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The Impact of a Municipal Solid Waste Dumpsite on Soil and Groundwater Using 2-D Resistivity Imaging Technique

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Authors' contributions

The work was carried out by both authors. Both authors were involved in the geophysical data acquisition. Author AOB designed the study and managed the literature searches. Author GOI processed the data. Authors AOB and GOI interpreted the processed data. Author GOI compiled the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

The impact of a municipal solid waste dumpsite on soil and groundwater in Port Harcourt municipality was investigated using 2-D resistivity imaging technique. The resistivity data was acquired along six traverses, two of which was used as control line. The objective of the study was to determine the lateral and vertical limits of leachate contamination. The results of the 2-D resistivity imaging for the four profile lines investigated isolated two possible pollutants zone around the landfill sites. The zone exhibit anomalously high resistive with varying resistivities between 264 Ωm and 3459 Ωm. This anomaly is deduced to be associated with landfill gases such as Ammonia, Methane, Sulphur (IV) oxide or Carbon (IV) oxide, at depths exceeding 31 m and contaminant leachate plumes of low resistivities having values that vary between 0.203 Ωm and less than 388.5 Ωm at depths between 0.625 m to more than 31 m. This resistivity plausibly suggests that the aquifers and soil in the area haves been contaminated by leachates due to the in an un-engineered landfill. However, the soil and groundwater beneath the control lines have not been impacted by the municipal waste landfill.

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1. INTRODUCTION

The indiscriminate dumping of wastes in solid waste landfill has led to the contamination of soil and groundwater [1-3]. Landfills pose a serious threat to the quality of soil and groundwater. The extent of this threat depends on the quantity and composition of leachate and distance of the landfill to the groundwater. In the study area, solid wastes are mostly dumped in unsealed landfills. The solid wastes dumped in the landfills are domestic wastes, agricultural waste, building waste, hospital waste and industrial waste.

The study of landfills has been carried out by different researchers using 2-D resistivity imaging method [4-8]. The 2-D resistivity imaging has the capacity to determine the vertical and the lateral extent of resistivity changes of leachates pollution in soil and groundwater as a result of the landfill [8].

2. LOCATION AND ACCESSIBILITY OF THE STUDY AREA

The study was conducted around Eliozu community in Port Harcourt municipality, Rivers state (Fig. 1). The study area lies on latitude of about 7°04′ to 7°10′N and longitude 4°50′ to 4°52′E (Fig. 1). The study area can be accessed through tarred and un-tarred motorable roads and bush paths which were used for the traverses.

The study area is moderately vegetated with almost flat topography. It is characterized by alternate wet and dry seasons, with a total annual rainfall of about 240 cm, relative humidity of over 90% and mean annual temperature of 27°C [9].

The study area is located in the Niger Delta sedimentary basin South-East of Nigeria. Generally, the investigated area is underlain by three statigraphic units namely; Akata, Agbada and Benin formations from earliest to recent are identifiable in the modern Niger Delta. The study area is underlain by the Benin Formation, which is predominantly sandy with intercalations of thin shale beds (Fig. 2). It also consists of massive, high porous freshwater bearing sandstones with minor clay intercalation, and it is characterized by high permeability.The formation has a maximum thickness of about 2130 m [10], moderately porous and permeable.

The sands are fine to coarse grained, granular in texture and hardly consolidated [11]. The shale intercalations in the formation has resulted in a multi-aquifer system, and both unconfined and confined aquifers are encountered at varying depths and horizons, which serves as the major source of potable groundwater supply in the area. The depth to the water table varies from 3 m during the peak of the rainy season to 15 m during the dry season. The depth to the usable aquifer in the area is approximately 30-45 m, which is penetrated by most drilled boreholes in the vicinity of the landfill site. These aquifers are recharged predominantly by infiltrations from surface precipitation [11].

3. MATERIALS AND METHODS

The 2-D resistivity imaging technique is a geophysical method of data acquisition with equal electrode spacing "a" between the current and potential electrodes. Six (6) traverses were carried out with length 200 m for traverse A, 100 m for traverses B, C, D, E and F (Fig. 1).

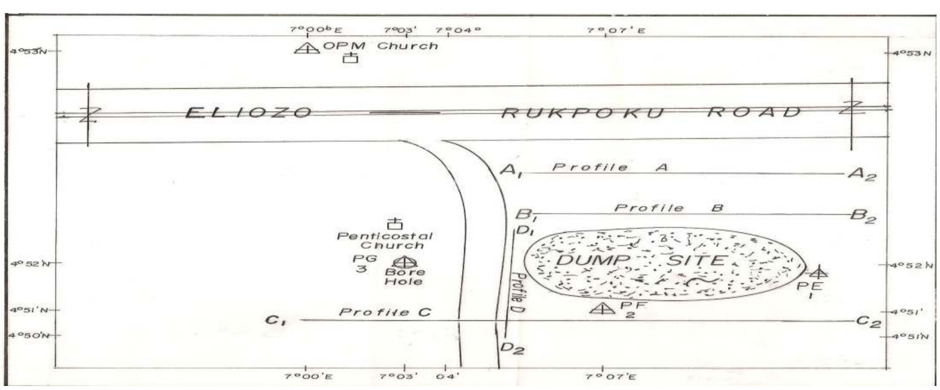

Fig. 1. Sketch map of the study area showing the dumpsite and 2-D profile lines

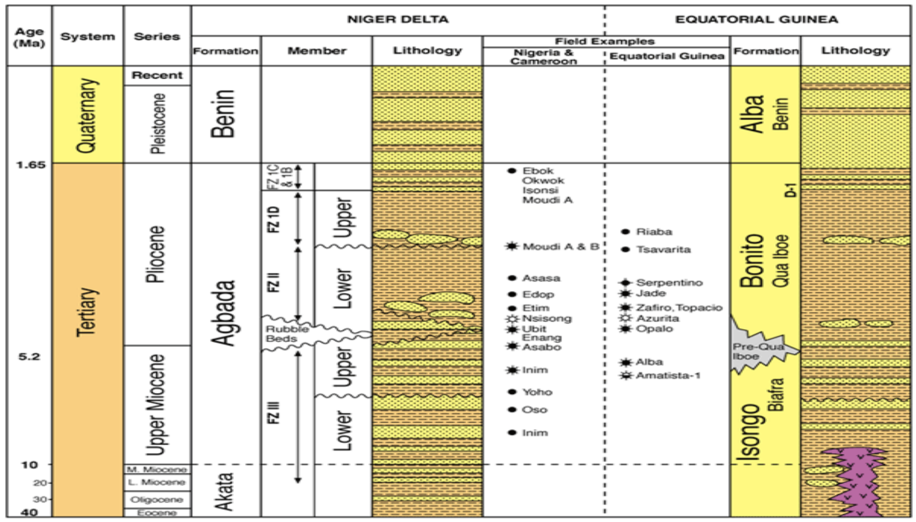

Fig. 2. Geologic and Stratigraphic map of the area [11]

Traverse D and E where used as control for the study. The control line is 1 km from the landfill site. The ABEM terrameter SAS 1000C with the Wenner-alpha electrode method were carried out in the geophysical survey. In the study, the terrameter measures the variation in the electrical resistivity of the subsurface by injecting electric current through current electrodes (C1, C2) and measuring the potential difference from the potential electrodes (P1, P2). The instrument is designed to measure the resistance. The initial parameters used for the survey include a current of 2 mA and four cycles for averaging the resistance value. The current, potential electrodes were moved from the beginning to the end of the traverse line in a leap frog manner until spacing's of 1a, 2a, to a maximum of 6a was acquired to build a pseudo section of the lateral and vertical variation in subsurface resistivity for all the entire traverses (Fig. 3).

The apparent resistivity values for the Wenner array were obtained using equation (1) by converting the resistance values obtained from the field.

$$\rho_a = 2\pi aR \qquad (1)$$

where

a = Electrode spacing
R = Resistance of the ground recorded in Ohms.

The apparent resistivities computed from equation (1) were recorded in a 2-D resistivity imaging field data sheet for subsequent data analysis.

4. RESULTS AND DISCUSSION

4.1 Presentation of 2-D Imaging Results

The apparent resistivity (ρ_a) values calculated, the X-location of the electrodes, and the electrode spacing's were keyed into the software template for the inversion using the RES2DINV resistivity imaging interpretation software [12].

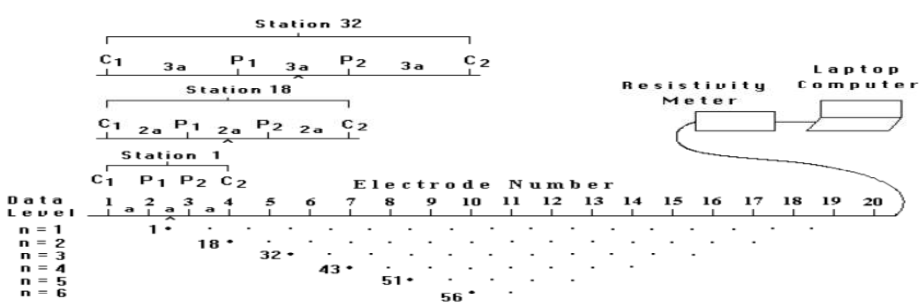

Fig. 3. 2-D electrical resistivity survey configuration [12]

The finite element approach to the forward model and least square inversion scheme were carried out in the inversion process [12]. The computer iteration process is continued until the root mean square (RMS) error between the measured and calculated apparent resistivity were minimized. The ideal root mean square (RMS) error should be less than 5% although this was not always achievable. In each of the 2-D resistivity imaging (pseudosection), the horizontal axis represents distance in metres along the surface and also spacing between electrodes while the vertical axis represents depth in metres. The colour codes at the bottom of the pseudosection indicate subsurface resistivity values in Ohm-metres. The resulted inverse model pseudosections shows a series of changes in resistivity with depth related to impact of the leachate contaminant as a result of the solid waste landfill in the study area (Figs. 4.0-4.3).

4.2 Traverse A

Traverse A is located along the northeast-southwest and is about 20 m away from the edge of the landfill to the direction of the North (Fig. 4.0). The result of the inverse model pseudosection mapped two distinctive anomalous resistivity zones and these are the high and low resistivity zones. The zones of high resistivity (pink-purple) in the direction of the south-west has resistivity values varying from 630 Ωm to >1361 Ωm at surface points between 12.4 m to 80 m, and depth ranging from 1.25 m to 6.30 m. The high resistivity zone was interpreted as probable landfill gas contaminated soil. Below the zone of high resistivity is a low resistivity zone (blue) stretching from the direction northeast-southwest of the pseudosection. The range of the resistivity values varies from 9.93 m to 26.1 m. This low resistivity zone were interpreted as probable leachate plume. The probable landfill waste gases and leachate are moving in the northwest-southeast direction in line with the trend of the Niger delta area and regional groundwater flow of the study area.

4.3 Traverse B

Traverse B is located along the northeast-southwest and is about 10 m away from the edge of the landfill to the direction of the North (Fig 4.1). The inverse model of the resistivity pseudosection mapped two distinctive anomalous resistivity zones and these are the high and low resistivity zones. The zone of low resistivity (blue) which is seen in the southwest of the pseudosection with resistivity values varying from <0.407 Ωm to 3.51 Ωm at surface points ranging from 12.6 m to 34 m and depth between 0.63 to 10.1 m. This low resistivity zone were interpreted as probable leachate plume. To the direction of the central and northeast of the pseudosection, is a high resistivity zone (purple-pink) with resistivity ranging from 145 Ωm to >778 Ωm and at surface points ranging from 51 m to 81 m and depth varying from 8.65 m to 15.7 m, semi-oval in shape and this were interpreted as probable landfill gas contaminated soil.

4.4 Traverse C

Traverse C is located in the direction northeast-southwest and 10 m away from the edge of the landfill to the direction of the north (Fig. 4.2). The inverse model of the resistivity pseudosection mapped two distinctive anomalous resistivity zones and these are the high and low resistivity zones. The zones of high resistivity (pink-purple) in the direction of the southwest and northeast has resistivity values varying from 714 Ωm to >1195 Ωm at surface points ranging from 24 m to 46 m and 61 m to 104 m, respectively, and the depths ranging from 0.624 m to 11.6 m. This was interpreted as probable landfill gas contaminated soil. There is a low resistivity zone (blue) sandwiched between the high resistivity zone with resistivity ranging from <33.1 Ωm to 92.2 Ωm at surface points ranging from 54 m to 71 m, and depth ranging from 0.624 m to 3.37 m. This low resistivity zone were interpreted as probable leachate plume seeping from the surface to the subsurface.

4.5 Traverse D

Traverse D is located in the direction northwest-southeast and 10 m away from the edge of the landfill to the direction of the south (Fig. 4.3). It is perpendicular to traverse A, B and C to the west. The inverse model of the resistivity pseudosection mapped two distinctive anomalous resistivity zones and these are the high and low resistivity zones. The zone of low resistivity (blue) is delineated at the entire surface of the pseudosection with resistivity values varying from < 2.08 Ωm to 5.04 Ωm and depth ranging between 0.625 m to 3.39 m. This low resistivity zone were interpreted as probable leachate plume contaminated soil. Below the low resistivity zone, is a high resistivity zone (purple to pink) with resistivity ranging from 2315 Ωm to >3458 Ωm and depth ranging from 6.72 m to 15.6 m. These were interpreted as probable landfill gas contaminated soil.

4.6 Traverse E

This traverse is situated along the northwest-southeast and 1 km from the dump to the north and it serves as control (Fig. 4.4). A high anomalous resistivity zones were delineated. This high resistivity anomaly (pink to purple) was mapped on the surface of the section stretching throughout the entire length of the traverse. It has a resistivity varying from 355 Ωm to > 1105 Ωm and depth varying between 0.938 m to >14.8 m, no leachate plume was observed in the inverse model section and these implies that the soil and groundwater within the study area have not been impacted upon by the landfill.

4.7 Traverse F

This traverse is situated along the northwest-southeast and 1 km from the edge of the dump to the north and it serves as control (Fig. 4.5). A high anomalous resistivity zones were delineated. This high resistivity anomaly (pink to purple) was mapped on the surface of the section stretching throughout the entire length of the traverse. It has a resistivity varying from 233 Ωm to > 678 Ωm and depth varying between 0.938 m to >14.8 m, no leachate plume was observed in the inverse model section and these implies that the soil and groundwater within the study area have not been impacted upon by the landfill.

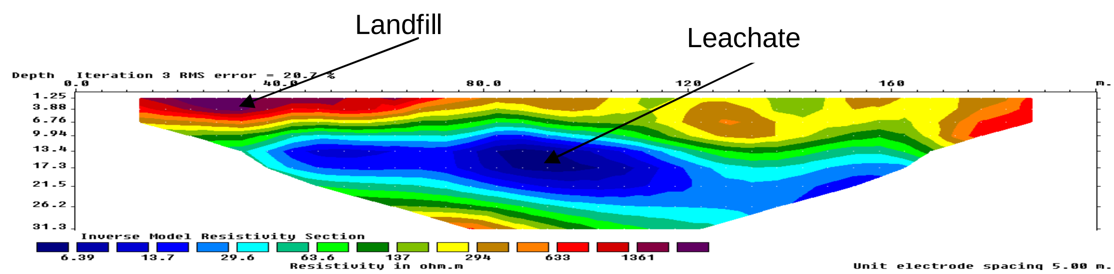

Fig. 4.0. Inverse model resistivity section along traverse A

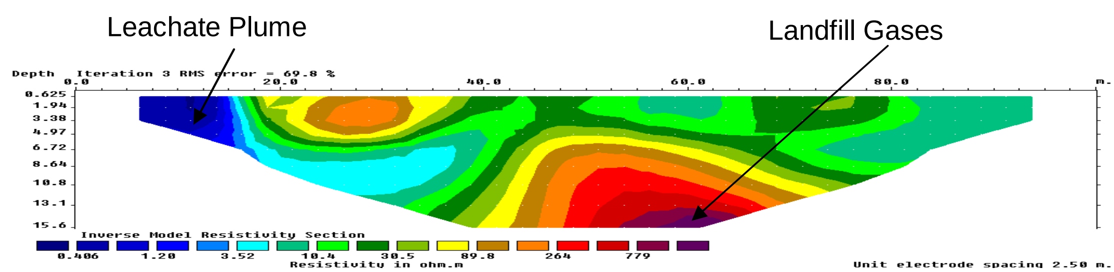

Fig. 4.1. Inverse model resistivity section along traverse B

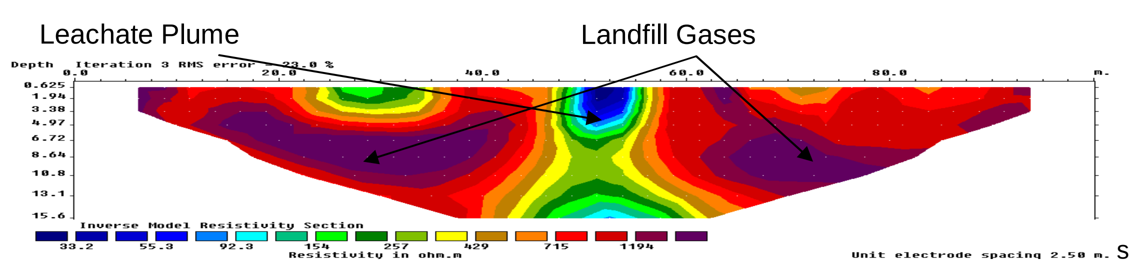

Fig. 4.2. Inverse model resistivity section along traverse C

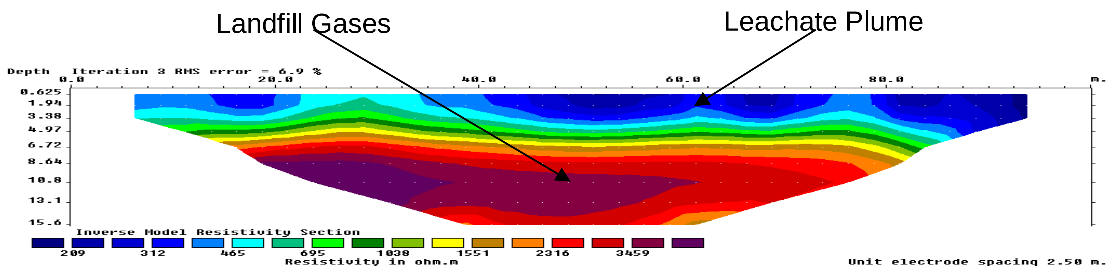

Fig. 4.3. Inverse model resistivity section along traverse D

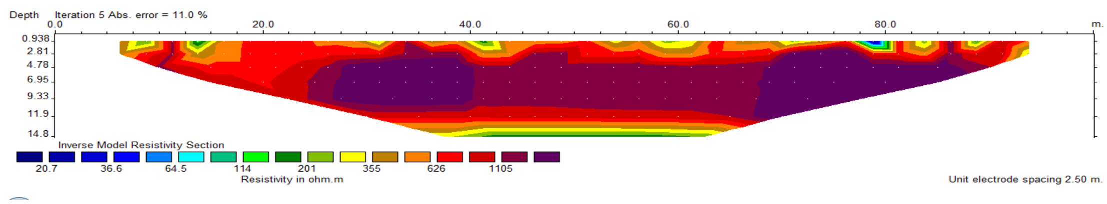

Fig. 4.4. Inverse model resistivity section along traverse E (Un-impacted background resistivity)

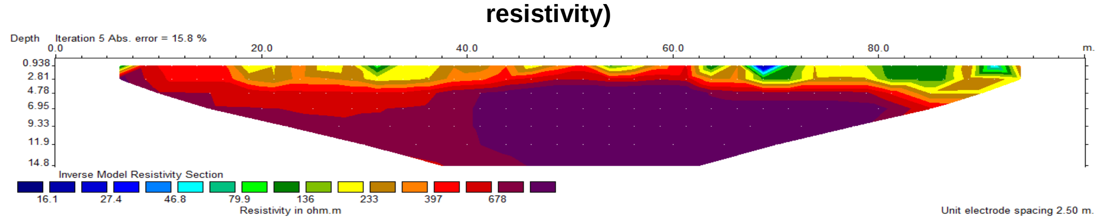

Fig. 4.5. Inverse model resistivity section along traverse F (Un-impacted background resistivity)

5. DISCUSSION OF RESULTS

The impact of municipal solid waste landfill on groundwater quality was investigated using 2-D resistivity imaging technique. The results of the 2-D resistivity pseudosection along the four traverses shows that the groundwater and soil within the vicinity of the landfill site have possibly been contaminated with leachate and waste gases such as NH_4, CH_4, CO_2, H_2S, and SO_2. The contaminants have, resistivity values varying from <0.406 Ωm to 388.5 Ωm, and 264 Ωm to >3459 Ωm, respectively. The low resistivity of leachates is as a result of its high conductivity. For landfill gases, it has a low conductivity hence its high resistivity. The results of the model section reveal that the surrounding soil and groundwater around the landfill might have been contaminated to depth exceeding 30 m and it lies within the aquifer zone of the study area. These solid waste landfill poses health risk to the people that rely on the groundwater from aquifers in the study area for their domestic needs. The results of traverse E and F which were used as control during the study reveals that the soil and groundwater have not been impacted upon by the landfill contaminants.

6. CONCLUSION

In the study, 2-D resistivity imaging mapped the probable leachate contaminant plumes and possible solid waste landfill gas in groundwater and soil within the landfill site in traverses A, B, C and D as compared to traverse E and F which serves as control and were not impacted upon by the municipal waste due to the landfill. These landfill contaminants have penetrated to depths exceeding 30 m which is within the groundwater aquifer system in the study area. This portends great risk to the resource users, due to disease causing micro-organisms and heavy metal poisoning due to the landfill.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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