Geophysical Contribution of Using 3D View in Landfill Site

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Abstract

Geophysical techniques are very useful tools in the characterization of the subsurface to determine the degree of conductivity and predict the nature of earth materials present within the survey area. Three 2D electrical resistivity profiles were established for the purpose of this research. The field survey was carried out using Dipole-dipole array with a spread of 164 m at the only State government approved landfill site in Ikpoba Okhia local government area, Benin City, Edo State. The 3D image maps were at three different depth slices of (5 m, 18 m and 38 m) in order to determine the rate of spread and migration of leachate as we probed deeper into the subsurface. The apparent resistivity values helped in identifying the nature, lateral spread and depth of the conductive sources in the study area. The resistivity data were imported into Voxler software to achieve the objective of the study. The image results from the electrical resistivity tomography (ERT) method revealed highly conductive zones with conductivity of less than 226 Ωm and above to the depth of 38 m. The images show subsurface resistivity distribution at the Eastern part of the study area trending Eastward with prominence at the center and distributed North - East which has been interpreted as loosed or migration zones of leachate. The depth estimate revealed lateral spread of leachate from the surface to maximum depth (38 m) probed which agrees with the borehole lithology of probable materials present within the study area. The study has revealed that the area is generally highly conductive due to the presences of toxic elements while the loosed zones are prospective locations for infiltration of contaminant plums (leachate) from the 3D model view.

Keywords: - Evaluate, Pseudo section Maps, Apparent Resistivity, Leachate, Benin City

Introduction

One of the adverse effects of landfill sites over the years to the environment is the production of toxic substances known as leachate which causes severe economic and biological damages to the soil and groundwater. Many landfill sites are “danger zones” to mankind and environment if necessary precautionary measures are not taken in future before allotting the sites for any developmental project. Many substances found in landfill environment have been reported to act as biological poison even at low concentration (parts per billion-ppb) level [1]. Geophysical survey using electrical resistivity method is a vital tool for exploring the subsurface because of its ability not only to identify lateral and vertical boundaries between different materials but also to identify the conductivity of the earth materials. In electrical resistivity survey current is applied to the subsurface through a pair of current electrodes and the potential different is measured using another pair of potential electrodes. From these measurements, the true resistivity of the subsurface can be estimated. Many authors [2 - 10] have used electrical resistivity method for many decades in hydrogeological, mining and geotechnical investigations. The method is also capable of determining the subsurface flow of contaminated groundwater resulting from pollution if the polluted water has a distinctive resistivity. The purpose of electrical survey is to determine the subsurface resistivity distribution by making measurements on the ground surface. Information on the ERT can be found in the works of authors such as [11 - 17] amongst others. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock.

Geology of the Area

The study area, Ikpoba Okhia Local Government Area is located in the southern part of Nigeria and lies within longitude 5°25'E and 5°75' E and latitude 6°33'N and 6° 36'N. The Snap Shot of Ikpoba Okhia Local Government Area Dumpsite is shown in Figure 1. Edo State has an area of 17,802 square kilometers and falls within the tropical equatorial climate. The landscape is flat, gently rising with hilly ridges covered by tick vegetation. The formation is characterized by top reddish to reddish brown lateritic massive fairly indurate clay and sand intercalation. The Benin formation consists of thick continental sand [18]. It extends from the west across the whole of Niger-Delta area and southward beyond the present coastline. The area of study is indicated in the geology map of Nigeria as shown in Figure 2, which reveals that the entire area is underlain by sedimentary rocks. These rocks are of ages between Paleocene to recent. The sedimentary rock contains about 90 percent of sandstone and shale intercalation. It is coarse grained locally fine grained in some areas, poorly sorted, sub-angular to well-rounded and bears lignite streaks and wood fragment [19]. The sedimentary rock of the study area constitutes the Benin formation. The Benin formation consist of high percentage of porous and coarse sand with little clay/shale layers [20] and is the most prolific aquifer in the region [21].

Figure 1:

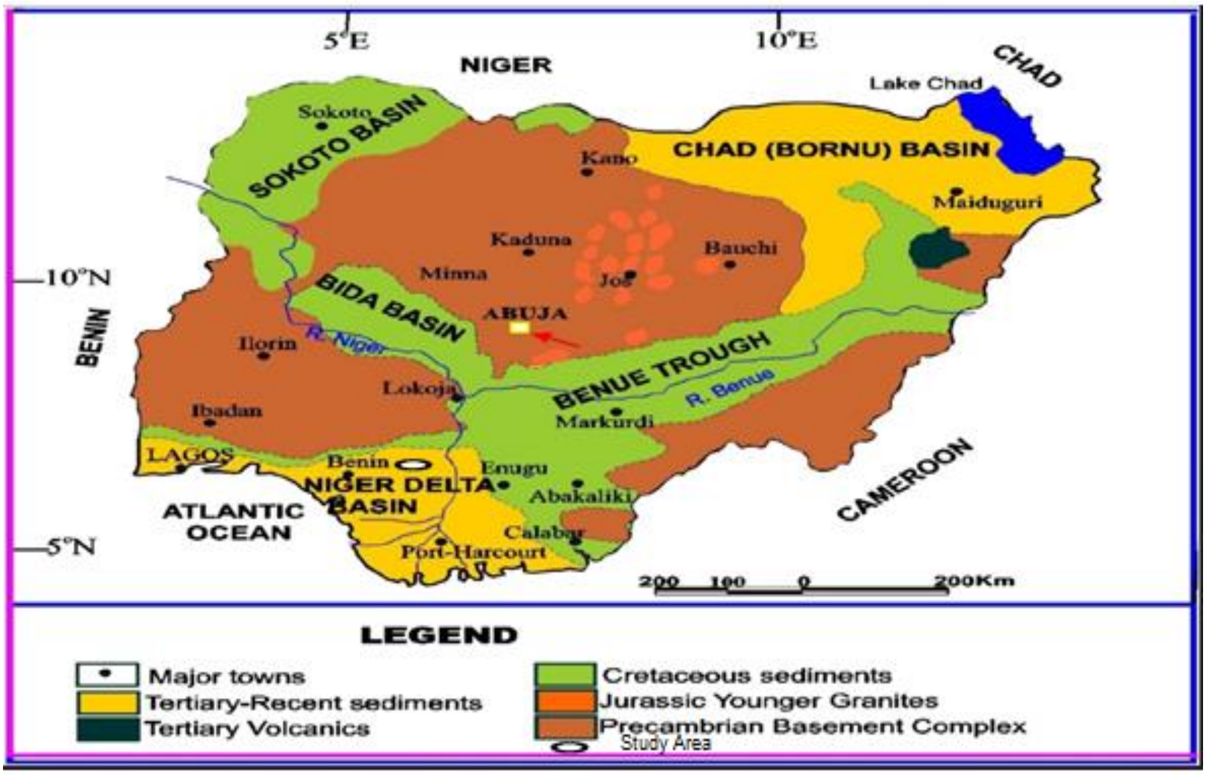

Figure 2: Geological Map of Nigeria. Showing Benin City and other Locations (Source: [22])

Materials and Method

3D Slice Electrical Resistivity Data Collection

The instrument used for the electrical resistivity tomography survey is the Superstring land imaging system with 84 take out electrodes. The instrument measures the resistance of the Earth's to current flow. Three traverses were established along the North – East direction with profile length of 164 m in the study area. Dipole–dipole array was used with 2 m electrode spacing. The 3D image was composed by three parallel 2D survey profile lines from the dumpsite. According to [23 – 25] to use this array effectively, the resistivity meter should have comparatively high sensitivity and very good noise rejection circuitry, and there should be good contact between the electrodes and the ground in the survey. All data were assembled into a single data set and submitted to 3D inversion routine. Data were processed with commercial Voxler 3 software which transformed the parallel 2D data set to 3D image. [26 – 28] recommends smoothness constrained least-square inversion method for environmental studies, where contamination plume produces smooth variations of electrical properties. The subsurface is divided into small rectangular blocks with position and size fixed by forward modelling. The resistivity of the block is then determined so that the calculated apparent resistivity values agree with the measured values from the field survey by adjusting the resistivity of the model block and consequently iterate to reduce the difference between the calculated and measured apparent resistivity [26]. These differences are expressed in form of root mean square (RMS) error.

Results and Discussion

Three 2D electrical resistivity profiles were used to plot a 3D resistivity map of the materials in the landfill site. The Easting and Northing in the 3D views represent the surface distance in meters and the contour showing the resistivity values at a particular depth. From the image result there are basically five different materials present within the study area with the characteristics colors: red, yellow, green, blue and purple which debit the nature of materials present within the study area. The red color is more conductive with conductivity values of 1 Ωm - 226 Ωm, yellow with conductivity of 266 Ωm - 234 Ωm, green from 334 Ωm - 619 Ωm, blue from 619 Ωm - 904

Ωm and purple from 904 Ωm - 1000 Ωm. The red color had a lateral spread of conductive substances from 66 m to 160 m, with average spread of 84 m on the profile followed by purple from 5 m - 65 m, with average spread of 60 m on the profile others with minimal spread of less than 8 m. The 3D models obtained from the inversion of the resistivity data set are displayed as horizontal slices as shown in Figures 3.1 – 3.2. From the image result on Figure 3.2, slice A at a depth of 5.8 m shows high conductive substances from 100 m - 140 m with a spread of 40 m on the profile while slice B, at a depth of 18 m shows highly conductive substances from 80 m - 160 m with a spread of 80 m on the profile and slice C, at a depth of 38 m shows highly conductive substances from 70 m - 160 m with a spread of 90 m on the profile. The slices show highly conductive substances with red color suspected to be (leachate) with lateral spread as we probe deeper into the subsurface which is the area of interest in this study.

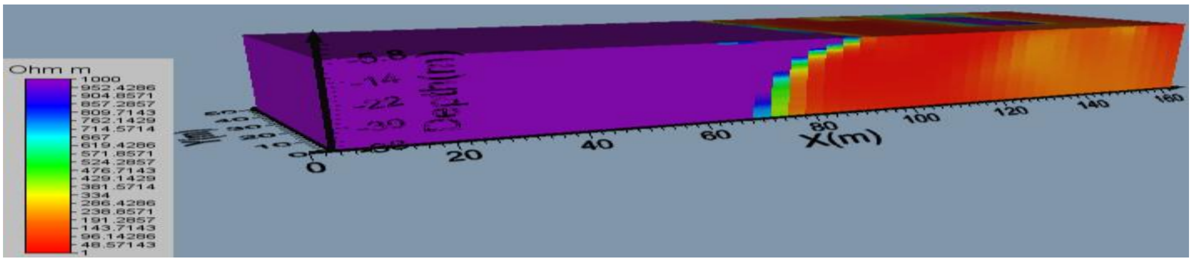

Figure 3.1: 3D Image of Ikheuniro Dumpsite

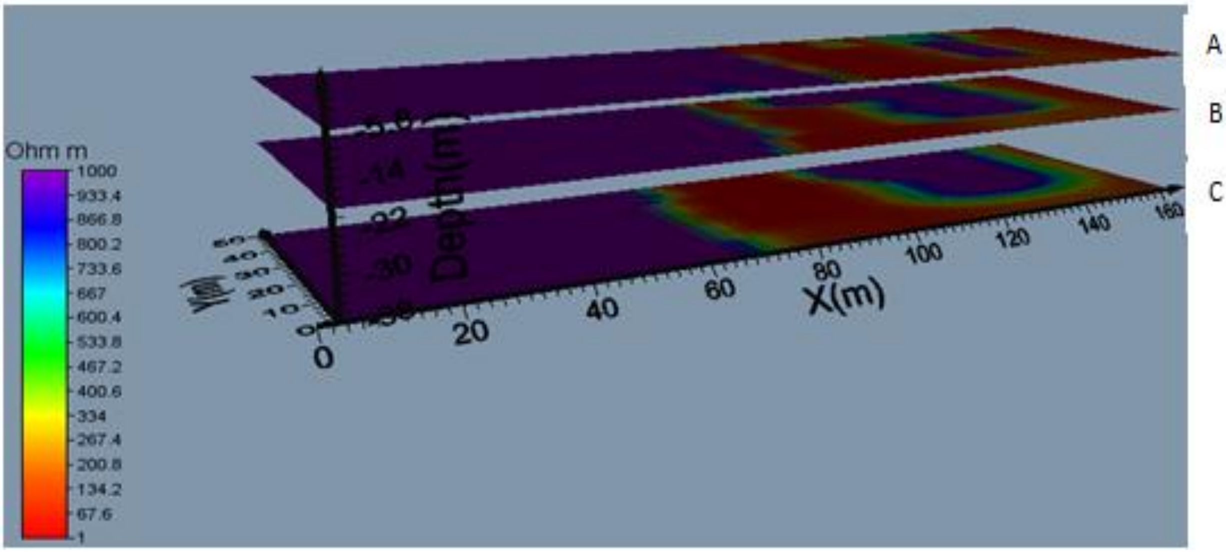

Figure 3.2: 3D Slices of Ikheuniro Dumpsite at 5m, 18m and 38m depth

Conclusion

The geophysical technique applied for this study proved to be ideal for revealing the depth, lateral spread and nature of conductive materials around (Ikpoba Okhia local government approved landfill area). In this study, we have demonstrated some of the advantages of 3 D ERT depth slices using Voxler 3 software at different depths from surface measurement. The research had revealed that there is a lateral downward spread of conductive materials as we probe deeper into the subsurface. The electrical resistivity imaging technique was used to locate and monitor the vertical and horizontal distribution of conductive materials within the study area. The leachate plumes have contaminated the subsurface soil to depth of more than 38 m in the study area. Because the electrical conductivity of landfill leachate is often so much higher than that of the natural groundwater, a large contrast in properties is seen enabling the detection of the migrating leachate plume. The above findings indicate the importance of using 3D ERT depth slices approach for environment study. The application of ERT technique allows the resolution of possible discrepancies and the most accurate description of landfill's characteristics.

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