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

ABSTRACT

Ilokun dumpsite, Ado-Ekiti was investigated with the aim of converting it to a sanitary landfill. Attempt was made to establish the possible impact of the contaminant plumes emanating from the dumpsite on the subsurface aquifers. The Vertical Electrical Sounding (VES) field technique of the electrical resistivity method was adopted for the study, and the half-electrode spacing AB/2 varied from 1 to 65 m. A total of three VES stations were occupied and a control VES point was located outside the dumpsite. The VES data were interpreted quantitatively by partial curve matching and computer iteration. The dipole-dipole electrode configuration was also used to carry out investigation on the dumpsite. The acquired data was inverted using DIPRO software to obtain 2-D resistivity structures.

The weathered layer beneath VES 1 was identified to be the aquifer unit, but the anomalously low resistivity of 12 ohm-m within the unit was interpreted as an evidence of pollution from conductive contaminant plume. The geoelectric section beneath VES1 to 3 delineated five layers, these include the topsoil; the lateritic sand, the weathered layer; the fresh basement and the fractured basement.. The resistivity and thickness range of the layers are 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 constitutes the main aquifer unit beneath the three VES points, but the anomalously low resistivity of 34.7–146.4 ohm-m within the fractured layer beneath VES 1 and 3 is suspected to be as a result of pollution from conductive contaminant plume emanating 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,

INTRODUCTION

Solid wastes are the unwanted or useless solid materials generated from combined residential, industrial, and commercial activities in a given area. It may be categorized according to its origin (domestic, industrial, commercial, construction or institutional); according to its contents (organic material, glass, metal, plastic paper. e.t.c.) or according to hazard potential (toxic, non-toxin, flammable, radioactive, inflections. e.t.c) (Ugwu, 2009). According to Basel convention, “Solid wastes are substances or objects which are disposed or are intended to be disposed or are required to be disposed by the provision of National law.”

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 (Divya *et al*., 2020, Nwankwo and Ogoro, 2020, Omeiza, 2023). Understanding the impacts of open dumpsites and its implication on groundwater systems is a critical component of water security for long-term environmental management strategies. However, predicting the impacts of dynamic dumpsites on environmental systems is a difficult task that requires a technical approach (Omeiza *et al*., 2023)

Nigeria, like most developing countries, is hindered by serious financial constraints in undertaking a program of providing adequate quality or potable water to all her inhabitants. This made people to resort to groundwater exploration for domestic, agricultural and industrial purposes. Various socio-economically developed activities caused by population pressure with their attendant waste generation and improper management of these wastes continue to threaten water quality (Hussain *et al*., 1989).

Solid waste management has emerged as one of the greatest challenges facing state and local government environmental protection agencies in Nigeria. The volume of solid waste being generated continues to increase at a faster rate than the ability of the agencies to improve on the financial and technical resources needed to parallel this growth. Solid waste management is characterized by inefficient collection methods, insufficient coverage of the collection system and improper disposal of solid waste (Ogwueleka, 2003). As a result, most of these wastes, indiscriminately dumped in landfill site, find their way into water course either through run-offs during rain (into surface water) or by leachate-percolation from the wastes which naturally infiltrates into the groundwater depending on the stratigraphy of the area hence, making it unwholesome for use (Badmus, *et al*., 2001)

Unarguably, uncontrolled citing of boreholes as the source of potable water in most of our urban and rural communities as the government seemingly no longer provides the populace with water has become a serious challenge. However, maintaining a potable groundwater supply that is free from microbial and chemical contaminants is far from reality in most of our urban centers, and particularly, Ado-Ekiti, Nigeria due to poor waste disposal and management practices. The challenge is worsened by the fact that there are inadequate trained waste disposal workers and equipment, poor waste collection, sorting and disposal sites without regards to the local geology and hydrogeology of the area. All these contribute significantly to the groundwater contamination as well as soil quality (Bou-Zeid and El-Fadel, 2004). Some of the major effects of poorly managed dumpsite are leachate formation, disease spread, attraction of Vermin, mosquito breeding, strong odour spread in the entire area, gas formation e.g methane, increase in soil acidity and alkalinity and destruction of the ecosystem (Hussain *et al*., 1989).

In Ado-Ekiti, Nigeria, groundwater serves as the main source of potable water for the population at large. Since the quality of groundwater is more important than its quantity, there is need to study the possible effect(s) of the leachate emanating from the Ilokun dumpsite on the surrounding aquifer unit(s).

LOCATION AND GEOLOGY

The dumpsite 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 (Figure 1) along Ado-Iworoko road. The site is very accessible. A small community of Ebira indigenes is located very close to the study area. The composition of Ilokun dumpsite are organic materials, polythene and plastic materials, meta scraps, animal wastes etc. The geology of the dumpsite is that of the Basement Complex of southwestern Nigeria (Rahaman, 1988). Migmatite is the main rock unit in the area (Figure 2). This rock unit manifests as surface outcrops around the study area.

METHODOLOGY

The electrical resistivity method of geophysical prospecting was adopted for this research. The method involves the supply of direct current (D.C.) or low-frequency alternating current into the ground through a pair of current electrodes. The ratio of voltage measured to current measured by the ammeter results to resistance and resistivity is gotten from the product of resistance and length or electrode spacing. A total of three (3) Vertical Electrical Sounding (VES) measurements were taken on and around the dumpsite. Two VES were taken on the dumpsite to delineate its resistivity properties and to identify the contaminant plume. The results of these Two VES points were compared with the result of control VES taken outside the dumpsite to assess the extent of contamination. Field resistance measurements were taken using ABEM SAS 1000 terrameter. The apparent resistivity values obtained were manually plotted against their respective current-electrode spacing values (AB/2) on a log-log graph. The curves were interpreted by partial curve matching and electronically iterated using WINRESIST 1.0 computer iteration program.

RESULTS AND DISCUSSIONS

Depth Sounding Curves and Geoelectric Sections

Three (3) different types of sounding curves (Figures 3a-c) were obtained from the study area, these include the 5-layer (KHA); the 5-layer (QH) and the 4-layer (HA) types. The H type is predominant in the area. Details of the geoelectric parameters of each VES are presented in Table 1. The very low/low resistivity (12-360.2 ohm-m) and (23.5-188.9ohm-m) characteristics observed on VES 1 and VES 2 (Figures 3a and 3b) which were established on the dumpsite depicts the nature of the wastes deposited on the dumpsite. As seen on the surface, the materials are majorly composed of metal scraps and other types of wastes. The geolectric column of VES point 1 (Figure 4) delineated five geoelectric layers. The first layer is the topsoil and it has a thickness of 0.5 m and resistivity of 61.8 ohm-m. The second, and third layers are typical of weathered layer and they are characterised by a resistivity range of between 12 and 360.2 ohm-m and a thickness range of 0.6 to 3m. The weathered layer is a significant aquifer unit in a typical basement complex environment (Olorunfemi, 2009; Ademilua and Eluwole, 2013; Obasi *et al.*, 2013; Eluwole and Ademilua, 2014) and the resistivity of the layer plays a vital role in the nature of the aquifer.

The geolectric column of VES point 2 (Figure 5) delineated four geoelectric layers. The first layer is the topsoil and it has a thickness of 0.9 m and resistivity of 188.9 ohm-m. The second, and third layers are typical of weathered layer and they are characterised by a resistivity range of between 23.5 and 177 ohm-m and a thickness range of 2.7 to 16.9m.

The geolectric column of the VES 3 (control point) (Figure 6) delineated five geoelectric layers. The first layer is the topsoil and it has a thickness of 1.5 m and resistivity of 934 ohm-m. The second, and third layers are typical of weathered layer and they are characterised by a resistivity range of between 28.3 and 665 ohm-m and a thickness range of 0.6 to 10.9m.

The very low resistivity zone (12 ohm-m and 23.5ohm-m) within the aquifer unit beneath the VES 1 and VES 2 respectively is suggestive of the presence of conductive contaminant plume emanating from the dumpsite. The resistivity of the sub-surface material observed is also a function of the magnitude of the current, the recorded potential difference and the geometry of the electrode array used.

The geoelectric section (Figure 7) was generated from the geoelectric parameters (thicknesses and resistivities) obtained from three VES points. Five geoelectric layers were delineated and these include the topsoil; the lateritic sands, the weathered layer; the fractured basement and the fresh basement. The resistivity of the topsoil varies from 61.8 and 933.6 ohm-m, while the thickness is between 0.5 and 15 m. The lateritic sand layer has a resistivity range of between 23.5 and 664.7 ohm-m and the thickness range is 0.6 to 2.7m. The resistivity of the weathered layer varies from 12 and 177 ohm-m, while the thickness is between 3 and 16.9m. The fresh basement rock beneath the topsoil and the weathered layer has a resistivity range of 2356.6 to 4800.2 ohm-m and thickness of between 16.3 and 33m at Control VES point and VES 1 but it is infinitely thick at VES 2. The fractured basement which constitutes another aquifer unit in the area has resistivity range of 34.7 to 146.4 Ohm-m and is infinitely thick at VES 3 (control point) and VES 1.

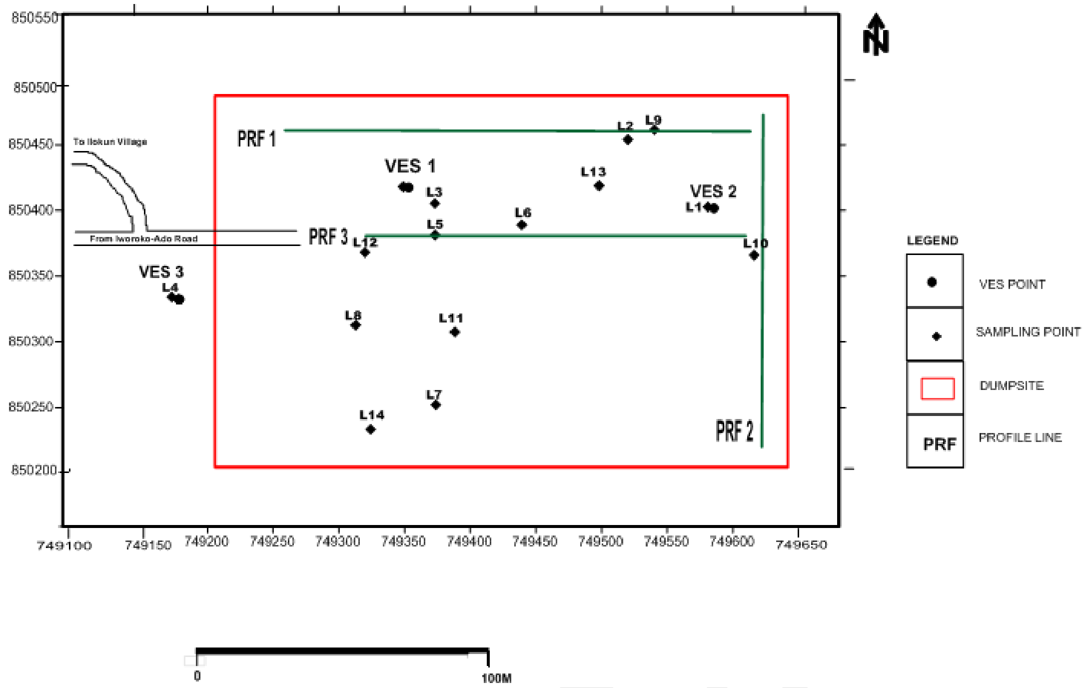


Figure 1: Geophysical Data Acquisition/Base Map of the Study Area

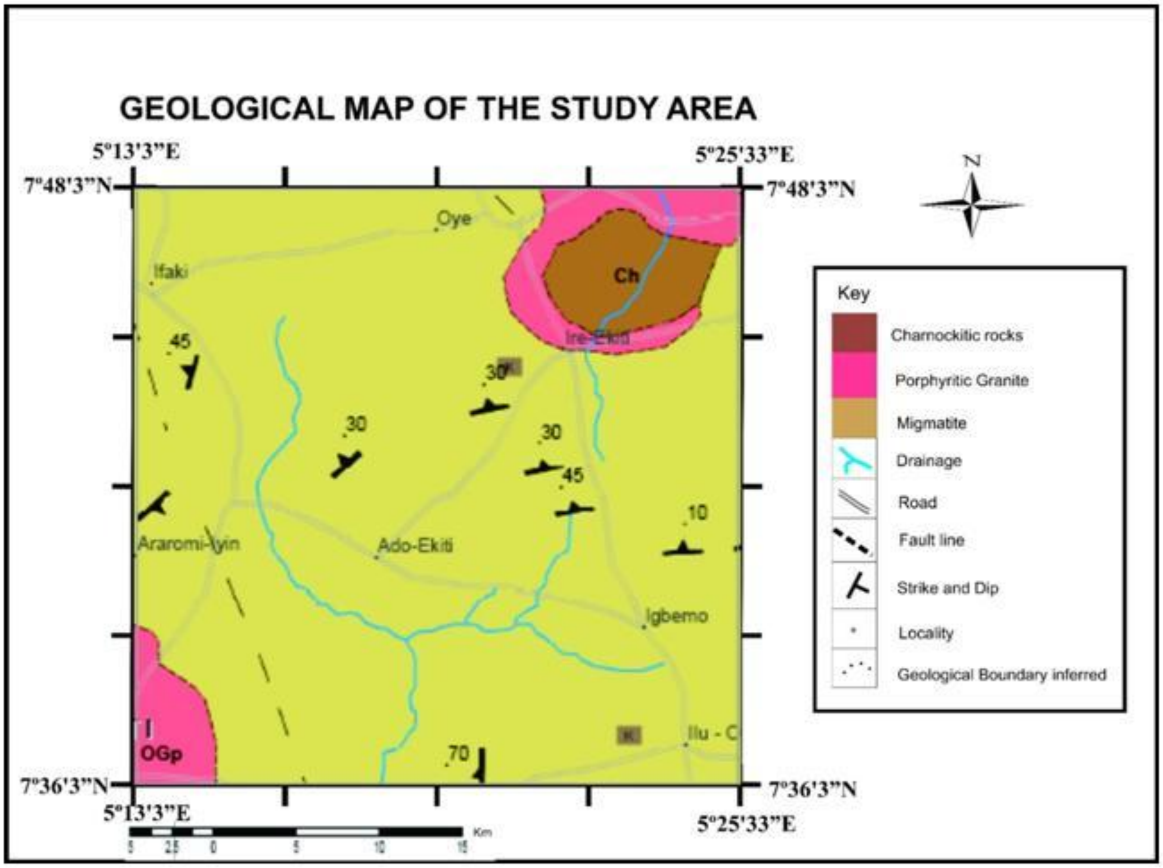
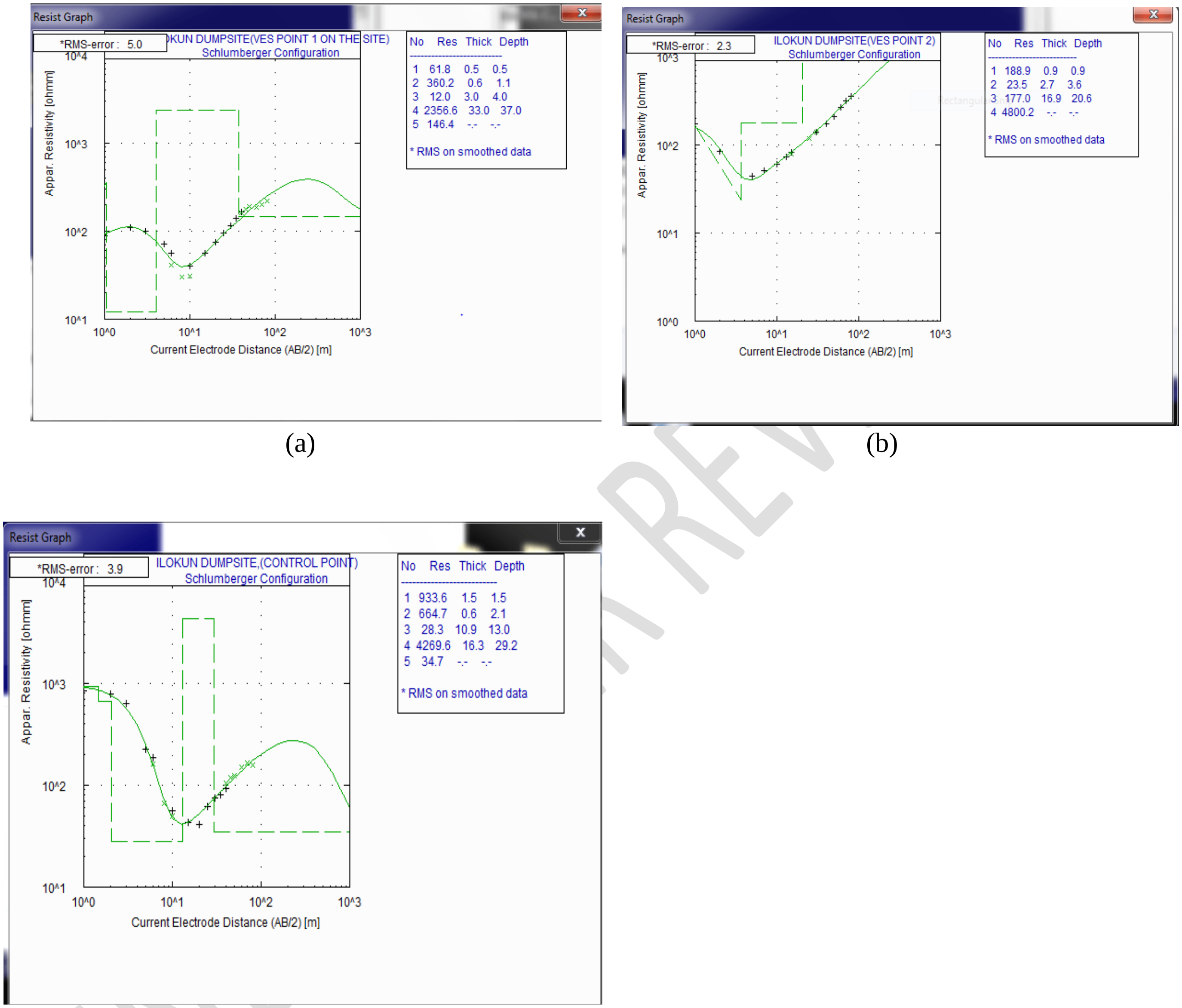


Figure 2: Geological Map of the study Area (Modified after NGSA, 2017)



*RMS-error : 5.0

KUN DUMPSITE(VES POINT 1 ON THE SITE)
Schlumberger Configuration

No	Res	Thick	Depth
1	61.8	0.5	0.5
2	360.2	0.6	1.1
3	12.0	3.0	4.0
4	2356.6	33.0	37.0
5	146.4	-.-	-.-

* RMS on smoothed data

(a)

*RMS-error : 2.3

ILOKUN DUMPSITE(VES POINT 2)
Schlumberger Configuration

No	Res	Thick	Depth
1	188.9	0.9	0.9
2	23.5	2.7	3.6
3	177.0	16.9	20.6
4	4800.2	-.-	-.-

* RMS on smoothed data

(b)

*RMS-error : 3.9

ILOKUN DUMPSITE,(CONTROL POINT)
Schlumberger Configuration

No	Res	Thick	Depth
1	933.6	1.5	1.5
2	664.7	0.6	2.1
3	28.3	10.9	13.0
4	4269.6	16.3	29.2
5	34.7	-.-	-.-

* RMS on smoothed data

(c)

Figure 3: Resistivity Sounding Curves Obtained from the Study Area. (a) QH-Type (b) HA-Type (c) KHA-Type

Having established from the interpretation of the Control VES point that the contaminant plume is conductive in nature, it is pertinent to note that a portion of the fractured basement identified as the aquifer unit in the surrounding of the dumpsite has been polluted with the contaminant plume emanating from the dumpsite. The polluted zone characterised by anomalously low resistivity of between 16 and 47 ohm-m is present within the fractured basement beneath VES 4, 5, 6 and 7 respectively. The resistivities of the overlying layers around the polluted zone is relatively high and portrays no evidence of pollution, this suggests that the mode of migration of the contaminant plume may not be vertical. The migration may be structurally controlled by the interconnectivity of nearby fractured/sheared zones that have been polluted.

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

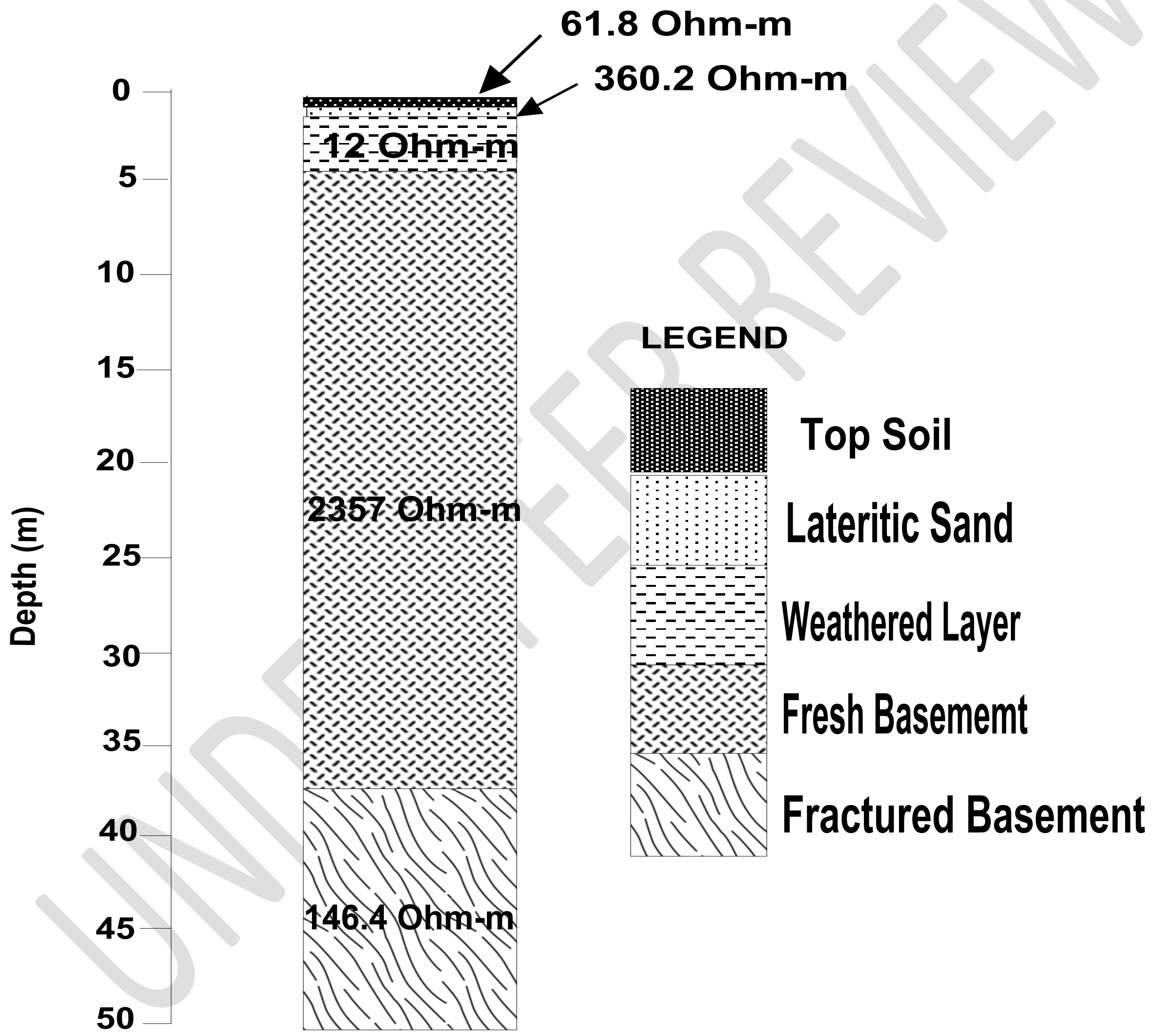


Figure 4: Geoelectric Column Beneath the VES 1

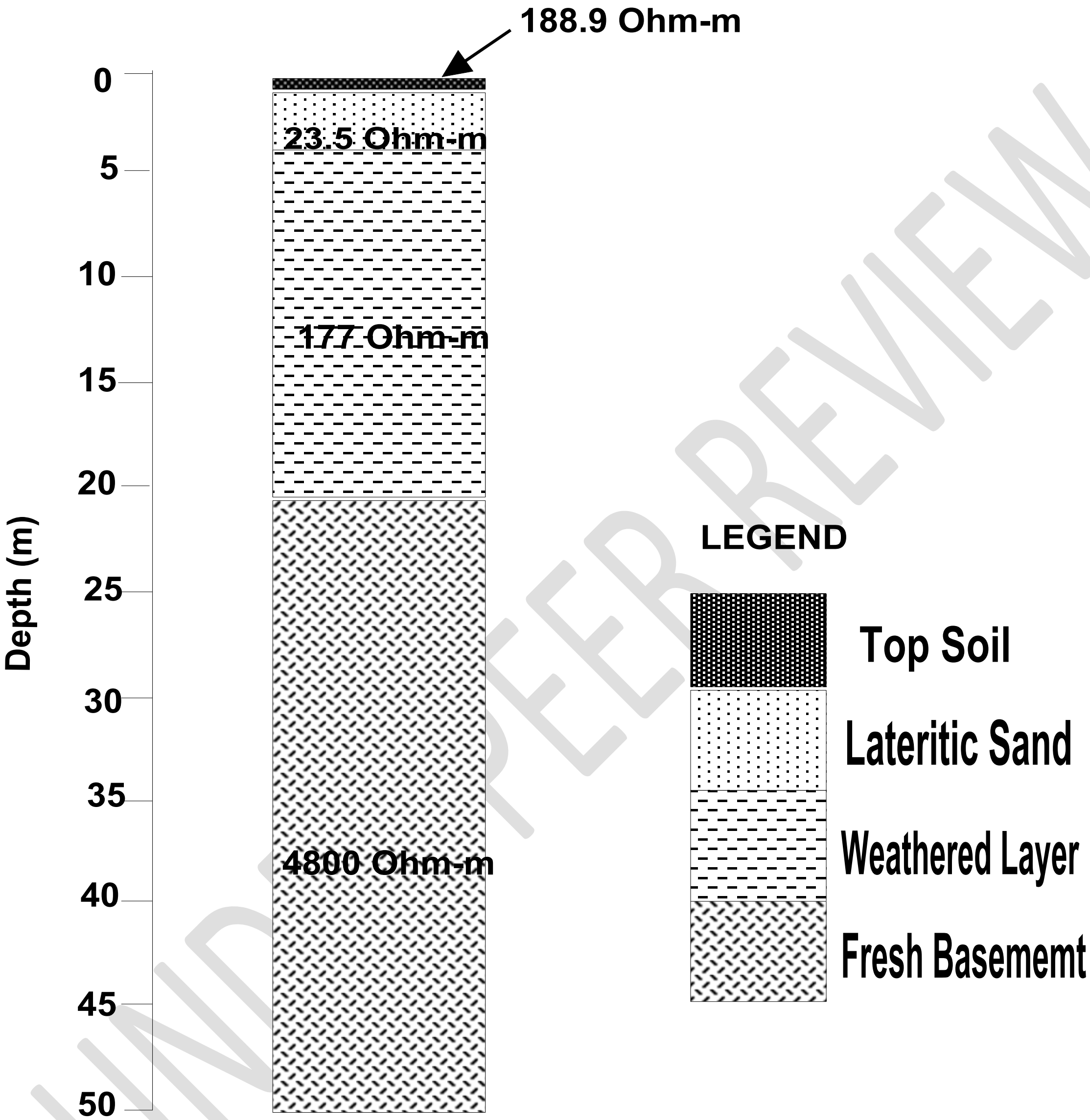


Figure 5: Geoelectric Column Beneath the VES 2

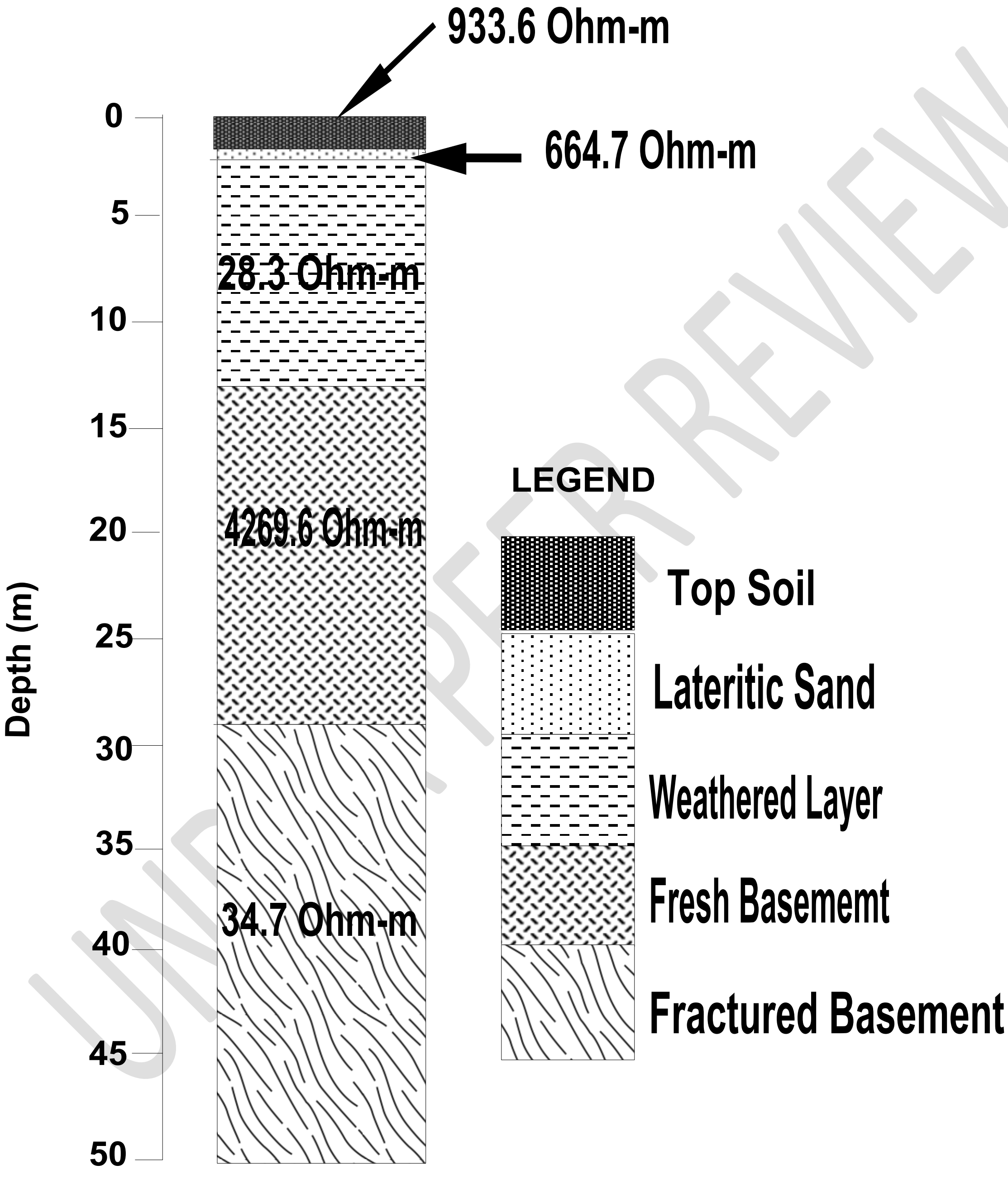


Figure 6: Geoelectric Column Beneath the VES 3 (ControPoint)

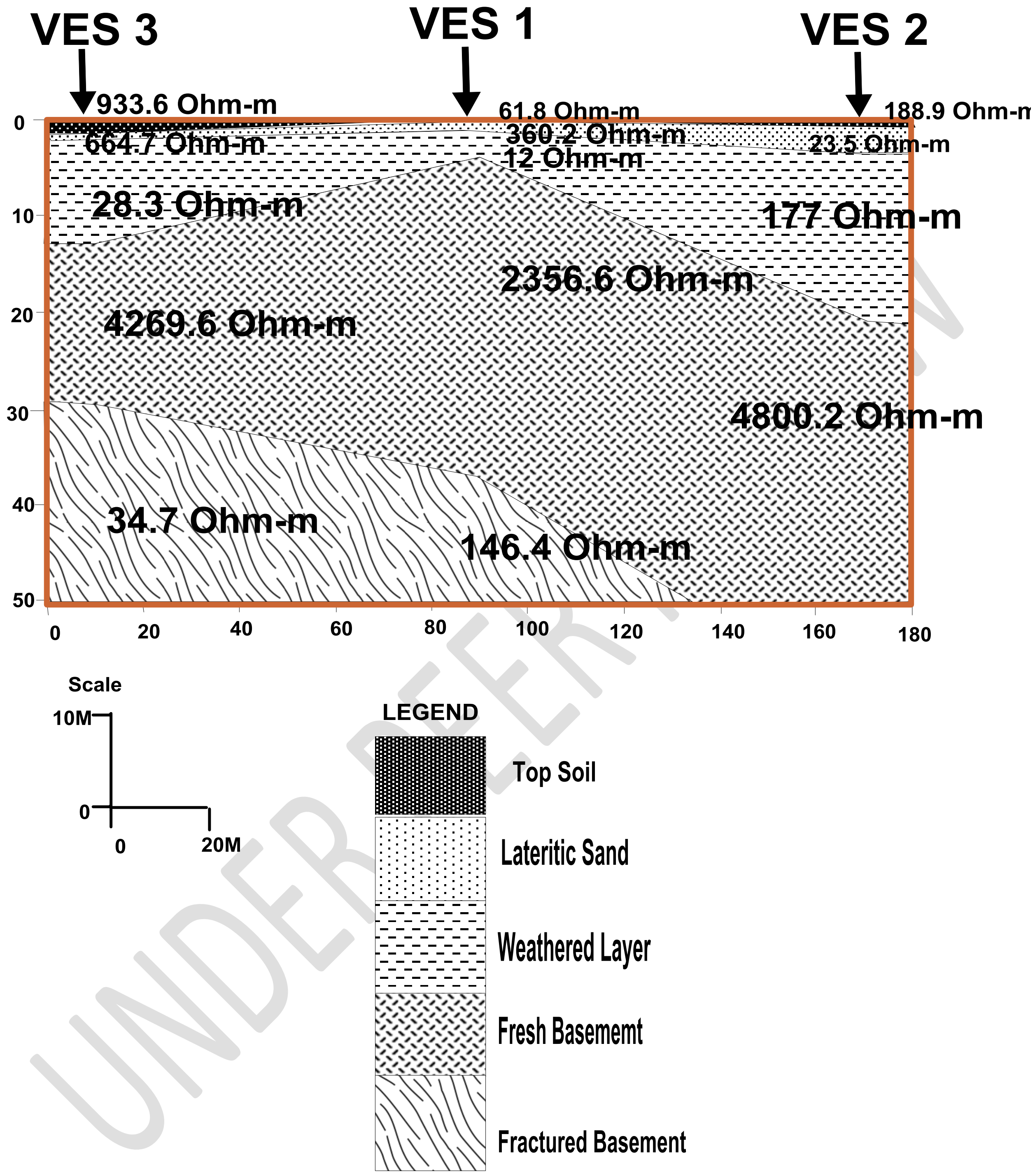


Figure 7: Geoelectric Section Beneath the Area Around Ilokun Dumpsite, Ado-Ekiti

2-D Electrical Resistivity Imaging

Electrical resistivity method was adopted with dipole-dipole electrode configuration to carry out investigation on the Ilokun dumpsite in Ado-Ekiti. The study area is located at the outskirt of Ado-Ekiti. It is a location where 80 percent of wastes generated in Ado-Ekiti metropolis are disposed. Figure 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.

Figure 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 (Figure 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. Partly weathered bedrock can be found within starting point and distance 85 m which are weathered rock materials but not yet penetrated by the dumpsite pollutant within the study area. Highly indurated bedrock can be found located within distances 115m to 140 m within the study area.

Figure 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 figure 11.

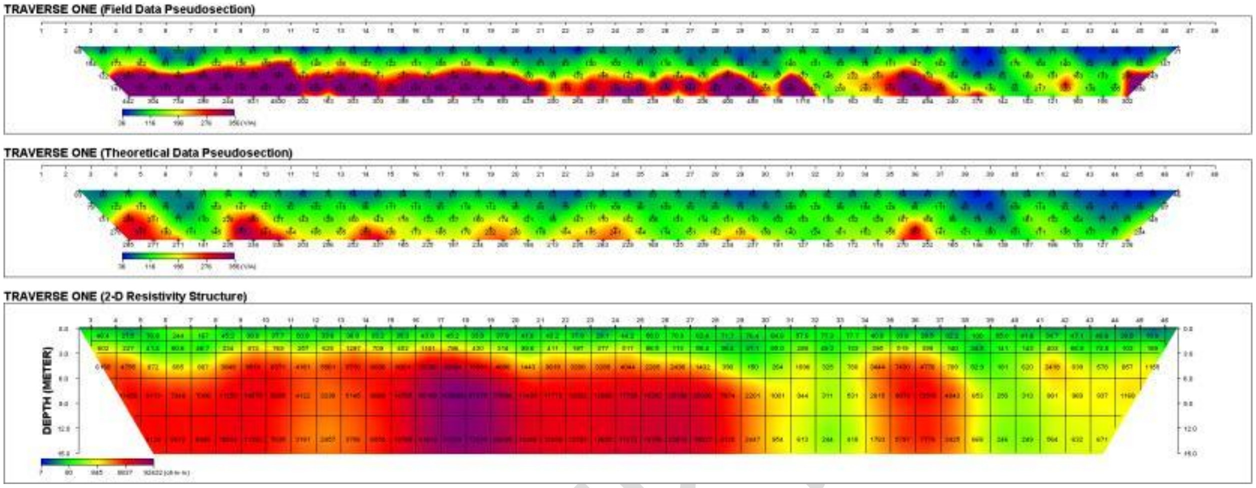


Figure 8: Resistivity 2-D image along Traverse one

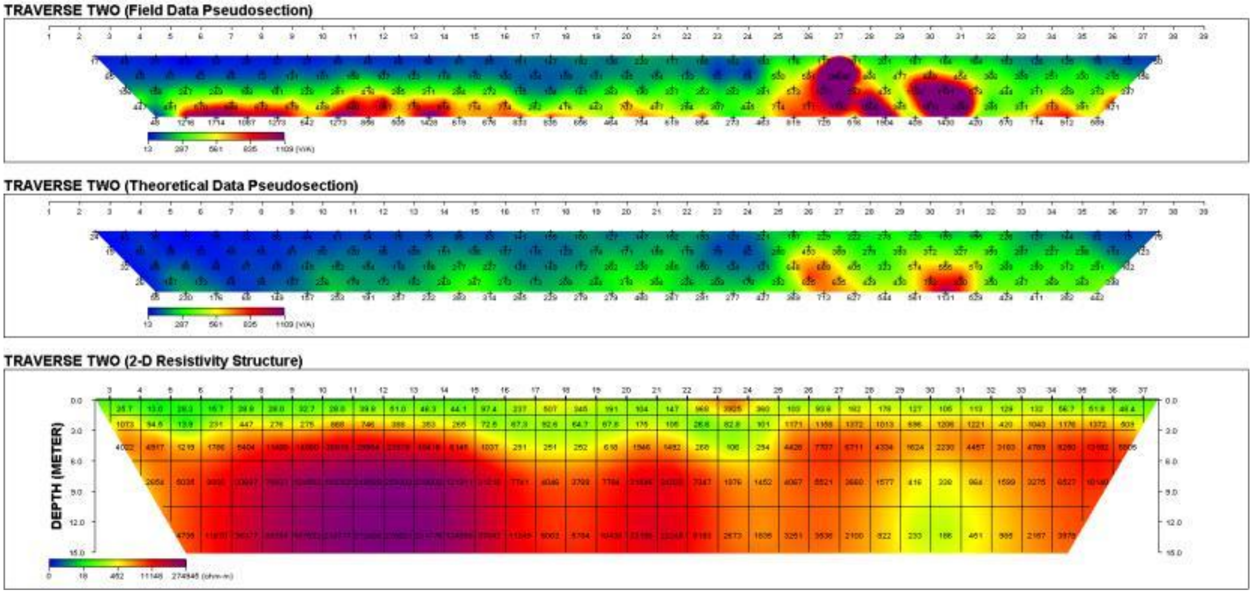
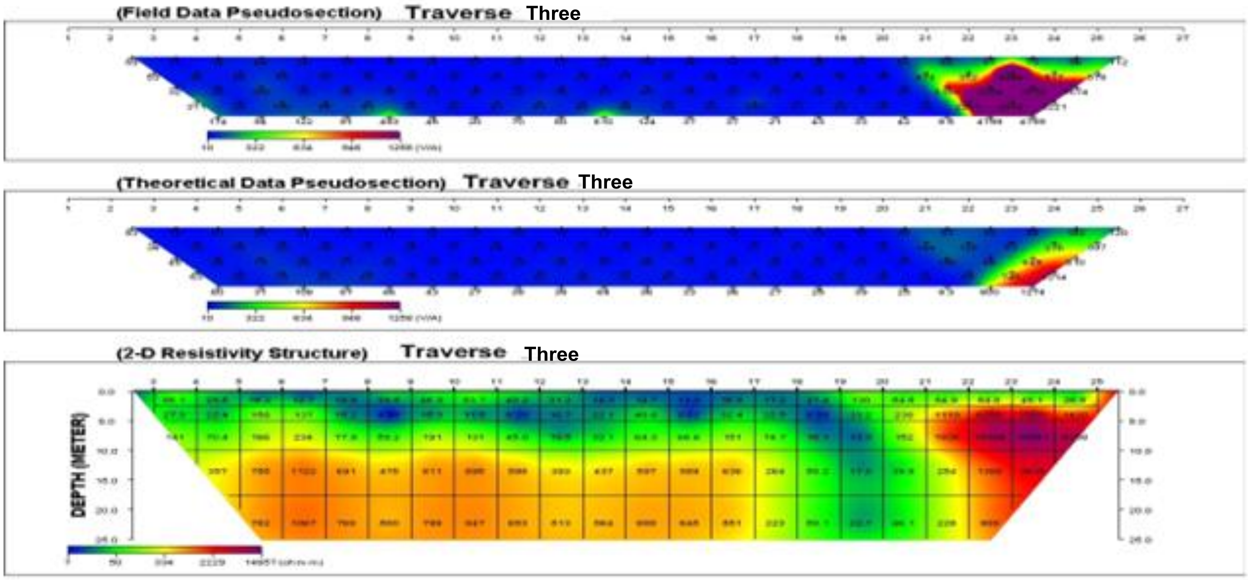


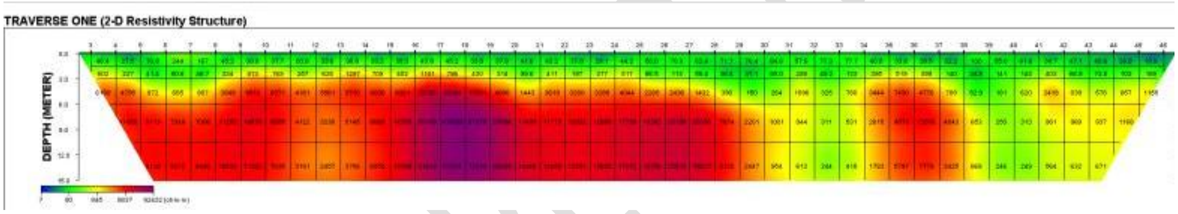
Figure 9: Resistivity 2-D image along Traverse two

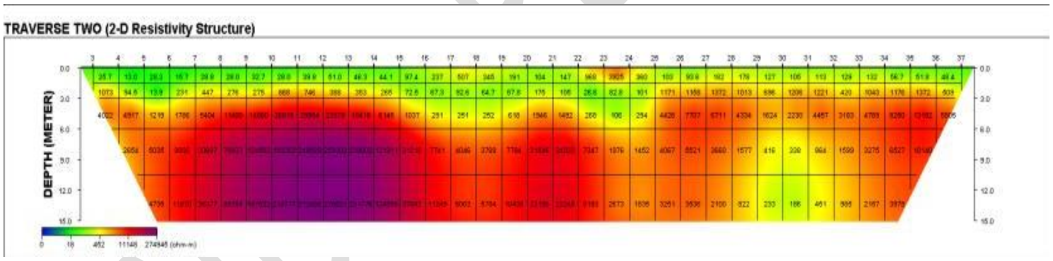

(Field Data Pseudosection) Traverse Three

(Theoretical Data Pseudosection) Traverse Three

(2-D Resistivity Structure) Traverse Three

Figure 10: Resistivity 2-D image along Traverse three


TRAVERSE ONE (2-D Resistivity Structure)


TRAVERSE TWO (2-D Resistivity Structure)

LEGEND

🟫	Fresh Bedrock
🟧	Partly Weathered Bedrock
🟨	Highly Weathered But Not Polluted Zone
🟩	Highly Weathered and Partly Polluted Zon
🟩	Highly Weathered and Well Polluted Zone
🟦	Leachate Accumulated Zone
↓	Fractured Zone

Figure 11: Resistivity 2-D image along the three traverses

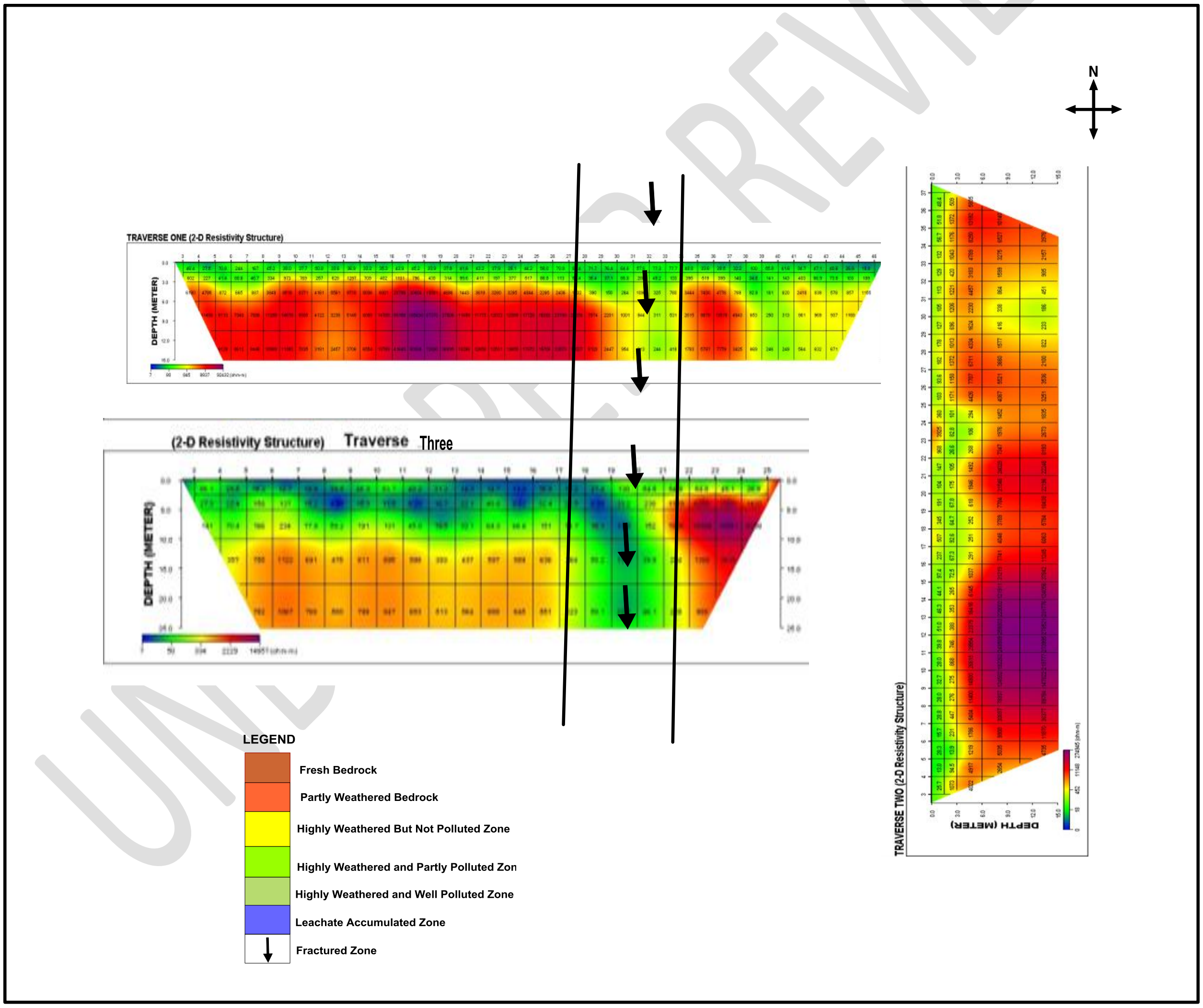


Figure 12: The 2-D Resistivity Structure along Traverse one, two and three indicating the fractured zone and the migration of the leachate in the study area.

CONCLUSION

Solid waste disposal is considered as one of the main environmental problems, most of the generated solid waste amount to household waste and is buried in landfill or dumpsite. The dumped solid waste produce large amount of leachate which is a potential harm to both human and environment and likely contaminate groundwater. This would adversely affect industrial and agricultural activities that depend on groundwater.

This study conducted electrical resistivity investigation on Ilokun dumpsite, Ado-Ekiti, via eight (8) vertical electrical sounding measurements. The anomalously low resistivity characteristics of the weathered layer beneath the Control VES point have been attributed to the presence of conductive contaminant plume. The anomalously low resistivity (16–47 ohm-m) within the fractured basement beneath VES 4, 5, 6 and 7 are evidences of pollution from the contaminant. The fractured basement beneath VES 2 and 3 which possess the characteristics of a good aquifer unit is under a threat of being contaminated due to its interconnection with the polluted fractured zones. The mode of migration of contaminant plumes was also identified to be independent of the layers overlying the polluted fractured basement. 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.

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