Geo- Electric Characterization Of Recent Hydrocarbon Contaminated Soil And Groundwater In Parts Of Ogale Community, Eleme Local Government Area Of Rivers State Nigeria.

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ABTRACT

Vertical Electrical Soundings (VES) and Electrical Resistivity Tomography (ERT) were jointly carried out to characterize petroleum hydrocarbon impacted site, in parts of Ogale Community, Eleme Local Government Area of Rivers State, using ABEM Terrameter SAS 1000. The objective is to delineate the lateral and depth extensions of the hydrocarbon contaminated soil and groundwater. The VES and ERT were taken parallel to NNPC oil pipeline. The interpreted geo electric sections from the VES result revealed five geo-electric layers. The first geo-electric layer has resistivity value of 59.80ΩM and a thickness of 1.93.m. This layer is interpreted as topsoil. The second layer which has a resistivity value of 143.32ΩM with a thickness of 2,92M was interpreted as lateritic sand. The third geo-electric layer has a resistivity value of 480.4ΩM and a thickness of 11,22M and this layer is interpreted as moderately hydrocarbon contaminated fine sand. The fourth geo-electric layer has a resistivity value of 793ΩM with a thickness of 32.7M and this layer is interpreted as hydrocarbon contaminated aquifer. The fifth geo-electric layer has a resistivity value of 319 ΩM, both depth and thickness are unknown. From the Tomogram results three resistivity zones were identified, the deep blue zone which has a resistivity value of 33.4ΩM with a depth of 0.89m and this is interpreted as topsoil. The second zone is the green –yellow resistivity zone which has a resistivity value of 694 ΩM with depth ranging from 0.98m to 14m and this is interpreted as moderately hydrocarbon contaminated fine sand. The third resistivity zone is the pick –purple zone. This zone has a resistivity value of 1328ΩM with depth ranging from 3.0m to 14m. The pink purple zone is interpreted as hydrocarbon contaminated aquifer. The vulnerability of the aquifer to hydrocarbon contamination is due to unconsolidated sand, high porosity, permeability, sands are poorly sorted and coarse grained, heavy rain fall, aquifer nearness to hydrocarbon spill site and ground surface. Soil degradation due to hydrocarbon contamination may alter the bulk density of the impacted soil and this may affect the compressibility and hydrogeology of the soil, infiltration rate and direction of groundwater flow which may alter groundwater recharge from precipitation in the investigated site

Keyword: resistivity, soil and groundwater, delineation, hydrocarbon, River State

INTRODUCTION

Ogale Community has experienced environmental pollution arising from hydrocarbon exploration and production. The soil which farming activities take place and the groundwater which is the major source of drinking water in the area has been polluted. Water boreholes are presently producing hydrocarbon product instead of potable water that the wells were made to produce. This is dangerous to the health of the people living in the community as petroleum polluted water can cause health effect like cancer and a host of

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 20
September 2018

other illness. Due to this development it has become necessary to take up this study to delineate the polluted site. The information obtained from this study is important for good groundwater management in the Community.

STUDY AREA DESCRIPTION

The study area is located between Lat. 04^0 79′ 0.913″ N and Lat. 04^0 47′ 32.772″ N and Long. 00 7^0 13′ 2039″ E and Long. 007^0 07 50′.083″ E of the Greenwich Meridian. Ogale Community is in Eleme Local Government Area of Rivers State. The entire state is located in the Nigerian Niger Delta. The Niger Delta Basin was formed in the Tertiary period due to inter play of subsidence and deposition of sediments arising from a succession of transgressions and regressions of the ocean, (*Short & Stauble 1967*). This cyclic event resulted in the deposition of three litho-stratigraphic units in the Niger Delta. These three units are Benin Formation, Agbada Formation and the Akata Formation in order of increasing. *(Reyment 1965)*. The Benin Formation is the major aquiferous stratigraphic unit in the study area. (*Amajor1991)*. It consists majorly of thick *sands inter fingered with clay bands and lenses.* The sands are medium to coarse grained and are poorly sorted. The sand and clay intercalations give rise to a multi-aquifer system in the area (*Murat 1970)*. All the electrical resistivity Survey that were done in this study terminated in the Benin Formation

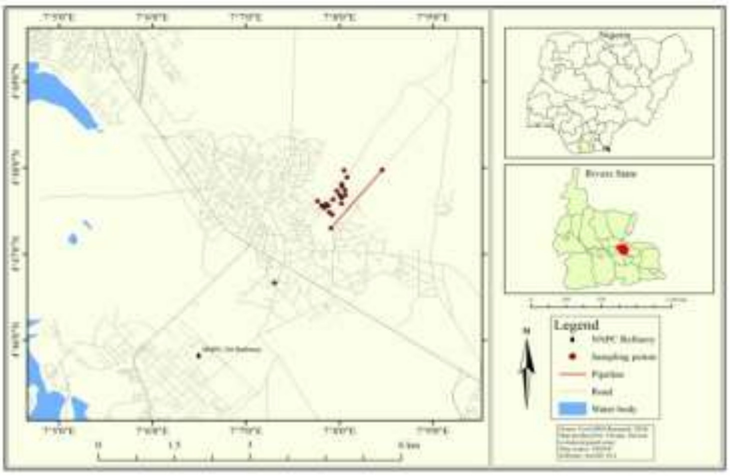


Fig.1: Map of the study area showing VES and ERT sampling points

METHODOLOGY

Five vertical electrical soundings were made employing the Schlumberger Array together with another five electrical resistivity Tomography employing Wenner Array close to NNPC oil pipeline in Ogale Community, Eleme local Government Area. The VES were situated at the centre of the ERT traverse for convenience in correlation and analysis of data. The instrument used was the ABEM SAS 1000 Terrameter, a digital signal averaging instrument for resistivity survey. The maximum current electrode separation for the VES was 400m and the electrode coverage for the 2-D was 100m. The VES data obtained in the field were processed and analysed using the IPI2WIN software whereas RES2DIV software was used to interpret the 2-D data in accordance with Loke and Baker (1996).

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 20
September 2018

Plate 1.Showing hydrocarbon spill in Ogale Community at NNPC pipeline right of way

RESULT AND DISCUSSION

This study relies on the fact that, the presence of hydrocarbon and clay in geologic materials produces changes in the electrical conductivity of such materials, (Abdel 2000). It is also proven that pore fluid strongly influences the resistivity of geologic materials. VES and ERT techniques both measure the resistivity of rock and can be use to obtain information on soils and groundwater quality, (Nwankwo & Emujakporue 2012). Boreholes in Ogale Community where the research was carried out tap water from the Benin Formation (Coastal Plain Sand), Reyment, (1965). Thus the VES and ERT were done on this Formation. A good understanding of the geology of the Formation was of great importance in the interpretation of the resistivity data obtained in the field. Fig.2 to 6 are the computer modelled curves for VES 1 to 5, while the corresponding tables (tables 1-5) show the resistivity values of the layers delineated, their depths and thicknesses for each VES. Moreover, the interpreted geo-electric sections are given in fig.7 to 11 w and fig 12 to 16 are the ERT Tomograms.

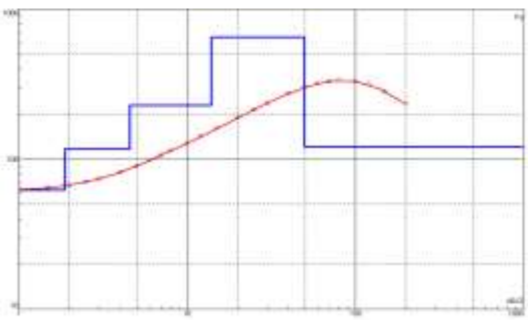


Fig. 2: Computer Modelling for VES 1

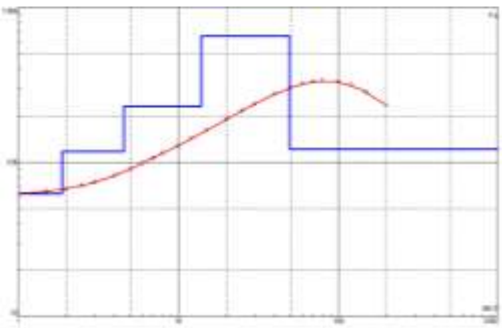


Fig. 3: Computer Modelling for VES 2

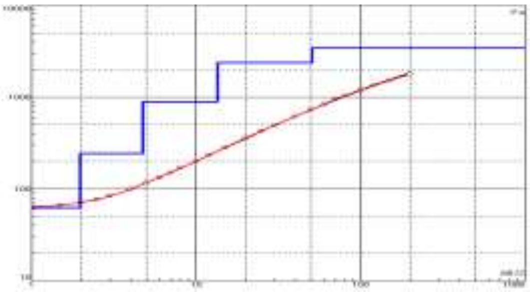


Fig. 4: Computer Modelling for VES 3

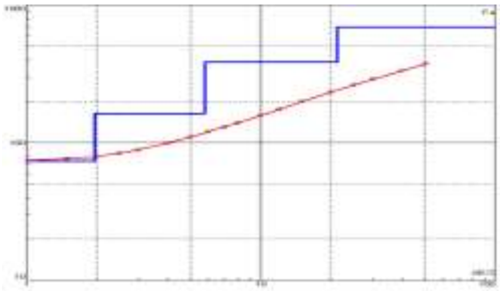


Fig. 5: Computer Modelling for VES 4

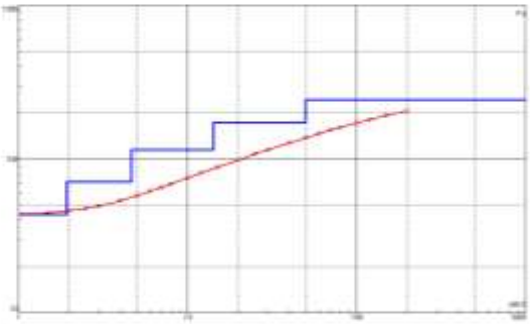


Fig. 6: Computer Modelling for VES 5

Table 1: The resistivity value, depth, thickness and the lithologic units for VES 1

Resistivity (Ωm)	Depth (m)	Thickness (m)	Interpreted Lithological Units
53.80	1.91	1.91	Top Soil
122.00	4.56	2.65	Lateritic Sand
783.00	13.50	8.94	Coarse Sand
383.00	48.90	35.4	Moderately Fine Sand
197.00	…….	……….	fine Sand

Table 2: The resistivity value, depth, thickness and the lithologic units for VES 2

Resistivity (Ωm)	Depth (m)	Thickness (m)	Interpreted Lithological Units
62.40	1.87	1.87	Top Soil
117.00	4.56	2.69	Lateritic Sand
229.00	13.90	9.34	Fine Sand
652.00	49.80	35.9	Coarse Sand
121.00	…….	……….	Fine Sand

(Table 3): The resistivity value, depth, thickness and the lithologic units for VES 3

Resistivity (Ωm)	Depth (m)	Thickness (m)	Interpreted Lithological Units
62.44	1.97	1.97	Top Soil
243.40	4.72	2.75	lateritic Sand
888.90	13.45	8.73	Medium Coarse Sand
2371.00	50.65	37.2	Coarse Sand
3421.00	…….	……….	Very Coarse Sand

(Table 4): The resistivity value, depth, thickness and the lithologic units for VES 4

Resistivity (Ωm)	Depth (m)	Thickness (m)	Interpreted Lithological Units
73.7	1.96	1.96	Top Soil
163.00	5.77	3.81	Lateritic Sand
386.00	21.00	19.04	Fine Sand
693.00	…….	……….	Coarse Sand

(Table 5): The resistivity value, depth, thickness and the lithologic units for VES 5

Resistivity (Ωm)	Depth (m)	Thickness (m)	Interpreted Lithological Units
43.70	1.92	1.92	Top Soil
71.20	4.64	2.72	Clayish
115.00	14.20	9.56	Lateritic Sand
173.00	49.80	35.60	Fine Sand
243.00	…….	……….	Medium coarse Sand

Geo-electric section for VES 1 – 5

Fig 7, VES 1

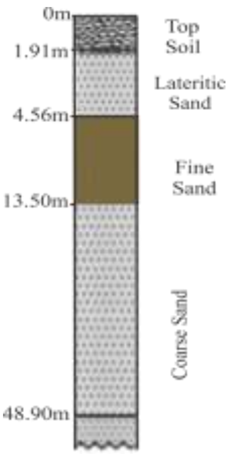


Fig 8, VES 2

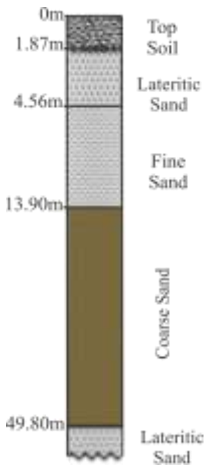


Fig 9, VES 3

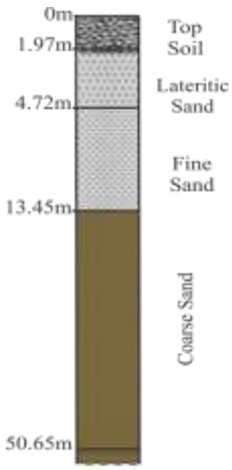


Fig 10, VES 4

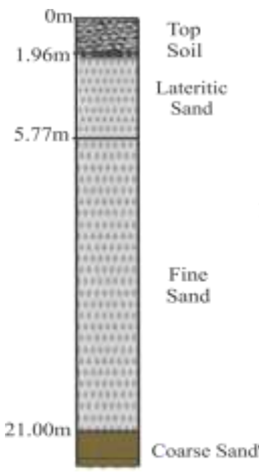
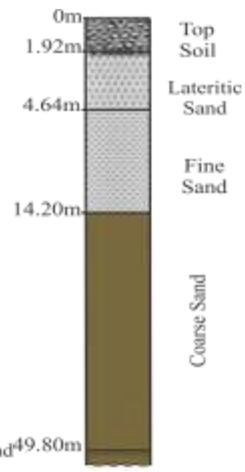


Fig 11, VES 5



VES 1

VES 1 (fig.2) is located at Lat. 4.790913N and Long. 7.132039E. It has five geo-electric layers with resistivity values, depths, and thicknesses as shown in Table 1. The first geo-electric layer has resistivity value of 53.80 Ωm, with a depth of 1.91m, and a thickness of 1.91m. This layer is interpreted as top soil, (Tab.1). The second geo-electric layer has a resistivity value of 122 ΩM, with a depth of 4.56m, and a thickness of 2.65m, (fig.7). This layer is interpreted as lateritic sand. The third geo-electric layer has a resistivity value of 783.0 ΩM, with a depth of 13.5m, and a thickness of 8.94m. This layer is interpreted as coarse sand. The fourth layer has a resistivity value of 383.00ΩM, with a depth of 48.90 m, and a thickness of 35.4m. This layer is interpreted as very coarse sand. The fifth layer has a resistivity value of 197.0 Ωm, with unknown depth and thickness. This layer is interpreted as fine sand.

VES 2

VES 2 (fig.3) is located at Lat. 4791377N and Long. 7.131462 E. It has five geo-electric layers with five resistivity values, depths and thickness as presented in (Table 2). The first geo-electric layer has a resistivity value of 62.4 ΩM, with a depth of 1.87M and a thickness of 1.87m. (fig.8), this layer is interpreted as uncontaminated topsoil. The second layer has a resistivity value of 117 ΩM with a depth of 4.56M, and a thickness of 2.69m, this layer is interpreted as uncontaminated lateritic fine sand. The third geo-electric layer has a resistivity value of 229.0Ωm, with a depth of 13.90m, and a thickness of 9.34m. This layer is interpreted as fine sand. The fourth geo-electric layer has a resistivity value of 652.00 ΩM, with a depth of 49.80m, and a thickness of 35.9m, this layer is interpreted as hydrocarbon contaminated aquifer. The fifth geo-electric layer has a resistivity value of 121 ΩM with unknown depth and thickness. This layer is interpreted as fine sand.

VES 3

VES 3 (fig.4) is located at Lat.4.792228 N and Long. 7.130615 E. It has five geo-electric layers also with five resistivity values, depths and thickness as presented in (Table 3.). The first geo-electric layer has a resistivity value of 62.44 ΩM, with a depth of 1.97m, and a thickness of 1.97m. (fig.9). this layer is interpreted as topsoil. The second geo-electric layer has a resistivity value of 243.40 ΩM, with a depth of 4.72m, and a thickness of 2.75 M, This layer is interpreted as lateritic sand. The third geo-electric layer has a resistivity value of 888.90ΩM, with a depth of 13.45m, and a thickness of 8.73m. This layer is interpreted as coarse sand. The fourth geo-electric layer has a resistivity value of 2371.00 ΩM, with a depth of 50.65m, and a thickness of 37.2M. This layer is interpreted as coarse sand. The fifth geo-electric layer has a resistivity value of 3421.00 ΩM with unknown depth and thickness. This layer is interpreted as coarse sand.

VES 4

VES 4 (fig.5) is located at Lat. 4.792722 N and Long. 7.130128 E. It has five geo-electric layers with five resistivity values, depths and thickness as presented in (Table 4.). The first geo-electric layer has a resistivity value of 73.7 ΩM, with a depth of 1.96m, and a thickness of 1.96m. (fig.9) this layer is interpreted as topsoil. The second geo-electric layer has a resistivity value of 163.00ΩM, with a depth of 5.77m, and a thickness of 3.81m. This layer is interpreted as lateritic fine sand. The third geo-electric layer has a resistivity value of 386.00m, with a depth of 21.00m and a thickness of 19.04m. This layer is interpreted as coarse sand. The fourth geo-electric layer has a resistivity value of

International Journal of Research
Available at https://pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
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693.00Ωm, depth and thickness are unknown. This layer is interpreted as coarse sand.

VES 5

VES 5 (fig.6) is located at Lat. 4.793548 N and Long. 7.139426 E. It has five geo-electric layers with five resistivity values, depths and thickness as presented in (Table 5). The first geo-electric layer has a resistivity value of 43.70 ΩM, with a depth of 1.92m, and a thickness of 1.92m. (Fig. 10). This layer is interpreted as topsoil. The second layer has a resistivity value of 71.20 ΩM, with a depth of 4.64m, and a thickness of 2.72 m. This layer is interpreted as clay. The third geo-electric layer has a resistivity value of 115.00Ωm with a depth of 14.0m, and a thickness of 9.5m, this layer is interpreted as clayish sand. The fourth geo-electric layer has a resistivity value of 173.00 ΩM with a depth of 49.80m and a thickness of 35.6m, this layer is interpreted as fine sand. The fifth geo-electric layer has a resistivity value of 243.00 ΩM with unknown depth and thickness. This layer is interpreted as fine sand.

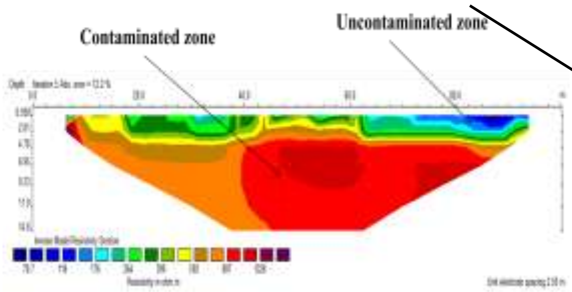

Fig 12: The geological interpretation for Tomogram 1.

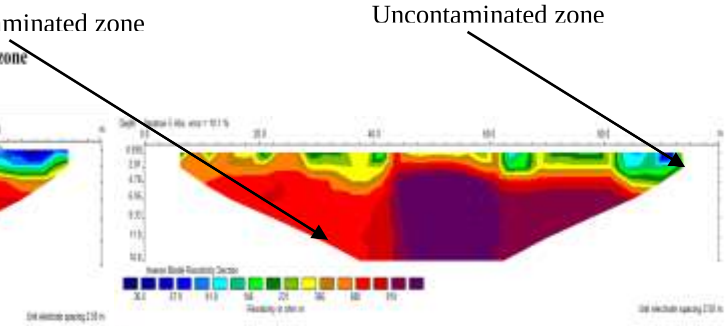

Fig.13: The geological interpretation for Tomogram 2

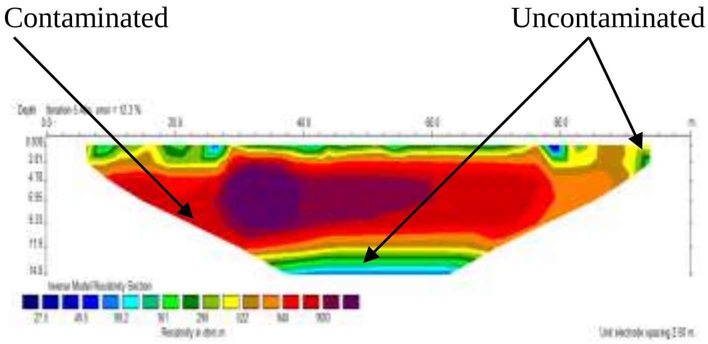

Fig.15: interpretation for Tomogram 4.

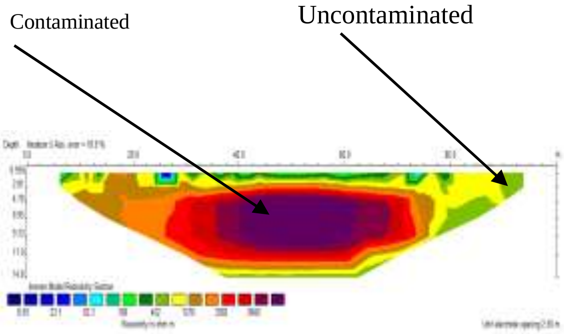

Fig.14: interpretation for Tomogram 3.

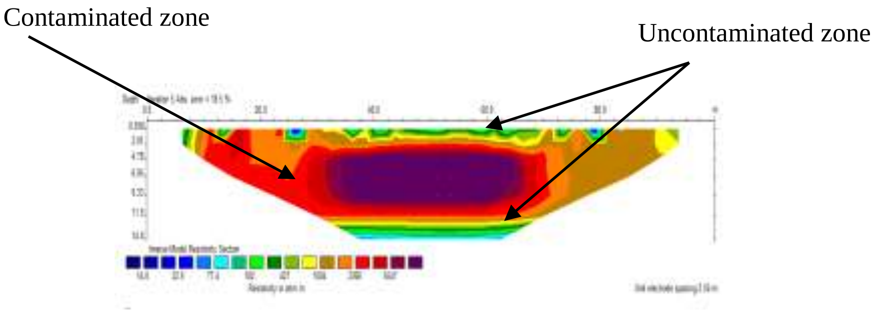

Fig. 16: interpretation for Tomogram 5.

Tomogram 1

Tomogram 1 (Fig.12), is located at Lat. 4.790913N and Long. 7.132039. It has a resistivity values ranging from 78.7Ωm to 1328Ωm with a depth of 14m, and a surface stretch of 100m. Three (3) resistivity zones were isolated in this tomogram and these are the deep blue zone, which has a resistivity value of 78.7Ωm with a thickness of 0.98m, and a surface stretch ranging from 65m to 100m. This low resistivity zone is interpreted as uncontaminated top soil. The second resistivity zone is the light green to yellow zone, which has a resistivity values ranging from 264ΩM to 594ΩM. It occurs at various depths up to 5m, it surface stretch ranging from 0 m to 100m. This layer is interpreted as moderately contaminated fine sand. The third resistivity zone is the purple to pink, it has resistivity values ranging from 740 Ωm to 1328 Ωm, it occurs at various depths up to 14m and a surface stretch of 100m. This resistivity zone is interpreted as hydrocarbon contaminated aquifer.

Tomogram 2

Tomogram 2 (Fig.13), is located at Lat. 4791377N and Long. 7.131462 E. It has five resistivity values ranging from 36.5 Ωm to 919Ωm with a depth of 14m and a surface stretch of 0m to 100m. Three resistivity zones were isolated on this tomogram, and these are the deep blue zone, which has a resistivity value of 36.5 Ωm with a depth from 0.93m to 2.6m and surface stretch ranging from 82.5m to 92.5m, this zone is interpreted as uncontaminated topsoil. The second resistivity zone is the light green to yellow zone which has a resistivity values ranging from 146 Ωm to 366 Ωm with depth ranging from 0.38m to 4.30m and a surface stretch ranging from 0m to 100m. This zone is interpreted as moderately contaminated fine sand. The third resistivity zone is the pink to purple zone. This zone has a resistivity value ranging from 473 Ωm to 919 Ωm with a depth of 14m, and a surface stretch ranging from 0m to 100m. This resistivity zone is interpreted as hydrocarbon contaminated aquifer.

Tomogram 3

In tomogram 3, (fig.14), is located at Lat.4.792228 N and Long. 7.130615 E. 40m. it has resistivity values ranging from 27.5Ωm to 1693Ωm, with depth ranging from 0.938m to 14m, and a surface stretch ranging from 0m to 100m. Three resistivity zones were isolated on this tomogram, and these are the low resistivity zones, (deep blue zone) which has a resistivity value of 27.5Ωm with depth ranging from 0.938m to 1.91m, and a surface stretch ranging from 67.5m to 81.7m. The low resistivity zone can also been seen at 14m depth and surface stretch ranging from 32.5m to 65.1m, and this is interpreted as topsoil. The second resistivity zone is the light green to yellow zone which has resistivity values ranging from 161Ωm to 522Ωm, with depth ranging from 0.938m to 2.62m, and a surface stretch ranging from 0m to 100m. This zone is interpreted as moderately contaminated fine sand. The third resistivity zone is a high resistivity zone (purple to pink) that underlying the second resistivity zone with resistivity value ranging from 731Ωm to 1693Ωm, with depth ranging from 1.24m to 12.2m and surface stretch ranging from 0 to 100m. This resistivity zone is interpreted as hydrocarbon contaminated aquifer.

Tomogram 4

Tomogram 4 (Fig. 15), is located at Lat. 4.792722 N and Long. 7.130128 E. It has a resistivity values ranging from 8.59Ωm to 8842Ωm, with depth ranging from 0.938m to 14m, and surface stretch ranging from 0m to 100m. Three resistivity zones were isolated on the tomogram, and these are the low resistivity zones (deep blue), which has a resistivity value of 8.59Ωm, with depth ranging from 0.938m to 2.70m, and surface stretch ranging from 25m to 27.5m, this low resistivity zone is also found at 14m depth, and is resistivity zone is interpreted as clay. The second resistivity zone is the light green to yellow zone, which has a resistivity value of 168Ωm, to 452Ωm, with depth ranging from 0.938m to 14.0m, and surface stretch ranging from 0m to 100m. This resistivity zone is interpreted as moderately contaminated aquifer. The third resistivity zone is the purple to pink zone. This resistivity zone has resistivity values ranging from 2250Ωm to 8842Ωm, with depth ranging from 0.938m to 14.0m, and surface stretch ranging from 15m to 77.5m. This zone is interpreted as hydrocarbon contaminated aquifer.

Tomogram 5

Tomogram 5, (Fig.16), is located at Lat. 4.793548 N and Long. 7.139426 E. It has a resistivity values ranging from 14.0Ωm to 5547Ωm, with depth ranging from 0.938m to 14m and surface stretch ranging from 0m to 100m. Three resistivity zones were isolated on this tomogram, and these are deep blue zone which has resistivity values of 14.0Ωm with depth ranging from 0.938m to 1.62m, and surface stretch ranging from 25m to 27.5m, and 77.5m to 80m. The low resistivity zone is also found at 14m depth and surface stretch ranging from 35.5m to 67.5m and these were interpreted as clayish. The second resistivity zone is the light green to yellow zone, which has resistivity values ranging from 182Ωm to 1004Ωm, with depth ranging from 0.938m to 3.98m and surface stretch ranging from 0m to 100m and is interpreted as moderately contaminated. This zone also occurred at depth ranging from 12.5m to 13.9m. The third resistivity zone is the purple to pink which has resistivity value ranging from 1682Ωm to 5547Ωm, with depth ranging from 0.938m to 13.4m and surface stretch ranging from 7.5m to 77.5m, and is interpreted as hydrocarbon contaminated aquifer.

CONCLUSIONS

The VES and ERT surveys showed that the soil and groundwater in the delineated site has been contaminated by hydrocarbon with a characteristic high resistivity values associated with hydrocarbon spill. The depth of impact is 14m, below the water table within the surveyed area.

The estimated groundwater table from geo-electrical survey average is 4.85 m, this reflects the proximity of the groundwater table to the ground surface and the shallow nature of the aquifer in the investigated site made the aquifer vulnerable to hydrocarbon contamination. Soil degradations in the hydro-geological properties of the aquifer may alter groundwater flow direction and recharge from surface precipitation.

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e-ISSN: 2348-6848
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