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DELINEATION OF LEACHATE ZONES AROUND A DUMPSITE USING 2D RESISTIVITY METHOD: A CASE STUDY OF SABON GARI, BAUCHI STATE, NIGERIA

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ABSTRACT: *The electrical resistivity method was employed to delineate leachate zones in Sabon Gari, Bauchi, Bauchi State, Nigeria. This involved the use of the 2D resistivity technique in specific locations within the study area. Two profile datasets were collected using the Wenner array with an Ohmega resistivity meter, covering a maximum distance of 100 meters. Subsequently, the 2D data obtained underwent interpretation through Res2Dinv and Surfer 11 software. The interpreted models revealed a leachate zone in profile 1, extending from a depth of 2 meters to 14 meters. In profile 2, the interpreted models displayed low resistivity in the topsoil due to the presence of water and ions in rock-bearing minerals, resulting in low resistivity from a depth of 1 meter to 12 meters. Notably, when this resistivity becomes exceptionally low (ranging from 0.47 Ωm to 7.10 Ωm), it indicates water contamination. In the event that drilling a borehole in the vicinity is deemed necessary, it is advisable to seal the near-surface water to prevent its infiltration into the borehole.*

KEYWORDS: Dumpsite, Leachate, Contamination, Migmatite-gneiss, 2D electrical resistivity, Res2Dinv.

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INTRODUCTION

The study area is part of sheet 149 Bauchi North East. The Area covered an area of about $300m^2$. It lies between Latitude N10^0 39' 82'' and N10^0 39' 81'' and Longitude E 009^0 82' 47" and E 009 82' 39". The area is located in the Southern part of Bauchi metropolis in Bauchi State, Northeastern Nigeria. Dumpsites are common features of the human environment, especially in urban and highly populated areas where they have become a predominant means of waste disposal. In most developing countries, the management of solid waste disposal is a major environmental problem and challenges as a result of open dump sites and are commonly located outskirt of large cities, releasing leachate which contains contaminants, thereby percolating of leachate into the shallow aquifers.

The environmental challenges of dumpsite include contamination of groundwater by pollutants, migration of pollutants away from site by surface run-off, groundwater or through release into the atmosphere. Geophysical techniques are widely used for evaluating and determining changes in physical properties of the subsurface in the presence of contaminants. Environmental geophysicists are mainly concerned with the detection of changes in the properties of the subsurface due to circulation of leachate and residence of contaminants in the subsurface. The contrast in the observed physical and chemical properties between the assessed locations and the surrounding areas with natural characteristics is normally used to delineate contaminated areas (Chen et al., 2012; Ramalho, 2013; McNeill, 1990; Kaya et al., 2007). Knowledge of the modifications of the subsurface physical and chemical properties due to the present of contaminants is very crucial for groundwater quality assessment.

In recent times the management of solid waste has been a serious challenge which tends to contaminate the water of the subsurface. The work attempted to use an electrical resistivity method to delineate leached contaminants in dumpsites around the study area.

Geology of the Study Area

Bauchi is mainly underlain by crystalline rocks which belong to the Nigerian Basement Complex, thought to be mostly Precambrian in age (Oyawoye, 1970) and a minor occurrence of tertiary sedimentary rocks. The rocks of the Basement Complex are the migmatites, migmatite-gneiss, quartzite complex and granite-gneiss. The migmatites, migmatite-gneiss and granite-gneiss complex form the oldest rock group and are presumably of Late Precambrian to Early Paleozoic age.

Migmatites and migmatite-gneiss are the dominant in the study area. Migmatites are variable in texture from medium to coarse-grained and they represent a high grade metamorphosed series with excellent banding. Generally, the migmatites are foliated with flakes of biotite defining foliation. The foliation is parallel to the general trend. In some cases as could be observed on an outcrop at Tiruan, north of Bauchi town, the bands are completely folded, giving rise to Migmatitic structure which is an indication of plastic flow. The migmatite is a composite rock of hornblende bearing gneiss granitic rock. The granitic rock is usually biotite alternating with the hornblende bearing gneiss.

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Resistivity of Geologic Materials

Resistivity is a fundamental electrical property of materials that is closely related to their lithology. The determination of the subsurface distribution of resistivity from measurement on the surface can yield useful information on the structure or composition of buried material. In geophysical investigation for water exploration, the electrical resistivity method can be used to obtain quickly and economically details about the location, depth and resistivity of the subsurface material (Parasnis, 1966).

The resistivity of rocks is strongly influenced by the presence of groundwater, which acts as an electrolyte. This is especially important in porous sediments and sedimentary rocks. The minerals that form the matrix of a rock are generally poorer conductors than groundwater, so the conductivity of sediment increases with the amount of groundwater it contains.

MATERIALS AND METHODS

Geological investigation

The geological investigation involves an initial study of the desktop study of topographic map and also a reconnaissance survey, a special visit was also paid to the study area in preparation for the geophysical survey. This was done in order to be acquainted with the study area. Reconnaissance survey (2D Electrical Sounding) also known as Electrical Resistivity Tomography was carried out. These were carried out to get a generalized idea of the terrain, the structural features and lithology of the area.

The geographic position (latitude and longitude) of each point that was sounded was determined using the Global Position System (GPS).

a. Geophysical Survey

The electrical resistivity technique using 2D electrical sounding was used to delineate latchet zones of the study area. Instrument used during data acquisition includes Omega terrameter, current wires (i.e. two potential and two current cables), electrodes (2 pair of electrodes), hammer, crocodiles clip, measuring tape, GPS (Global Position System), and RES2Dinv installed in system for the acquired data processing. Electrical resistivity survey is a method in which current is applied between electrodes implanted in the ground and the resulting voltage is measured. Rock containing fluids or water, latches, faults, fractures usually have low resistivity.

b. 2D electrical sounding and Data Acquisition

The 2D electric sounding employs collinear arrays designed to output 2D vertical apparent resistivity versus depth model of the subsurface at a specific observation point. In this method a series of potential differences are acquired at successively greater electrode spacing while maintaining a fixed central reference point. The induced current passes through progressively deeper layers at greater electrode spacing. The potential difference measurements are directly proportional to the changes in the deeper subsurface. Apparent resistivity values calculated from measured potential differences can be interpreted in terms of overburden thickness, water

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table depth, and the depths and thicknesses of subsurface strata. The most common arrays used for 2D electrical sounding are the Wenner array which was employed in this research work.

Two profile points were marked out. The locations (coordinate and elevation) of each point were recorded with the aid of Global Positioning System (GPS) meters. The equipment arrangement consists of a pair of current and potential electrodes which are driven into the subsurface to make a good contact with the Earth at each sounding point and connected to the terrameter by means of cables. After the setup has been completed and the current sent, the earth medium resistance reading at each electrical sounding point was automatically displayed on the digital readout screen and then recorded on the data sheet, The current and potential electrode were moved equally away on the opposite site of the fixed point according to designed acquisition parameters in this study the design was 2, 4, 6, 8, 10, 12, 16, 18, 20. (C_1 C_2) >> (P_1 P_2) and the readings were recorded at every new position. Then the apparent resistivity of the subsurface was then derived using $\rho a = RG$, where G is the geometric factor and R is the resistance.

DISCUSSION

The qualitative interpretation was done using the 2D resist inversion software adopted for use on computers. Basically the 2D resist inversion software is a 2D forward and inverse modeling program for interpreting resistivity, IP data taken with various resistivity sounding and IP methods.

The data was carried out around a dumpsite which is about 9600 m^3, aimed at delineation of the leachate zone around the study area. The result of the resistivity measurement for the two locations around the dumpsite are plotted in 2D maps as shown in figure 1 and 2 respectively.

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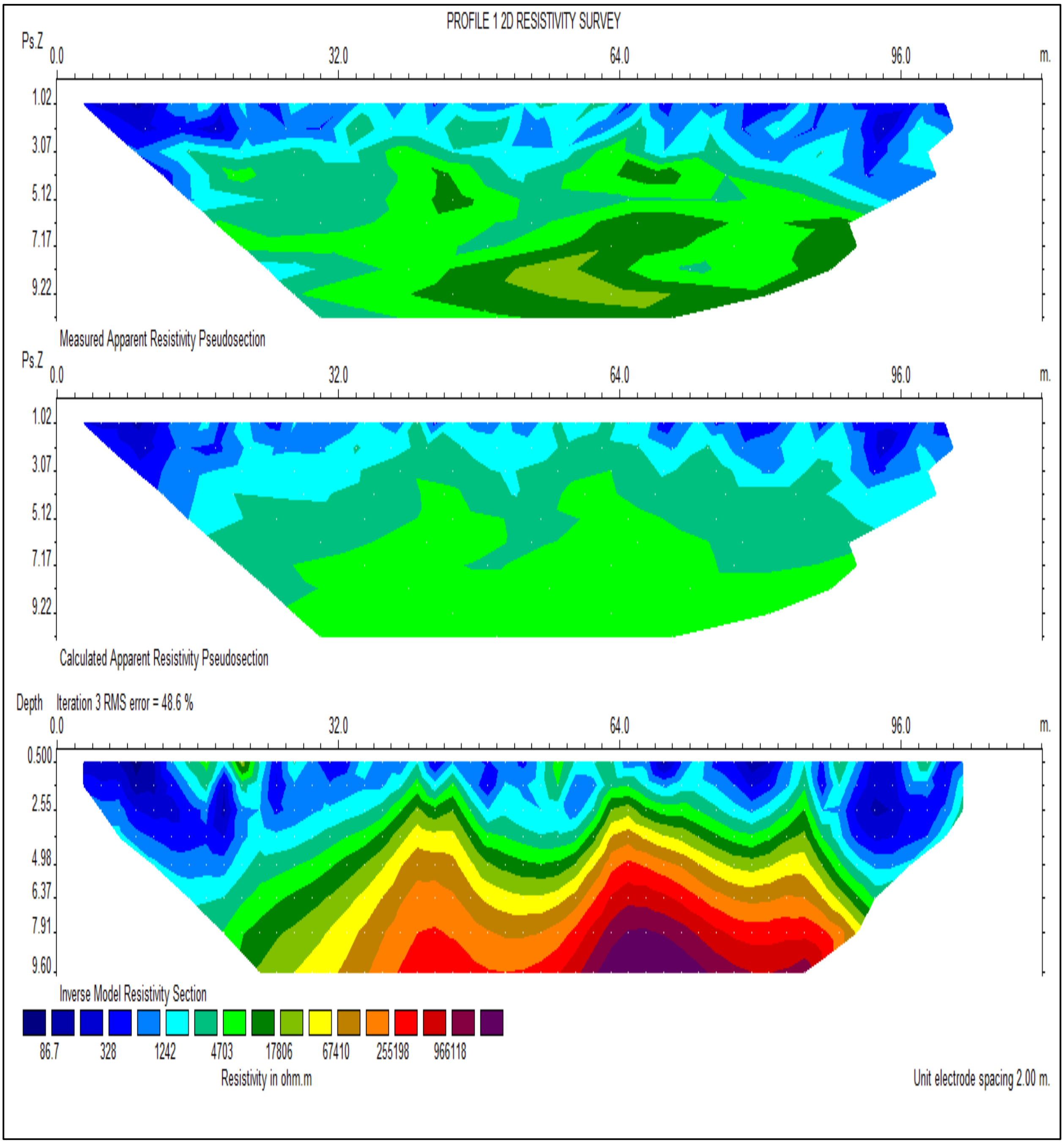

Profile 1 Figure 1: The pseudo sections color layering of (a) measured apparent resistivity values of profile 1. (b) Calculated apparent resistivity pseudo section values of layers of profile 1. (c) Computer interpreted iterated inverse model resistivity sections of profile 1

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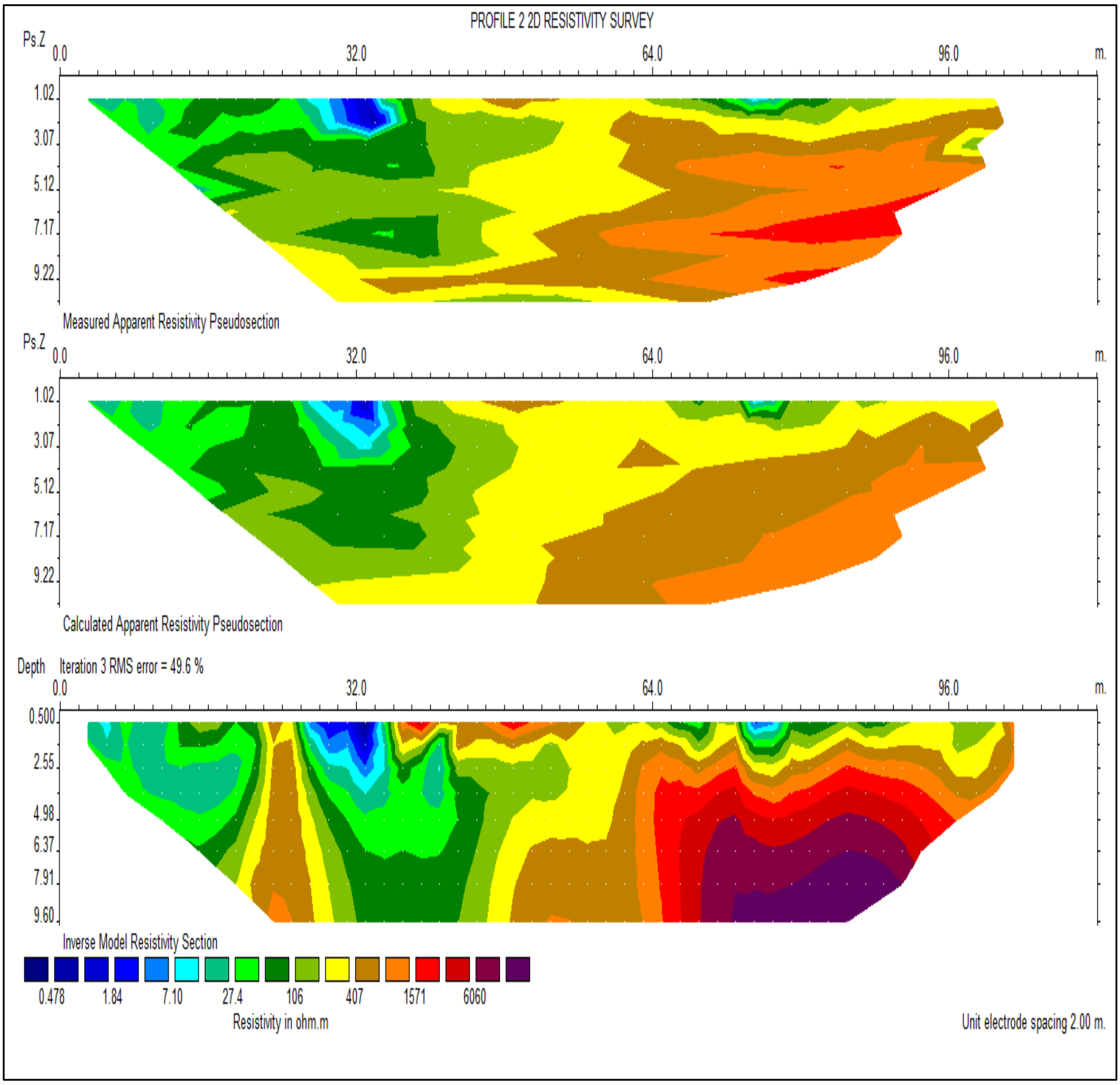

Profile 2 Figure 2: The pseudo sections colored layering of (a) Measured apparent resistivity of pseudo section values of profile 2. (b) Calculated apparent resistivity pseudo section values of layers of profile 2. (c) Computer interpreted iterated inverse model resistivity sections of the profile 2.

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In the pseudo-section of Profile 1, the blue area delineates leachate zones, as indicated in the resistivity key in the table above. Regions colored in red and purple represent high-resistivity areas, referred to as uninterfered zones. The green areas signify an intermediate zone, which lies between the delineated leachate zone and uninterfered zones. This profile demonstrates high resistivity, akin to fresh crystalline rocks.

However, between depths of 2 meters and 14 meters, there is a relatively low resistivity, likely attributed to redox reactions due to the biodegradation of contaminants in the subsurface around the dumpsite. Weathered rocks may also contribute to this low resistivity, potentially due to structures such as fractures that accumulate groundwater, altering the parent rock's resistivity. The calculated apparent resistivity pseudo-section reveals a systematic arrangement of lithologies, transitioning from relatively low resistivity.

The measured resistivity section illustrates the lateral succession of various lithologies in terms of resistivity towards the surface. Here, a series of low-resistance materials is observed, with resistivity values ranging from 87.7 Ωm to 328 Ωm. Within this range, delineated leachate migration is likely, as the in-situ materials exhibit relatively low resistivity from a depth of 2m to about 14m. These materials probably contain leachate, facilitating water transmission between points, which significantly impacts the resistivity values around the dumpsite. The flow and migration direction is primarily towards the southeast at Latitude N100 39’ 83’’ and Longitude E90 82’ 46’’.

Similarly, in the pseudo-section of Profile 2, the blue areas indicate low-resistivity values, typically associated with decomposed, weathered, or fractured zones. Red and purple areas represent high-resistivity zones, designated as uninterfered zones, while the green areas denote the intermediate zone. This profile displays anomalies closer to the surface, particularly within the depth range of 2m to 12m, where very low resistivity areas are likely zones saturated by ions or delineated leachate from subsurface materials. These shallow depths typically do not exceed 12 meters.

From 12 meters to 40 meters, the intermediate zone is encountered, and beyond 40 meters to 100 meters is the uninterfered zone. The low-resistivity zone exhibits values ranging from 0.47 Ωm to 7.10 Ωm, mainly attributed to the presence of ions and water from the subsurface around the dumpsite.

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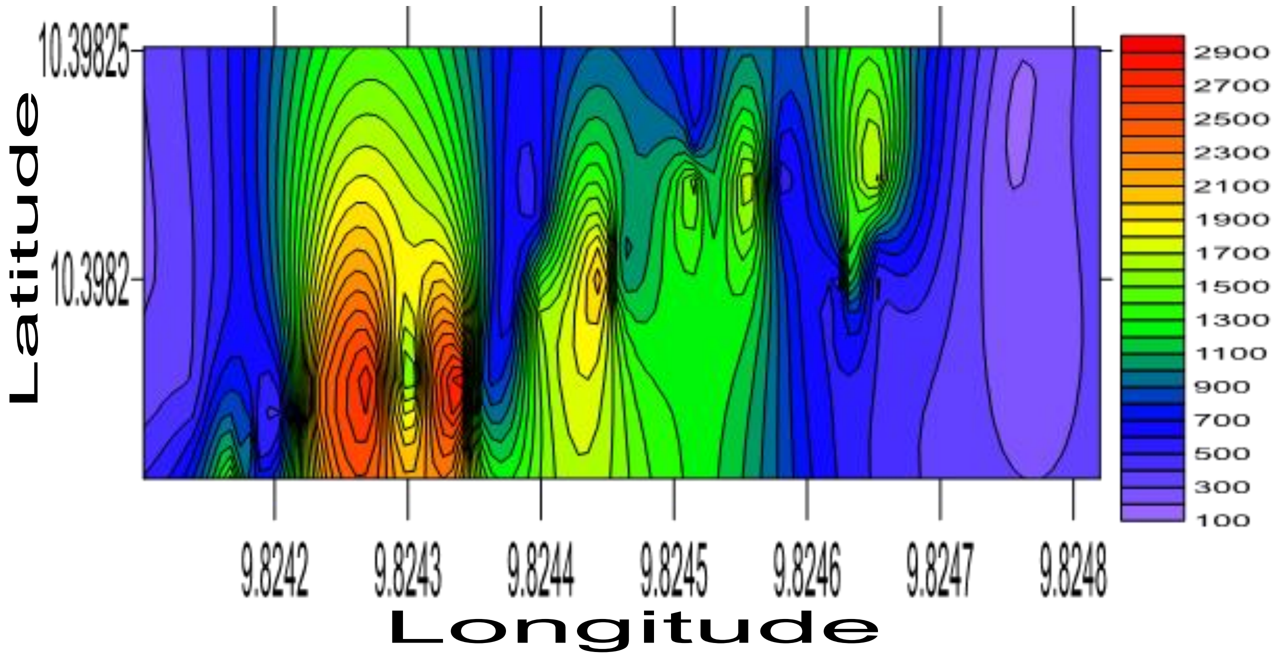

Figure 3: Iso-resistivity contour map of Profile 1

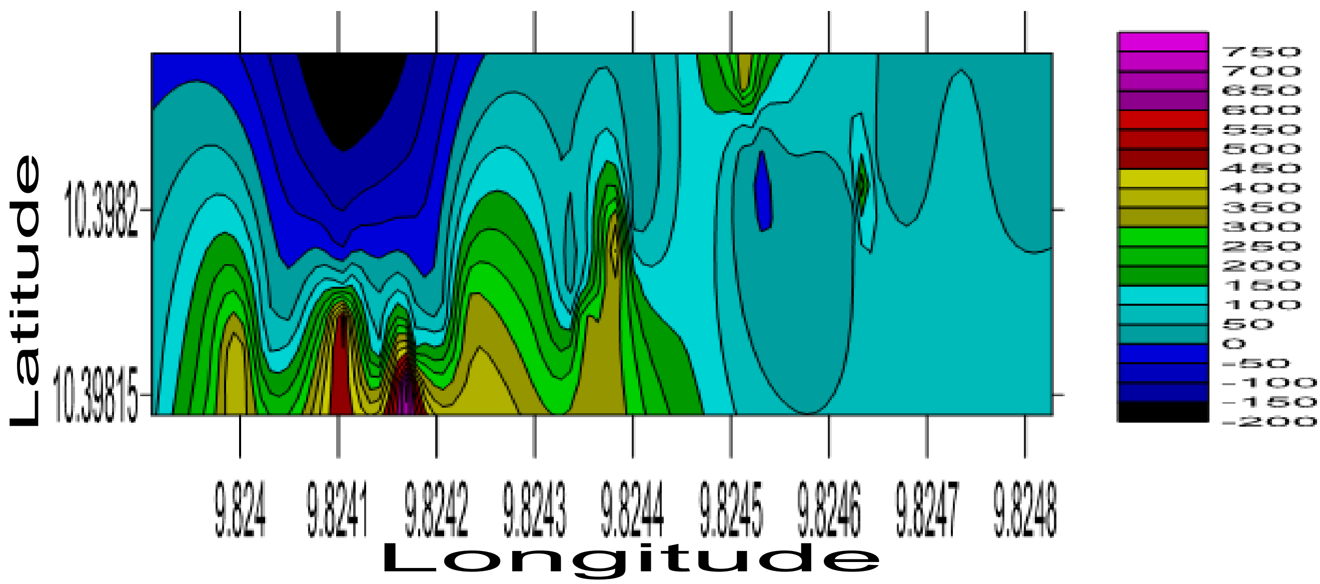

Figure 4: Iso-resistivity contour map of Profile 2

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CONCLUSION

Based on the results of the geo-electrical investigation of delineated leachate zone around the dumpsite at Sabon Gari, the following conclusion are drawn: Sandy nature of the topsoil and sub-grade soil beneath the dumpsite which have porosity and permeability and the tendency of absorbing water which makes leachate flow through pore spaces as observed at the blue pseudosection of profile 1 and 2 and also the low resistivity series of profile 1 ranges between the distance of 2m to 14 m, at this point there exists leachate migration. In profile 2, the low resistance materials are from 2m to 12m. At this portion, there exists leachate distribution of dumpsite materials of subsurface material. Below these zones are layers with low resistivity which might be due to fractures, weathered rock, and possibilities of decomposed basement which are rich in ions.

RECOMMENDATION

The following recommendations are necessary, these include:

1. To achieve more comprehensive results, it is advisable to conduct a detailed study by integrating additional geophysical techniques, such as self-potential, in the mapping of leachate zones around the dumpsite.

2. It is recommended to perform surveys for leachate zone delineation before drilling boreholes or cultivating certain crops in areas that overlap with a dumpsite or have highly porous overburden/topsoil.

3. In cases where a borehole is required in the vicinity, it is crucial to identify and isolate the zone impacted by contaminants to prevent the consumption of impure groundwater.

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