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# Geophysical Evaluation of a Landfill Site in Ikpoba Okhia Local Government Area, Edo State, Nigeria

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Author MNU designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors II and TNO managed the analyses of the study. Author GNE managed the literature searches. All authors read and approved the final manuscript.*

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## ABSTRACT

Electrical resistivity tomography (ERT) technique has been used in this research to evaluate the contamination zones at a dumpsite in Benin City. Three electrical resistivity profiles were established for the purpose of the research. The pseudosection maps and the apparent resistivity values helped in identifying the nature and depth of the conductive sources in the study area. The field survey was carried out using Dipole-dipole array with a spread of 164 m at Ikpoba Okhia local government approved dumpsite in Benin City, Edo State. 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 center 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).

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## 1. INTRODUCTION

One of the adverse effects of dumpsites over the years to the environment is the production of toxic substances known as leachate which causes serious damages to the groundwater. Many of these substances have been found to act as biological poison even at low concentration (parts per billion-ppb) level [1]. Groundwater is considered a very important natural resource because it provides a reasonable percentage of public water supplies. In Africa, three quarters of farm land is severely degraded [2] due to poor management of waste. Each year about two million people die as a result of poor sanitation and consumption of contaminated water, ninety percent (90%) of the victims are children [3]. In Nigeria, majority of the rural populace do not have access to potable water and therefore, depend on well, stream and river water for domestic use. Groundwater monitoring is a process used to determine the effects of human activities or operations on the groundwater aquifers and the soil layers bearing such water resource [4]. Electrical resistivity method has gradually and systematically made their way to the top in the successful search of groundwater pollution. In electrical resistivity survey, current is applied to the subsurface through a pair of current electrodes and the potential difference is measured using another pair of potential electrodes. 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. From these measurements, the true resistivity of the subsurface can be estimated. Many authors [5–13] have used electrical resistivity method for many decades in hydrogeological, mining and geotechnical investigations. More recently, it has been used for environmental surveys. 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.

## 2. 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. Fig. 1 shows the Snap Shot of Ikpoba Okhia Local Government Area Dumpsite. 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 surface of the study area is composed of dry lateritic sand. Geologically, Edo State is basically sand witched between the Niger-Delta basin and Anambra basin and lies within the Benin formation and Ogwashi-Asaba formation. The Benin formation consists of thick continental sand [14]. It extends from the west across the whole of Niger-Delta area and southward beyond the present coastline. The geology map of the study area is shown in Fig. 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 [15]. The sedimentary rock of the study area

**Fig. 1. Snap shot of Ikpoba Okhia Local Government Area dumpsite**

constitutes the Benin formation. The Benin formation consist of high percentage of porous and coarse sand with little clay/shale layers [16] and is the most prolific aquifer in the region [17]. The three dimensional (3D) view to the depth of bedrock of the study area is shown in Fig. 3.

## 3. MATERIALS AND METHODS

The instrument used for the electrical resistivity survey is the Superstring land imaging system with 84 take out electrodes. The instrument measures the resistance of the Earth to current

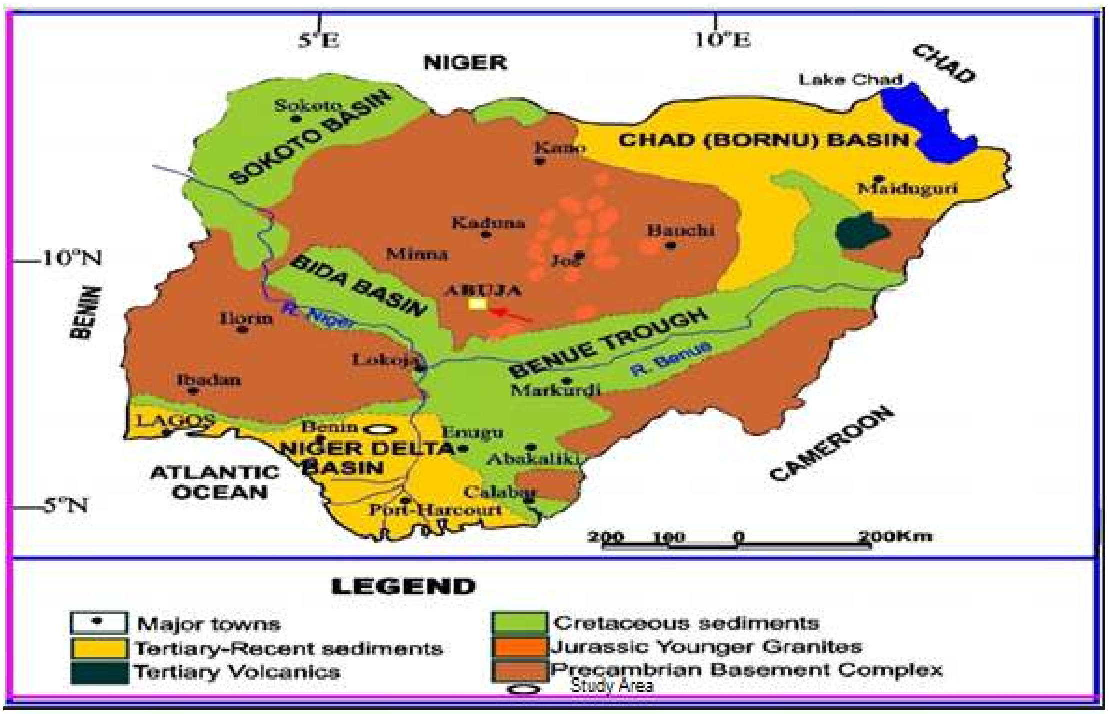


**Fig. 2. Geological Survey Map of Nigeria. Showing Benin City and other locations**
*(Source: [18])*

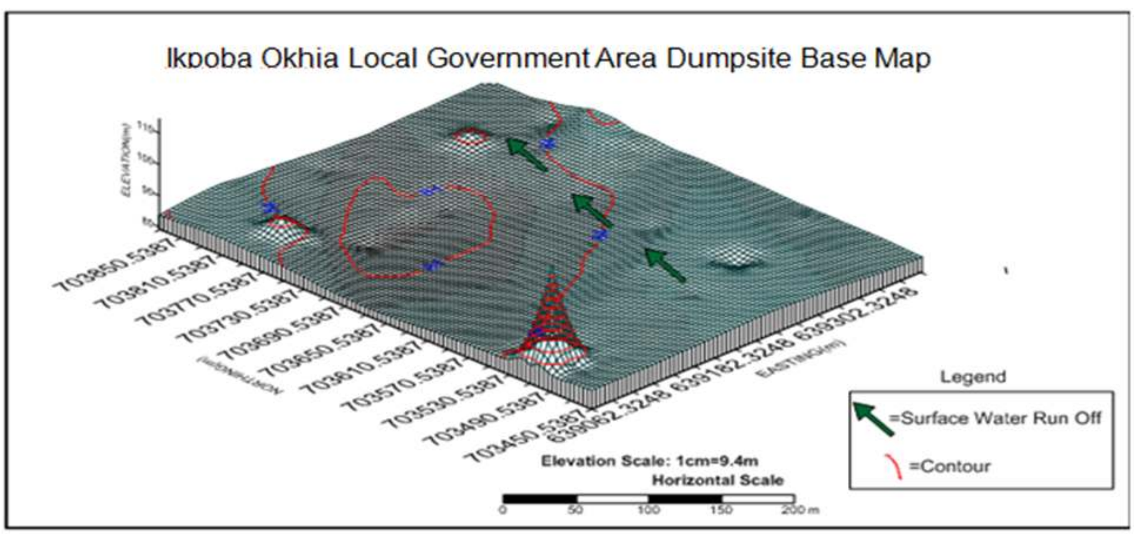


**Fig. 3. 3-D elevation model of Ikpoba Okhia Local Government Area dump site, showing the direction of surface water run off**
*(Source: Surfer plot)*

flow. The Dipole-dipole array was used for this survey because of the sensitive of the array to horizontal changes in resistivity. The research was carried out on the 10th of March, 2013. Three traverses were established along the North – East direction with profile length of 164 m in the study area. Minimum electrode spacing of 2 m for all the profiles was maintained. Previous geophysical survey established 20 m away from the dumpsite was used as a control while the other profiles were rightly located on the dumpsite. Resistivity data were inverted using the Earth Imager computer program. Each commercial system comes with its conversion program [19]. The Earth Imager computer program automatically reduces the measured resistance to apparent resistivity values, based on smoothness-constrained least-square technique of [20-21] applied by [22-23]. 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 blocks and consequently iterate to reduce the difference between the calculated and measured apparent resistivity [24]. These differences are expressed in form of root mean square (RMS) error.

## 4. RESULTS AND DISCUSSION

The pseudosections derived from the 2-D inversion of ERT field data are presented (Figs. 4-6) and discussed here with their resistivity depth models. The "true" resistivity of the area is from 0.34 Ωm to 239549 Ωm. The low resistivity zones identified as (blue colour) with resistivity values of 0.3 Ωm to 36 Ωm were interpreted as leachate contaminant zones containing toxic substances that contaminate groundwater. These leachate migration zones are more pronounce at 96 m to 110 m and 80 m to 120 m marks on the profiles (Figs. 5 and 6). The leachate is observed to have seeped from the surface soil to depths ranging from 0.34 m to more than 37 m in the study area. The observed leachate migration is enhanced by the loosed sandy soil layer at the study area. Layers of high resistivities (light Green to Yellow) with resistivities ranging from 150 Ωm to 871 Ωm were mapped and identified as porous and permeable sandy layers of varying grain sizes

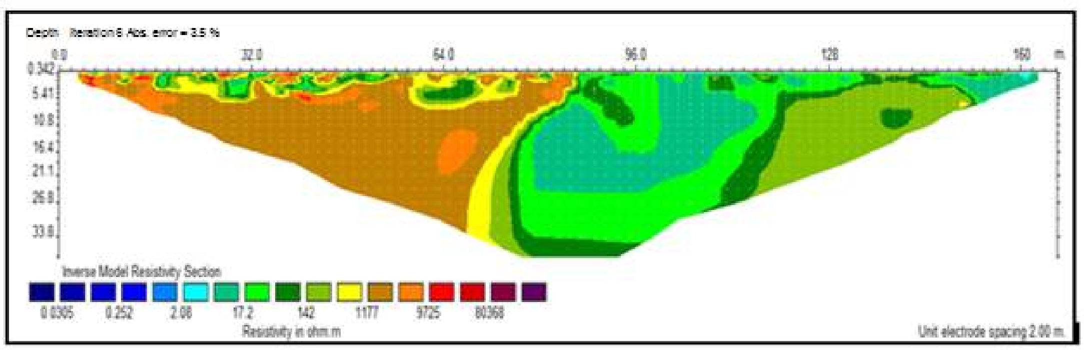


Fig. 4. The 2D inverse model resistivity section of profile 1

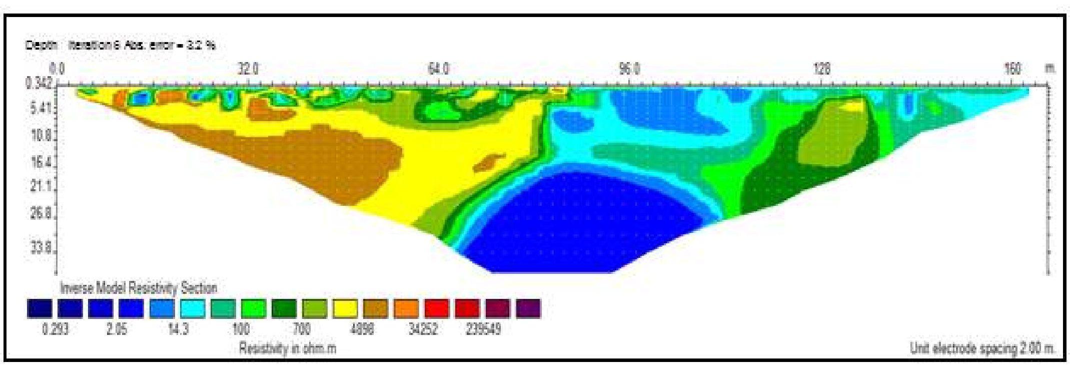


Fig. 5. The 2D inverse model resistivity section of profile 2

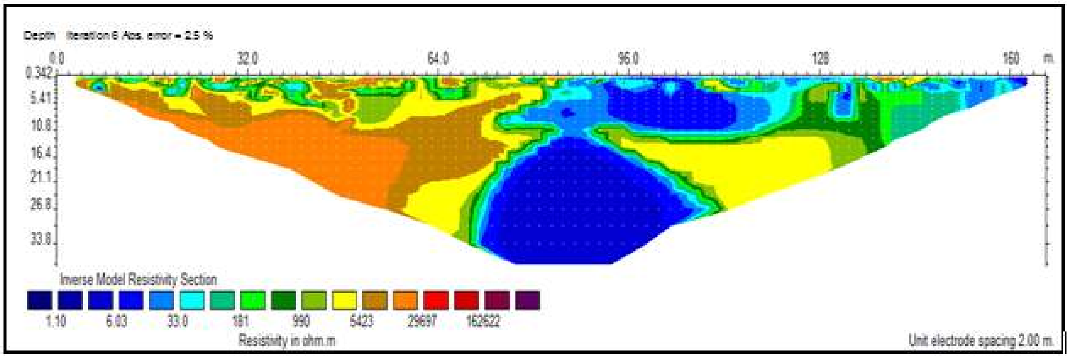


**Fig. 6. The 2D inverse model resistivity section of profile 3**

and moisture contents. Finally, compounds of anomalously high resistivities between 808Ωm and 4069Ωm (purple to Red) suspected to be landfill gases (Ammonia, Methane or Carbon (IV) Oxide) at depths exceeding 26 m. The pseudosection results show no significant clay formation in the study area an indication that the subsurface zone is prone to contamination because of the permeable (sandy) layer.

## 5. CONCLUSION

The results of the geophysical survey of landfill environs to evaluate the contamination zones at Ikpoba Okhia local government area in Benin City was quite revealing. In this study, we have demonstrated some of the advantages of ERT information from surface measurement. The electrical resistivity imaging technique was used to locate and monitor the vertical and horizontal distribution of leachate plumes in landfill site. The leachate plumes have contaminated the surface soil to depths of more than 37 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 ERT approach of geophysical techniques for acquiring the physical properties of landfills. The employment of ERT technique allows the resolution of possible discrepancies and the most accurate description of landfill's characteristics.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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