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Volumetric Analysis Of 3-D Resistivity Distribution of Leachate Plume in Third Cemetery, Benin, South-South, Nigeria

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Abstract.

This paper aims to carry out the volumetric analysis of 3-D resistivity distribution of leachate plume in Third Cemetery, Benin City, South-South, Nigeria. If not appropriately located or not sufficiently protected, cemeteries pose a significant health problem for the people (Fisher and Croupkamp,1993). Health concern about the possible impact of the cemeteries in Nigeria on the water supply has prompted this research. The research engaged 2-Dimensional and 3-Dimensional imaging (tomography) to investigate the presence and migration of leachate plumes in the cemetery and computation of time-lapse to detect the time rate of migration in both the vertical and horizontal directions. The geoelectric models obtained for the surveys displayed leachate plumes starting from the laterite (the burial environment) down to the sandy formation (the regional water supply source). The leachate plumes presence in the sand bed is modeled and described as shown in the 2-D and 3-D displays. This study showed that parts of the cemetery had been contaminated. This contamination was also observed to have infiltrated into the aquifer in the cemetery. 3-D block model, using Voxler 4.0 software was employed to carry out the volumetric analysis of the 3-D resistivity distribution of leachate plume in the Third Cemetery.

Keywords: Third Cemetery, Leachate, Groundwater, Volumetric Analysis.

1. Introduction

Interment of bodies in cemeteries remains a widespread practice and the only alternative endpoint to dead bodies in Nigeria. In Nigeria, this practice had not been perceived as having a significant potential contaminant effect in the environment and especially the groundwater component. However, the implications of land utilization for the burial of dead human bodies in the form of cemeteries and many cases associated with coffin and caskets used for the interment of remains has received no consideration in Nigeria. According to DOC (2016), cemetery sites/graveyards have the potential to impact the local water environment and in particular, the groundwater underlying such sites. Studies carried out from the contamination arising from cemeteries originated from minerals that are released by burial loads (Borsted and Niquette, 2000). The minerals that are needed in coffin-making may corrode or degrade releasing harmful toxic substances (Spongberg and Becks, 2000). These may be transported from the graves through seepage and diffuse into surrounding soils. From there they may leach into groundwater and become a potential health risk to the residents on areas surrounding the cemetery (Jonker and Olivier, 2012; Engelbrecht, 2010; Dent and Knight, 1998; Kim *et al.*, 2008 Williams *et al.*, 2009; Canninga and Szmigina, 2010).

This underpins the importance of carrying out studies aimed at investigating the impact and attendant risks that cemeteries present to the populace living close to them. This paper has been carried out to find the volumetric analysis of 3-D resistivity distribution of leachate plume in Third Cemetery, Benin City, South-South, Nigeria.

2. Study Area (Third Cemetery)

This study was conducted in Benin City located in South-South geopolitical zone of Nigeria. Benin City is the capital of Edo State, bounded by latitudes 06° 06′ N, 06° 30′ N and longitudes 005° 30′ E, 005° 45′ E and an area of about 500 square kilometers. The city is located within the rain forest ecological zone with annual mean temperature of 27.5 °C (Ikhuoria, 1987) and an annual mean rainfall of about 2095 mm (Ikhile and Olorode, 2011). Three cemeteries namely First, Second and Third cemeteries are located within this city. The Third cemetery which has existed for over 50 year was considered for this study because of its proximity to human residents. The cemetery which is the biggest among the cemeteries in Benin City covers an area of about 5.167 ha (Ibhadode *et al.*, 2017). Geological siting of Benin City is underlain by sedimentary formation described by Short and Stauble (1967).

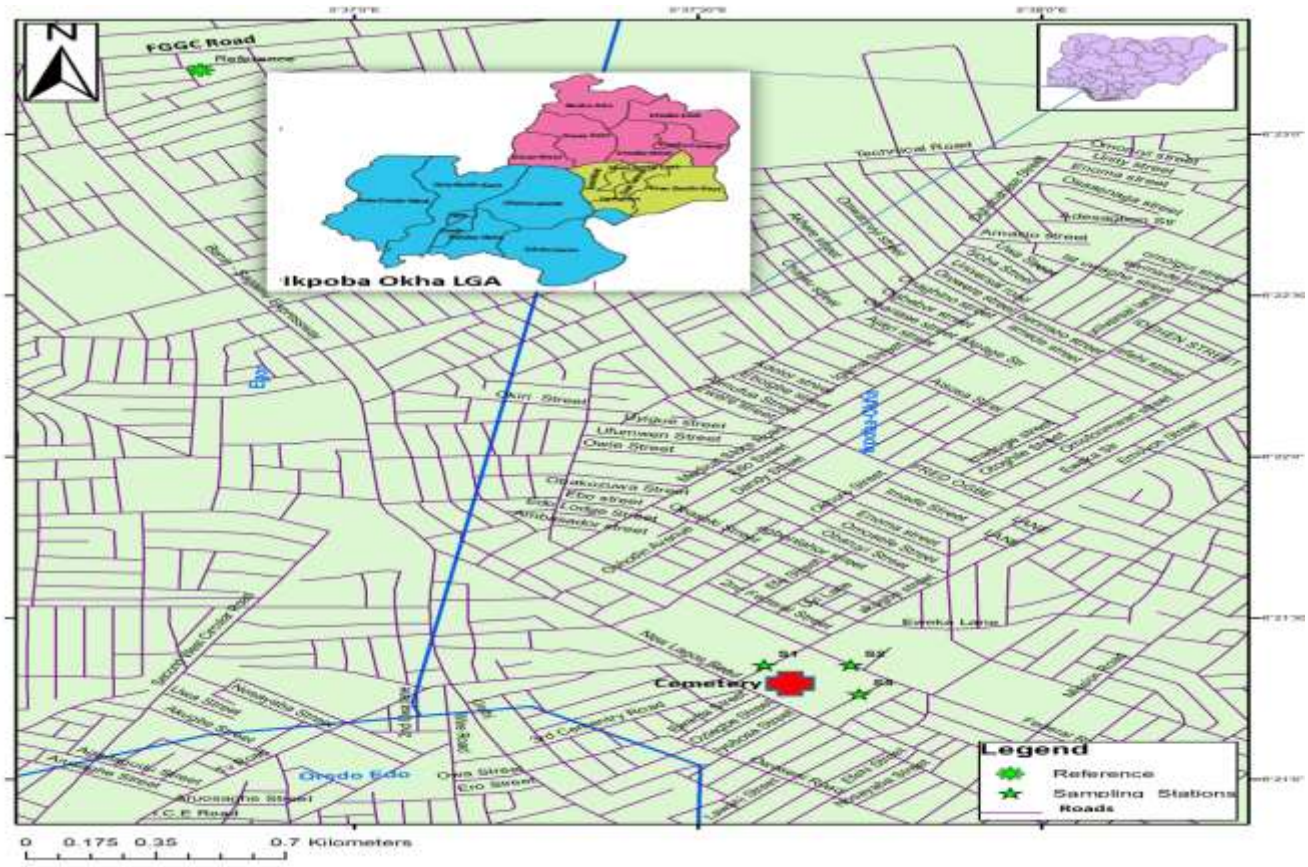


Fig 1: Map of Study Area (Third Cemetery)

3. Materials and Methods

3.1 Data Acquisition and Field Procedure

Electrical resistivity imaging data was acquired using Pasi Earth Resistivity Meter. The data coverage was made over an area defined by rectangular loop measuring 30 m by 200 m. The electrical resistivity data was collected in seven equidistant lines as 2-D data set using Wenner-Schlumberger Array at 5 m interval in both periods. The first survey, the inter-electrode spacing in each line was 10 m while in the second survey was 5 m. The resistance values read from the measuring instrument was then transformed to apparent resistivity using the geometrical factor each sequence of measurement. Wenner -Schlumberger spread was used. In first survey, in each line location, electrodes numbered 0- 41 were placed into the ground at intervals of 5 m along the line. Each time

measurement, was to be taken, array of four electrodes are selected manually and connected to the Petrozenith earth resistivity meter via single core cable.

3.2 The Wenner-Schlumberger Array

This array is the hybrid between the Wenner array and the Schlumberger array arising out of the recent work with electrical imaging surveys. This array is moderately sensitive to both horizontal structure and vertical structures (Loke, 2014).

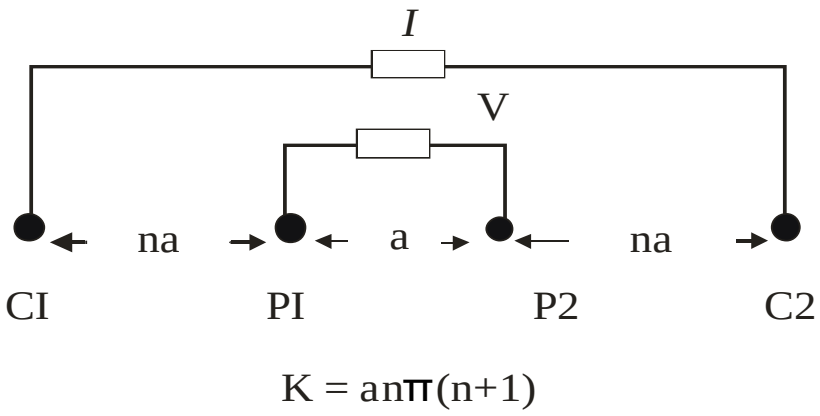


Fig 2: Wenner-Schlumberger Array

(Anthony *et al.*, 2012)

$K = an\pi(n + 1)$ (1)

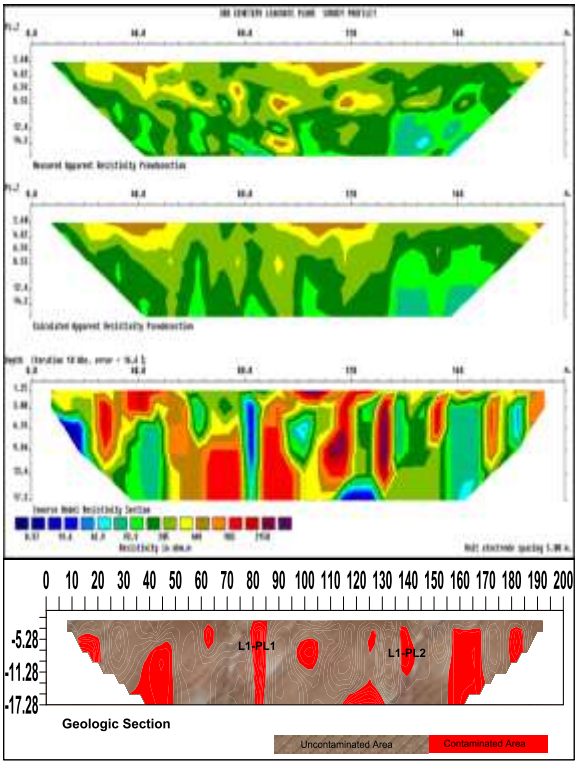
$$\rho = KR \quad (2)$$

That is apparent resistivity equals geometric factor times resistance.

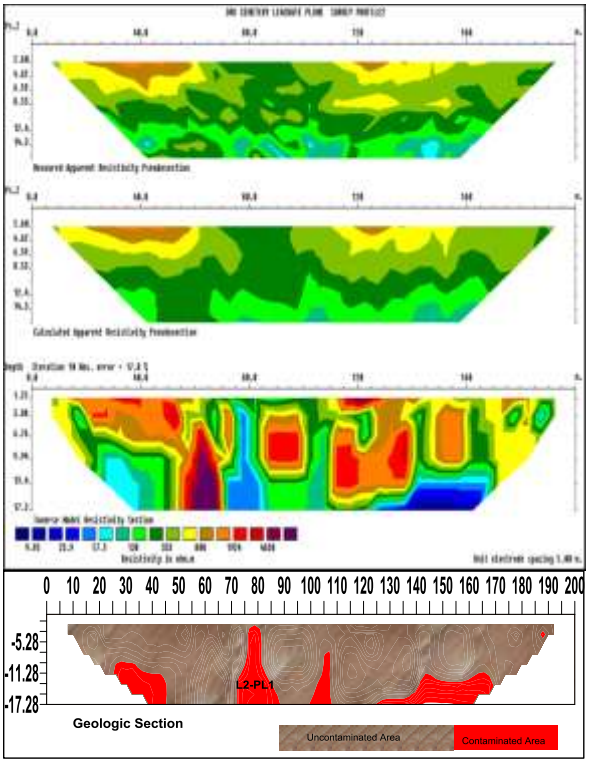
$C_1 \longleftarrow na \longrightarrow P_1 \longleftarrow a \longrightarrow P_2 \longleftarrow na \longrightarrow C_2$ {K=anπ (n+1)}

4. Data Processing and Interpretation

The electrical resistivity data collected in parallel equidistant lines was processed to obtain geoelectric models using Res2Dinv and the second survey data set was also merged and inverted as a single 3-D data set using Res3Dinv software, which is then visualized in detail using Voxler4.0. The processed data depicted clearly the locations of low resistivity (blue) which occur at depths below 5.19 m and 2.60 m in the first and second surveys (subsurface data collection started at these depths) that are most likely to indicate accumulation of leachate plumes. The second 2-D data set was collated into 3-D data set, inverted using Res3Dinv and then modeled using 3-D data visualization software, Voxler4.0 for detail visualization and analysis. The subsurface geoelectric models were shown in the form of vertical stacking of the various horizontal sections displayed by the Res3Dinv application and a model showing only the leachate plumes configurations (3-D distribution of the leachate plumes with the background sediment removed). Voxler4.0 command was used to obtain volume of the subsurface sediment contaminated by leachate plume.

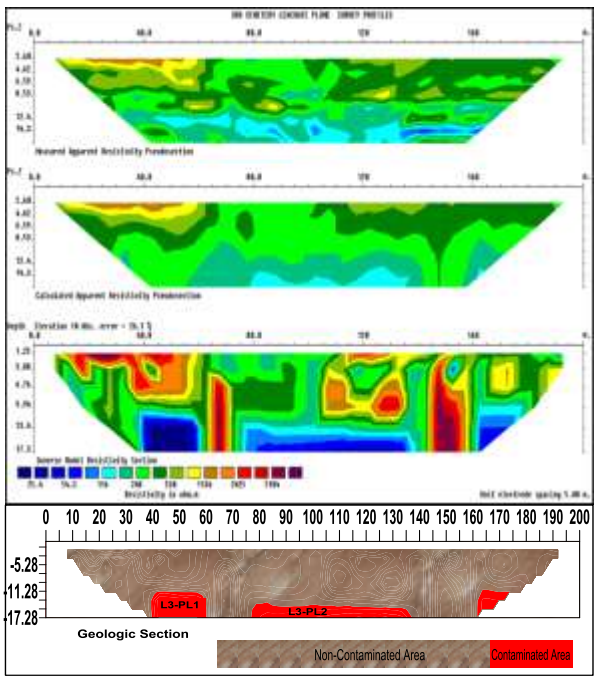


Survey Profile 1

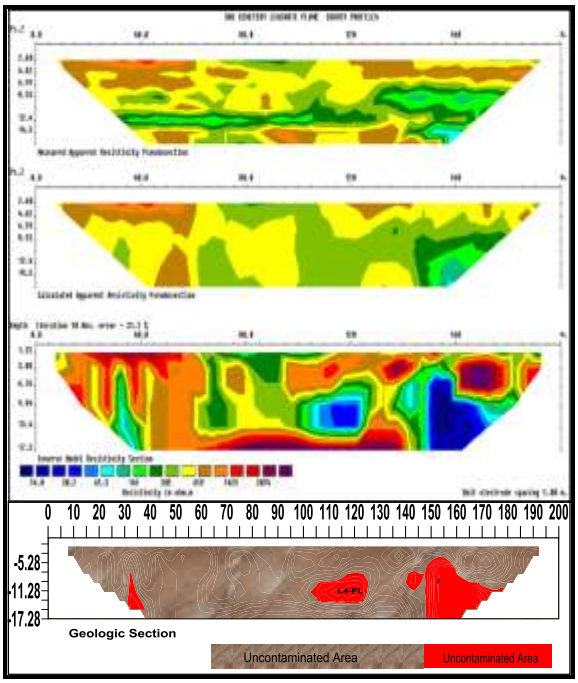


Survey Profile 2

Fig 3: 2-D Geoelectric Models of Profile1 and Profile 2 in the Survey



Survey Profile3



Survey Profile 4

Fig 4: 2-D Geoelectric Models of Profile 3 and Profile 4 in the Survey

4.1 Discussion of Geophysical Tomography

The aim of this paper is to carry out the volumetric analysis of 3-D resistivity distribution of leachate plume in Third Cemetery, Benin City, South-South, Nigeria. The acquired two-dimensional electrical resistivity data covered section of the surface laterite, fine sand just below it, very coarse sand and section of medium sand. The sandy formation is porous and highly permeable, and hence the flow leachate through it is rapid. The clay layer at depth of 46 m (152 ft) underlain the well sorted coarse sand impede further downward migration of leachate of plume leachate, and hence the coarse sand is most likely saturated with water forming the unconfined aquifer. The water table likely occurs between the very coarse sand and medium sand. As leachate plume is detected in the medium sand, water in the well sorted coarse sand will be contaminated. If this shallow aquifer is polluted, there is high probability that the nearby deep confined, coarse sand aquifer at depth of 60 m (200 ft) is at risk (if the protection capacity of the underlain clay is not satisfactory). The repeated resistivity survey revealed displacement of the detected plumes over a time.

The geoelectric models obtained for the surveys displayed leachate plumes starting from the laterite (the burial environment) down to the sandy formation (the regional water supply source). The leachate plumes presence in the sand bed are modeled and described as shown in the 2-D and 3-D displays in Fig. 3 and Fig. 4.

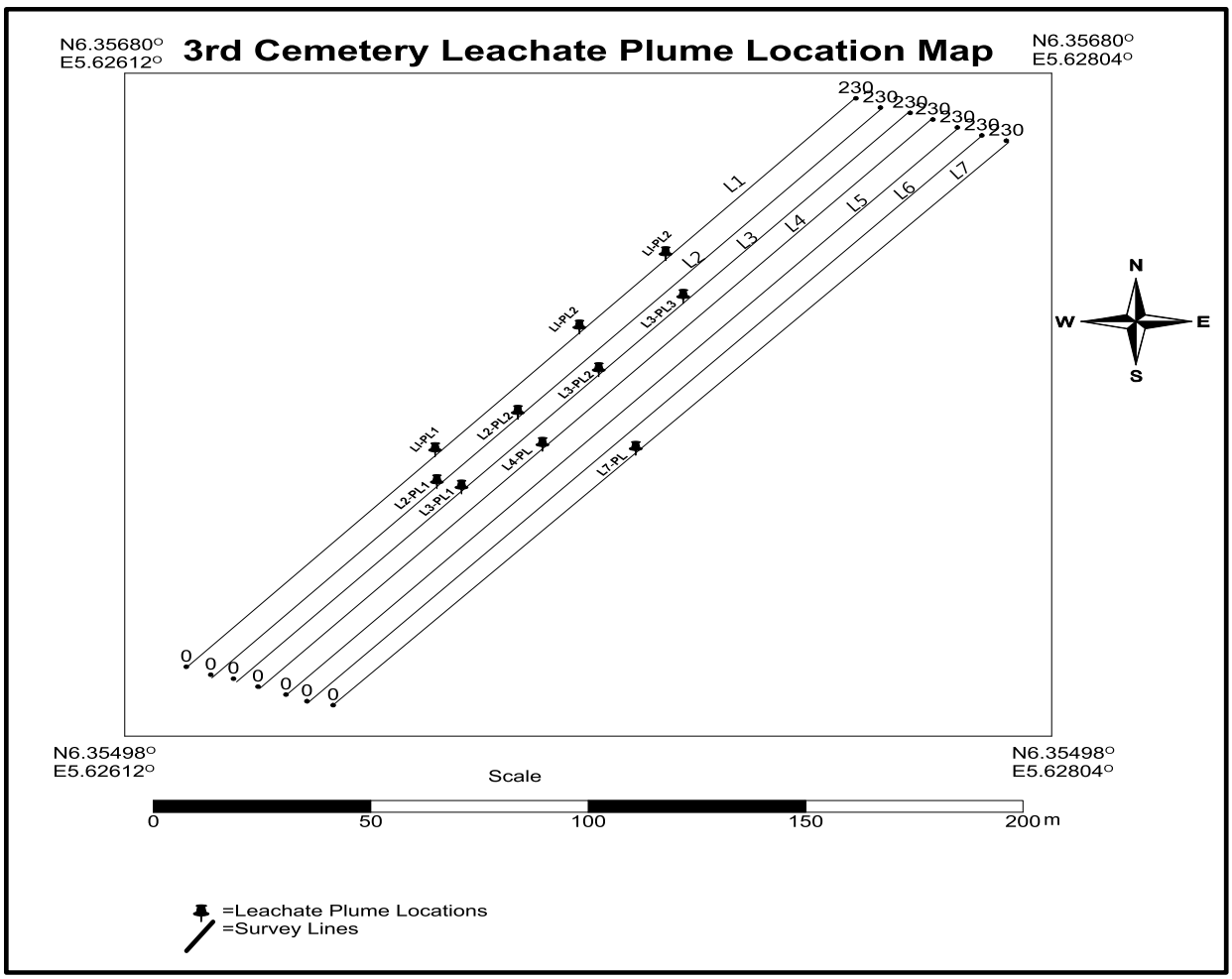


Fig.5: Surfer Plot of 3rd Cemetery Leachate Plume Locations

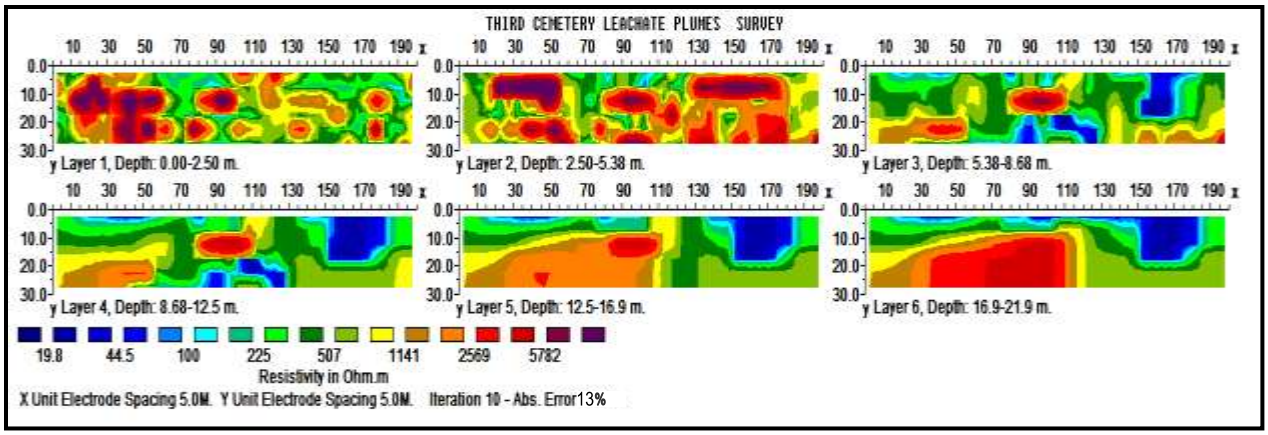


Fig. 6: Horizontal Geo electric Section of Second Survey 3-D Data Set

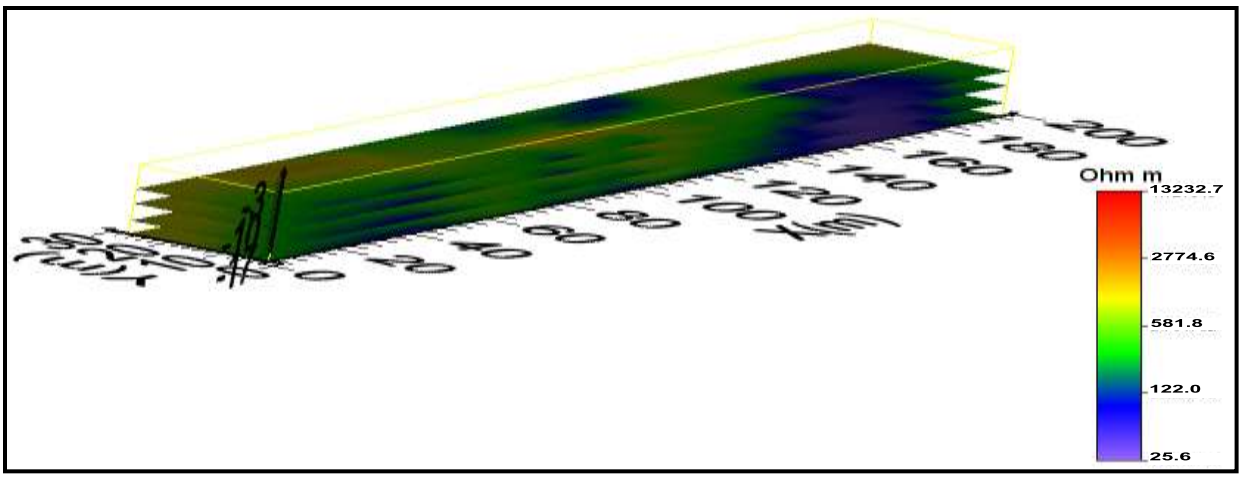


Fig. 7: 5.28 m, 8.68 m, 12.5 m and 17.3 m Horizontal Geoelectric Sections of Survey 3-D Data Set.

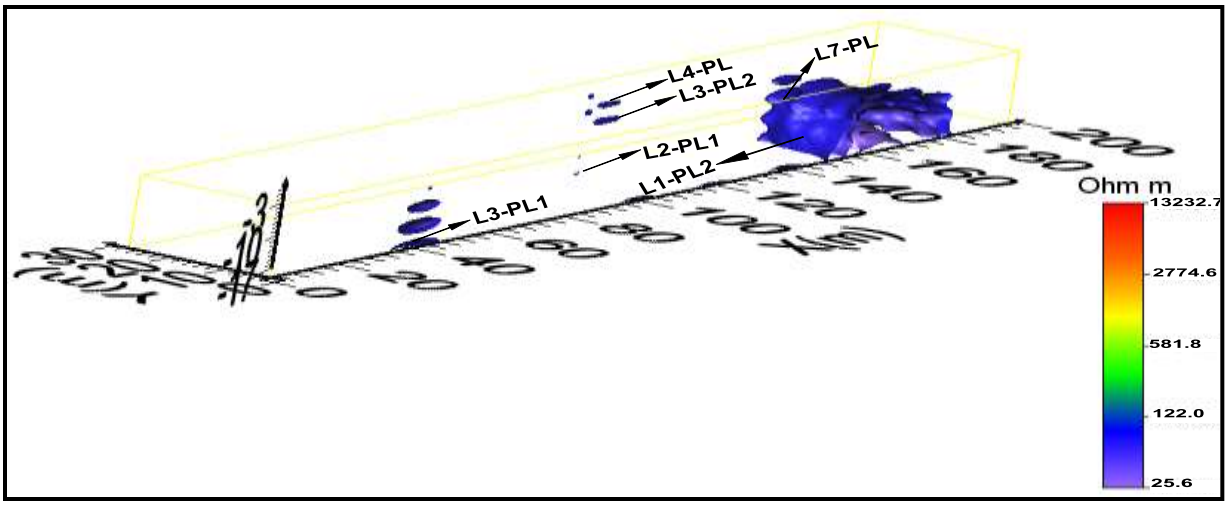


Fig. 8: 3-D Resistivity distributions of Leachate plume zones

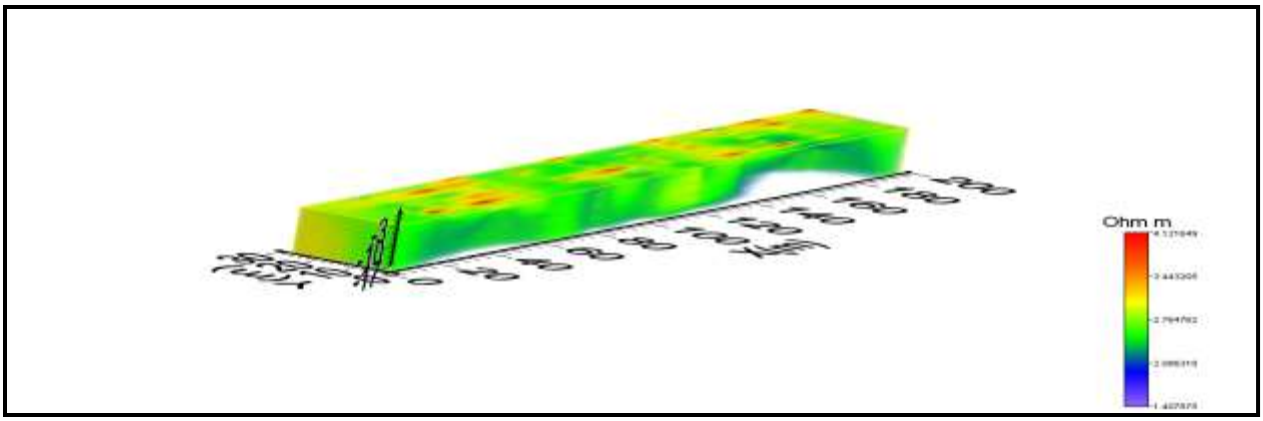


Fig. 9: 3-D Volume Render showing inhomogeneity in the subsurface

The leachate plumes interpreted from the 2-D vertical display were located in the 3-D distribution plot using their depths of occurrence and lateral locations on the 2-D survey profiles. 3-D display of the leachate plumes was then made.

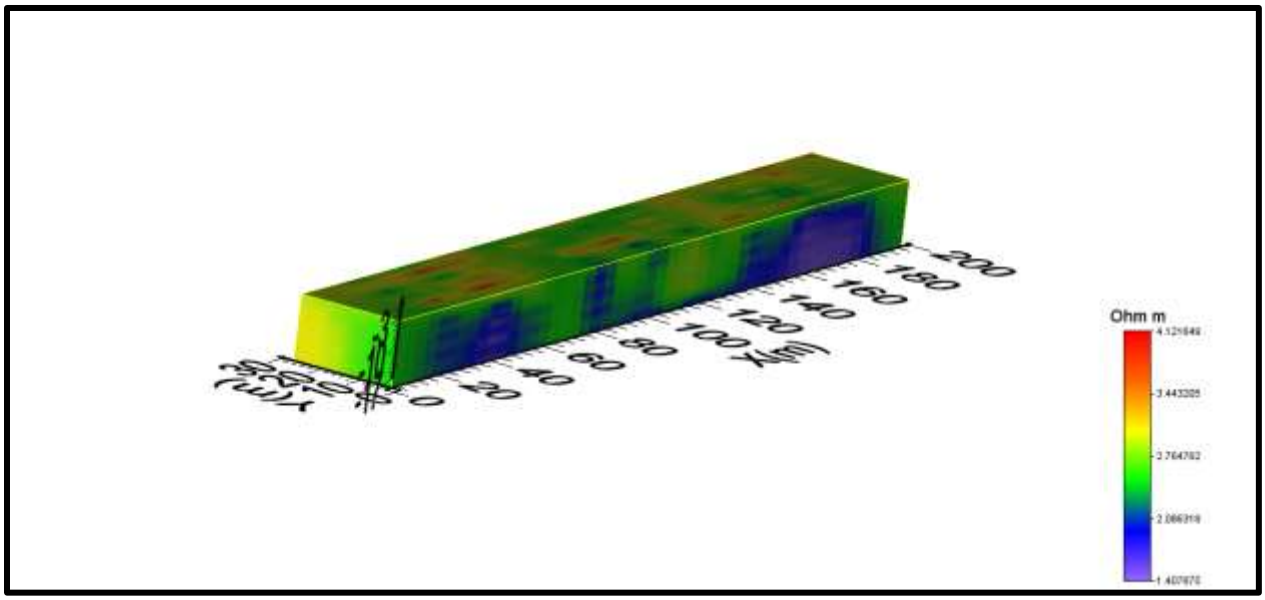


Fig. 10: 3-D Face Render of the Earth Volume Investigated

The leachate plumes interpreted from the 2-D vertical display were located in the 3-D distribution plot using their depths of occurrence and lateral locations on the 2-D survey profiles. The volumetric analysis (carried out at the Voxler4 window) of the plume zones indicate that, out of 75,231m^3 of the subsurface visualized, 6,322 m^3 is the zone contaminated by leachate plume that is 8.4% of the earth volume investigated contain leachate plume.

5. Conclusion

The geoelectric models obtained for the surveys displayed leachate plumes starting from the laterite (the burial environment) down to the sandy formation (the regional water supply source). The leachate plumes presence in the sand bed are modeled and described as shown in the 2-D and 3-D displays. This study showed that parts of the cemetery had been contaminated. This was evident in the attendant low resistivity values. This contamination was also observed to have infiltrated into the aquifer in the cemetery. The volumetric analysis of the plume

zones indicates that out of the 75,231 m^3 of the subsurface that was imaged 6,322 m^3 is the zone contaminated by leachate plume. That is 8.4 % of the earth volume investigated contain leachate plume.

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