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2D GEOPHYSICAL EVALUATION OF SUB-SOIL CONTAMINATION - A CASE STUDY

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Abstract

In this study, 2D surface resistivity survey was undertaken around two power houses in Covenant University Ota in Ogun State, Nigeria to investigate the possible spread within the subsurface, of disposed used hydrocarbon products. The 2D resistivity imaging technique using the Wenner array method was adopted for the survey with the aid of the SAS 1000 Terrameter. Five traverses were occupied with two of them (traverses 1and 4) obtained 3 m away from the two power houses, while the remaining three served as control. The study delineated three subsurface geoelectric layers with resistivity values ranging from 57 Ωm to 1258 Ωm on all the profiles. The inferred lithologies from the 2D resistivity inversion are topsoil, sandy clay and lateritic materials. The high resistivity values (800 Ωm - 1258 Ωm) on traverse 1 near the power house behind College of Science and Technology (CST) building may be as a result of the contamination arising from the disposed hydrocarbon products. Traverses 2 to 5 however showed no evidence of contamination of the soil around the study area. The results of the analysis have shown that no appreciable amount of contamination has been observed as a result of the disposal of used hydrocarbon products around the study area. However, continuous disposal of used diesel and other hydrocarbon products around the power houses in the University pose a lot of danger of contamination to the environment and underground water body with time.

Keywords: Contamination; Hydrocarbon; Resistivity Structure; Subsurface; Traverse.

1. Introduction

Contamination from hydrocarbon products such as gasoline, diesel and heavy oils as well as the possible scope of the groundwater bodies is one of the major current environmental issues of great concern in Nigeria. The spills may occur as a result of blowouts due to overpressure, equipment failure, operators errors, corrosion, sabotage (vandalisation of pipelines), pigging operations, flow line replacement, flow station upgrades, tank rehabilitation and natural phenomena such as heavy rainfall, flooding, falling of trees and lightening [1]. When this happens, the ecosystem suffers tremendously. Whenever there is oil spillage within an environment either by surface tank or pipes, it percolates the subsurface and the underlying strata. The degree of infiltration of the oil is dependent on a number of factors: Viscosity (physical properties of oil that determine the degree of free flow through a medium). Less viscous petroleum products like kerosene, diesel, and gasoline constitute a major source of contamination than the more viscous products like oil and other lubricant. The former will infiltrate and transmit faster through any sand medium than the later. Both surface and underground water may be negatively affected as the percolating hydrocarbon substances mixes with the underground water and get them contaminated. Thus, the need to ascertain the extent the subsurface water has been affected by hydrocarbon leakage from the pipelines and other sources of discharge of these products into the environment. The study aims at investigating the likelihood of contamination of groundwater around some power houses in Covenant University, where used hydrocarbon products like diesel and gas are disposed on the ground around these power houses.

2. Location of Study area

Covenant University is located in Ado Odo Ota local Government of Ogun State, Southwestern Nigeria. The area lies within Latitude 3° 9' 29" E and Longitude 6° 40' 17" N (Figure 1), with an elevation of approximately 40 m above sea level. Covenant University is located at Km 14 along the Sango-Idi-roko road with topography of the area relatively flat and gentle undulations.

Figure 1 Google Earth map showing location of study area and traverses (T)

3. Geology of the study area

The study area is located in the eastern Dahomey basin of the southwestern Nigeria. The stratigraphy of the eastern Dahomey basin has been discussed by various workers and several classification schemes have been proposed. These notably include those of [2-9] among others. Inspite of all these classification schemes, there are still controversies on age assignments and nomenclatures of the different lithological units within the basin. Omatsola and Adegoke [3] proposed the Cretaceous sequence in the eastern Dahomey basin as beginning with the Abeokuta Group, made up of three formations from oldest to the youngest namely; the Ise, Afowo and Araromi Formations. The Ise Formation unconformably overlies the basement complex of southwestern Nigeria and consists of conglomerates and grits at base and in turn overlain by coarse to medium grained sands with interbedded kaolinite. The conglomerates are unimbricated and at some locations, ironstones occur [7]. The age is Neocomian to Albian. Overlying the Ise Formation is the Afowo Formation, which is composed of coarse to medium grained sandstones with variable but thick interbedded shales, siltstones and claystone. The sandy facies are tar-bearing while the shales are organic - rich [10]. The lower part of this formation is transitional with mixed brackish to marginal horizons that alternate with well sorted, sub-rounded sands indicating a littoral or estuarine near-shore environment of deposition. Using palynological assemblage, Billman [6] assigned a Turonian age to the lower part of this formation, while the upper part ranges into the Maastritchtian. The Araromi Formation overlies the Afowo Formation and has been described as the youngest Cretaceous sediment in the eastern Dahomey basin [3]. It is composed of fine to medium grained sandstone at the base, overlain by shales, siltstone with interbedded limestone, marl and lignite. This Formation is highly fossiliferous containing abundant planktonic foraminifera, ostracods, pollen and spores. Omatsola and Adegoke [3] assigned a Maastritchtian to Palaeocene age to this formation based on faunal content. The lithostratigraphic units of the Cretaceous to Tertiary sedimentary sequence of eastern margin of Dahomey basin is summarized in Table 1. The Ewekoro Formation overlies the Araromi Formation in the Eastern Dahomey basin. It is an extensive limestone body, which is traceable over a distance of about 320km from Ghana in the west, towards the eastern margin of the Dahomey basin in Nigeria [11]. Elueze and Nton, [8] has reported that the limestone is of shallow marine origin owing to abundance of coral line algae, gastropods, pelecypods, echinoid fragments and other skeletal debris. It is Palaeocene in age. Overlying the Ewekoro Formation is the Akinbo Formation, which is made up of shale and clayey sequence [4].

Table 1 Stratigraphy of eastern Dahomey basin

ERA	Jones & Hockey (1964)			Omatsola & Adegoke (1981)		
	Age	Formation	Lithology	Age	Formation	Lithology
Quaternary	Recent	Alluvium				
Tertiary	Pleistocene-Oligocene	Coastal Plain Sands		Pleistocene-Oligocene	Coastal Plain Sands	
	Eocene	Ilaro		Eocene	Ilaro Ososhun	
	Paleocene	Ewekoro		Paleocene	Akinbo Ewekoro	
Late Cretaceous	Late Senonian	Abeokuta		Maastrichtian Neocomian	Araromi Afowo Ise	
PRE - CAMBRIAN CRYSTALLINE BASEMENT						

- Alluvial sediments
- Siltstone/mudstone
- Unconsolidated sands and silty sands
- Poorly consolidated shale/clay
- Laminated fossiliferous shale
- Limestone, fossiliferous
- Basal conglomerate with grits and siltstone

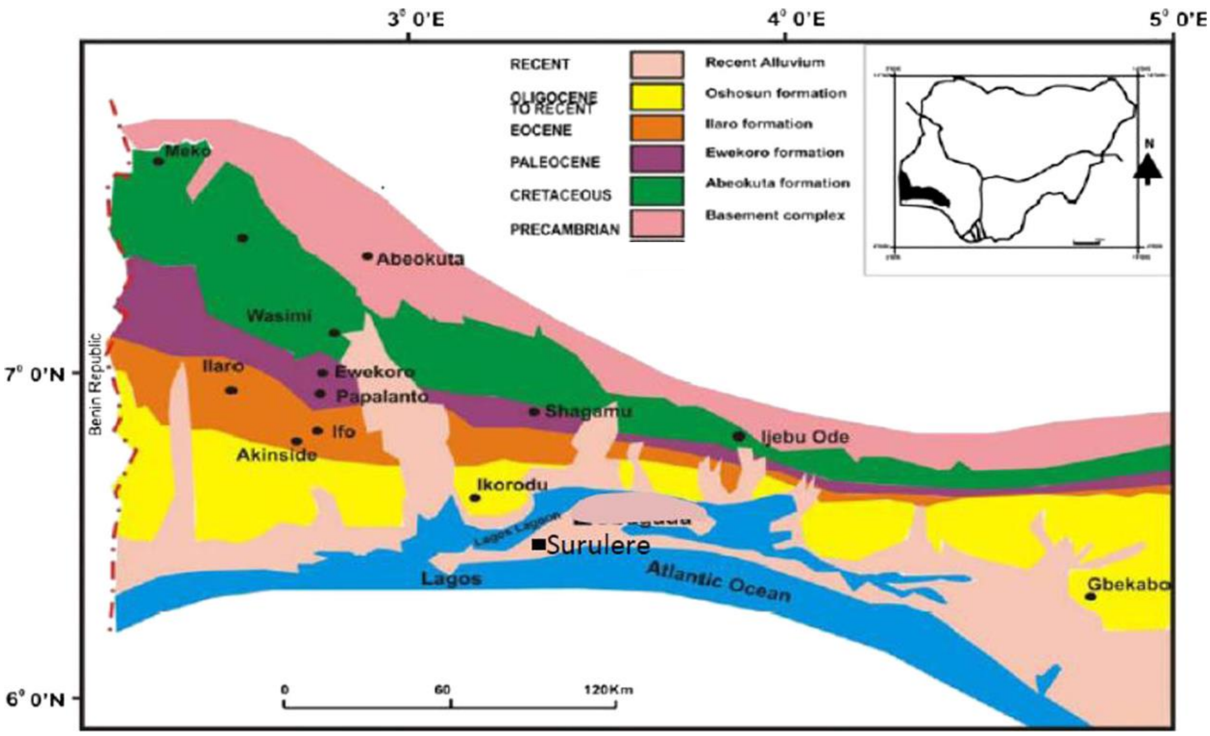

Figure 2 Geological map of eastern Dahomey Basin (modified after Billman [6])

4. Method of Investigation

In order to map the possibility of soil contamination, a total of five Constant Separation Traverses were carried out within the study area using the Wenner array electrode configuration and electrode spacing between 2 to 12 m along the traverses. Traverses 1 and 4 were occupied 3 m away from the polluted portion around the power houses behind the College of Science and Technology (CST) (figure 2) and Dorcas Hall (figure 1), while traverses 2, 3 and 5 located at 30 and 20 meters away from the power houses served as control traverses (figure 1).

Figure 3 Pollution around the power house behind CST

Figure 4 Pollution around the power house behind Dorcas Hall

The Abem Terrameter SAS 1000 and the Universal Traverse Mercator (UTM) coordinates with the aid of a GERMIN 12 channel personal navigator (GPS) unit were deployed to obtain the resistance of the subsurface and the location of each of the traverses. The resistance was later multiplied by the appropriate geometric factor to obtain the apparent resistivity values, [12-14]. The observed field data were used to produce pseudosections for each of the traverses which were used as initial model for the computer iteration technique via Dipro software to produce model contours.

5. Results and discussion

The results of the 2D resistivity inversion around the two locations are shown in figures 5 to 9 as 2D inverted resistivity depth models.

Traverse 1

This traverse was obtained about 3 m from the power house behind CST and 90 m in length. A critical view of the model indicates that the subsurface under this profile is characterised by materials with apparent resistivity ranging from 93-1258 Ωm. The top soil here has resistivity values ranging from about 93-150 Ωm and thickness of about 1.5 m with sandy-clay lithology. Underlying the top soil are materials with resistivity values ranging from 150-600 Ωm (green and red colours) indicating lateritic clayey materials. The zones with very high resistivity values (purple colour) ranging from about 800-1258 Ωm indicate vertical migration of the contaminants from the power house to the subsurface environment right from the surface to a depth of 5 m.

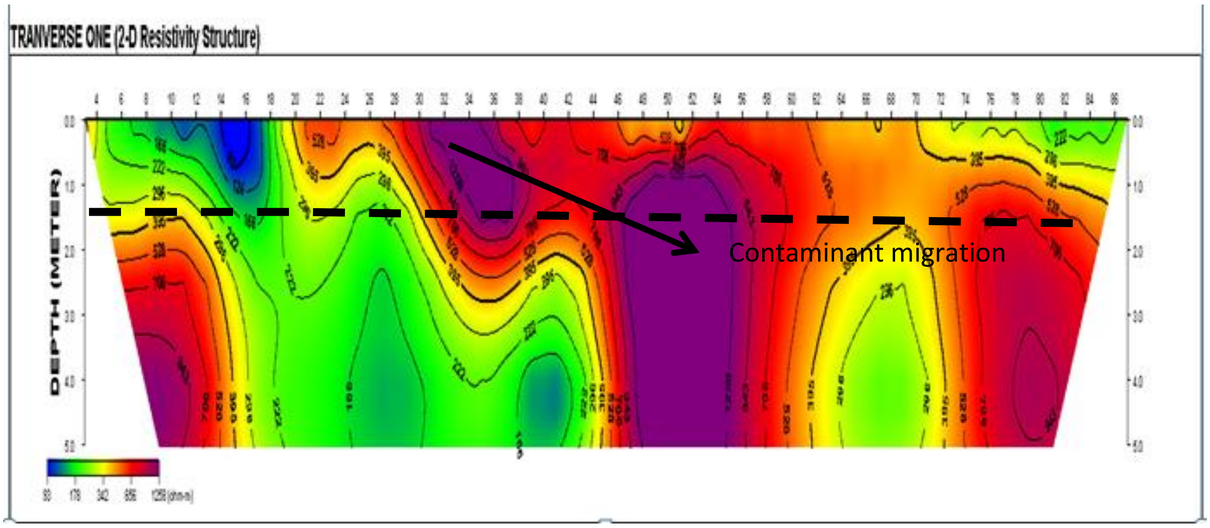

Figure 5 Inverted 2D resistivity structure along traverse 1

Traverse 2

The length of profile 2 was 100 m and was obtained about 30 m away from the overhead water tank opposite the Department of Chemical and Petroleum Engineering building, about 80 m away from the power house. From this control model, the resistivity values for the entire profile ranges from 57-746 Ωm with three distinct subsurface layers. The top soil along this traverse has resistivity values ranging from about 57-150 Ωm and thickness of about 1.0 m with sandy-clay lithology. The second layer extends from 1.0-2.0 m of depth with resistivity values ranging 206- 400 Ωm and a sandy composition. The third layer with resistivity values ranging from 400-746 Ωm represents lateritic/clayey materials. This is confirmed from excavation of laterite currently going on behind the University for road construction purpose nearby (about 500 m away from this point). Compared with traverse one, the maximum resistivity values obtained here does not suggest any likelihood of contamination of the subsurface from the nearby power house.

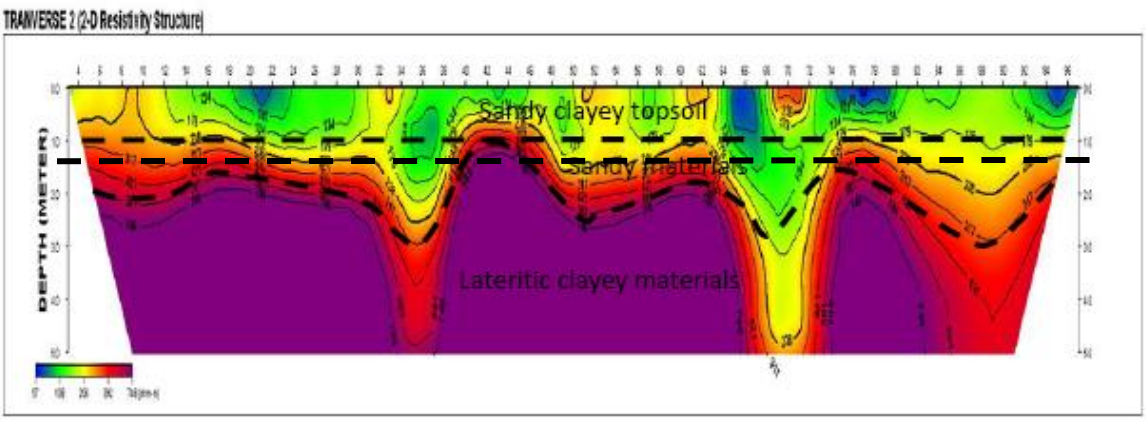

Figure 6 Inverted 2D resistivity structure along traverse 2

Traverse 3

Traverse 3 was obtained about 30 m away from the power house and 50 m in length. The inverted 2D resistivity structure delineates three subsurface geoelectric layers. The top soil (sandy clayey material) with resistivity values ranging from 247-300 Ωm from the surface to a depth of about 1.0 m. This zone is underlain with materials with medium resistivity values ranging from 300-570 Ωm and extending from 1.0 m to 2.0 m depth. This region represents sandy materials. The relatively higher resistivity zone (red to purple), with values ranging from 571-753 Ωm, and extending from the origin to about 26 m along the profile is suggestive of a huge deposit of lateritic material. The portion from the 26 m mark to the end bounding the laterite indicates gradual weathering of the laterite deposit.

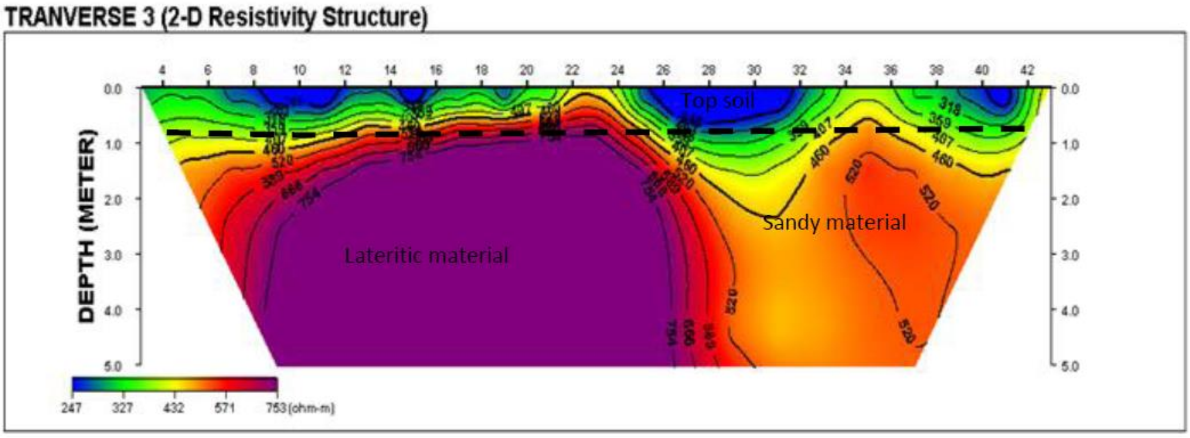

Figure 7 Inverted 2D resistivity structure along traverse 3

Traverse 4

Traverse 4 was 50 m in length and was acquired 3 m away from the power house near Dorcas Hall. The aim was to, like profile one observe if there is migration of the contaminants from the power house towards the subsurface environment. From the 2D resistivity model, the entire profile is characterised by three geoelectric layers with resistivity values ranging from 203 to 536 Ωm. The top soil along this traverse has resistivity values ranging from about 203-300 Ωm and thickness of about 1.0 m with sandy-clay lithology. The second layer extends from 1.0-2.0 m of depth with resistivity values ranging 300- 420 Ωm and a sandy composition. The third layer with resistivity values ranging from 420-536 Ωm represents lateritic/clayey materials. Again we can see evidence of weathering occurring on the lateritic material from the 16 m to 24 m mark along the traverse.

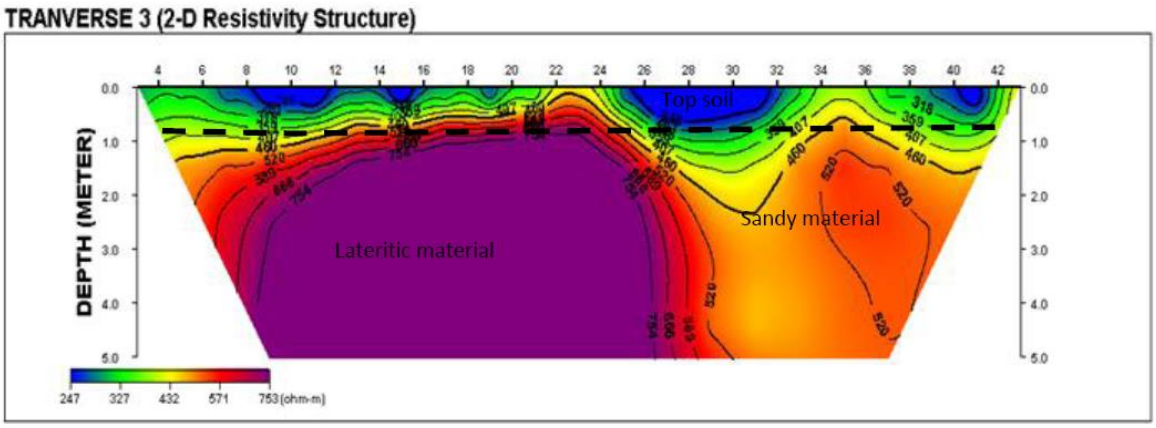

Figure 8 Inverted 2D resistivity structure along traverse 4

Traverse 5

Traverse 5 was 50 m in length and was acquired 20 m away from the overhead water tank near Dorcas Hall to serve as control. The inverse 2D resistivity model shows variation of resistivity values ranging from 197 to 645 Ωm. The top soil has resistivity values ranging from about 197 to 300 Ωm (blue and green) and thickness of about 1.0 m. The second inverted layer has resistivity values varying from 300 to 500 Ωm. The thickness of this layer varies from 1.0 to 2.0 m across the profile with sand and clay lithology. The last layer (purple colour) with relatively higher resistivity values ranging from 500 to 645 Ωm is reflective of lateritic materials that characterise the area.

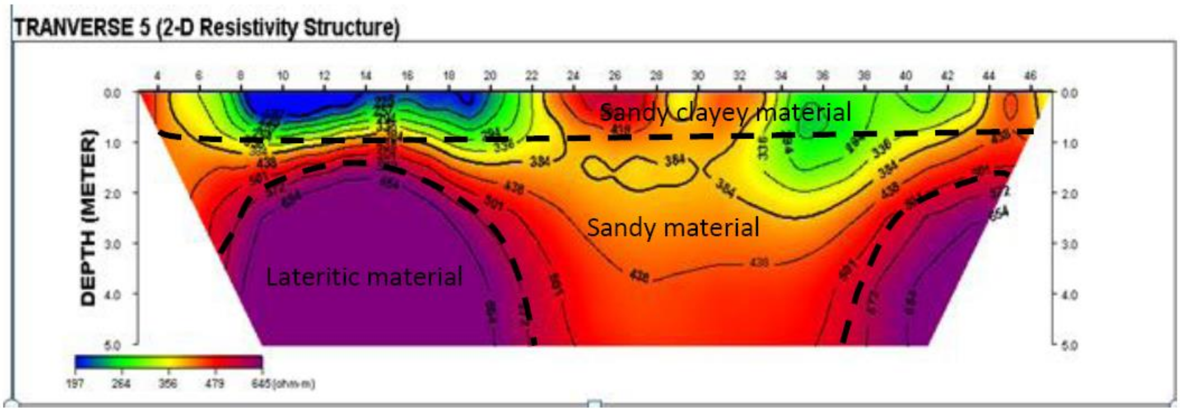

Figure 9 Inverted 2D resistivity structure along traverse 5

6. Conclusion

The results of the analysis generally showed no evidence of contamination on traverses 2, 3, 4 and 5 except for traverse 1 where we see some level of contamination as reflected in the anomalously high resistivity values (800-1258 Ωm) associated with the traverse. However, continuous disposal of used diesel and other hydrocarbon products around the power houses in the University pose a lot of danger of contamination to the environment and underground water body with time. Also from the analysis of the models generated from the study, three major lithologies have been identified due to the shallow depth of investigation. These geo-electric layers have resistivity values ranging between 93 to 300 Ωm for the first layer, while the second layer with sandy clayey composition has resistivity values between 200 to 500 Ωm. The third layer with the highest resistivity values on all the traverses ranges from 420 to 753 Ωm.

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