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Research

2D Resistivity imaging for mapping contamination around an abandoned dumpsite in Ido - Osun, Southwestern Nigeria

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Abstract

The use of open waste dumps for waste disposal remains common practice in most developing countries. This waste management method is grossly ineffective as the leachates generated from decomposed wastes infiltrate and contaminate the soil and groundwater of host communities and consequently pose serious environmental threat. It is therefore important to assess the leachate migration path with a view to providing remediation measures. 2D Wenner electrical resistivity profiling was carried out to detect and map leachate contamination around an abandoned solid waste dumpsite in Ido-Osun Southwestern Nigeria. The resistivity profiling measurements were taken along twelve traverses of length ranging from 70 m to 150 m around the dumpsite with the aid of a read-out ABAEM SAS 1000 resistivity meter, by using electrode spacing (a) of 5 m, 10 m, 15 m and 20 m. The data were interpreted by using 2D resistivity inversion procedures. The results of the study reveal several anomalous resistivity lows of values less than 10 Ωm typical of leachate plumes reflecting contamination around the dumpsite. Areas with relatively low resistivity greater than 10 Ωm are equally contaminated but with lower solute concentration. The waste dump has contaminated the subsoil within the distance of about 30 m away from its edges to depths greater than 7 m beneath the traverses. The contamination constitutes potential threat to soil and groundwater resources in the nearby developing community and are likely to be affected if prompt and adequate measures are not taken. Geochemical tests should be conducted to determine the concentration of the contaminants while appropriate remediation measures should be applied to forestall further spread of the contaminants toward the developing residential community.

Keywords: Dumpsite, leachate plumes, contamination, resistivity profiling, resistivity lows.

Introduction

Open waste disposal is a major environmental challenge in developing countries despite the development and availability of effective methods in the advanced world. Waste dumps are sited indiscriminately without considering the consequent environmental implication on the host communities (Aweto and Mamah, 2014; Babbar *et al*., 2017). Soil and groundwater quality are mostly affected in urban centres as increase in human activities lead to generation of huge amounts of solid wastes (Ojekunle *et al*., 2018; Agada *et al*., 2020). The soil and groundwater resources are impacted by leachates formed by dissolution of the decomposed wastes as precipitation and rain water percolate through the waste dumps and the underlying soil (Abdullahi et al., 2011; Ajani *et al*., 2021). Leachates from solid wastes are composed of harmful substances which include organic matter, inorganic ions and heavy metals which put shallow sources of groundwater at high risk of contamination. Contaminants released into the soil environment around a dumpsite seldom remain at the point of discharge. They are transported through the pores in the soil by the processes such as adsorption, advection, molecular diffusion and dispersion.

The electrical resistivity method has been widely used for mapping and detecting subsurface contamination resulting from contact of leachate with groundwater through the soil (Adebayo *et al*., 2015; Bayowa *et al*., 2015; Olagunju *et al*., 2017; Ademila and Ololade, 2018; Nwankwo and Ogoro, 2020). It is a fast, non-invasive and cost-effective method of mapping subsurface resistivity anomalies such as those presented by leachate plume. Leachates generated from waste dumps have high conductivity since they are composed of dissolved salts (Cristina et al., 2012). The electrical resistivity of leachates is often very much lower than that of unpolluted, leachate-free, fresh groundwater. Soil and rock environment containing leachates are characterized by anomalously low resistivity since leachates are generally associated with high ion concentrations (Carpental *et al*., 2012; Agada *et al*., 2020). The electrical resistivity contrast that exists between the conductive leachate and the soil and groundwater makes the electrical resistivity method most suitable for detecting and mapping contamination generated from waste disposal sites.

Areas around waste dumps are susceptible to soil and groundwater contamination since the leachate generated from the decomposed wastes tend to migrate vertically and laterally through the soil and reach the water table. Results of an earlier study (Bayowa et al., 2015) revealed the existence of low resistivity zones interpreted as probable contamination plumes beneath the dumpsite but did not assess the lateral extent of contamination around the waste dump. It has therefore become imperative to extend the subsurface resistivity mapping around the waste dump to ascertain subsurface spread of contaminants from the source.

The study area is an abandoned open dumpsite situated at Onibu-Aje in Ido-Osun near Osogbo, southwestern Nigeria. It lies within latitudes N07° 47.575′ - N07° 47.875′ and longitudes E04° 29.359′ - E04° 29.957′ (Figure 1). The area is underlain by Precambrian basement rocks of southwestern Nigeria. The dominant rock type is quartzite (Oyelami *et al*., 2014). The climate of the study area is that of tropical rainforest with two distinct seasons namely: wet and dry seasons. The wet season is experienced from April to November, with a marked break in August, while the dry season occurs from November to March. The average annual rainfall is about 1000 mm while the annual temperature varies from 21.1°C to 31.1°C (OSSADEP, 1997).

Methodology

2D electrical resistivity profiling was conducted by using Wenner electrode array along twelve traverses of lengths ranging from 70m to 150 m (Figure 1). The traverses were separated one another by a distance of 10 m. The resistivity profiling measurements were taken with a digital read-out ABEM SAS 1000 resistivity meter with electrode spacing (a) of 5 m, 10 m, 15 m and 20 m. The resistivity data were processed by using 2D resistivity inversion procedure which automatically subdivide the subsurface into a number of blocks and use a least–squares inversion scheme to determine the appropriate resistivity values for each blocks so that the calculated apparent resistivity values agrees with the measured apparent resistivity values from the field survey (Loke *et al*., 2017). The results were displayed as inverted model resistivity sections versus depth of the subsurface. The sections were visually inspected to identify areas of anomalously low resistivity zones related to contamination plumes.

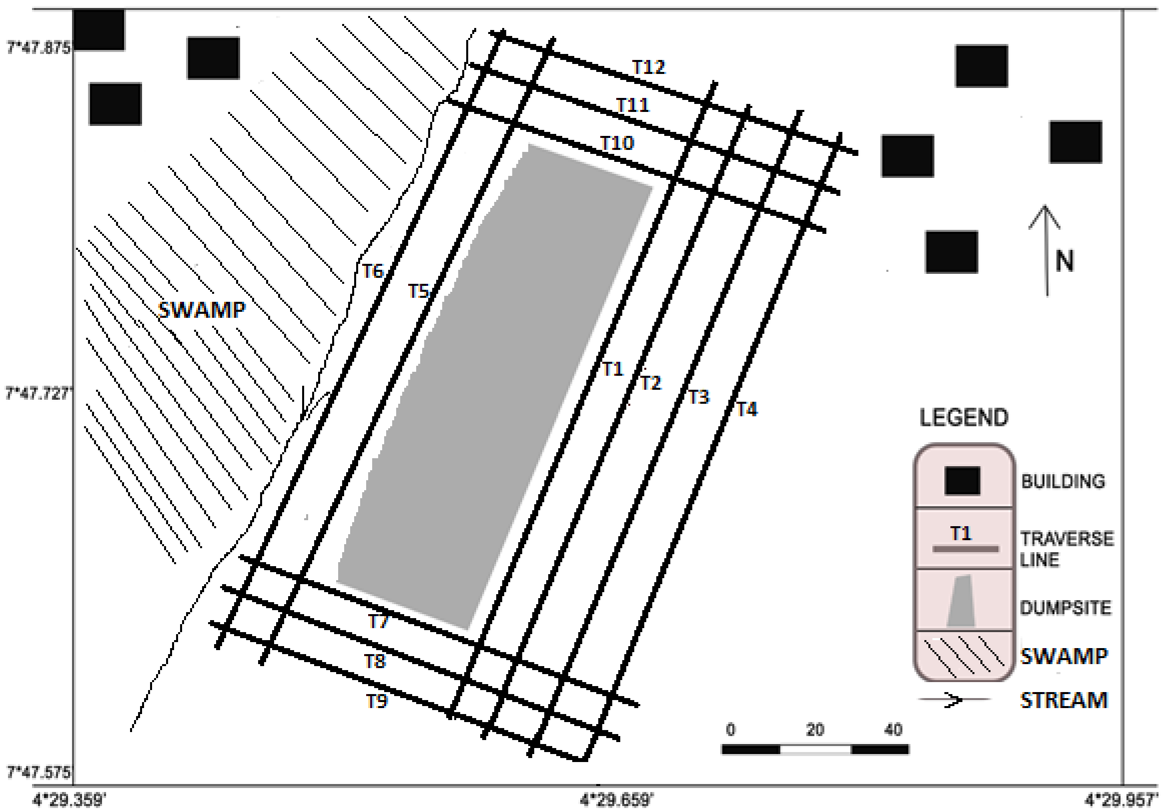

Figure 1: Base map of the study area showing the traverses around the dumpsite

The basis for the interpretation is the characteristic low resistivity of contaminant plumes relative to the background resulting from its increased content of dissolved salts.

Results and discussion

The results of the 2D resistivity survey are presented as inverted resistivity sections which furnish subsurface information beneath the traverses. Figure 2 shows resistivity sections beneath Traverses 1, 2, 3 and 4 trending NE-SW on the eastern side of the waste dump. The resistivity of the overburden beneath the traverses is characteristic of sand-clay mixture. The anomalously low

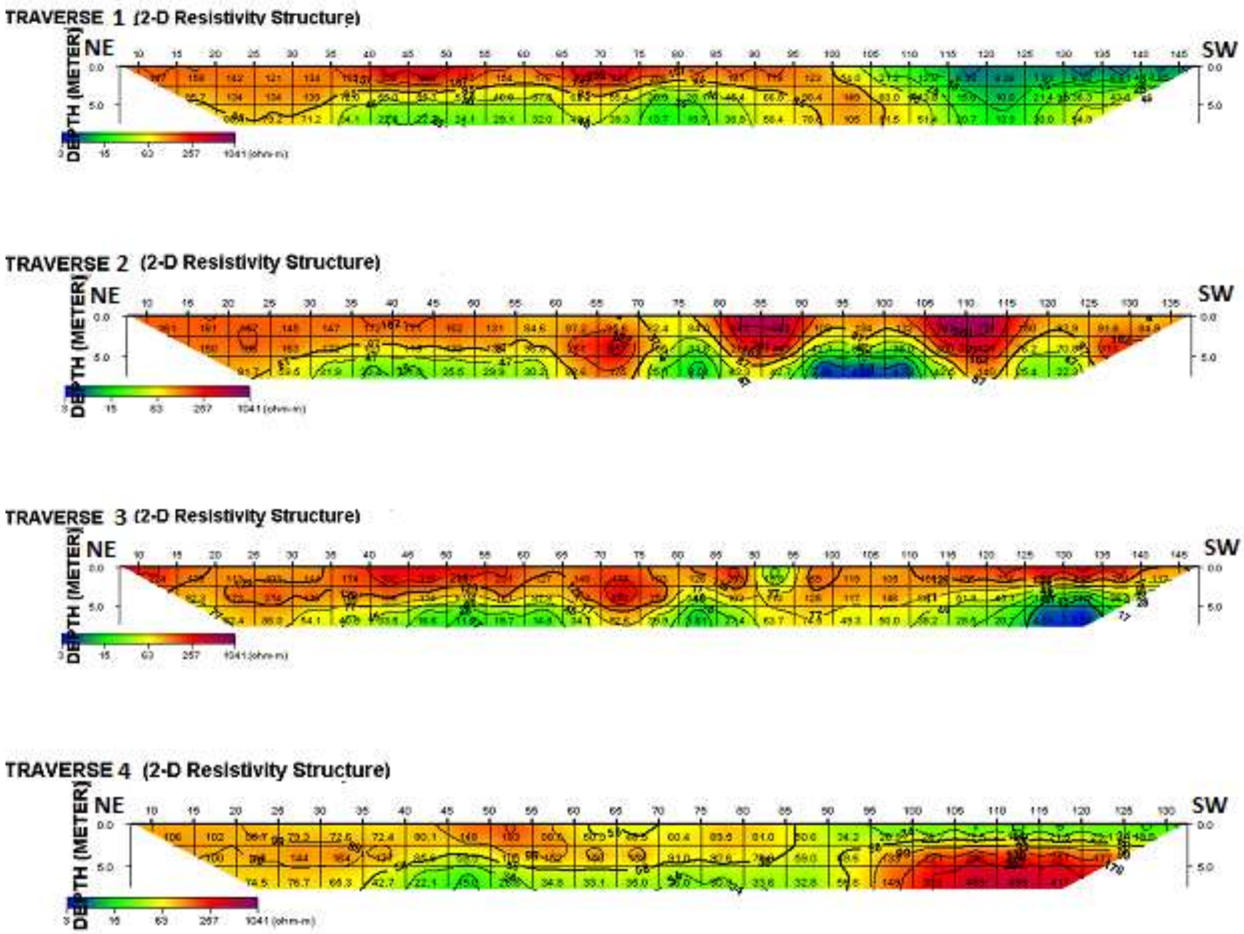

Figure 2: Inverted 2D sections beneath NE-SW traverses east of the dumpsite

resistivity values of 6.32-10 Ωm observed within lateral distance 115-150 m and depth of 5 m from the surface, at the NE end of Traverse 1 indicate leachate contamination. The resistivity values are in the range earlier reported by Bayowa *et al*., 2015 for leachate observed beneath the dumpsite. Anomalous resistivities less than 10 Ωm have been reported to be associated with leachate plumes generated from decomposed wastes at disposal sites (Samsudin *et al*., 2006; Adebayo et al., 2014; Nwankwo and Ogoro, 2015; Olagunju *et al*., 2017). This zone is bounded by relatively low resistivity values of 12.8-21.4 Ωm which extend from the surface at lateral distance 105-115m to areas beneath the depths of 2-5 m toward the end of the traverse. Relatively low resistivity values of 13.7-34.1 Ωm were also observed within distance 35-90 m beneath 3-4 m depth indicate contamination possibly of reduced degree due to lower solute concentration (Amidu and Olayinka, 2006). These resistivity values are in the range of 0-50 Ωm obtained by Olayinka and Olayiwola (2001) and Oladunjoye *et al*., (2011) for similar studies around waste dumpsites in Ibadan. The anomalously low resistivity values of 3.46-8.01 Ωm observed beneath Traverse 2 at distances 75-80 m and 90-105 m beneath 5 m depth are characteristic of leachate contamination. Relatively low resistivity values of 20.4-38.1 Ωm indicative of contamination were also recorded at distances 30-60 m, 70-82 m, 87-108 m and 115-125 m beneath 2.5-5.0 m depths. The anomalously low resistivity values of 3.53-4.51 Ωm observed within lateral distance 125-135 m beneath about 4 m depth at the NE end of Traverse 3, and 9.81 Ωm at distance 80-85 m within 0-2.5 m depth are characteristic of leachate. The relatively low values of11.3-34.7 Ωm recorded within the lateral distances 40-67 m, 77-90 m, 91-94 and 110-140 m also indicate contamination. Traverse 4 is underlain by clay-sandy clay overburden with resistivity ranging from 42.7 to 183 Ωm. The relatively low resistivity values of 15 to 35 Ωm observed within lateral distances 40-90 m and 90-140 m beneath the depths of 5.m and 2 m respectively suggest reduced contamination possibly due to lower solute concentration. The overburden is overlain by bedrock of resistivity 312-499 Ωm within lateral distance of 100-140 m at the NE end of the traverse.

The 2D resistivity sections beneath Traverses 5 and 6 on the western side of the waste dump are shown in Figure 3. Traverse 5 is underlain by overburden with resistivity ranging from 35.5-381 Ωm characteristic of clay-sandy clay mixture. Anomalously low resistivity values of 8.58-10.3 Ωm typifying leachate contamination were observed at lateral distances 85-95 m and 135-140 m beneath about 4 m and 3 m depths respectively. Relatively low resistivity values of 13.2-37.9 Ωm from lateral distance of 35 m to the NE end of the traverse within 2.5-3.5 depths indicate reduced contamination possibly due to lower solute concentration. This zone occur at the surface from distance 130 m to the end of the traverse. Traverse 6 is characterized by resistivity values generally less than 100 Ωm suggestive of contamination and water saturation due to its proximity to the stream and swamp.

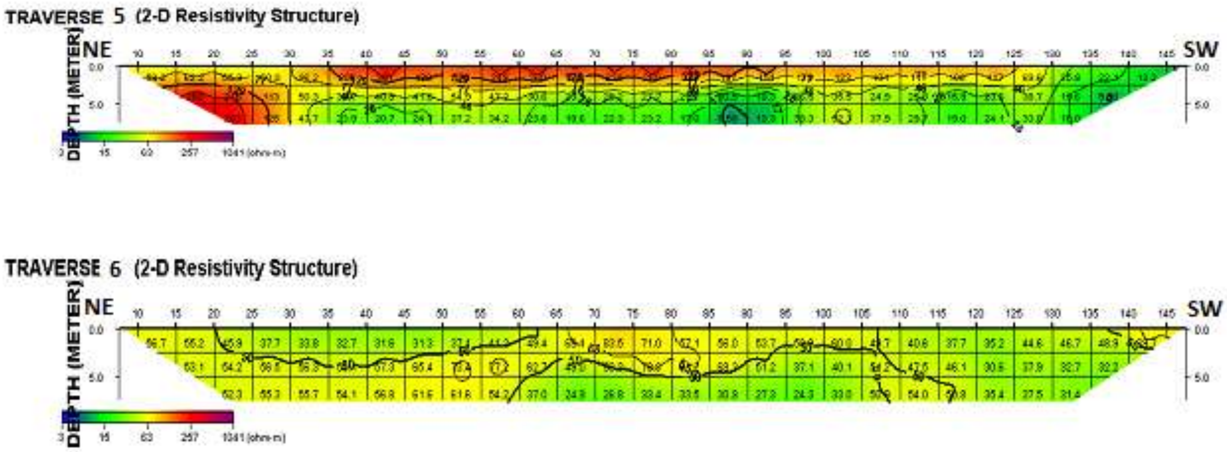

Figure 3: Inverted 2D sections beneath NE-SW traverses west of the dumpsite

Figure 4 shows the resistivity sections beneath Traverses 7, 8 and 9 at the southern end of the dumpsite. The resistivity values beneath Traverses 7 and 8 are generally less than 100 Ωm and attributable to leachate saturation. The anomalously low resistivity values of 2.78-11-7 Ωm within lateral distance 25-70 m from the surface to about 5 m depth observed beneath Traverse 7 indicate leachate contamination. This zone is surrounded by relatively low resistivity values of 13.4-25.2 Ωm suggestive of less degree of contamination. For Traverse 8, the anomalously low resistivity values of 9.91-13.8 Ωm observed within the lateral distances 28-37 m and 40-50 m, and beneath the depths of 3-4 m are indicative of leachate contamination. The relatively low resistivity values of 12.4-21.4 Ωm recorded above this zone also indicate contamination. Degree of contamination reduces with distance from the waste dump. The resistivity section beneath Traverse 9 shows topsoil with resistivity ranging from 207 to 484 Ωm, characteristic of sandy clay/clayey sand mixture, underlain by a relatively low resistivity values of 28.3-58.1 Ωm indicative of clay. The relatively low resistivity values of 12.4-21.6 Ωm observed within the lateral distance of 28-56 m beneath the depth of about 3 m indicate reduced contamination possibly due to lower solute concentration.

The inverted resistivity sections for the NE-SW

Traverses 10, 11 and 12 at the northern end of the waste dump are characterized by resistivity values less than 100 Ωm (Figure 5). The anomalously low resistivity values of 4.35-9.14 Ωm observed beneath 2.5 m depth within lateral distance 20-37 m, and from the surface with the distance 40-70 m on Traverse 10 indicate leachate contamination. Traverse 11 is characterized by low resistivity values ranging from 5.40 to 9.86 Ωm within lateral distance of 10-20 m, 25-37 m, 43-70 m indicate leachate contamination. The resistivity values of 124-209 Ωm observed at the ends of Traverse 12 within the lateral distances of 0-23 m and 57-70 m are typical of sandy clay while the relatively lower values of 13.8-15.5 Ωm observed at the SE end of the traverse beneath about 2.5 m depth indicate reduced contamination.

It is evident from the results of this study that the waste dump has contaminated the subsoil within the distance of about 30 m away from its edges to depths greater than 7 m. The contamination would pose serious threat to groundwater quality in the neighbouring areas as the leachate migrate through the soil and reach the water table.

Conclusions

2D electrical resistivity survey was carried out around an abandoned waste dump in Ido-Osun, southwestern Nigeria to detect and map the extent of contamination. The inverted resistivity sections revealed anomalously low resistivity values attributable to leachate contamination. The subsoil around the dumpsite has been contaminated by the leachate generated from the

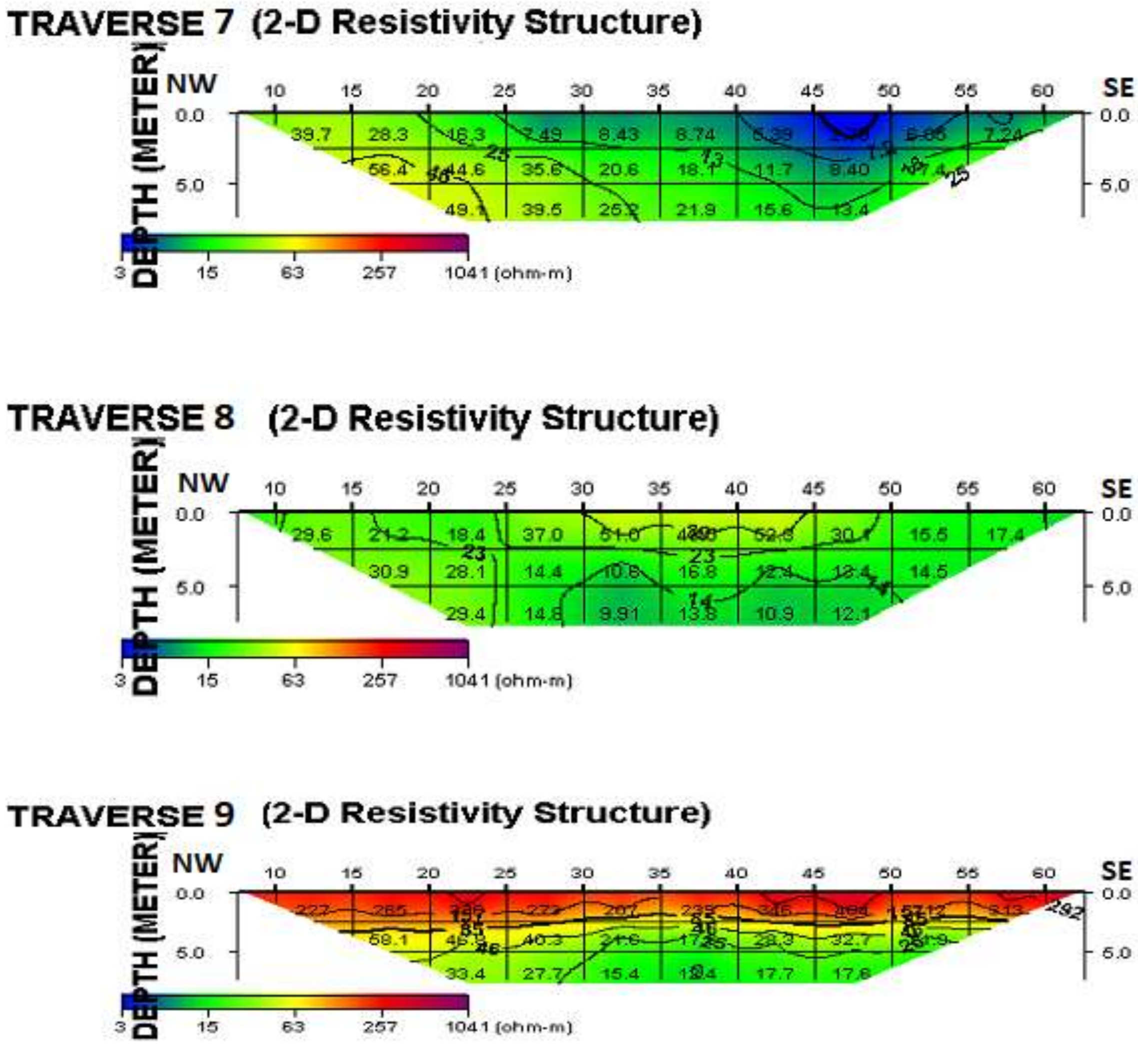

Figure 4: Inverted 2D sections beneath NW-SE traverses south of the dumpsite

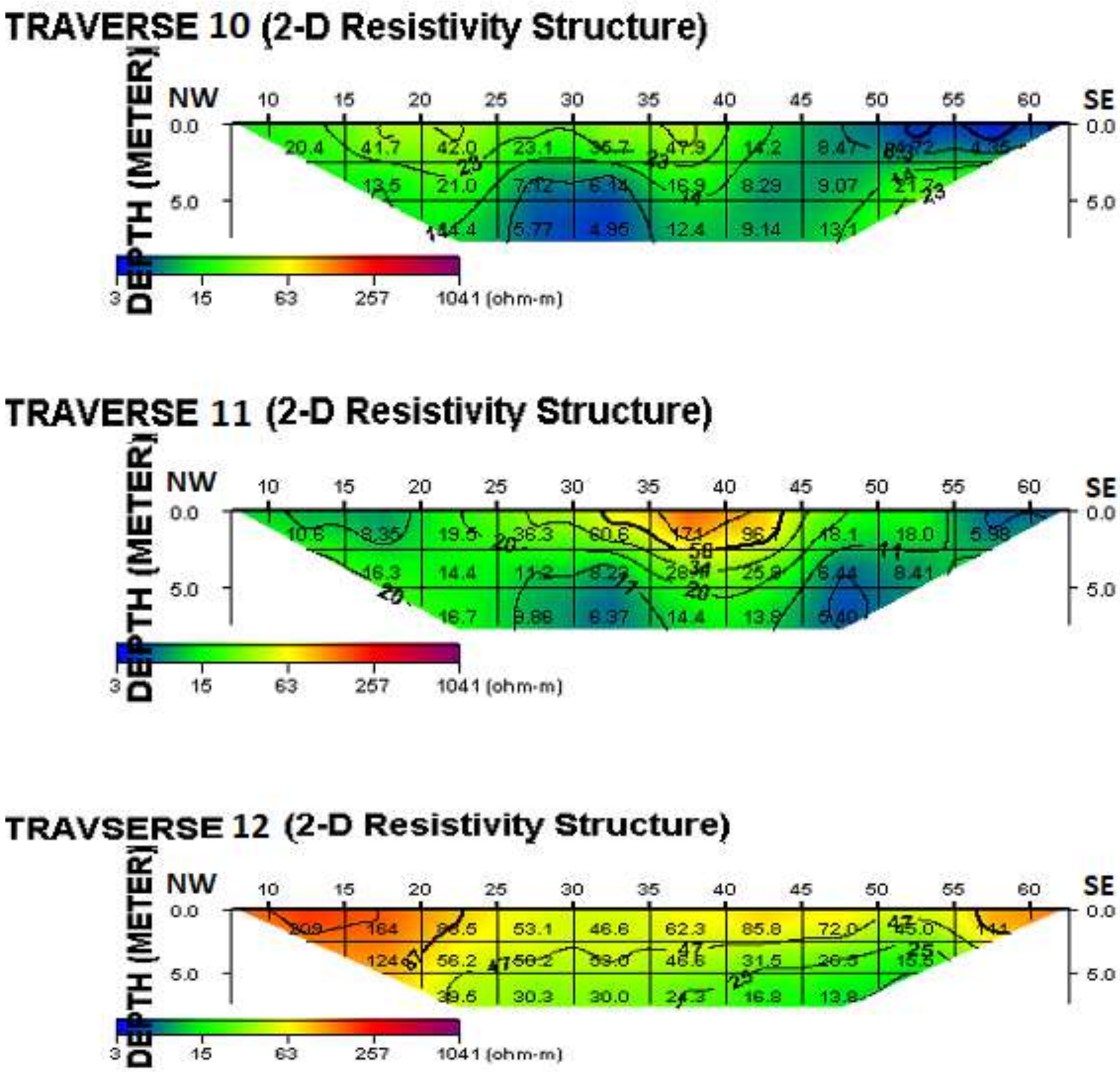

Figure 5: Inverted 2D sections beneath NW-SE traverses north of the dumpsite

decomposed wastes which have apparently migrated to its vicinity. The aquifer units in the area are likely to be contaminated if prompt and adequate measures are not taken. It is recommended that geochemical analyses be conducted to determine the concentration of the constituents of the contaminants and appropriate remediation measures be taken to forestall further spread and salvage the groundwater within the developing residential community.

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