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Geophysical Evaluation of the Impact of Solid Waste Dumpsite on the Groundwater in Ilokun, Ado-Ekiti, Southwestern Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An investigation was carried out at the Ilokun dumpsite in Ado-Ekiti with the intention of converting it into a sanitary landfill. The goal was to determine the potential impact of the liquid waste draining from the dumpsite on the underground water sources. The study utilized the Vertical Electrical Sounding (VES) field technique, which measures the electrical resistivity, with the spacing between half-electrodes (AB/2) ranging from 1 to 65 meters. Three VES stations were set up for data collection, while a control VES point was established outside the dumpsite. The VES data were then quantitatively analyzed through methods such as partial curve matching and computer iteration. The dipole-dipole electrode configuration was also employed to carry out investigation on the dumpsite. The data acquired in this study was inverted using DIPRO software to generate 2-D resistivity structures. The geological layer below VES 1 was recognized as the aquiferous zone,

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although its remarkably low resistivity of 12 ohm-m was interpreted as an indication of pollution from a conductive contaminant plume. The geoelectric profile beneath VES 1 to 3 revealed the presence of five distinct layers, which are the topsoil, the lateritic sand, the weathered layer, the fresh basement, and the fractured basement. The resistivity and thickness of these layers vary within certain ranges: 61.8–933.6 ohm-m and 0.5–1.5m; 23.5–664.7 ohm-m and 0.6–2.7m; 12–177 ohm-m and 3 –16.9m; and 2356.6–4800.2 and 16.3-33m; and 34.7-146.4 ohm-m respectively. The fractured layer observed in the three VES points is considered the primary aquifer zone. However, the abnormally low resistivity values ranging from 34.7 to 146.4 ohm-m within the fractured layer beneath VES 1 and 3 are believed to be indicative of contamination caused by a conductive plume of pollutants originating from the dumpsite. The 2-D resistivity structures also confirm that the dumpsite is posing a serious threat to the surrounding formations and groundwater especially those located along the east-west direction of the dumpsite. The potential of leachate accumulation is relatively higher along the east-western axis.

Keywords: Aquifer; contaminant plumes; geophysical evaluation; Ilokun dumpsite; sanitary landfill.

1. INTRODUCTION

Solid wastes can be defined as unwanted or nonessential solid substances that arise from a combination of residential, industrial and commercial operations within a specific region. These materials can be classified based on their source (such as household, industrial, commercial, construction, or institutional waste), their composition (including organic matter, glass, metal, plastic, paper, etc.), or their potential for causing harm (such as toxic, non-toxic, flammable, radioactive, infectious waste, etc.) [1]. Studies have shown that open dumpsites remain the most popular source of groundwater and environmental pollution. Areas near dumpsites are prone to groundwater and soil contamination because of the presence of leachate emanating from the source to the natural environment [2-4]. Understanding the impacts of open dumpsites and their implications on groundwater systems is a crucial aspect of ensuring water security and implementing effective long-term environmental management strategies. However, accurately predicting the effects of dynamic dumpsites on environmental systems is a challenging task that requires a technical approach [5].

In Nigeria, like many developing countries, limited financial resources hinder the provision of adequate and safe drinking water to all residents. As a result, people rely on groundwater exploration for domestic, agricultural, and industrial purposes. The socio-economic activities driven by population pressure, along with the improper management of generated waste, continue to pose a threat to water quality [6].

Solid waste management has emerged as one of the major challenges faced by state and local government environmental protection agencies in Nigeria. The volume of solid waste generated is increasing at a faster rate than the agencies' capacity to improve their financial and technical resources to keep pace with this growth [7,8]. Inefficient collection methods, inadequate coverage of the waste collection system, and improper disposal practices characterize solid waste management [9]. Consequently, a significant portion of these wastes, which are indiscriminately dumped in landfill sites, find their way into water bodies through rain runoff or leachate infiltration into groundwater, depending on the geological characteristics of the area. This renders the water unsuitable for use [10].

The uncontrolled drilling of boreholes for potable water in most urban and rural communities, as the government fails to provide adequate water supply, has become a serious challenge. However, maintaining a safe groundwater supply free from microbial and chemical contaminants remains far from reality in many urban areas, including Ado-Ekiti, Nigeria, due to poor waste disposal and management practices. Insufficiently trained waste disposal personnel, lack of proper equipment, inadequate waste collection, sorting, and disposal sites without consideration for local geology and hydrogeology all contribute significantly to groundwater contamination and soil degradation [11]. Some of the major consequences of poorly managed dumpsites include leachate formation, spread of diseases, attraction of pests, mosquito breeding, strong odor permeating the area, gas generation (such as methane), soil acidity and alkalinity increase, and destruction of the ecosystem [6].

In Ado-Ekiti, Nigeria, groundwater serves as the primary source of drinking water for the population. Given that water quality is of utmost importance, it is necessary to investigate the potential effects of leachate from the Ilokun dumpsite on the surrounding aquifer(s).

2. LOCATION AND GEOLOGY

The study area is located within Longitude 5° 13´ 30´´E and 5° 25´ 33´´E and Latitude 7° 36´ 30´´N and 7° 48´ 30´´N respectively (Fig. 1) along Ado-Iworoko road. The site is very accessible. A small community of Ebira indigenes is located very close to the site. The materials found in the dumpsite are polythene, plastic materials, metal scraps, animal wastes, and organic materials, among others, are some of the waste components found in the study area. The region and its surrounding areas are primarily characterized by crystalline rocks (Fig. 2), including migmatite-gneiss-quartzite complexes, older granites, quartzite, charnockites, and fine to medium-grained granites. The field relationships between the charnockites and granitic rocks in the Basement complex rocks of Nigeria indicate a close association between them.

3. METHODOLOGY

This research employed the electrical resistivity method as a geophysical prospecting technique. The method involves the introduction of direct current (D.C.) or low-frequency alternating current into the ground through a pair of current electrodes. Resistance is obtained by calculating the ratio of the measured voltage to the measured current using an ammeter, and resistivity is determined by multiplying resistance with electrode spacing or length. Three Vertical Electrical Soundings (VES) measurements were conducted in and around the dumpsite. Two VES measurements were performed within the dumpsite to evaluate its resistivity characteristics and identify potential contaminants. The results of these two VES measurements were compared with the control VES taken outside the dumpsite to assess the extent of contamination. Field resistance measurements were conducted using ABEM SAS 1000 terrameter. The apparent resistivity values obtained were plotted manually against their corresponding current-electrode spacing values (AB/2) on a log-log graph. The curves were then interpreted through partial curve matching and electronically iterated using the WINRESIST 1.0 computer iteration program.

4. RESULTS AND DISCUSSION

Depth sounding curves and geoelectric sections were obtained from the study area. The sounding curves (Figs. 3a-c) exhibited three types: the 5-layer (KHA), the 5-layer (QH), and the 4-layer (HA). Detailed geoelectric parameters for each VES measurement are presented in Table 1. VES 1 and VES 2, which were conducted within the dumpsite (Figs. 3a and 3b), displayed very low to low resistivity values (12-360.2 ohm-m and 23.5-188.9 ohm-m, respectively), indicating the nature of the waste materials deposited in the dumpsite. Five geoelectric layers were identified in the VES 1 geoelectric column, including the topsoil with a thickness of 0.5 m and resistivity of 61.8 ohm-m. The weathered layer, which serves as a significant aquifer unit in a typical basement complex environment, exhibited resistivity ranging from 12 to 360.2 ohm-m and a thickness ranging from 0.6 to 3 m [12-16]. VES 2 showed four geoelectric layers, including the topsoil with a thickness of 0.9 m and resistivity of 188.9 ohm-m. The weathered layer exhibited resistivity ranging from 23.5 to 177 ohm-m and a thickness ranging from 2.7 to 16.9 m. VES 3 displayed five geoelectric layers (Fig. 6), with the topsoil having a thickness of 1.5 m and resistivity of 934 ohm-m. The weathered layer exhibited resistivity ranging from 28.3 to 665 ohm-m and a thickness ranging from 0.6 to 10.9 m. The presence of a very low resistivity zone (12 ohm-m and 23.5 ohm-m) within the aquifer unit beneath VES 1 and VES 2, respectively, indicates the possible existence of a conductive contaminant plume originating from the dumpsite.

A geoelectric section (Fig. 7) was constructed using the geoelectric parameters (thicknesses and resistivities) obtained from the three VES measurements. The section revealed five geoelectric layers, including the topsoil, the lateritic sands, the weathered layer, the fractured basement, and the fresh basement. The resistivity of the topsoil ranged from 61.8 to 933.6 ohm-m, with thicknesses varying from 0.5 to 15 m. The lateritic sand layer exhibited a resistivity range of 23.5 to 664.7 ohm-m, with thicknesses ranging from 0.6 to 2.7 m. The resistivity of the weathered layer ranged from 12 to 177 ohm-m, with thicknesses ranging from 3 to 16.9 m. The fresh basement rock beneath the topsoil and weathered layer displayed a resistivity range of 2356.6 to 4800.2 ohm-m, with thicknesses varying from 16.3 to 33 m at the control VES point and VES 1, while it was considered infinitely thick at VES 2. The fractured basement, which serves as another aquifer unit in the area, exhibited anomalously low resistivity ranging from 34.7 to 146.4 ohm-m and was considered infinitely thick at VES 3 (control point) and VES 1. This suggests the presence of a conductive contaminant plume.

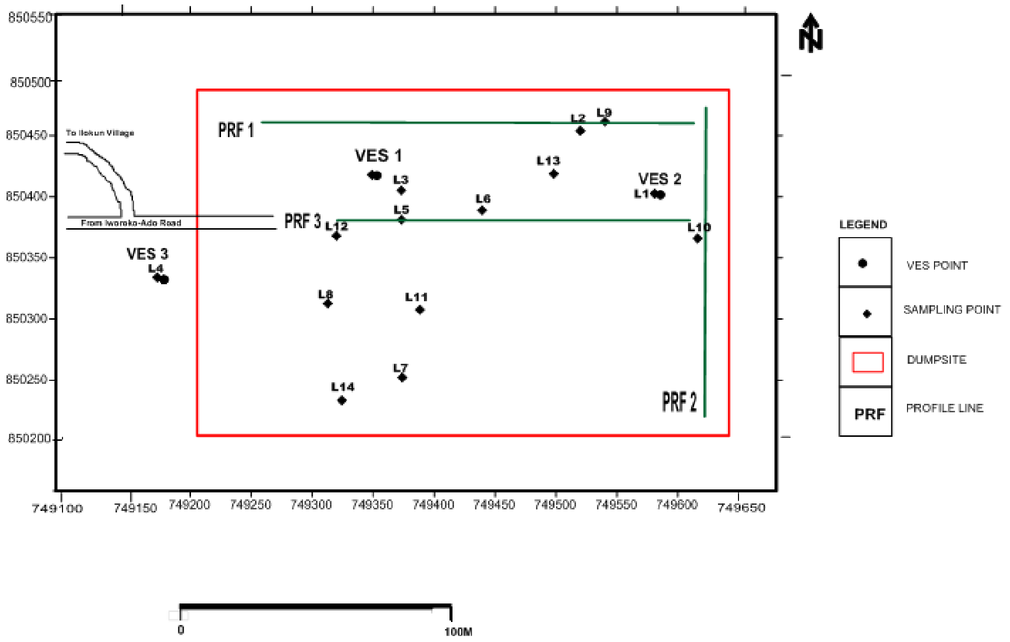


Fig. 1. Geophysical data acquisition/base map of the study area

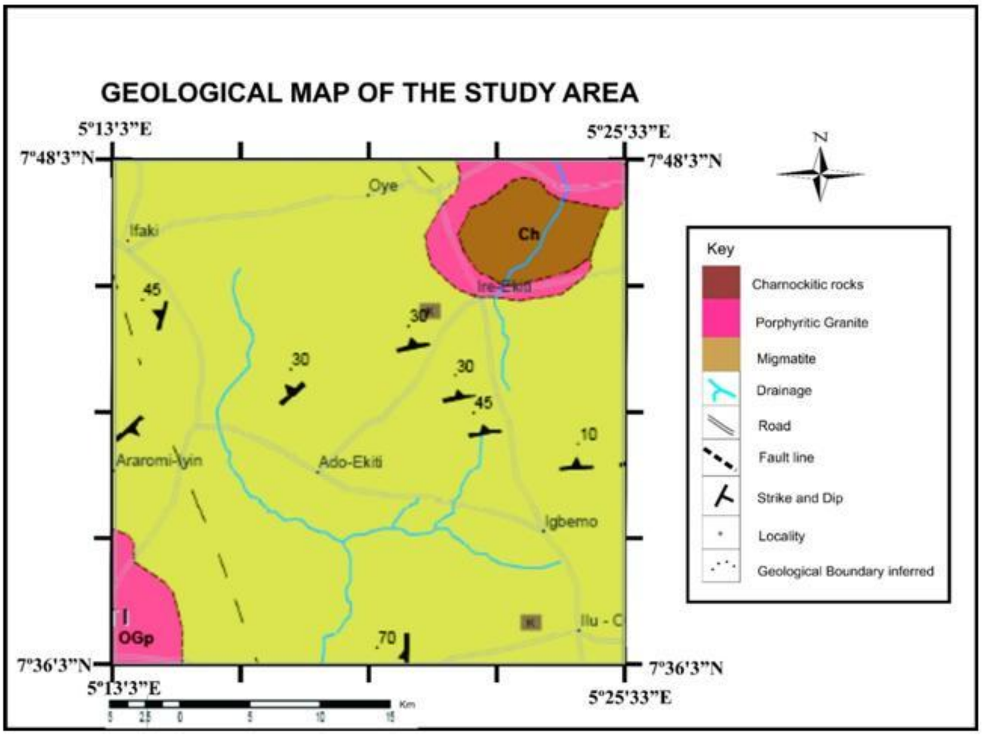
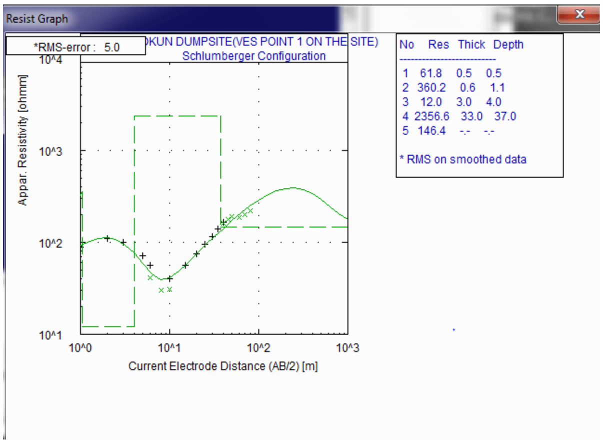
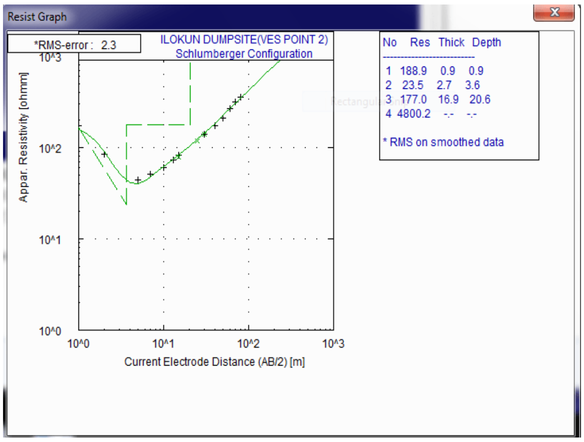


Fig. 2. Geological map of the study area (Modified after NGSA, 2017)



(a)



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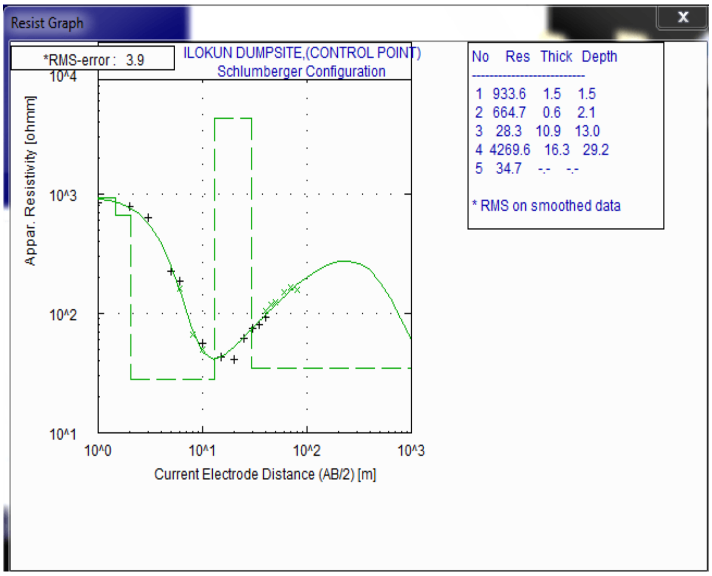

(c)

Fig. 3. Resistivity sounding curves obtained from the study area. (a) QH-Type (b) HA-Type (c) KHA-type

Table 1. Summary of the geoelectric characteristics of the study area

VES Stn.	No. of Layers	Resistivity (Ohm-m)	Curve Type	Thickness (m) $h_1/h_2.....h_{n-1}$	Depth(m) $d_1/d_2.....d_{n-1}$
1	5	61.8/360.2/12/2356.6/146.4	QH	0.5/0.6/3.0/33	0.5/1.1/4/37
2	4	188.9/23.5/177/4800.2	HA	0.9/2.7/16.9	0.9/3.6/20.6
3(Control)	5	933.6/664.7/28.3/4269.6/34.7	KHA	1.5/0.6/10.9/16.3	1.5/2.1/13/29.2

4.1 2-D Electrical Resistivity Imaging

The electrical resistivity method was employed using the dipole-dipole electrode configuration to conduct an investigation at the Ilokun dumpsite in Ado-Ekiti. The study area is situated on the outskirts of Ado-Ekiti. It is a location where 80 percent of wastes generated in Ado-Ekiti metropolis are disposed. Fig. 8 shows a 2-D electrical resistivity image of traverse one located on the dumpsite as indicated in the base map. Readings were taken along west to east direction in the study area. This traverse was established to study the migration of the leachate into the formations on the dumpsite area. The 2-D image shows that the formation along the traverse is majorly characterized with partly weathered rock materials with reddish coloration, while accumulation of migrated leachate material is located within distances 45 to 60m at a depth range of 5 to 15m. The traverse further confirms the fractured zone and that it is oriented along North-South direction of the study area. From 90m distance on the traverse to the end of the traverse is composed of predominantly of highly weathered and partly polluted zone with a small portion of partly weathered bedrock.

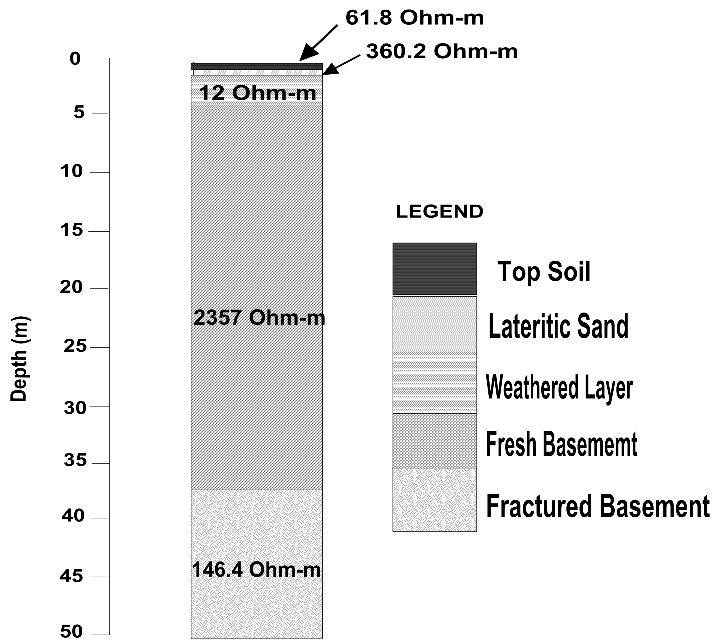

Fig. 4. Geoelectric column beneath the VES 1

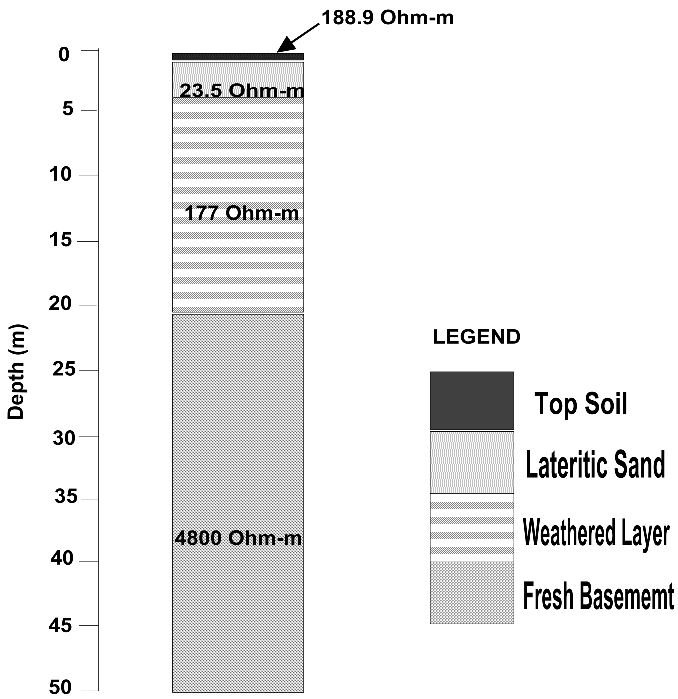

Fig. 5. Geoelectric column beneath the VES 2

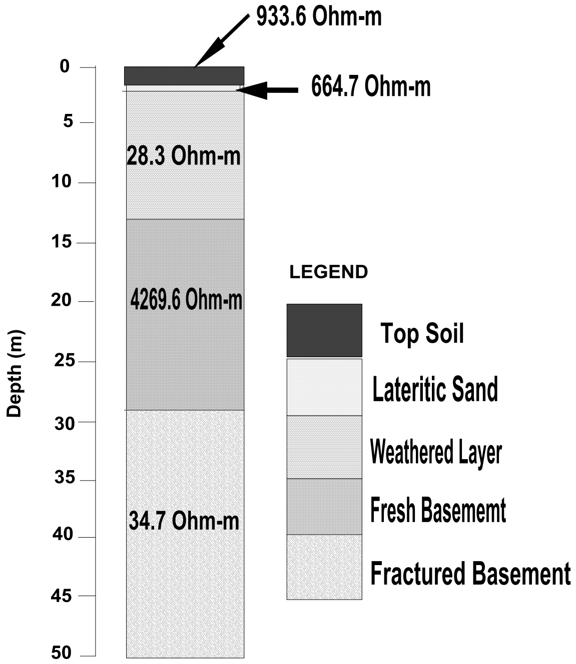

Fig. 6. Geoelectric column beneath the VES 3 (Contro Point)

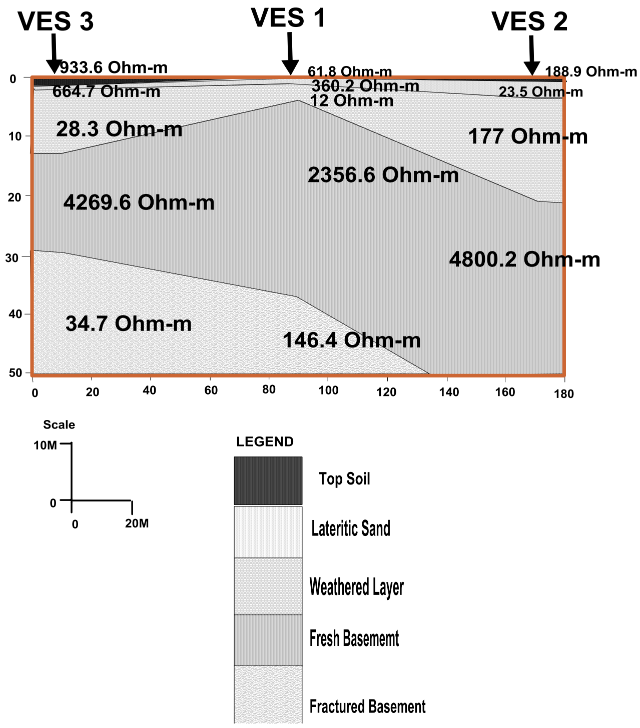

Fig. 7. Geoelectric section beneath the area around Ilokun Dumpsite, Ado-Ekiti

Fig. 9 is an indication of 2-D resistivity image along traverse two. Readings were taken along South to North direction in the study area. The traverse was established on the dumpsite to observe the migration of the leachate along east-west direction. The section indicates that the leachate is moving also along west-east direction. It shows that the migration of the leachate is more pronounced along the west-east direction than the North-South movement on the traverse. The 2-D image shows that the formation along the traverse is majorly characterized with partly weathered rock materials with reddish colouration. The deposition of migrated leachate with relatively very low resistivity values as indicated with bluish colouration is found within distances 20 to 45m at depth range between 6 to 15 m within the partly weathered rock. Highly weathered and partly polluted zone with greenish colouration is found within distances 87-97m in the east-west direction.

The Traverse three located at the center of the dumpsite is 140m long. Observed from the 2-D resistivity image (Fig. 10) is leachate accumulation with bluish colouration to a depth of 10m from the starting point to a distance of about 85 m long. Fracture was noticed within distances 90 m to 110 m along the traverse. The leachate permeates the hollow created by the fractured zone into the subsurface formation. This can pose a great risk to the groundwater. The groundwater formations around this area are more susceptible to the dumpsite leachate pollution as a result of the widely opened fractured bedrock. Highly weathered but partly polluted zone with greenish coloration are areas where the pollution of the leachate is much pronounced. Highly indurated bedrock can be found located within distances 115m to 140 m within the study area.

Fig. 11 confirms that the dumpsite is posing a serious threat to the surrounding formations and groundwater especially those located along the east-west direction of the dumpsite. The potential of leachate accumulation is relatively higher along the east-western axis as indicated in Fig. 11.

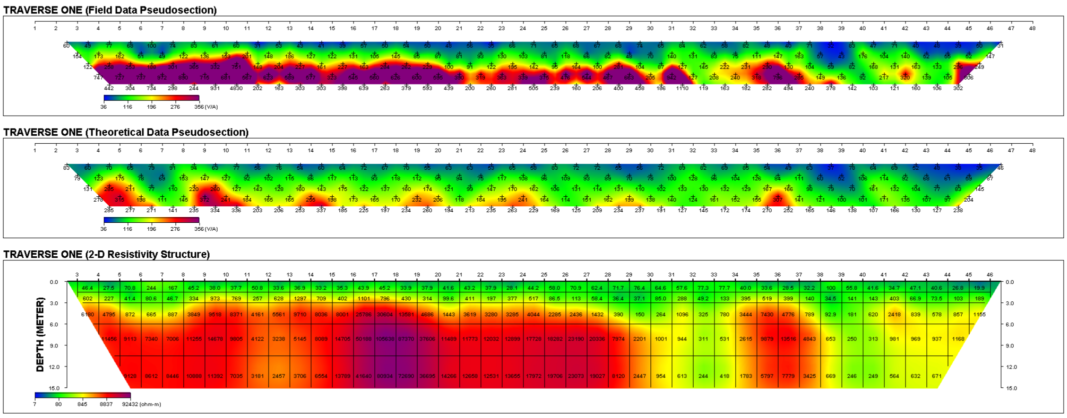

Fig. 8. Resistivity 2-D image along Traverse one

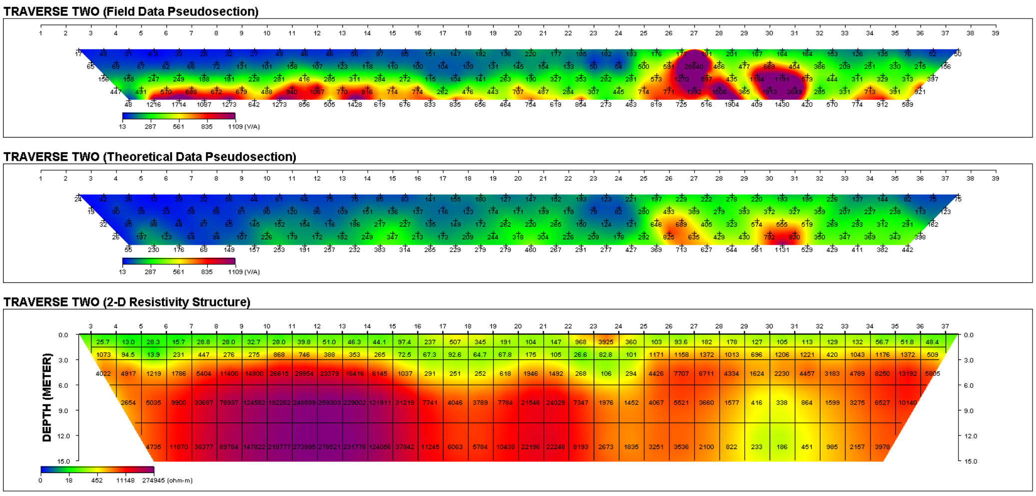

Fig. 9. Resistivity 2-D image along traverse two

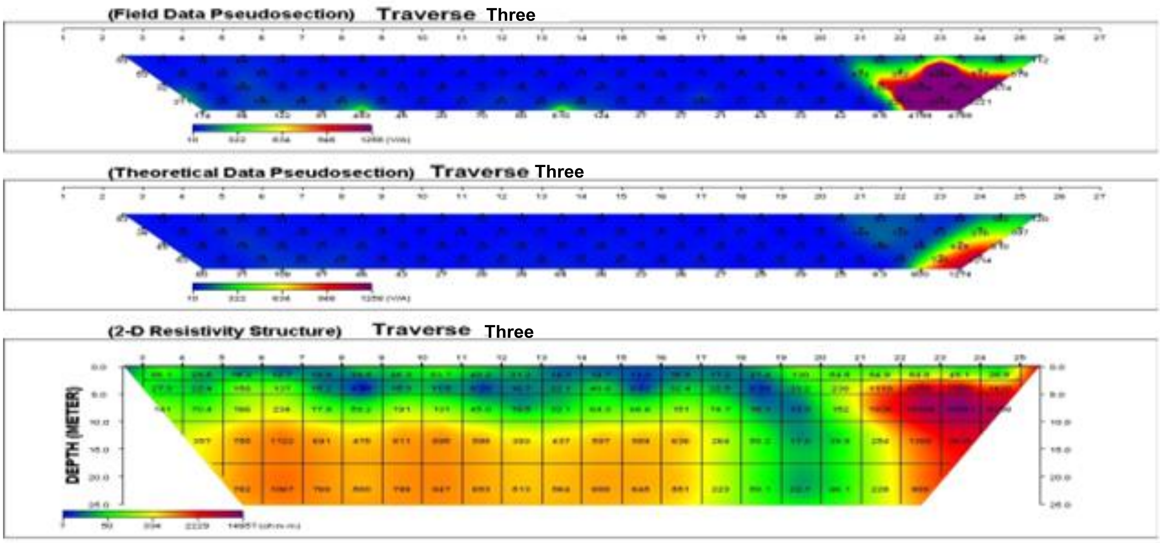

Fig. 10. Resistivity 2-D image along traverse three

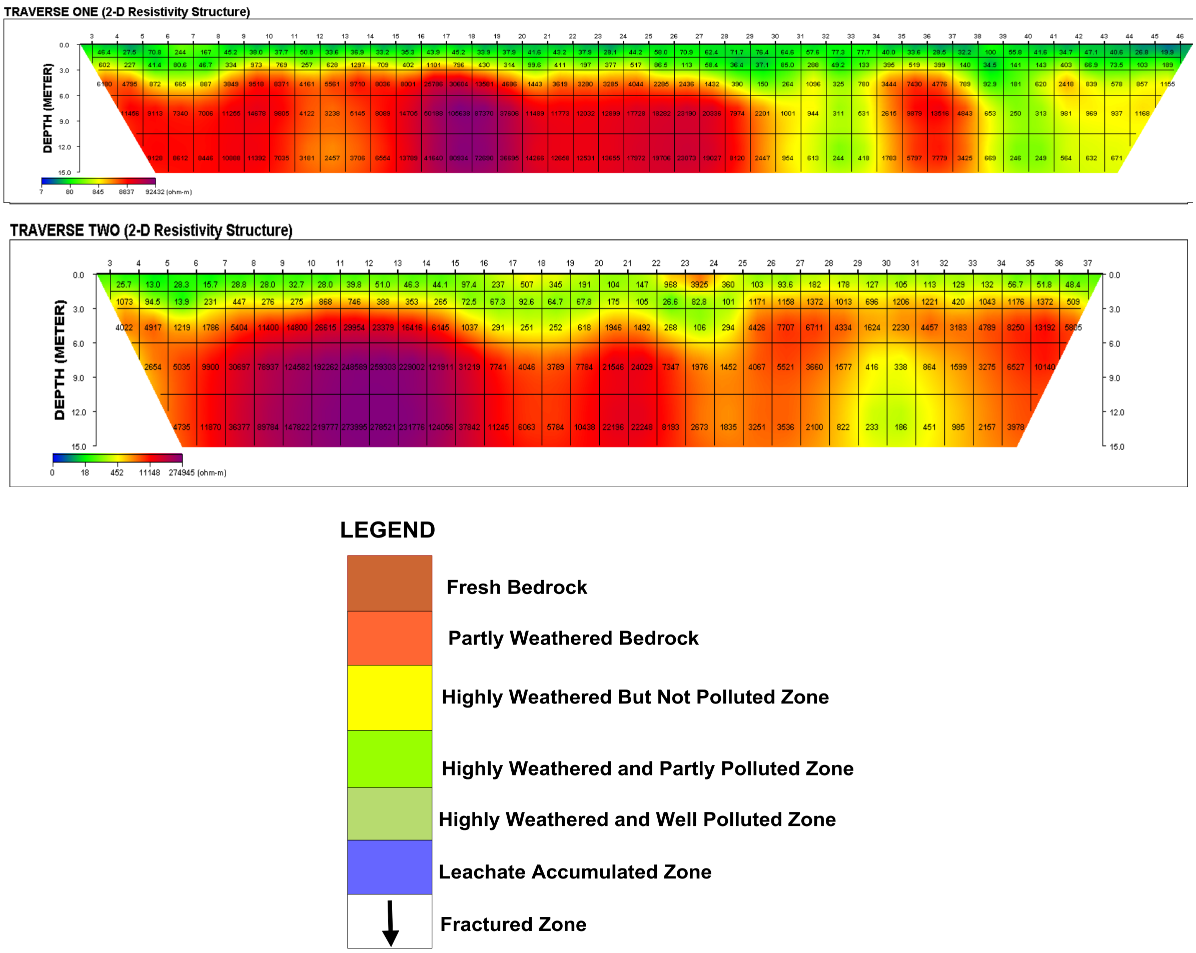

Fig. 11. Resistivity 2-D image along the three traverses

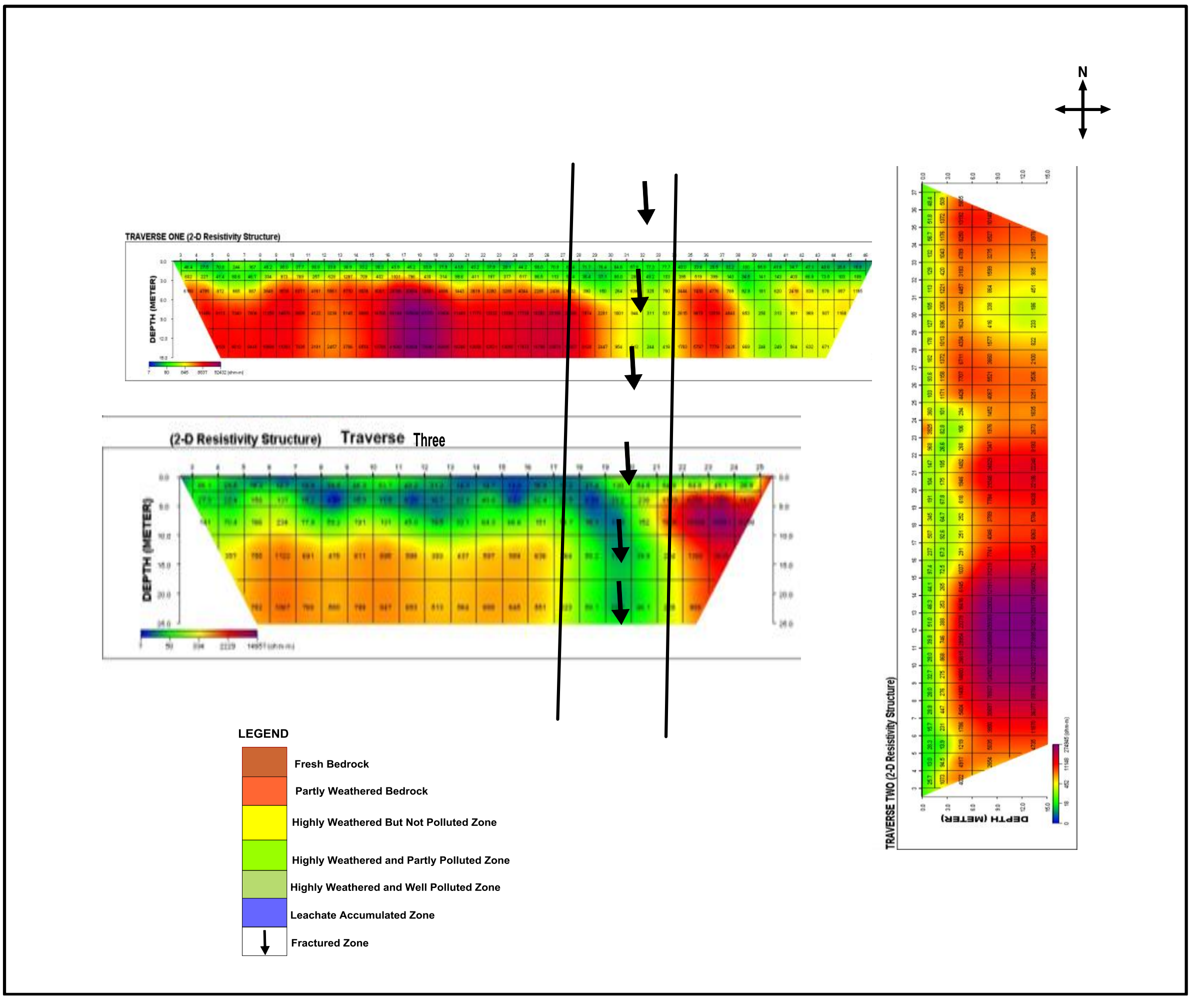

Fig. 12. The 2-D Resistivity Structure along Traverse one, two and three indicating the fractured zone and the migration of the leachate in the study area

5. CONCLUSIONS

Vertical electrical sounding measurements and the dipole-dipole technique were utilized to conduct the electrical resistivity method at the Ilokun dumpsite in Ado-Ekiti. The objective was to transform the dumpsite into a sanitary landfill. The unusually low resistivity observed in the weathered layer below the Control VES point is believed to be caused by leachate presence. Similarly, the abnormally low resistivity values (34.7–146.4 ohm-m) within the fractured basement beneath VES 1 and 3 indicate the presence of contaminant plumes and further evidence pollution. The 2-D resistivity structures also confirm that the dumpsite is posing a serious threat to the surrounding formations and groundwater especially those located along the east-west direction of the dumpsite. The potential of leachate accumulation is relatively higher along the east-western axis. Environmental studies using geophysical survey is important in the reduction of ground water contamination and also helps in siting good areas or good location for dumpsite which will not have any effect on the ground water or surrounding environment and also helps in locating proper area for borehole sinking.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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