

## APPLICATION OF CONVENTIONAL GEOPHYSICAL METHOD IN INVESTIGATING AND CHARACTERIZING LANDFILLS

Lawal L. Adebayo\*, Fatai A. Wahaab, Sulaiman K. Lawal

Department of Physics and Material Science, Kwara State University, Malete, Nigeria

Received April 1, 2019; Accepted June 13, 2019

### Abstract

The geophysical investigation was conducted using integrated Wenner-Schlumberger Array to determine the extent of waste on soil and groundwater around Madi area of Ilorin West L.G.A of Kwara State, Nigeria. 2-D resistivity meter with a digital read out resistivity meter (ABEM SAS 1000) was used to acquire data on the study area. Contaminant leachate plume was delineated with both electrical sounding curve 1-D and 2-D resistivity sections as low resistivity zones. The results are presented in terms of resistivity, thickness, and depth (1-D). The 2-D sections are identified as bluish zones of lower resistivity (less than  $17\Omega\text{m}$ – $36\Omega\text{m}$ ) with the depth ranging from 5 m to 40 m. The result of the electrical resistivity survey also showed three layers of geo-electric sections and an H type sounding curve. Groundwater at 5 m and above will pose a major threat to the health of the inhabitants of the study area due to contaminant leaching.

**Keywords:** Landfill gas; Geo-electric; Wenner-Schlumberger array; Resistivity; Contaminant plume.

### 1. Introduction

Water is one of the most valuable natural resources vital to the existence of any form of life. Groundwater is widely distributed under the ground, and it is replenished resource unlike other resources of the Earth. Groundwater has become immensely important for human water supply in urban and rural areas in developed and developing nations alike [3]. Groundwater contamination can occur in many ways and from many sources, both natural and humanly induced. Groundwater commonly contains one or more naturally occurring chemicals, leached from soil or rocks by percolating water, in concentrations that impair its uses. Water can be contaminated from the smallest activities, throwing plastics into the body of water, throwing the trash into a river, dumping oil into streams, improper disposal of wastes all this leads to water contamination.

Much geophysical technique has subsequently been used for groundwater characterization, but the greatest success has been shown with the electrical and electromagnetic method [4]. In the electrical resistivity method, direct current or low-frequency alternating current is applied at the ground surface, and the potential difference is measured between two points. Variations in resistance to current flow at depth cause distinctive variations in the potential difference measurements, which provide information on subsurface structure and materials [5]. Ohm's law ratio given by equation (1) is the governing principle of the electrical resistivity method.

$$\rho_a = 2\pi k \frac{V}{I} \quad (1)$$

where  $\rho_a$  is the apparent resistivity ( $\Omega\text{m}$ ) which is equivalent to the resistivity of an electrically homogenous and isotropic half-space earth;  $I$  the applied current (A);  $V$  the measured potential gradient and  $k$  is the geometric factor in ( $\Omega\text{m}$ ) which depends on the electrode array configuration. For the Wenner-Schlumberger array employed in this research, the apparent resistivity equation becomes equation (2) [6], which corresponds to the arrangement in Figure 1.

$$\rho_a = \pi a n(n+1) \frac{V}{I} \quad (2)$$

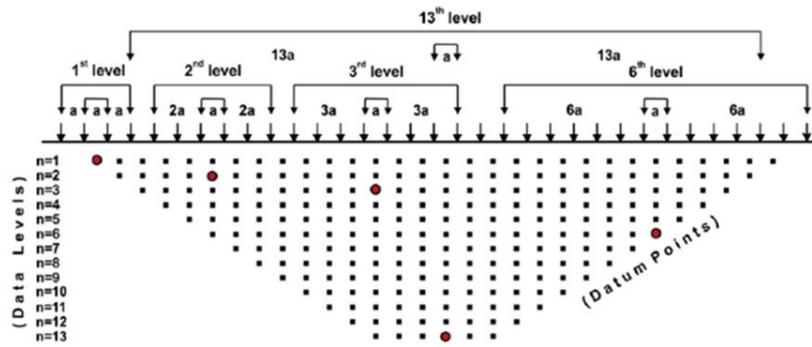
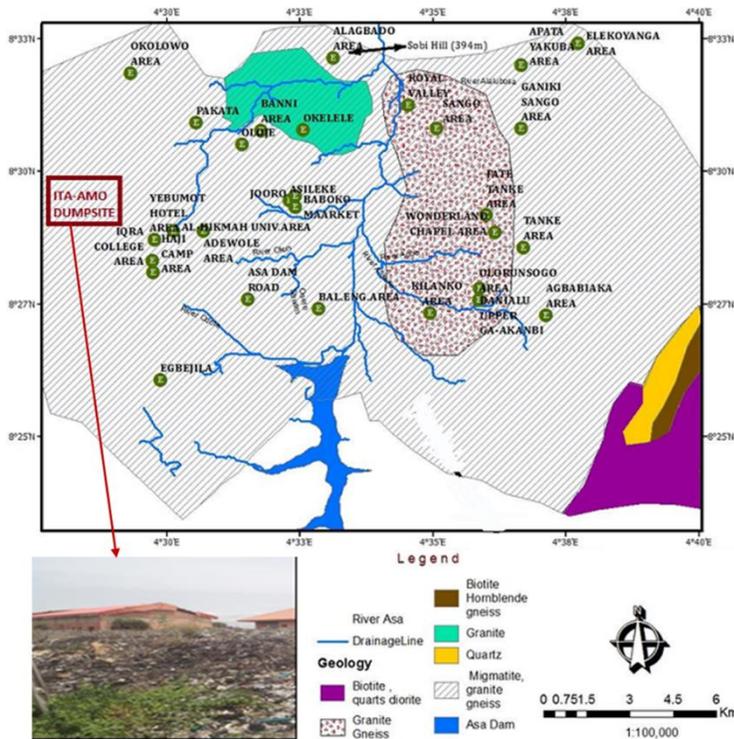


Figure 1. Schematic of Wenner-Schlumberger electrode array configuration [1]

Numerous geophysical investigations have been carried out in different parts of the world for groundwater investigation. Etu-Efeotor *et al.* [7], Amadi *et al.* [8], and Ugwu & Nwosu [9] carried out studies in various parts of Rivers State. Ehrim *et al.* [10] carried out a geophysical and hydro-physiochemical study of the contaminant impact of a solid waste landfill (SWL) in Port Harcourt municipality, Nigeria and concluded that the contamination of ground water and soil is dominantly by landfill gases, while the excessive amounts of microorganisms is an indication of leachate contamination. Previous research work at a public dumpsite in Ita-amo Ilorin, Kwara State has indicated the direction of groundwater flow through the aid of surface topography. The presence of leachate and their pattern of migration using electrical resistivity method in the study area have also been previously outlined. Several other studies have investigated [11-14] have investigated the possibility of producing gas from old municipal landfill as an alternative form of energy.



The study area (Abandoned Ita-Amo waste disposal site, Ilorin) is located within latitude 8°25'N and 8°30'N, and longitude 4°20'E and 4°30'E as outlined in Figure 2. The approximate area extent of the dumpsite is  $3.63 \times 10^6 m^2$  with average dump thickness of 7-9 m. Geologically, the area lies in the Precambrian basement complex of southwestern Nigeria and is underlain by the rock of metamorphic and igneous type [15]. However, weathered lateritic soils are predominant in the study area. Also, intrusive and extrusive conglomerate lateritic rocks are present in Figure 3(b).

Fig. 2. Location map of the study area (modified after reference [2])



Figure 2. Pictures from the study area. (a) Data acquisition process at the study area, showing cable reel, electrode and resistivity meter (ABEM SAS 1000) (b) Rock formation in the study area

## 2. Experimental

The geo-electric resistivity field survey was carried out to obtain the apparent resistivity data around the Ita-Amo dumpsite. Wenner-Schlumberger electrode array was employed because of its moderate sensitivity to both horizontal and vertical variations in the apparent resistivity of the subsurface. This was used to characterize the various lithological units and, to determine the depth to the water table, the extent of percolation (depth) of contaminants, and migration path of contaminants. The two outer electrodes are the current electrode, and two inner ones are the potential electrode, but unlike other configurations, equal spacing does not exist between the four electrodes as illustrated by

Wenner-Schlumberger configuration with maximum current electrode separation ( $AB/2$ ) of 90m was employed. This method consists of four electrodes like all other types of Wenner configurations. However, there exist equal spacing between the first two electrodes and the last two electrodes.

A total of four profile were selected, each consisting of ten sounding points. Two of these traverses were chosen at the northward axis of the dumpsite. The first of the northern axis traverse was 3m away from the dumpsite and the second was 13m away from the dumpsite with profile lines oriented in the east-west direction. The profile lines covered a length of 200m with inter stations of 20m. The third and fourth profile were oriented in the north-south and west-east directions, respectively with a sounding point interval of 30m as depicted by Figure 4: Profile line of the sounding points.

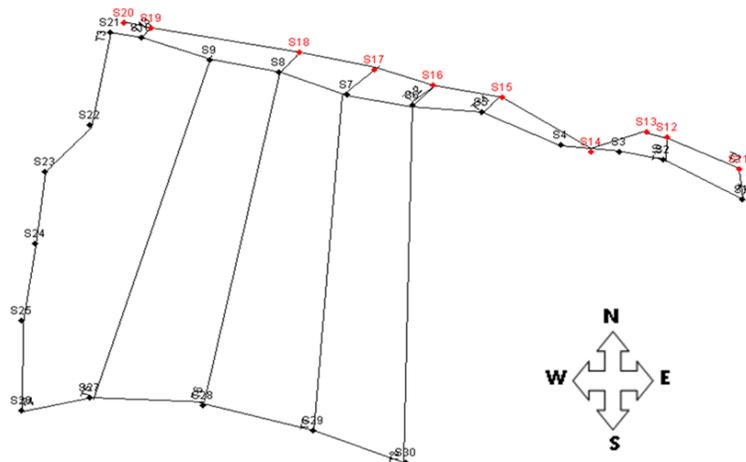


Figure 3. Profile line of the sounding points

### 3. Results and discussion

The topographic map of the area was obtained by analyzing the coordinates data obtained through the Global Positioning System (GPS). The obtained data were processed using Surfer 8. The result from the software revealed that the dumpsite area is fairly-undulated and sloped towards the north-western axis of the neighboring environment with elevation ranging from 308–330 m illustrated by the topography (Figure 4) and contour map (Figure 5).

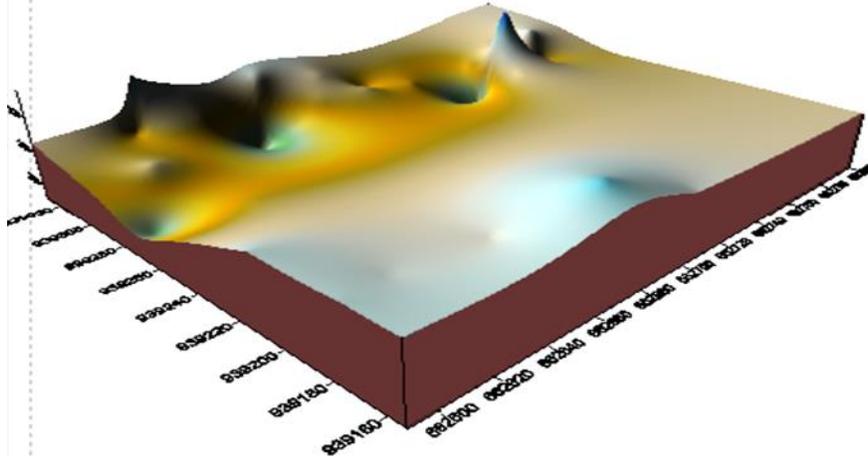


Figure 4. Topography of the study area

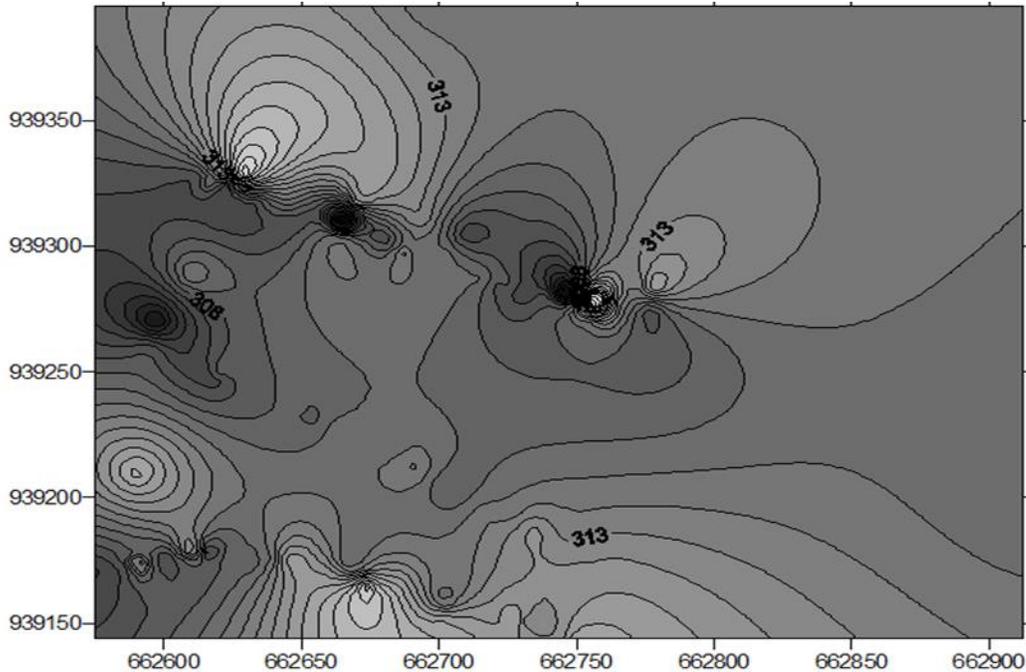


Figure 5. Contour map of the study area

The field curves and the interpreted 1D models are presented in. The curves show a characteristic type H curve across the dumpsite (Figure 6). The 2-D pseudosections map out zones of high and low resistivity. Comparing the pseudosections along with each profile, we could identify the drift pattern of the contaminant plume, the depth of the plume and other characteristics across each profile.

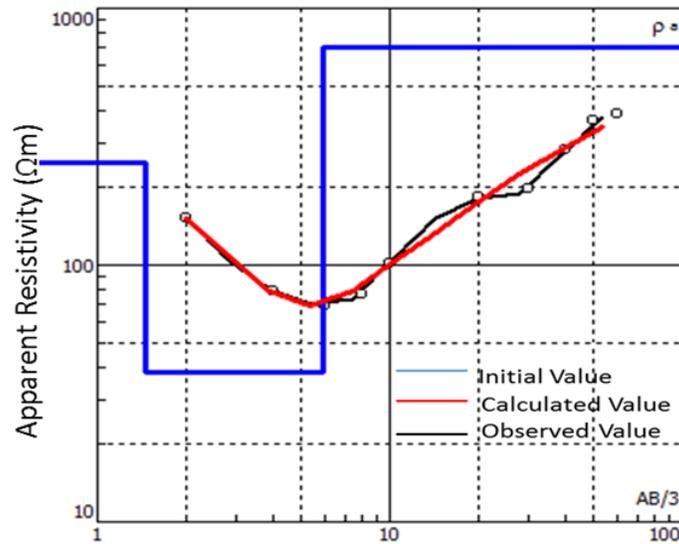


Figure 6. Observed and calculated apparent resistivity value in 1D at a VES point

Profile 1 is located 3m away from the dumpsite, and it is 16m away from community settlement near the dumpsite. The average elevation along this profile is 307.3m. The contaminant is highly concentrated along with this domain of the dumpsite. 2D shows that the contaminant plume is drifting from the southern to the northern axis. This shows that the contaminant is drifting toward the settlements enveloping the dumpsite. The apparent resistivity value ranges from 30–606  $\Omega\text{m}$ . Zones of high resistivity value ranging from 134–606  $\Omega\text{m}$  existed near the surface. Underlying the zone of a high resistive chemical compound is the zone of low resistivity (less dense zone) with resistivity value ranging from 36–121  $\Omega\text{m}$  with the depth ranging from 1.5–30 m.

Profile 2 is located 13m away from the dumpsite and 6m away from a settlement near the dumpsite. It was parallel to profile 1 and has a separation distance of 10m. The average elevation along this profile is 314.94m. The contaminant is highly concentrated along this axis of the dumpsite. 2D Pseudosection maintains the pattern of contaminant drift as depicted in profile 1. The apparent resistivity value is ranging from 13–4014  $\Omega\text{m}$ . Zones of high resistivity values range from 148 $\Omega\text{m}$ –4014 $\Omega\text{m}$  exists near the surface. Underlying the zone of a high resistive chemical compound is the zone of low resistivity (less dense zone) with resistivity value ranging from (14 $\Omega\text{m}$ -148 $\Omega\text{m}$ ) with the depth ranging from 1.5–32 m (Figure 7).

The average elevation along profile 3 is 311.45m. The apparent resistivity value is ranging from 64–712  $\Omega\text{m}$ . Zone of highly resistivity value ranges from 124 – 712  $\Omega\text{m}$  existed near the surface. Underlying the zone of a high resistive chemical compound is the zone of low resistivity (less dense zone) with resistivity value ranging from 64 – 124  $\Omega\text{m}$  with the depth ranging from 1.5 - 38 m (Figure 8).

Profile 4 is along the entrance of the dumpsite. The average elevation along this profile is 317.64m. 2-D Pseudosection shows that the contaminant plume is not concentrated along this axis; therefore, we may assume this profile to be the true resistivity of the surroundings. The apparent resistivity value is ranging from 27 -1200  $\Omega\text{m}$ . Zone of high resistivity value ranges from 114 – 1200  $\Omega\text{m}$  existed near the surface. Underlying the zone of the high resistive structure is the zone of low resistivity (less dense zone) with resistivity value ranging from 27 – 77  $\Omega\text{m}$  with the depth ranging from 1.5 – 23 m. between the high resistive chemical compound and the low resistive zone are sands of varying sizes and thickness. The bluish portion shows zone of low resistivity (contaminant leachate plume), red to brownish portion shows zone of high resistivity (solid waste and maybe lateritic soil or rock) and the yellow portion shows zone of water bearing (sands). The migration of the leachate to the bottom is an indication that it is denser.

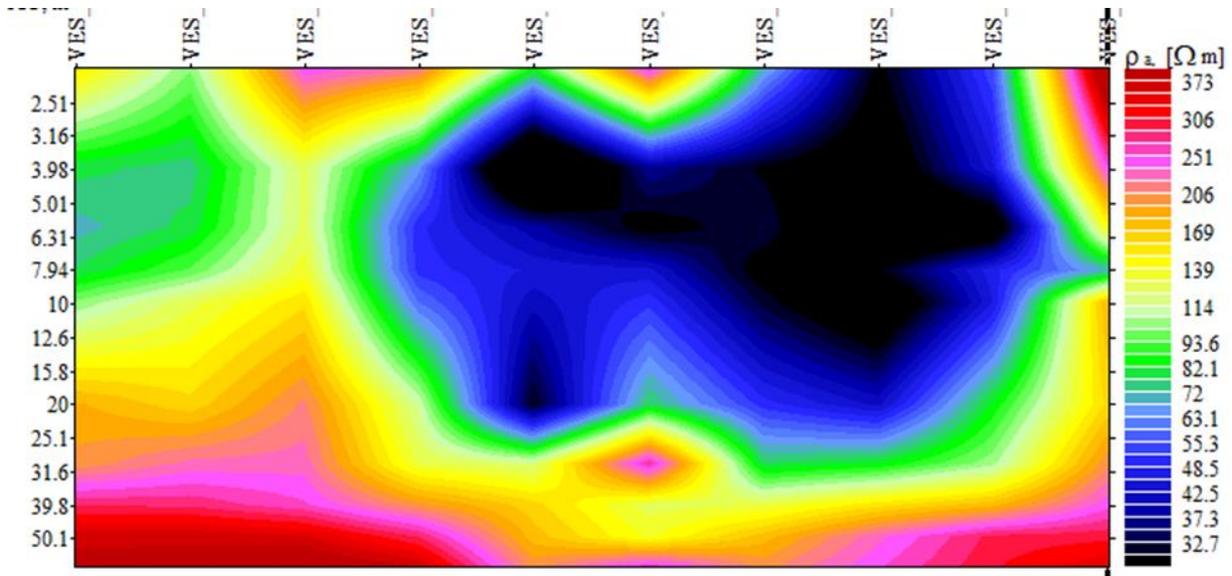


Figure 7. 2D Pseudosection showing profile 2

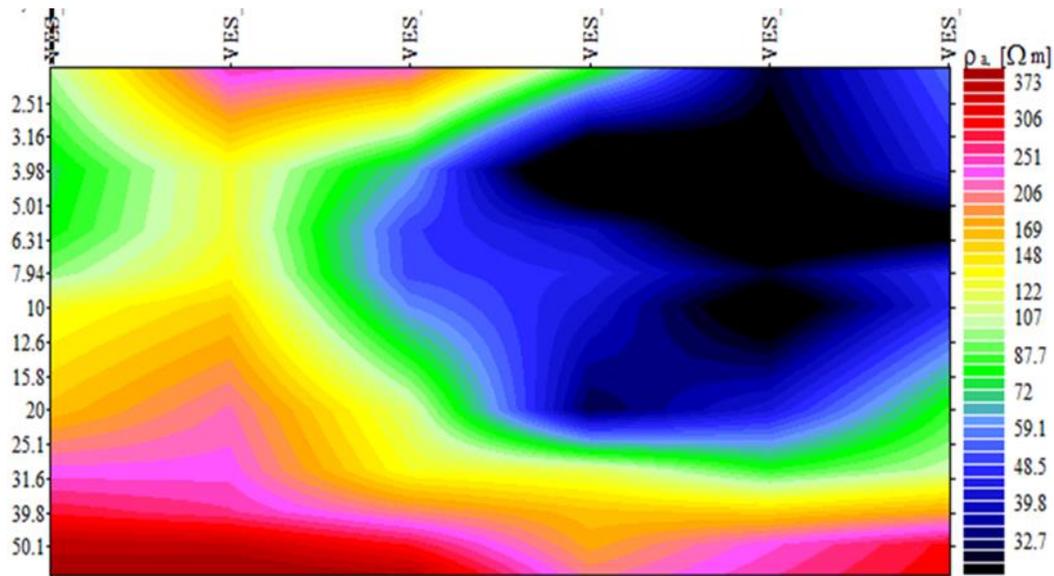


Figure 8. 2D Pseudosection showing profile 3

#### 4. Conclusion

High and low resistive zones were identified in the study area (Ita-Amo dumpsite). The high resistive areas may indicate gravel, sand and rock fragments lying on top of elevated solid rock, while the low resistive areas indicate areas where the host rock has been hampered by faulting, void, and fracture. The very low resistive with high conductivity contains contaminant plume due to percolation of leachate (heavy metals, toxic chemical and carcinogenic), making the area less resistive to electrical current. Contaminants occur at depths between 0–30 m, and the migration path of the plume is toward the north-west direction. The more detailed geochemical and biological investigation should be conducted for water obtained at this site for precise characterization of the contaminant. Borehole exceeding 30 m depth should be dug in this settlement if there is no alternative water source.

## Acknowledgement

*The authors would like to appreciate the entire staff of Physics and Material Science department of Kwara State University for their support during the cause of this project.*

## References

- [1] Ekinci YL, Türkeş M, Demirci A, and Erginal AE. Shallow and deep-seated regolith slides on deforested slopes in Çanakkale, NW Turkey. *Geomorphology*, 2013; 201: 70-79.
- [2] Ifabiyi I, Ashaolu E, and Omotosho O. Hydrogeological Characteristics of Groundwater Yield in Shallow Wells of the Regolith Aquifer: a Study from Ilorin, Nigeria. *Momona Ethiopian Journal of Science*, 2016; 8(1): 23-36.
- [3] Omosuyi G. Geoelectric assessment of groundwater prospect and vulnerability of overburden aquifers at Idanre, southwestern Nigeria. *Ozean Journal Of Applied Sciences*, 2010; 3(1): 19-28.
- [4] Eke K, and Igboekwe M. Geoelectric investigation of groundwater in some villages in Ohafia Locality, Abia State, Nigeria. *British Journal of Applied Science & Technology*, 2011; 1(4): 190.
- [5] Burger HR, Sheehan AF, and Jones CH. Introduction to applied geophysics: Exploring the shallow subsurface. WW Norton, 2006, ISBN-13: 978-0393926378.
- [6] Wightman W, Jalinoos F, Sirles P, and Hanna K. Application of geophysical methods to highway related problems. *Blackhawk GeoSciences, A Division Of Blackhawk GeoServices* 2004. <http://www.ce.memphis.edu/7137/PDFs/Geophysical/geotechPdf.pdf>
- [7] Etefeotor J, and Odigi M. Water supply problems in the eastern Niger Delta. *Journal of Mining and Geology*, 1983; 20(1-2): 183-193.
- [8] Amadi U, and Amadi P. Salt water migration in the coastal aquifers of southern Nigeria. *J Min Geol*, 1990; 26: 35-44.
- [9] Ugwu S, and Nwosu J. Effect of waste dumps on groundwater in Choba using geophysical method. *Journal of Applied Sciences and Environmental Management*, 2009; 13(1): 85-89.
- [10] Ehirim C, Ebeniro J, and Olanegan O. 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 Journal of Science and Technology*, 2009; 10(2): 604-613.
- [11] Hayati A, Emalya N, Munawar E, Schwarzböck T, Lederer J, and Fellner J. Analysis the potential gas production of old municipal solid waste landfill as an alternative energy source: Preliminary results. in *IOP Conference Series: Materials Science and Engineering*, 2018; 334(1): 012031.
- [12] Njoku PO, Odiyo JO, Durowoju OS, and Edokpay JN. A Review of Landfill Gas Generation and Utilisation in Africa. *Open Environmental Sciences*, 2018; 10(1): 1-15.
- [13] Siddiqui FZ, Zaidi S, Pandey S, and Khan ME. Review of past research and proposed action plan for landfill gas-to-energy applications in India. *Waste Management & Research*, 2013; 31(1): 3-22.
- [14] Idehai IM, and Akujieze CN. Estimation of landfill gas and its renewable energy potential in Lagos, Nigeria. *International Journal of Energy and Environmental Engineering*, 2015; 6(3): 329-343.
- [15] Zonge K, Wynn J, and Urquhart S. Resistivity, induced polarization, and complex resistivity. in *Near-surface geophysics: Society of Exploration Geophysicists*, 2005; pp. 265-300.

*To whom correspondence should be addressed: Dr. Lawal L. Adebayo, Department of Physics and Material Science, Kwara State University, Malete, Nigeria, E-mail: [adebayolawallanre@yahoo.com](mailto:adebayolawallanre@yahoo.com)*