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2D RESISTIVITY IMAGING FOR LEACHATE MIGRATION IN NKWELLE-EZUNAKA FARM ESTATE, SOUTHEASTERN NIGERIA

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ABSTRACT: *Leachate effluence from wastewater Leachate migration and solid waste are major sources of soil and groundwater pollution. Assessing the impact of leachate is an active area of soil and groundwater research. This study evaluated the extent of leachate migration at Nkwele-Ezunaka Farm Estate in Anambra State of Nigeria using a 2D resistivity imaging technique. The study area lies within longitude 6° 51' 27" − 6° 59' 37" E and latitudes 6° 13' 18" − 6° 20 '27" N and covers an area of about 60 km^2. A total of five profile lines were carried out in a resistivity survey using a digital read-out resistivity meter (ABEM SAS 1000). The data obtained were interpreted using RES2DINV software. A contaminant leachate plume was delineated in 2D resistivity sections as low resistivity zones (less than 80.0 Ωm). The maximum depth of penetration of leachate determined was 10.6 m and hence could not penetrate the groundwater in the study area. The groundwater flow in the study area was revealed to be in the West-East direction.*

KEYWORDS: Contaminated Zones, Groundwater Flow, Leachate Migration, Pseudosection, Profile Lines. Resistivity Imaging.

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INTRODUCTION

Safe drinking water is one of the most essential basic needs of human beings universally. Most communities tap into the closest water source in their area, whether it is groundwater via a borehole or surface water such as a river (Odukoya and Abimbola, 2010). These water sources are easily susceptible to contamination by anthropogenic sources such as household waste (HHW), municipal waste dumps, agricultural runoff and industrial waste, among other pollution sources (Han *et al*., 2013). The degree of pollution from any of these sources depends on environmental control, waste management practices and environmental protection laws in a given area. Wastes, which are described as materials that result from activities or processes but have no immediate economic value or demand and must be discarded, have been managed in a manner that has engendered the quest for government to actualise the mega city status as a difficult task positively. In Anambra State, most individuals and companies discard their waste indiscreetly, not minding the implications for the people and the environment. This practice is very common in the community where the study area is located. The physical, chemical and biological processes that occur simultaneously at dumpsites can result in the generation of leachate and other waste gases. The leachate and waste gases formed are the sources of pollutants that can lead to environmental health problems (Rushbrook, 2001). Therefore, communities that tap into polluted groundwater may be exposed to various levels of harmful chemical contaminants that can lead to chronic diseases. The increasing demand for potable water, especially as the area under study is a residential settlement, is a huge challenge. A common feature in the estate is that municipal drainage systems contain solid waste materials, which could cause environmental pollution and heavy metal contamination in the subsurface aquifer. The safety of drinking water in the area is thus very important and needs to be properly monitored. At present, there is no knowledge of the depth of the water table and the level of contaminants in the groundwater in the area. There is, therefore, the need to evaluate the protective capacity of the overburdened materials and the depth of leachate penetration through the area's groundwater.

Researchers in environmental geophysics have proved geophysical techniques to be very useful tools in evaluating and characterising contaminants generated by urban residues (domestic and/or industrial)(Soupio *et al*., 2005; Soupio *et al*., 2006). Among those geophysical methods, electrical methods have been found very suitable for such kinds of environmental studies due to the conductive nature of most contaminants. Electrical methods applied to environmental studies are well documented (Karlik and Kaya, 2001; Aristedemau and Thomas−Beths, 2000). The Wenner array has been proven to be useful for resolving the differing resistivity of the subsurface layers straight down from the midpoint of the array (Nzemeka and Obiekezie, 2020). Therefore, this study used the electrical resistivity imaging technique to detect the leachate contaminant, the extent of its migration and the direction of groundwater flow in the study area.

Location and Geology of the Study Area

The study area is the Nkwelle-Ezunaka Farm Estate in Anambra State, Southeastern Nigeria. The area lies between longitude 6° 51' 36' '− 6° 59' 34" E and latitude 6° 13' 7" − 6° 20' 12" N and covers an area of about 60 km^2 (Figure 1). The study area lies within the Anambra Basin in the Lower Benue Trough tectonic unit. Anambra Basin is a synclinal structural depression and one of the intracratonic basins in Nigeria (Figure 2). It is bounded to the north by Bida Basin and Northern Nigerian Massif, to the east by Benue Trough, to the west by the West

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African Massif and to the southwest by the Niger Delta Complex (Whiteman, 1982). The Anambra Basin is characterised by enormous lithologic heterogeneity in lateral and vertical extensions derived from various paleoenvironmental settings. The basin is mainly held to have originated after the Santonian folding and uplift of the Abakaliki region during the Campanian to Mid-Eocene, which resulted in the shifting of the depocenter into the Anambra Plateform and Afikpo region (Nwachukwu, 1972). Subsequently, it became an active depocenter (Doust and Omatsola, 1990).

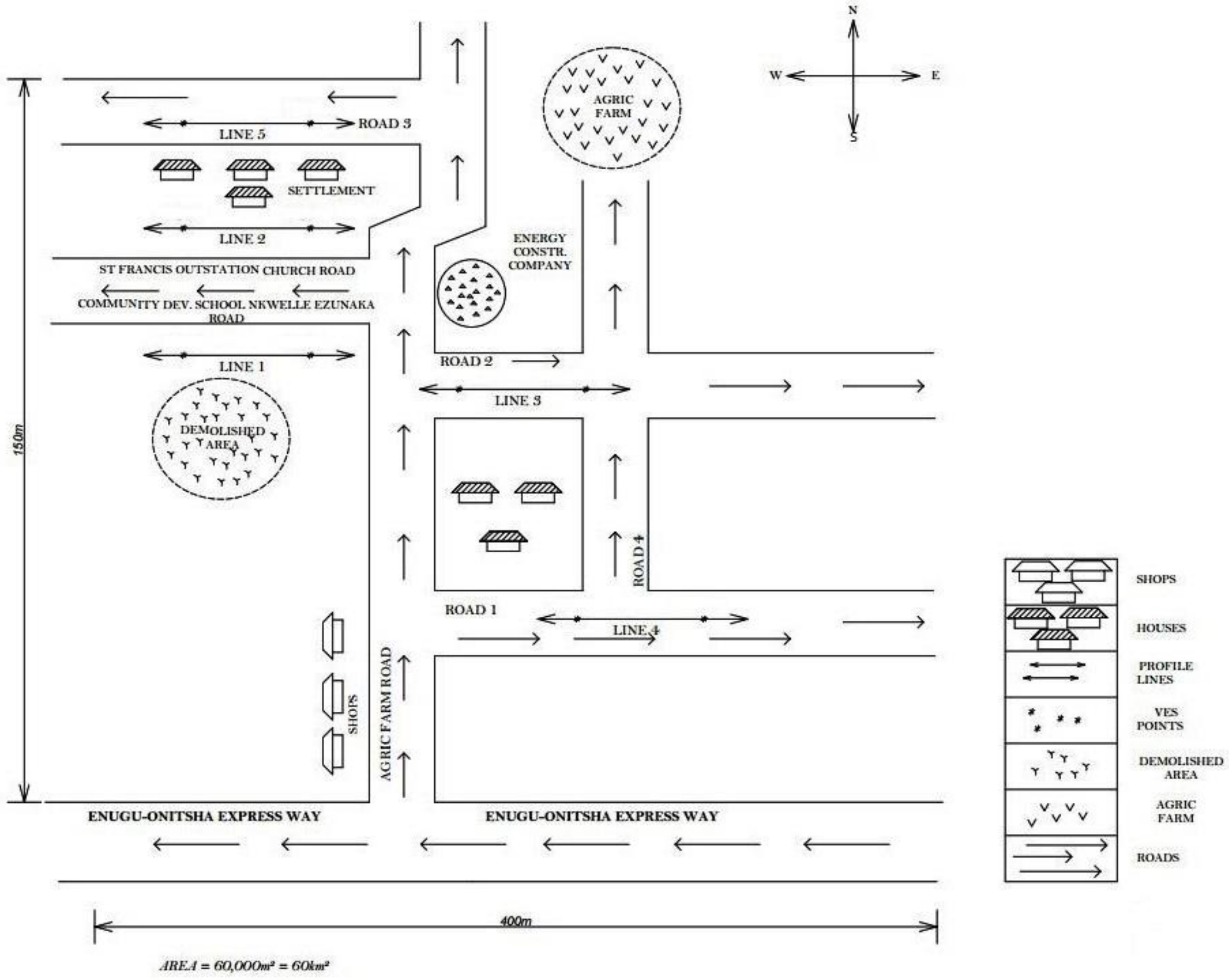

Figure 1: Sketch map of Nkwelle−Ezunaka farm estate

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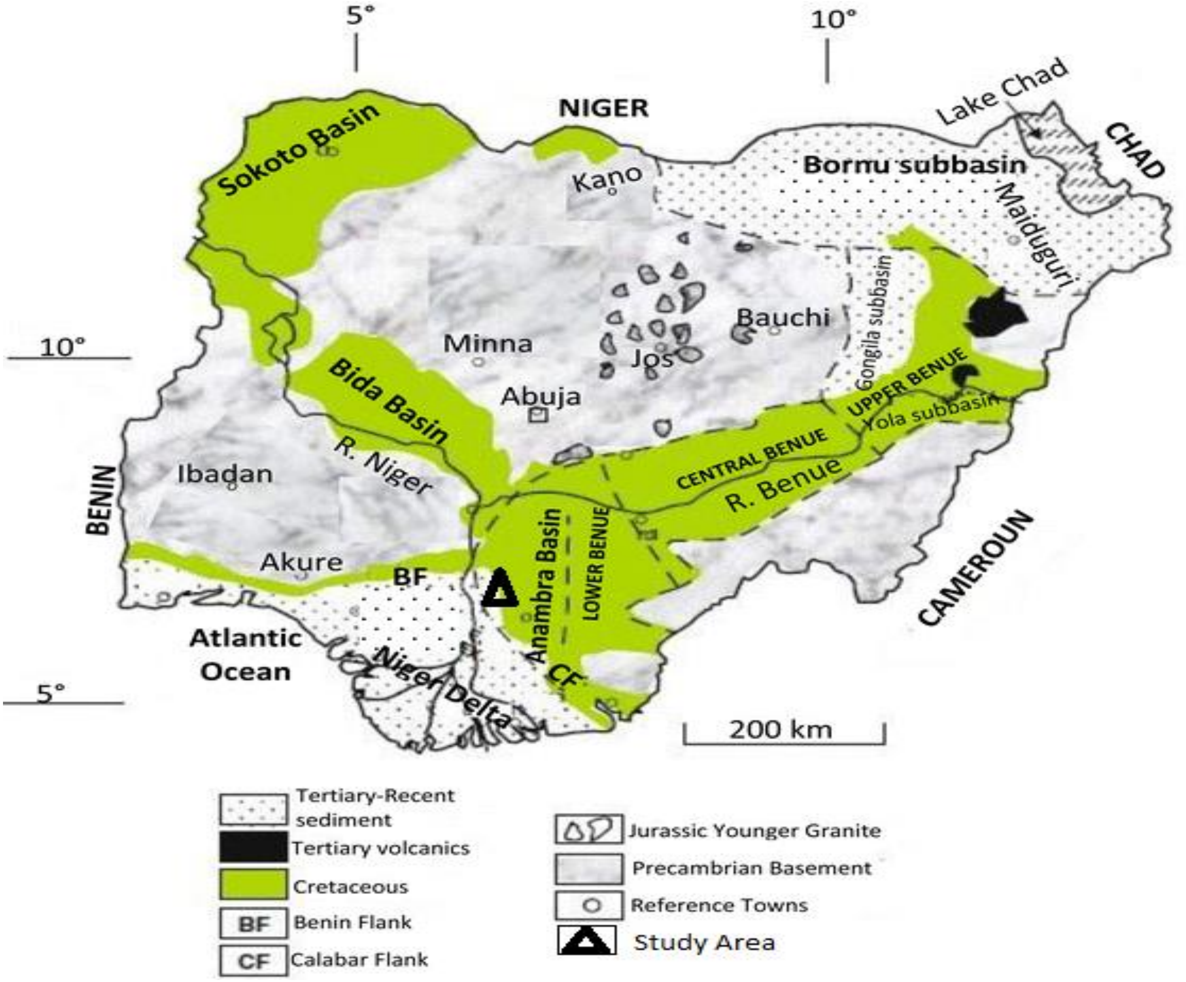

Figure 2. Geological map of Nigeria showing the study area (Obaje, 2009).

MATERIALS AND METHODS

The basic equipment used for this geophysical survey is the ABEM SAS 1000 resistivity meter. The resistivity meter is equipped with a 12 volts battery, two current transmission cables on reels, two potential cables, four metal electrodes and a salt solution. Auxiliary equipment used includes a Global Positioning System (GPS) for determining the survey location and topography, geologic hammers for driving electrodes into the ground, two measuring tapes and cutlasses for clearing the traverses.

The study involved the electrical resistivity method, and the technique adopted is 2D resistivity imaging. The electrical resistivity method generally involves passing current I into the ground through a pair of current electrodes and measuring the potential drop ΔV through a pair of potential electrodes. The apparent resistivity, ρ_a, of the model earth formation, is related to the potential difference and the current by:

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$$\rho_a = k\frac{\Delta V}{I} \tag{1}$$

where K is the geometric factor of the electrode array used. For the Wenner array (Figure 3), the four electrodes are uniformly spread collinearly a distance, a, to give the geometric factor K = 2πa. Hence the apparent resistivity becomes:

$$\rho_a = 2\pi a\frac{\Delta V}{I} \tag{2}$$

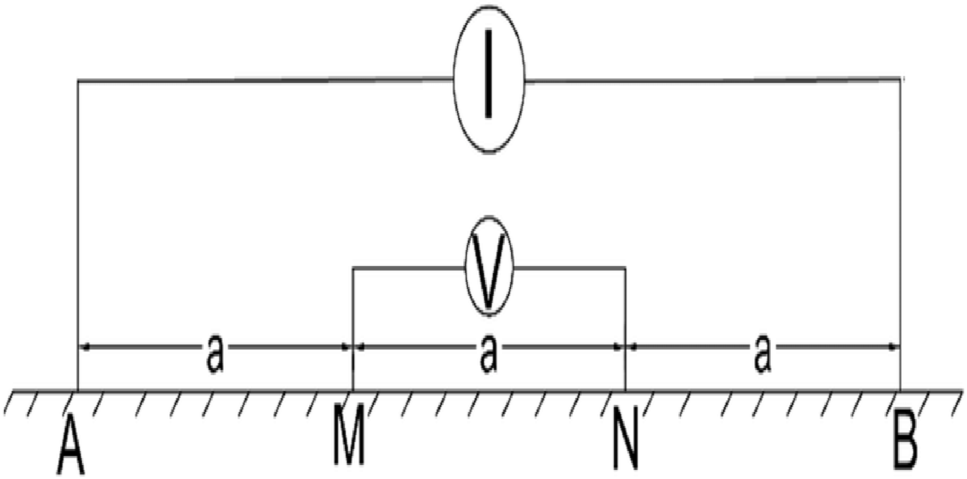

Figure 3. Wenner electrode array

A total of five profiles were carried out in this resistivity imaging technique. The 2D resistivity field data were processed using the RES2DINV software, which subdivided the subsurface into blocks and used the square inversion to determine the values of each block. The data were first filtered to remove the bad data points whose resistivity values were clearly not comparable to the neighbouring data points. Least-squares inversion was then carried out on the resistivity data using the RES2DINV software to generate the 2D inverse resistivity models.

The direction of water flow was determined by a 3D plot of latitude against longitude and elevation using Surfer 8 software.

RESULTS AND DISCUSSION

Figures 4–8 show the 2D pseudo sections of the resistivity inversion results for profiles 1–5, respectively. The profile lines run in an East-West direction and vice versa. The Profile lines show a maximum depth of 24.9 m and a lateral extent of 115m. From the surface down to about 7.8m, there are indications of contamination as represented by low resistivity values, ranging from 19.2– 72.7 Ωm and indicated by the bluish colour in profiles 1 - 3 (Figure 4 - 6) in accordance with Oyeku and Eludoyin (2010), Uma (2003). This contamination, indicated by the bluish colour, penetrates to a depth of about 10.6 m in profiles 4 and 5 (Figures 7 and 8).

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The bluish colour suggests lateritic silt, while the sky bluish colour is clayey sandy topsoil, with resistivity values ranging from 19.2 – 823 Ωm and 130 – 1490 Ωm, respectively. The green and lemon colours suggest lateritic sandstone and wet lateritic shale in profile 4, with resistivity values ranging from 304−5273 Ωm. The yellow colour suggests lateritic sandstone in profiles 1 and 4, lateritic shale in profiles 2 and 5 and shaly sandstone in profile 3 with resistivity values ranging from 1509−9918 Ωm. The red colour suggests sandstone and wet shale in profile 4 with resistivity values ranging from 3365−18654 Ωm. The purple colour suggests sandstone with a resistivity value of 7504−35087 Ωm.

Water-saturated sandstone and water-saturated shaly sandstone constitute the aquifer in the study area at depths ranging from 53.6−124.7 m (Nzemeka *et a*l., 2023). Though the overburden layers of the aquifer in the study area have a poor protective capacity (Nzemeka *et al.*, 2023)**,** the depth of penetration of the leachate revealed by the present study shows that it does not reach the aquifer to affect the groundwater quality of the area.

A 3D plot of the latitude and longitude of the study area against elevation (Figure 9) also shows that the groundwater flow in the area is in the West−East direction.

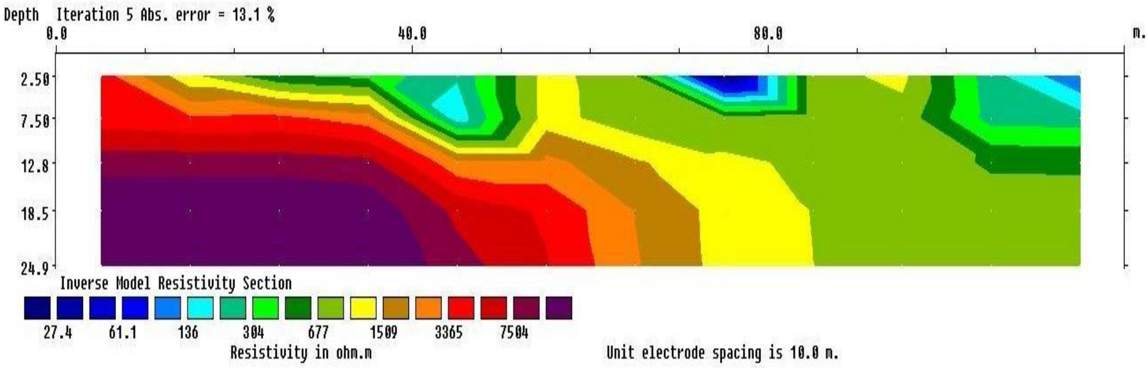

Figure 4. 2D Pseudosection of Profile1

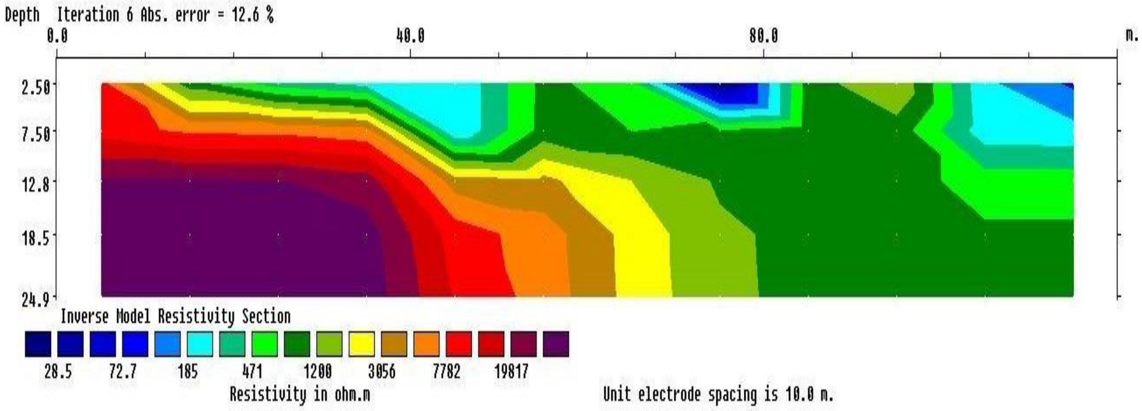

Figure 5. 2D Pseudosection of Profile 2

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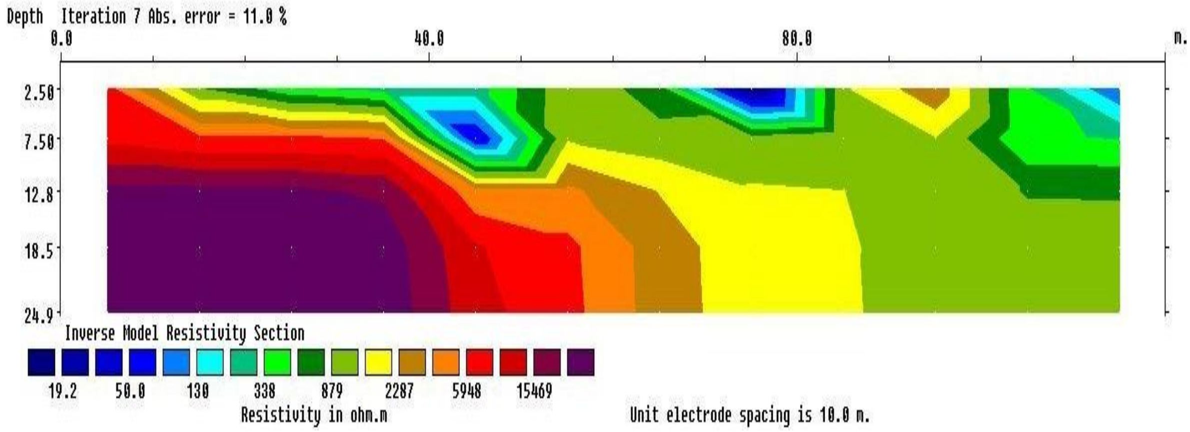

Figure 6. 2D Pseudosection of Profile 3

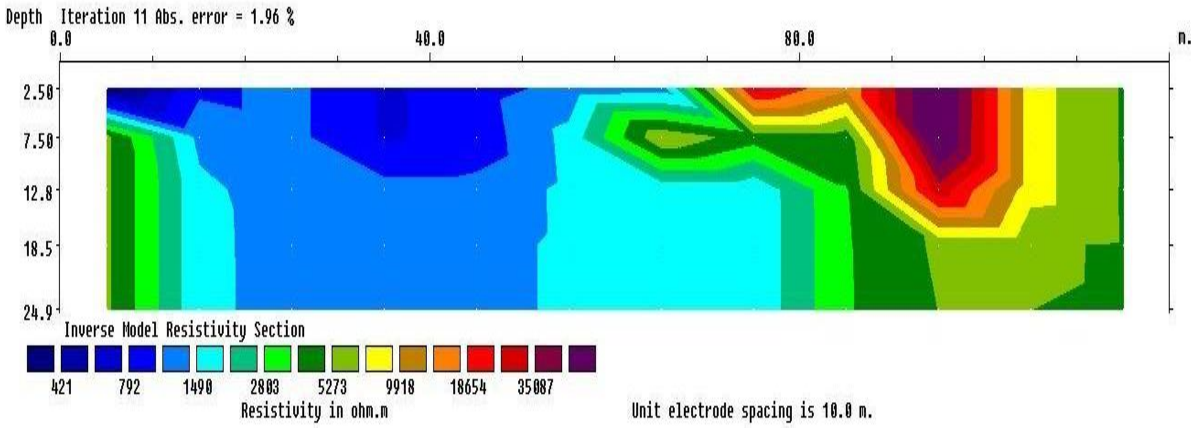

Figure 7. 2D Pseudosection of Profile 4

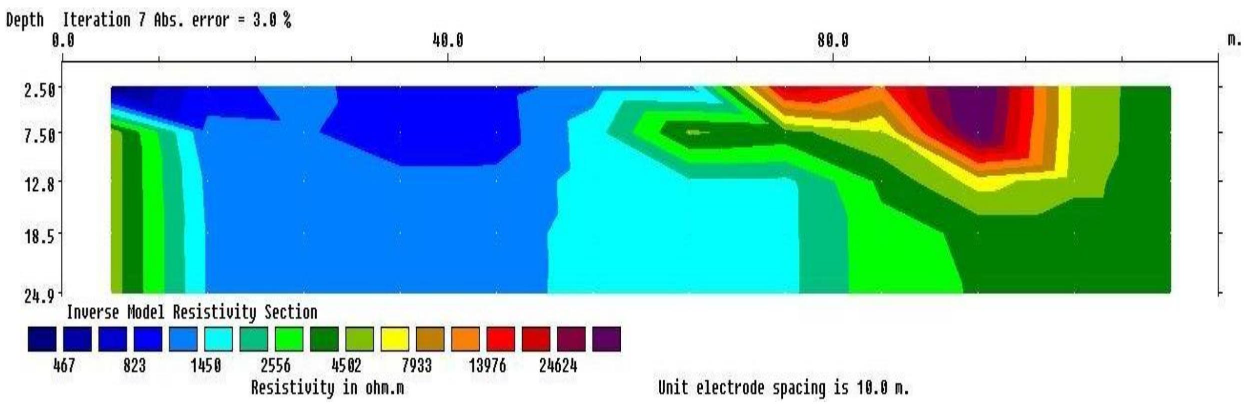

Figure 8. 2D Pseudosection of Profile 5

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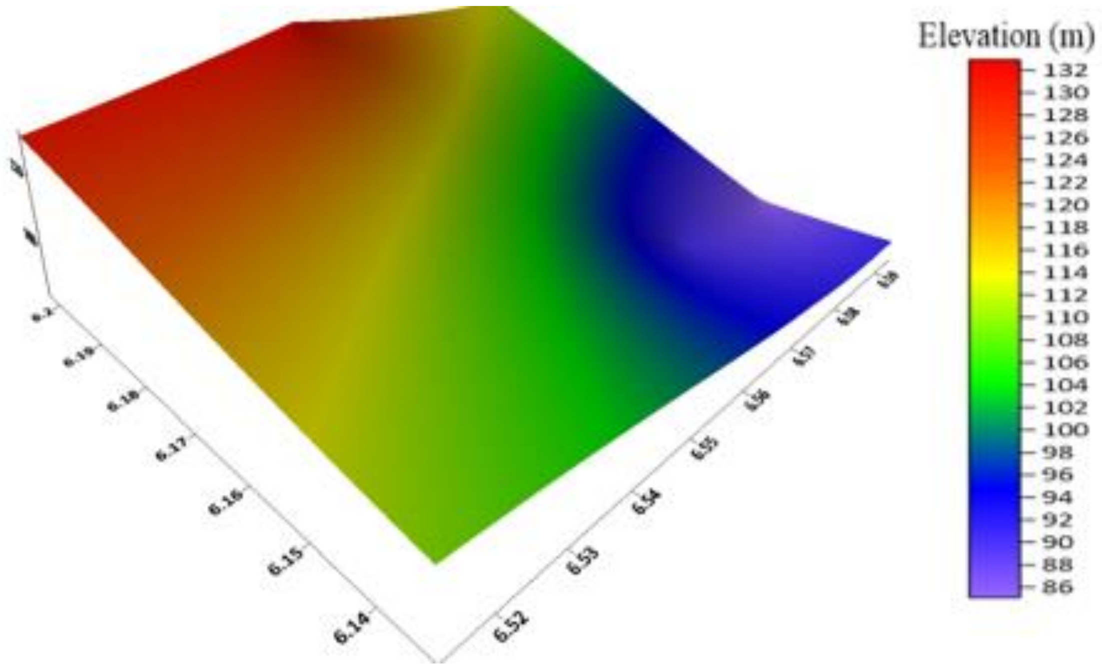

Figure 9. 3D plot of groundwater flow in the study area.

CONCLUSION

In this study, an evaluation of the contamination level of the rock and soil units within the Nkwelle–Ezunaka farm estate in Anambra State of Nigeria was carried out using a 2D resistivity imaging technique. The result of the study shows that some parts of the study area (around profiles 1–3) are contaminated by the leachate. The contaminated zones were observed to have low resistivity values, ranging from 19.2 – 72.7 Ωm. They could be migrating through the fractures, joints and weathered zones in the lateritic silt and clayey sandy layers that characterised the upper layers of the study area. The contamination is remarkably deeper at profiles 4 and 5, where the depth of migration of leachate plume in the area reached 10.6 m.

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