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2D ELECTRICAL RESISTIVITY SURVEY FOR GROUNDWATER CONTAMINATION AT AKWANGA DUMPSITES AND ABATTOIR, NASARAWA STATE

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ABSTRACT

Groundwater represent an excellent source of water due to its renewable nature, its availability throughout the year and relatively high quality than surface water. However it is more difficult to remediate a contaminated groundwater source. So due to the fact that about 90% of the citizens make use of groundwater for drinking and other domestic purposes, It is therefore, necessary for groundwater to be safe from any form of contamination. The 2D-Electrical Resistivity Tomography (2D-ERT) were carried out with the aim to investigate groundwater contamination in Akwanga town, Nasarawa State Nigeria. Nine (9) profiles of 2D-ERT was conducted along two dumpsites and one abattoir within the study area employing the dipole-dipole array with inter electrode spacing of 2.5 m which covers a total lateral distance of 100 m thereby allowing for about 15 m depth of investigation below the subsurface, Abem SAS 4000 terameter was used for the data acquisitions while the data interpretation was carried out using Res2Dinvers software for the 2D-ERT respectively. The 2D-ERT results revealed the presence of contaminated plume (leachate) within the investigated area with true resistivity model revealing anomaly of very low resistivity of <20 Ωm from top soil down to a maximum depth of about 15 m, this low resistivity value is associated with leachate due to the dumpsite and abattoir respectively, the 2D structures has shown various conductive path ways via fractures and openings, thus contaminating the groundwater. I recommend that further geochemical analysis of the water should be done to ascertain the level of contamination.

Keywords: Contamination, Dumpsites, Groundwater, Leachate, Resistivity

INTRODUCTION

Ground water is a vital resource and it supports human existence on earth, therefore its quality are very important with regards to domestic consumption, irrigation and industrial water supplies (Nura *et al.,* 2019). Groundwater represents an excellent source of water due to its renewable nature and relatively higher quality than surface water (Aisha *et al*., 2022). It is readily available throughout the year and it is cheaper to access than exploring for and exploiting surface water, it is more portable and not easily contaminated as surface water (Ahzegbobor, 2010). However, it is more difficult to remediate a contaminated groundwater source. Groundwater resource is under threat due to contaminant load introduce into it through urbanization, industrialization, agriculture and exploitation of natural resources (Aisha, 2022). Contamination can have serious consequences, as groundwater is a vital source of drinking water for many communities (Ikhifa *et al.,* 2017). Clean-up of contaminated groundwater can be challenging and expensive, requiring specialized techniques and technologies to restore the water to a safe level. The most common contaminants found in groundwater include Nitrates which is Often from agricultural fertilizers and animal waste, these can cause health issues, especially in infants (Ocheri *et al.,* 2014).

Akwanga is a densely populated area and majority of Akwanga inhabitants, regardless of social status, depend on hand-dug wells and bore-holes for their daily water supply needs. The quality of ground water has received much attention at several points in time by different researchers as poor quality water has huge health and economic implications (Anigilaje *et al.,* 2018). Considering the growing population, increased agricultural activities in the study area, it is therefore very important to be informed about the quality of groundwater supply for various purposes in the study area.

Geophysical methods are increasingly becoming more relevant in hydrological investigations. They provide information about the spatial and/or temporal distribution of subsurface features. Electrical methods of geophysics are widely used in addressing a variety of hydrologic problems including groundwater exploration, groundwater quality and contamination studies (Adamu *et al.,* 2017). Electrical resistivity methods provide resistivity values of the subsurface for entire survey line. The principal of electrical resistivity technique is in term of how current is opposed to flow between two electrodes.

D.C Resistivity

Rocks consist of atoms which are electrically charged particles and so, the electrical methods are based on current flow. By convention current is considered to flow from a positive source to a negative sink even though the current flow is due to electrons moving the other way (Jatau *et al.*, 2020). The electric current I is measured in amperes A and it is the amount of current that passes any point in the circuit in one second the current is caused by a potential difference V which is measured in volt v. For most rock materials the current increases with increasing potential difference. The relation between V and I is described by the resistance R of the materials by Ohms law as:

$$V \propto I \quad (1)$$

$V = IR$ (2)

$R = \frac{V}{I}$ (3)

R is measured in ohms (Ω) the overall resistance of a certain media depends on its electrical properties and size of the media. The resistance also depends on the diameter of materials.

The resistivity ρ is defined as

$\rho = \frac{RS}{l}$ (4)

S is the area of cross section of the materials and l is the length of the materials. The unit is the Ωm. The reciprocal of resistivity is σ given by

$\sigma = \frac{1}{\rho}$ (5)

Unit of is σ Siemens per meter (s/m) If there are more layers of different resistivity between the measuring electrodes an overall value of resistivity is measured. The overall value of resistivity is called apparent resistivity and is denoted by ρ_a (Kwarki *et al.*, 2021).

Ganiyu *et al*. (2016) carried out assessment of groundwater contamination around active dumpsite in Ibadan southwestern Nigeria using integrated electrical resistivity and hydrochemical methods to delineate groundwater contamination due to leachate percolation and thus assessment of quality of groundwater from nearby hand-dug wells bordering the dumpsite for drinking purpose. A total of ten resistivity traverses were acquired within and outside the dumpsite using Wenner configuration with constant electrode separation ranging from 5 to 25 m. Geochemical assessment of groundwater samples were carried out according to APHA standards while hydrochemical facies of the sampled groundwater was evaluated using Piper Trilinear software. The inverse resistivity models of the subsurface from 2D and 3D imaging revealed low resistivity value less than 10 Ω m suspected to be leachate. The extent of migration was more pronounced in the southern part of the dumpsite, hence possible contamination of shallow groundwater system as dumpsite ages. The results of physico-chemical analyses showed the groundwater samples to be within the limits of WHO/NSDWQ for drinking purpose. However, higher values of concentrations of most analyzed parameters were noticed in well 1 due to its nearness to dumpsite and well 10 due to agricultural activities, respectively.

Ikhifa *et al*. (2017) employed Electrical resistivity tomography (ERT) technique to evaluate the contamination zones at a dumpsite in Benin City. Three electrical resistivity profiles were established and the ERT method revealed highly conductive zones of less than 20 Ωm of leachate to the depth of 39.4 m. The area shows subsurface resistivity distribution at the Eastern part of the study area trending East with prominence at the centre and distributed North - East which has been interpreted as fractured or migration zones of leachate. The depth estimate revealed the apparent depth to the causative body from the surface with depth range from 0.34 m to 39.4 m which agrees with other literatures. The study has revealed that the area is generally highly conductive due to the presences of toxic elements while the fractured zones are prospective locations for infiltration of contaminant plums (leachate).

MATERIALS AND METHODS

The Study Area

The study area is Akwanga local government area in Nasarawa state, North-Central Nigeria (Figure 1). It is bounded by longitudes 8º18′E and 8º54′E of the Greenwich Meridian and latitudes 8º15′N and 9º20′N of the Equators. The study area is accessible through a network of roads along Keffi-Lafia Express Way.

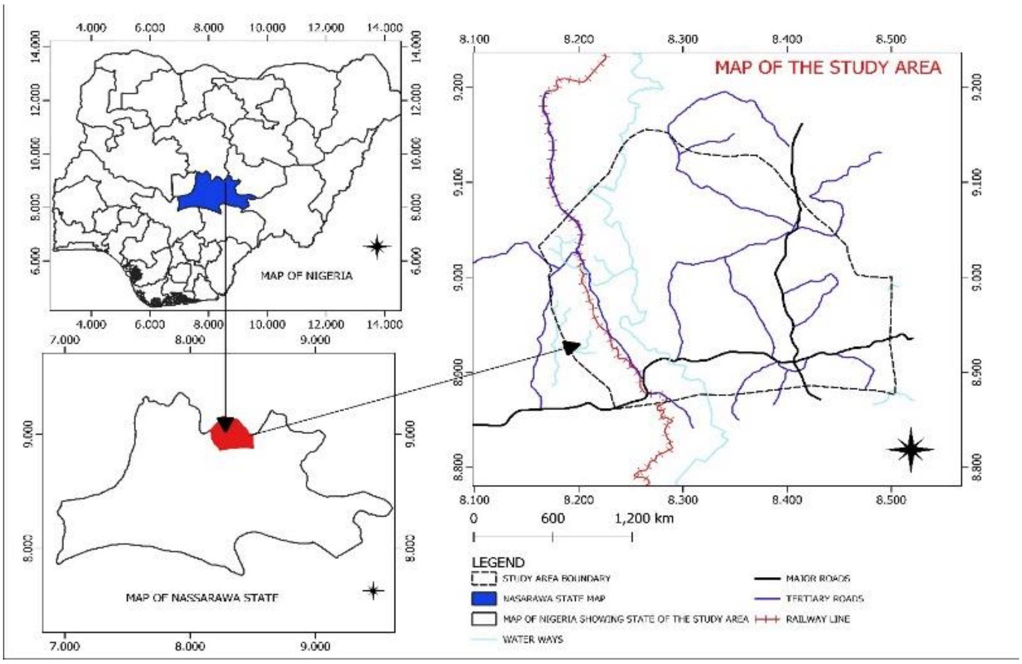

Figure 1: Location Map of the Study Area

Geology of the Study Area

The study area lies within the basement complex of the north-cetral Nigeria, The Precambrian Basement Complex rocks of Nigeria outcropping in North central Nigeria show predominant structural trends of N-S to NE-SW but remnant of E-W and NW-SE also exist (Ayanninuola *et al.*, 2018). It consist of various rock unit with the predominant including granite-gneiss, schist-gneiss and pegmatite (Figure 2) which mostly occur as vein and not mapable (Jatau *et al*., 2020).

The granite gneiss in the study area is light grey with a medium grained texture composed of plageoclase, quartz, microcline, muscovite and biotite. The rock exposure are mostly low lying having a lot of joints which was as a result of both biological and physical weathering process. The schist-gneiss is dark gray with very fine grained texture composing of quartz, plagioclase-fieldspar and biotite. The pegmatite is coarse grained, white to pinkish composed of quartz, feldspar (potassium feldspar and plagioclase), and mica (biotite and muscovite), which occur as late intrusive members (veins & dykes) in the rock exposure trending NW-SE and thickness of about 2 cm - 1.5 cm.

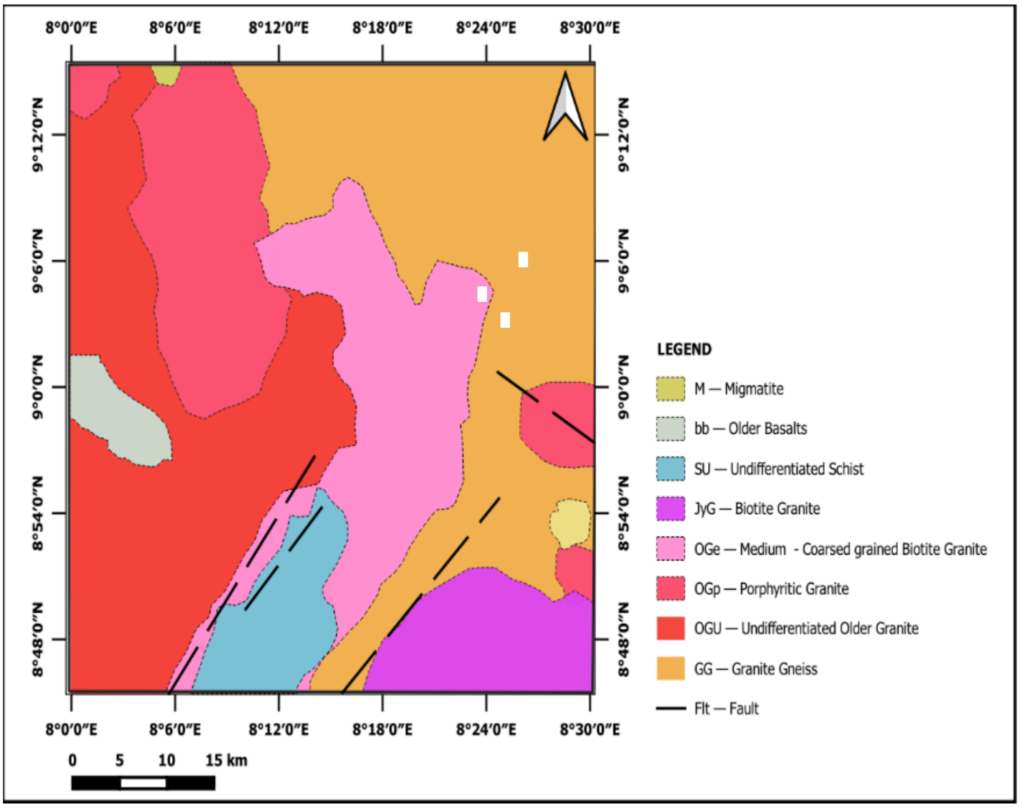

Figure 2: Gelogical Map of the Study Area

Materials

Materials and Equipment for the Electrical Resistivity Survey include:

Abem SAS 4000 Terrameter with multi-core electrode connector (Plates 1)
Metal electrodes
Field hammer
Measuring tape
Electric cable and Reels
Crocodile or electrode clips
Car battery
Global Positioning System (GPS)
Pen and data sheet

Plate 1: Abem SAS4000 terrameter

Methods

Electrical resistivity imaging (ERI) was conducted along nine (9) 2D profiles at different locations, the subsurface resistivity measurements was obtained by the Abem SAS4000 terrameter. Resistivity acquired from the field measurements is known as the apparent resistivity given by equation (6) for schlumberger array

$$\rho_a = \frac{K\Delta V}{I} \quad (6)$$

And the geometric factor K in the above equation is given by the relation

$$K = \frac{\pi}{2}\frac{\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]}{\left(\frac{MN}{2}\right)} \quad (7)$$

where ρ is the apparent resistivity in Ωm, AB is the electrode spacing, MN defines the distance between the potential electrodes, I is current in Amp, and V is the voltage in volts.

The apparent resistivity values acquired from the field were drawn on a log–log graph against AB/2 (half-current electrode spacing). The basic principle to acquire the resistivity measurements as shown in Figure 3.

The Abem SAS4000 terrameter equipment was setup, ensuring that the batteries were fully charged and that, electrodes were well hammered into the ground. Cables were connected to both current and potential electrode terminals and the Schlumberger protocol was chosen. Direct current was induced into the ground through the current electrodes and the resulting potential difference measured by another pair of potential electrodes in the region of the current flow. Expanding the electrode system varied the depth of investigation. The resistivity values of each of the VES sites was read directly from the tetrameter and to ensure reliable and consistent readings, measured results were plotted in the field during the measurements and inconsistent values were repeated to ensure uniformity in the readings.

The 2D electrical Resistivity Imaging was carried out along nine (9) traverses using the Dipole-Dipole array, dipole-dipole was choosing because of its high resolution and multichannel capability, it actually provide detailed image. The dipole-dipole is also fast due to its support for multiple receiver channel simultaneous measurements for each current injection, in addition it is relatively simple to perform a survey along profile lines using the dipole-dipole array.

The 2D electrical Resistivity Imaging operation theory is based on fact that potential difference develops between two points on the earth surface when an electric current flows between them as shown in Figure 3. Each electrode was checked through the electrode test to make sure the good ground-contact. Salt solution will be used to enhance the performance of the electrodes having poor ground-contact. The field data acquired by ERT survey was processed using the inversion program of RES2DINV (Loke *et al*., 2003). The software inverts 2D apparent resistivity data sets into the pseudo-section of true resistivity using the least squares technique. The misfit between the measured and observed values of resistivity is minimized in the algorithm scheme. In this program, the subsurface formation is shown by a number of rectangular cells with constant resistivity values. At the beginning, a homogeneous resistivity value is assigned to each cell with a homogeneous resistivity value to generate an initial model; afterwards, the modeled resistivity is updated according to the misfit between the calculated and observed values in a pseudo-section after the iteration. The iterative process continues until a certain level of RMS error is obtained (Ganiyu *et al.*, 2016). A principle procedure to generate a pseudo section in ERT is shown in Figure 4.

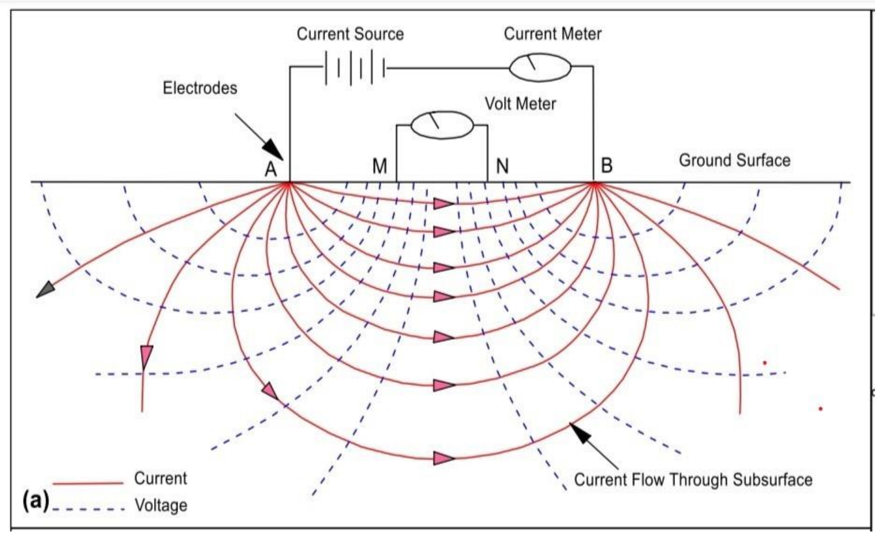

Figure 3: Fundamental conceptual model for resistivity measurement (modified after Todd and Mays 2005)

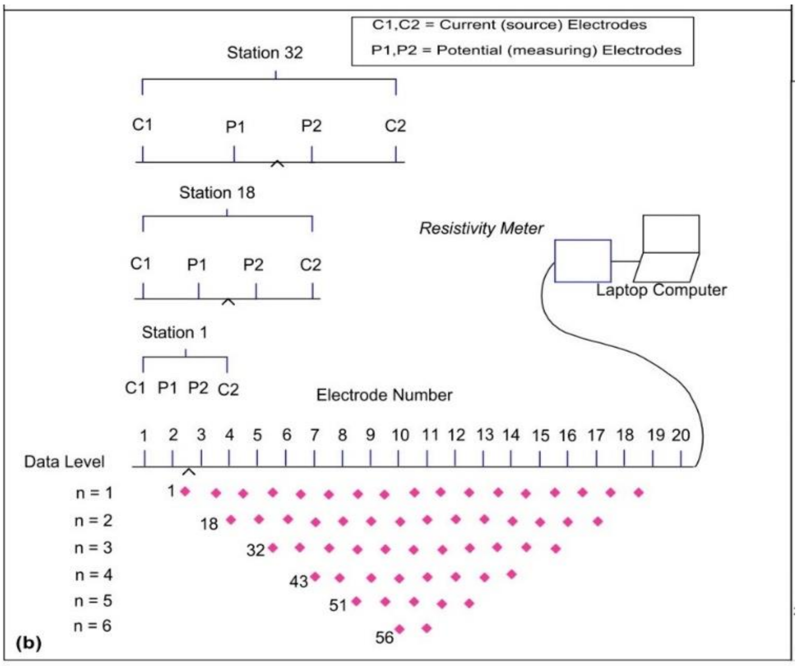

Figure 4: Principle diagram to generate a pseudo section in ERI

RESULTS AND DISCUSSION

2D electrical resistivity imaging

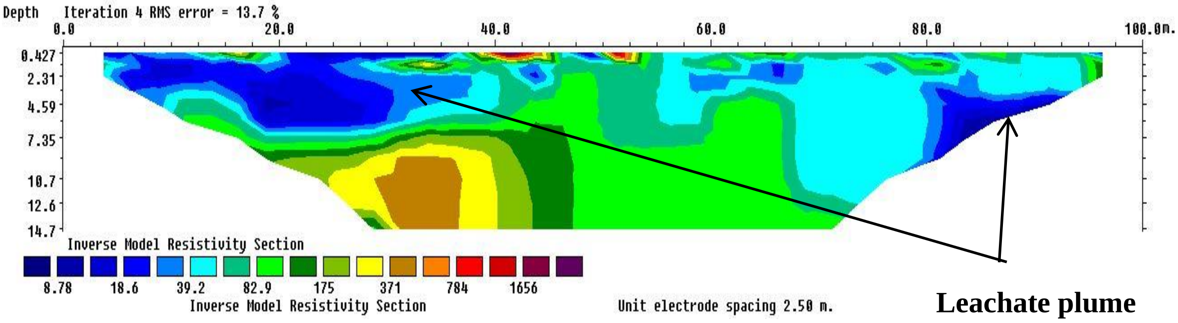

Figure 5: Results of 2D electrical inversion of Dipole-Dipole array along profile 1

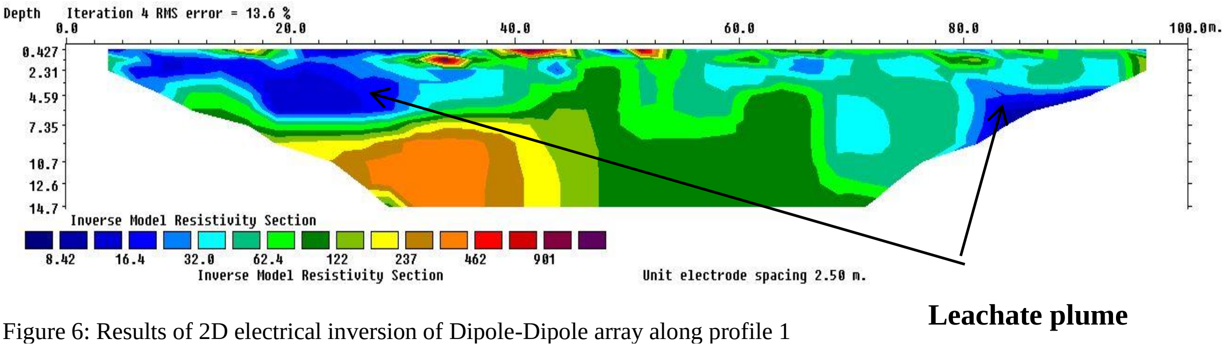

Figure 6: Results of 2D electrical inversion of Dipole-Dipole array along profile 1

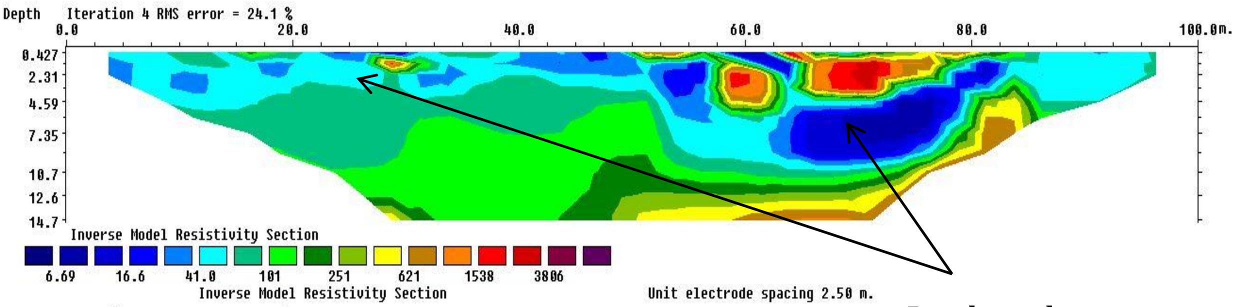

Figure 7: Results of 2D electrical inversion of Dipole-Dipole array along profile 3

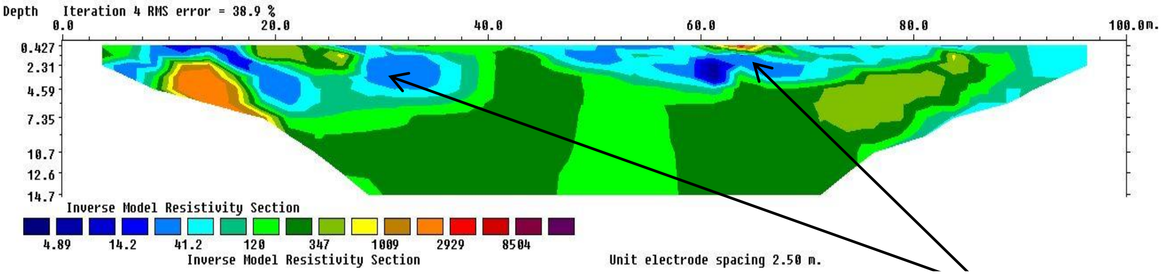

Figure 8: Results of 2D electrical inversion of Dipole-Dipole array along profile 4

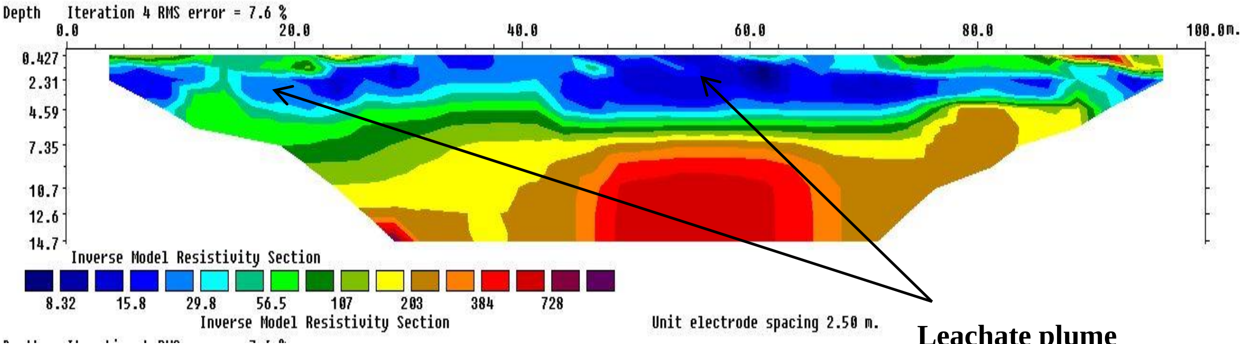

Figure 9: Results of 2D electrical inversion of Dipole-Dipole array along profile 5

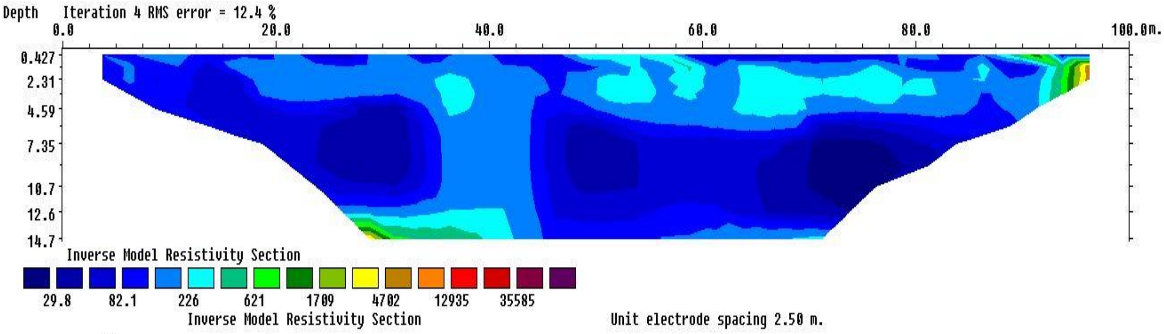

Figure 10: Results of 2D electrical inversion of Dipole-Dipole array along profile 6

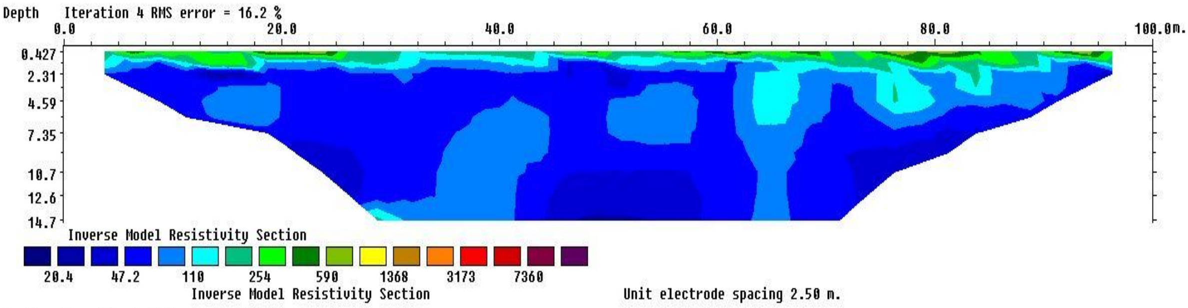

Figure 11: Results of 2D electrical inversion of Dipole-Dipole array along profile 7

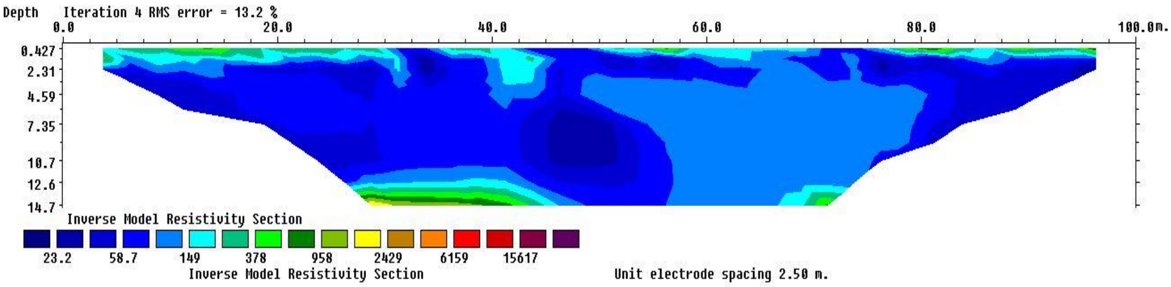

Figure 12: Results of 2D electrical inversion of Dipole-Dipole array along profile 8

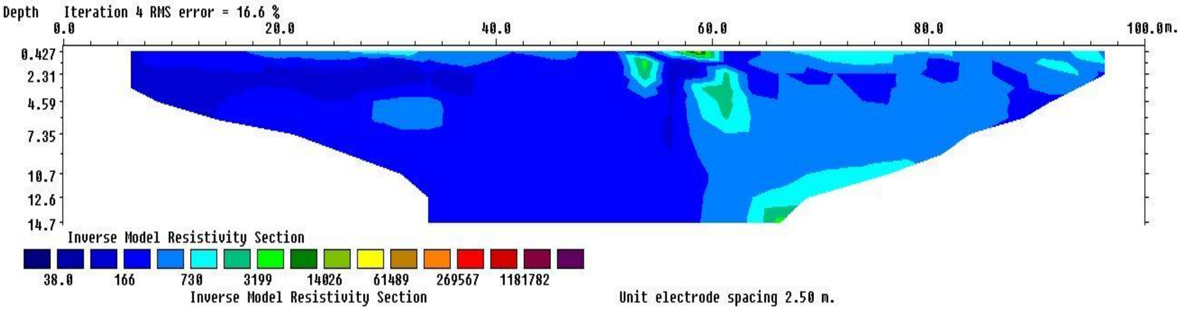

Figure 13: Results of 2D electrical inversion of Dipole-Dipole array along profile 9

Discussion of 2D electrical resistivity imaging

Figure 5 Shows a 2D inversion model of profile 1, which is oriented along the N-E direction across the dumpsite through an existing accessible path with inter-electrode spacing of 2.5 m and a total lateral distance of 100 m thereby allowing for a depth of investigation vertically down to 14.7 m. The true resistivity of the area ranges from 8.78 – 1656 Ωm, there is anomalous low resistivity zone ranging between 8 – 40 Ωm (Blue color) which was observed almost throughout the top soil down to a depth of 10 m, this indicate the presence of leachate due to the dumpsite and that shows that the surface soil down to 10 m is contaminated. The result also shows that the leachate migrate laterally with ease and vertically with little resistance as observed that the colour scaling changes from deep blue to light blue reflecting the changes in the concentration of the leachate as it seeps down due to infiltration by the sediments. The weathered basement underlies the top soil at depth of about 8m which mostly appear at the southern part of the profile with resistivity value of about 500Ωm. this was interpreted as coarse sand and it's extended to a depth of 14.7m. The fresh basement could not be mapped due to limited profile length.

Figure 6 Shows a 2D inversion model of profile 2, which is oriented along the N-E direction across the dumpsite through an existing accessible path with inter-electrode spacing of 2.5 m and a total lateral distance of 100 m thereby allowing for a depth of investigation vertically down to 14.7 m. The true resistivity of the area ranges from 8.78 – 1656 Ωm. A low resistivity zone was observed from 0-32m along the profile which extended from the topsoil to a depth of 7.35 m and 80-92.5m along the profile to a depth of 10.6m. The zone was observed to be directly underlying the portion of the refuse dump with the highest elevation during the survey. The low resistivity is due to percolation of leachate. There is gradual decrease in apparent resistivity with depth (11m beyond). The fresh basement could not be mapped due to limited profile length.

Figure 7 Shows a 2D inversion model of profile 3, which is oriented along the N-W direction across the dumpsite through an existing accessible path with inter-electrode spacing of 2.5 m and a total lateral distance of 100 m thereby allowing for a depth of investigation vertically down to 14.7 m. The true resistivity of the area ranges from 8.78 – 1656 Ωm. A very low resistivity is visible at a varying depth of 0.427-10 m which constitutes the top layer. This low resistivity is associated with leachate contamination originating from the waste dumpsite. An increased resistivity >600Ωm beneath the dump site.

Figure 8 Shows a 2D inversion model of profile 4, which is oriented along the N-W direction and a perpendicular direction to the profile 1 and 2. the dumpsite through an existing accessible path with inter-electrode spacing of 2.5 m and a total lateral distance of 100 m thereby allowing for a depth of investigation vertically down to 14.7 m. The true resistivity of the area ranges from 8.78 – 1656 Ωm. Varying resistivity values between 5-40Ωm within the dumpsite area were observed at the top soil (thickness of 4m). This low resistivity showed that the topsoil in this area is contaminated (leachate plume), there is an increased in high resistivity value >120Ωm with depth. The low resistivity value may imply that the leachate plume originated from both the Northern and the Southern parts of the dumpsite area.

Figure 9 Shows a 2D inversion model of profile 5 (Abattoir), which is oriented along the N-E direction across the abattoir through an existing accessible path with inter-electrode spacing of 2.5 m and a total lateral distance of 100 m thereby allowing for a depth of investigation vertically down to 14.7 m. The true resistivity of the area ranges from 8.78 – 1656 Ωm. A region of low resistivity was observed between 30-70 m along the profile down to a depth of 5m which spread laterally easily. The low resistivity contrast; indicate contamination by leachate plume due to its lateral migration from the abatoir. The weathered basement underlie the top soil at a depth of 7m with resistivity ranging from 200-550Ωm. The fresh basement could not be mapped due to limited profile length.

Figure 10 Shows a 2D inversion model of profile 6 (Control 1), which is oriented along the N-E direction through an existing accessible path with inter-electrode spacing of 2.5 m and a total lateral distance of 100 m thereby allowing for a depth of investigation vertically down to 14.7 m. The traverse is characterized by apparent resistivity ranging from about 29.8-35585Ωm. the profile was taken 300m away from the dump site. From the inversion result, the top soil have a slightly high resistivity ranging between 20-450Ωm. This suggests that the lithology of the control site most probably comprises of lateritic clay soil. There is a gradual decrease in apparent resistivity with depth (20Ωm) from the topsoil. This could be a flow of contaminant from the dump site as a result of leachate

Figure 11 Shows a 2D inversion model of profile 7, which is oriented along the N-E direction across the dumpsite through an existing accessible path with inter-electrode spacing of 2.5 m and a total lateral distance of 100 m thereby allowing for a depth of investigation vertically down to 14.7 m. The true resistivity of the area ranges from 8.78 – 7360 Ωm,

The 2D resistivity transverse indicated that the topsoil has a resistivity 180Ωm (thickness of 2m). Underlie the topsoil is a low resistivity material ranging between 20-80Ωm and almost all over the area. This is suspected to be clay formation or may be due to the overburden relative permeability, probable linear features along the profile. This is considered as leachate saturation which later migrated to relatively porous and permeable neighboring part with increasing depth. Thus there is a correlation between the low resistivity values, along the pathways

Figure 12 Shows a 2D inversion model of profile 8, which is oriented along the N-E direction across the dumpsite through an existing accessible path with inter-electrode spacing of 2.5 m and a total lateral distance of 100 m thereby allowing for a depth of investigation vertically down to 14.7 m. The true resistivity of the area ranges from 8.78 – 15617 Ωm. A region of low resistivity was observed between 30-34 m along the profile, 42-48m along the profile down to a depth of 10.7m and also 70-72m along the profile. This is also considered as leachate saturation which also later migrated relative to porous and permeable neighbouring part with increasing depth. The same overburden relative permeability in profile seven is also observed leading to the low resistivity (20-90Ωm) contrast observed underlie the topsoil.

Figure 13 Shows a 2D inversion model of profile 9 (control 2), which is oriented along the N-E direction across the dumpsite through an existing accessible path with inter-electrode spacing of 2.5 m and a total lateral distance of 100 m thereby allowing for a depth of investigation vertically down to 14.7 m. The true resistivity of the area ranges from 8.78 – 1181782 Ωm. The same overburden relative permeability in profile seven is also observed leading to the low resistivity (20-90Ωm) contrast observed underlie the topsoil. From the inversion result, the overburden layer and weathered basement overlapped each other with resistivity between 160-700Ωm. This suggests that that the lithology of the control site most probably comprises the clay/laterite material.

CONCLUSION

The electrical resistivity method involving 2D-Electrical Resistivity Tomography has revealed ground water contamination in the study area. The 2D-ERT results revealed the presence of contaminated plume (leachate) within the investigated area with true resistivity model revealing anomaly of very low resistivity of <20 Ωm from top soil down to a maximum depth of about 15 m, this low resistivity value is associated with leachate due to the dumpsite and abattoir respectively which is in consistent with the findings of Ganiyu *et al*., (2016) which revealed in his study that low resistivity value lessthan 10 Ωm is suspected to be leachate, this is also in agreement with the study of Ikhifa *et al*. (2017) where revealed that high conductive zones of less than 2 Ωm is also suspected to be leachate. The 2D structures has shown various conductive path ways via fractures and openings, thus contaminating the groundwater. I recommend that further geochemical analysis of the water should be done to ascertain the level of contamination.

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