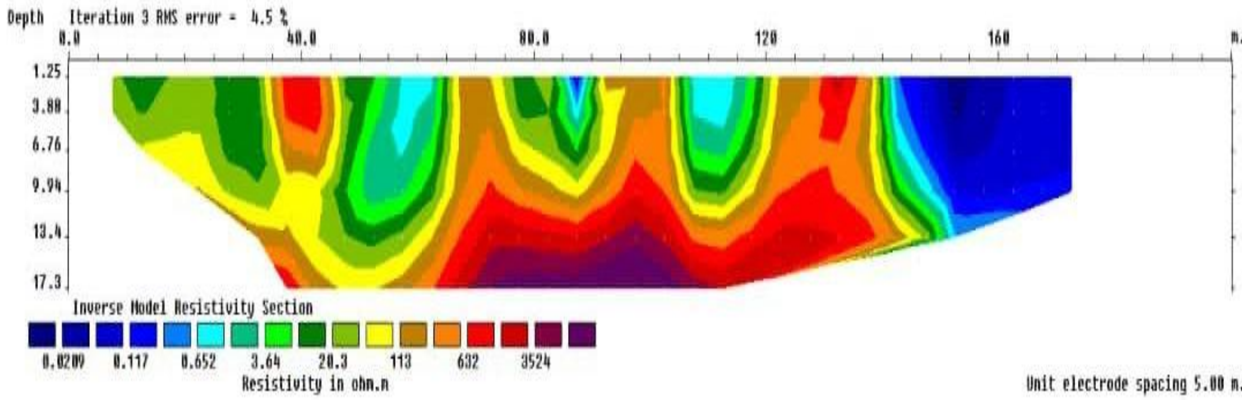

Figure 7 ERT Obtained Over Profile 2 at Baga Road

Profile 5 Ngomari Custin

The tomographic images for the profile Ngomari Custin show that good fit between the measured and calculated apparent resistivity data were achieved (Figure 8). The Apparent resistivity is plotted against pseudo-depth. The Profile is located within the dumpsite, running from East to West direction, on top of the dumpsite and it is 180m long. Low resistivity zone (< 10Ωm) were identified near the surface with depth between 60m to 6.5m (Dark Blue-light Blue). This indicates a possible zone of contamination and composed of leachate and decaying materials within the formation. Low resistivity zones (< 25Ωm) were identified with a more pronounce portion at the tail end of the profile 130 – 140m (Dark Blue-light Blue). This indicates a possible zone of contamination and composed of leachate and decaying materials within the formation (Figure 9).

The green to yellow colouration indicates the moderate resistivity zone that dominate the upper portion of the profile (9.94 - 1.25m) and having no possible contamination which is most likely composed of sand to little clay formation. From brownish to purple colouration indicates high resistivity and it dominates the lower portion of the profile (9.94 – 17.3m). This is zone of no contamination with possible dry sand. From the brownish to purple colouration indicates high resistivity at the depth of (6.76 – 17.3m). This is zone of no contamination with possible dry sand (Figure 9).

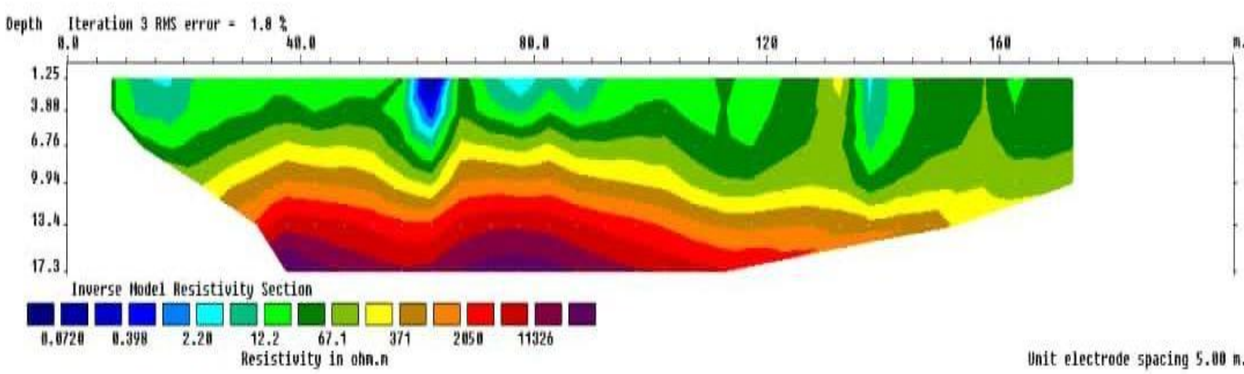

Figure 8 ERT obtained over profile1 at Ngomari Custin

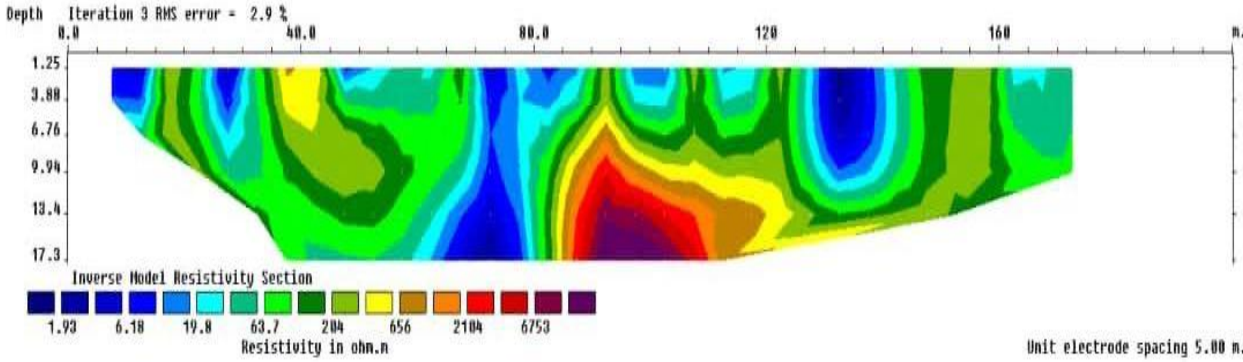

Figure 9 ERT obtained over profile 2 at Ngomari Custin

Profile 7 Arabic College

The tomographic images for the Arabic College profile indicate that a good fit between the measured and calculated apparent resistivity data was achieved (Figure 9). The Apparent resistivity is plotted against pseudo-depths. The Profile is located within the dumpsite, running from West to East direction and it is 180m long. Pockets of low resistivity zones (< 69Ωm) were identified at the vertical length of the profile with more pronounce ones being the 40 – 55m, 80 – 90m, 155 – 165m (Dark Blue-light Blue). This indicates a possible zone of contamination and composed of leachate and decaying materials within the formation. Low resistivity zones (< 80Ωm) were identified at the vertical length of the profile (Dark Blue-light Blue). This indicates a possible zone of contamination and composed of leachate and decaying materials within the formation (Figure 11). The green to yellow colouration indicates the moderate resistivity zones and having no possible contamination, which most likely composed of sand to little clay. From the brownish to purple colouration indicates high resistivity which dominates the lower portion of the profile. This is zone of no contamination with possible dry sand (Figure 11).

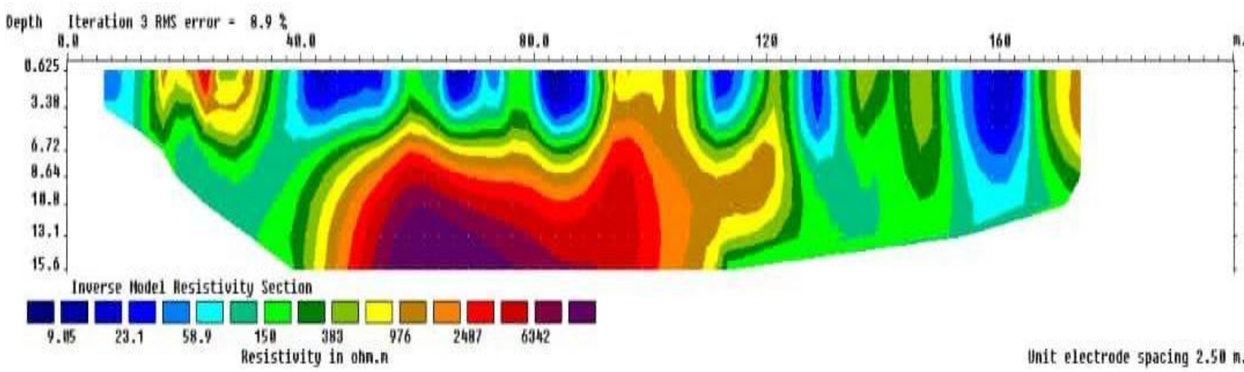

Figure 10 ERT obtained over profile1 at Arabic College

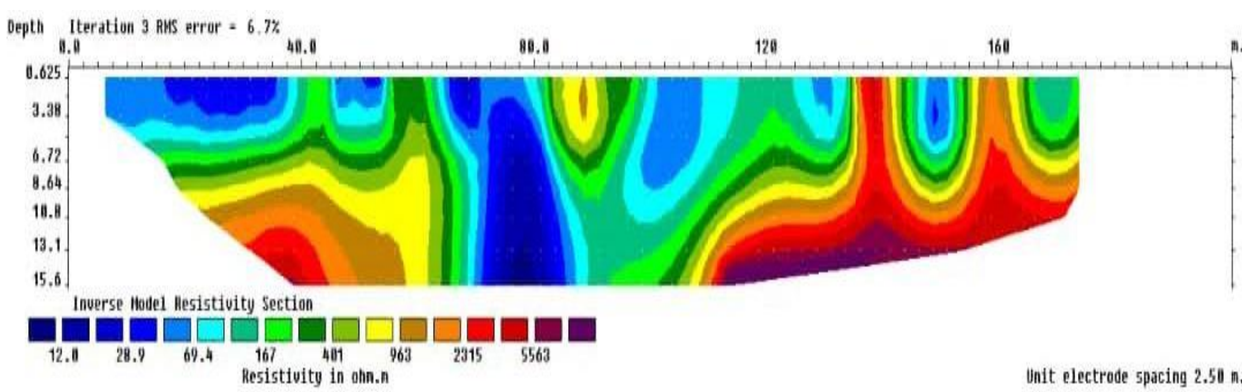

Figure 11 ERT obtained over profile 2 at Arabic College

4. DISCUSSION

The results of this survey revealed three layers: The topsoil, which consists mostly of sand with decaying materials (leachate), has its resistivity ranging from 0.0209 – 69.4m. The second layer consists of the intercalation of sand and clay with resistivity values that ranged from 3.64 – 976m. The resistivity value of the third layer varies from 41.2 – 6753m and it is a layer of possible dry sand. The 2D inversion delineated contamination plumes as zones with low resistivity values ranging from 1Ωm to 49Ωm from the ground surface to varying depths of 0-13 m in profile 1, 4, 5, 7 and profile 8 which is believed to be leachate derived from decomposed waste of higher concentrations while profile 2, 3 and profile 6 delineated contamination plumes with resistivity zones ranging between 0.0209Ωm to 6753Ωm, from the ground surface to varying depths and it is believed to be leachate from decomposed waste of lower concentrations. The interpretation shows that the contaminants are present within the unsaturated zone and there are structures that will allow for continuous downward movement of these contaminants into the subsurface and might eventually find their way with time into the groundwater.

Ugwu and Nwankwoala, (2015) carried out a Geo-electrical evaluation on the effects of waste dumpsites on Groundwater in Eneka, Rivers State using resistivity method. Two dumpsites and a dump-free site were investigated in the area. The investigation involved seven horizontal resistivity profiling and four vertical electrical soundings. The result of the investigation revealed that the surrounding soil and water in the waste dumpsites have been contaminated to depths below 20m which is within the aquifer system of the area evident by low resistivity values of 0.04Ωm - 60.07Ωm around the dump sites relative to the high resistivity values greater than 500Ωm in the dump-free areas. The dumpsites of Maiduguri metropolis could attain this status sooner than later if the leachates move unabated. The leachates could exploit the fractures and openings as the migratory path to the underground water table (Cyril, 2013; Ugbor et al., 2021).

Informed consent

Not applicable.

Ethical approval

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Funding

The study has not received any external funding.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Cyril CO. Application of 2D Electrical Resistivity Tomography in Landfill Site: A Case Study of Iku, IkareAkoko, South western Nigeria 2013.
2. Dahlin T, Bernstone C. A roll-along technique for 3D resistivity data acquisition with multi-electrode arrays. Proceedings SAGEEP' 97, Reno, Nevada 1997; 927-935.
3. Dahlin T, Loke MH. Resolution of 2D Wenner resistivity imaging as assessed by numerical modeling. J Appl Geophy 1998; 38(4):237–248.
4. Ehirim CN, Ebeniro JO, Olanegan OP. A Geophysical Investigation of Solid Waste Landfill Using 2-D Resistivity Imaging and Vertical Electrical Sounding Methods in Port Harcourt. Municipality, Rivers State, Nigeria 2013.
5. Foster S, Lawrence A, Morris B. Groundwater in Urban Development – Assessing Management Needs and Formulating Policy Strategies. World Bank Tech Pap 1998; 39 0.
6. Ikem A, Osibanjo O, Sridhar MK, Sobande A. Evaluation of Groundwater Quality Characteristics near Two Waste Sites in Ibadan and Lagos. Water Air Soil Poll J 2002; 140(1):307-333.
7. Kumar P. Tracing the factors responsible for arsenic enrichment in groundwater of the middle Gangetic Plain, India: A source identification perspective. Environ Geochem Health 2010; 32(2):129-146.

8. Loke MH. Electrical Imaging Surveys for Environmental and Engineering Studies: A Practical Guide to 2D and 3D Surveys. 2001; 62.
9. Loke MH, Barker RO. Rapid least-squares inversion of apparent resistivity pseudo sections by a quasi-Newton method. Geophys Prospect 1996; 44:135-152.
10. Nwankwoala HO, Ugwu SA. Geoelectrical evaluation on the effect of waste dump sites on ground water in Eneka, Rivers State Nigeria 2015.
11. Telford WM, Geldart LP, Sheriff RE, Keys DA. Applied Geophysics. Cambridge University Press, London, New York 1976; 860.
12. Ugwu NU, Ogubazghi G. Application of Geo-electrical Resistivity Method to the Assessment of Groundwater Pollution: A case Study of OnibuEja Active Open Dumpsite, Osogbo, Southwestern Nigeria 2014.