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Polycyclic Aromatic Hydrocarbons (PAHs) Load and Geo-Electric Characterization of Soils from Ogale Community, Eleme, Rivers State, Nigeria

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Abstract:
The aim of this study was to evaluate the polycyclic aromatic hydrocarbons load in soils of Ogale community, Rivers State, Nigeria and as well delineate the lateral and vertical extensions of the soils and groundwater. Geo-electric characterization of the soils and groundwater, using Electrical Resistivity methods (vertical electrical sounding, VES by Abem Terrameter and Gas chromatograph - Flame Ionization Detector (GC-FID) for finger-print was employed. The interpreted VES results revealed four geo-electric subsurface layers. The first layer which has a resistivity value of 60Ωm and a thickness of 2.0M was interpreted as top soil. Underlying the first layer is the second layer which had a resistivity value of 122Ωm with a thickness of 3m, interpreted as lateritic sand. The third layer had a resistivity value of 750Ωm and a thickness of 9.0m, and is interpreted as coarse sand. The fourth layer which had a resistivity value of 1255Ωm and a thickness of 49m is interpreted as very coarse sand. Borehole one was used as control and it is 1.85km away from the Resistivity sampling points. The results revealed that the presence of C10-C40 hydrocarbon which indicates un-weathered to fresh hydrocarbon in parts of the study area and heavy metals were below detection limits. The vulnerability of the aquifer to hydrocarbon contamination was due to high permeability, unconsolidated coarse grained and poorly sorted sands, of the vadose zone as well as shallowness of the aquifer. It is recommended that boreholes in the study area should be of deeper depths, and well constructed to avoid contaminated water from the polluted zone entering the borehole through the annulus.

Keywords: Geo-electric; characterization; load; PAHs; Ogale community; Eleme; vertical electrical sounding

1.0. Introduction

Groundwater quality studies have become unavoidable because it is well thought-out to be the most vital natural and fresh resource on earth which is used for drinking purposes, irrigation and its poor quality may badly affect its users [1,2].

Ogale community is located in Eleme Local Government Area, Rivers State, Nigeria. The entire state falls within the Niger Delta Geopolitical zone. For the past six decades, Petroleum exploration and production in the Niger Delta and export of oil and gas resources by the petroleum sector have substantially improved the economy of the nation. Unfortunately, activities associated with petroleum exploration, development and production operations have detrimental and significant adverse impacts on the atmosphere, soils, sediments, surface and groundwater, marine environment and terrestrial ecosystems in the Niger Delta. Discharges of petroleum hydrocarbons and petroleum derived wastes on land, streams, and rivers have caused environmental pollution, human health effects, socio-economic problems and degradation of host communities in the Niger Delta.

As a result of oil activities in Ogale community like some other parts of the Niger Delta, experience environmental degradation arising from these activities. The soil on which farming activities take place and the groundwater which is the main source of domestic water supply in the area may be polluted. Indeed, water wells are currently producing substances that look like petroleum products and no potable water facilities were constructed to produce quality water in the area. This is deleterious to the health of the inhabitants as petroleum impacted water can cause severe effects on human such as cancer, respiratory problems, skin, and eye irritation, coughing, throat problems, diarrhea, stress, and neurotoxicity. In view of this development, it has become important to carry out this study to properly delineate the impacted area and extent of the impact. This information is necessary for proper groundwater management in the area.

Organic pollutants that consist of two or more benzene rings in a straight chain, angular or strung form structurally stable, difficult to degrade, and some PAHs have the characteristics of persistent organic pollutants (POPs) such as carcinogenic, bioaccumulative, and long-range migration effects are called polycyclic aromatic hydrocarbons (PAH)s. The US Environmental Protection Agency has selected 16 PAHs as their priority monitoring indicators) [3-5]. They include:naphthalene (Nap), acenaphthylene (Acy), acenaphthene (Ace), fluorene (Flu), phenanthrene (Phe), anthracene (Ant), fluoranthene (Fla), pyrene (Pyr), benzo[a]anthracene (BaA), chrysene (Chr), benzo[b]fluoranthene (BbF),benzo[k]fluoranthene (BkF), benzo[a]pyrene (BaP), dibenzo[a,h]anthracene (DahA), benzo[g,h,i]perylene (BghiP), and indeno (1,2,3-cd]pyrene (IcdP).

Baumard *et al*., 1998 stated that PAHs may come from natural sources, but anthropogenic activity is generally considered the major source. Anthropogenic PAHs primarily originate from pyrogenic and petrogenic sources [6]. Pyrogenic PAHs are mainly from incomplete combustion of various fossil fuels (such as coal, oil, and natural gas), residential heating, industrial activity, wood, tobacco, and other hydrocarbons [7].

A group of reserachers documented that PAHs have been attracting increasing attention, because many are known to be carcinogenic, mutagenic, or teratogenic which are serious health threats to organisms [8,9]. A study reported that A number of them are genotoxic, mutagenic, carcinogenic or teratogenicin nature with long range of transport and well implicated in endocrine system disruption at levels higher than the maximum allowable limit within a very short time [10,11]. The study of polycyclic aromatic hydrocarbons (PAHs) load and geo-electric characterization of soils from Ogale Community, Eleme, Rivers State, Nigeria has not been undertaken by previous workers.

The objectives of this study include: (1) To delineate the impacted areas (soil and groundwater) in Ogale Community using Resistivity method. (2) Assess PAHs and some heavy metals in near surface aquifer in Ogale community.

2.0. Materials and Methods

Ogale community is located at Latitude 4.790913° N and Longitude 7.132039° E in Eleme Local Government Area, Rivers State, Nigeria. The area has been severely impacted with crude oil spillages from multi-national oil companies operating in the region.

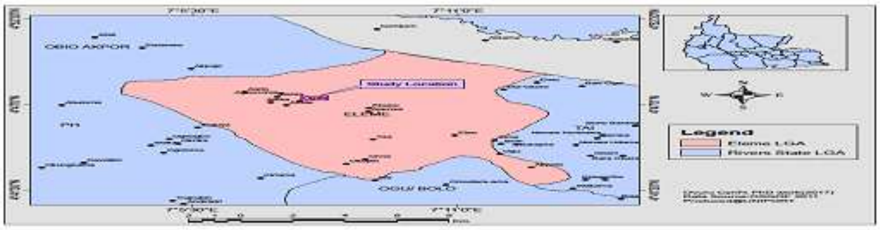


Figure 1: Map of the study area (Eleme LGA) showing sampled VES and ERT ponts

2.1. Data Collection

A total of fifty three (53) study sites were selected, 25 of the sites were for Vertical Resistivity Sounding (VRS), while another 25 sites were for Electrical Resistivity Tomography (ERT) and three water samples from boreholes were also analyzed for PAH and heavy metals using standard methods [12,13].

2.2. Instrumentation

The geophysical equipment used in this research work for measuring the earth's resistivity value is the Abem Terrameter SAS 1000, a Signal Averaging System (SAS), using a method whereby consecutive readings were taken automatically and the results were averaged continuously.

The accessories used in the survey include stainless steel electrodes, four reels of copper cables, wooden pegs, four hammers, and two measuring tapes. The global positioning system (GPS) was used in taking the coordinates of the profile points and the elevation.

The Abem Terrameter is a digital meter that operates with a current range of 1- 1000mA. It has 12-Volts external battery source which is connected to the instrument through a cable in-built, in the instrument. The instrument has a digital screen display for the earth's resistance value. The electrically isolated transmitter sends out well defined and regulated signal currents, with strength up to 1000mA and voltage up to 400V.

2.3. Heavy Metals and PAHs

Three water samples were analyzed for heavy metals using AAS and PAH using Gas Chromatograph-Flame Ionization Detector (GC-FID) in accordance with standard methods [12,13].

The heavy metals were determined by Atomic Absorption Spectrophotometry (AAS) using Nitric Acid-Perchloric Acid Digestion. Samples are digested with a mixture of concentrated nitric acid and Perchloric acid. The concentration of each metal is determined by spraying the extracts into flame. The absorption of each metal is proportional to its concentration in the sample.

3.0. Results and Discussion

The results of the twenty five (25) Vertical Electrical Resistivity Soundings (VES) that were carried out together with another twenty five (25) 2-D resistivity imaging at various locations and Gas Chromatograph-Flame Ionization Detector fingerprint result from three water samples obtained from three boreholes in Ogale Community and environs were presented in Table 1. However, for the purpose of the paper 10 VES and 10 2-D resistivity imaging were under considered.

3.1. Presentation of Vertical Electrical Sounding Data

The vertical electrical sounding data obtained for this study are presented in this section as a series of graphs (curves) expressing the variation of apparent resistivity with electrode separation for the purpose of geological interpretation and the interpretation of the data is in accordance with Loke chat. The processed twenty five (10) VES data yielded four interpretative sounding curves in terms of the true resistivity as well as their respective depths to geo-electric layers (Table 1).

Table 1: Geo-Electric Parameters

VES	Location in decimal degrees		Resistivity of layers (m)					Thickness of layers (m)			
No	Latitude	Longitude	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	h_1	h_2	h_3	h_4
1	4790913	7.1320239	53.80	122.0	783.0	383	197	1.91	2.65	894	35.4
2	4.791377	7.131462	62.40	117.0	229.0	652.0	121.0	1.87	2.69	9.34	35.9
3	4.792228	7.130615	62.44	243.4	888.9	2371	3421	1.97	2.78	8.73	37.2
4	4.792722	7.130728	73.7	1630	386.0	6930		1.96	3.81	19.04	
5	4.793548	7.139426	43.7	71.2	115.0	173.0	243.0	1.92	2.72	9.56	35.6
6	4792994	7.13096	225	420	621	1441	828	1.6	2.37	9.05	36.0
7	4.792638	7.131337	364	616	985	1940	617	1.92	3.83	10.8	25.8
8	4.793375	7.132205	4.73	671	934	1637	559	2.08	2.58	4.77	34.8
9	4.793058	7.133656	311	840	6145	914	286	3.81	7.44	28	55.6
10	4.794112	7.133675	101	706	1609	415	700	3.20	8.55	28.5	48.9

This was achieved by using the IPI2WIN resistivity sounding interpretation software version 3.0. The resulting VES curves (Fig 2 - Fig 11) with their depths to geo-electric layers, thicknesses, and resistivity values were presented below in (Table 2 - Table 11). These finding are in concomitant with other studies VES 1 (Fig 2-3) is located at Latitude 4.790913^0 N and Longitude 7.132039^0 E. It has four (4) interpretative geo-electric layers, resistivity values, depths, and thicknesses are presented in (Table 2-3). The geo-electric section shows the type of soil in each of the layers and the layer depth below the surface. The first layer which has a resistivity value of 53.80Ωm and thickness of 1.91m was interpreted as the topsoil. Underlying the first layer is the second layer which has a resistivity value of 122.00Ωm, with a depth of 4.56m, and a thickness of 2.65m was interpreted as fine sand. The third layer which has a resistivity value of 783.00 Ωm, with a depth of 13.5m and thickness of 8.94m was interpreted as coarse sand. This high resistivity layer could probably be hydrocarbon contaminated aquifer. There is a fourth layer with a resistivity value of 383.0Ωm with a depth of 48.90m and thickness of 35.4m was interpreted as fine sand. The next layer with a resistivity value of 197Ωm with an unknown thickness was interpreted as fine sand. These finding are in concomitant with other studies. This results are in agreement with those represented [14-16].

Table 2: Resistivity, depths, thickness and lithological 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	Sand
783.00	13.50	8.94	Coarse Sand
383.00	48.90	35.4	Sand
197.00	…….	……….	Sand

Table 3: Resistivity value, depth, thickness, and lithological 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	Sand
229.00	13.90	9.34	Sand
652.00	49.80	35.9	Coarse Sand
121.00	…….	……….	Sand

VES 2 (Fig 4-5) is located at Latitude 4791377^0 N and Longitude 7.131462^0 E. It has four (4) interpretative geo-electric layers resistivity values, depths and thicknesses are presented in (Table 4-5). The geo-electric section shows the type of soil in each of the layers and the layer depth below the surface. The first layer which has a resistivity value of 62.40Ωm and thickness of 1.87m was interpreted as the topsoil. Underlying the first layer is the second layer which has a resistivity value of 117.00Ωm with a depth of 4.56m and a thickness of 2.69m was interpreted as fine sand. The third layer which has a resistivity value of 229.00Ωm with a depth of 13.9m and thickness of 9.34m was interpreted as fine sand. There is a fourth layer which has resistivity value of 652.00Ωm with a depth of 49.80m and thickness of 35.9m was interpreted as coarse sand. This high resistivity layer could probably be hydrocarbon contaminated aquifer. The next layer with a resistivity value of 121Ωm with an unknown thickness was interpreted as fine sand. These results are in agreement with those represented [14-16].

Table 4: Resistivity value, depth, thickness, and lithological 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	Sand
888.90	13.45	8.73	Sand
2371.00	50.65	37.2	Coarse Sand
3421.00	…….	……….	Coarse Sand

Table 5: Resistivity value, depth, thickness, and lithological 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	Sand
386.00	21.00	19.04	Sand
693.00	…….	……….	Coarse Sand

VES 3 (Fig.6-7) is located at Latitude4.792228^0 N and Longitude 7.130615^0 E. It has four (4) interpretative geo-electric layers; resistivity values, depths, and thicknesses are presented in (Table 6-7). The geo-electric section shows the type of soil in each of the layers and the layer depth below the surface. The first layer which has a resistivity value of 62.44Ωm and thickness of 1.97m was interpreted as topsoil. Underlying the first layer is the second layer which has a resistivity value of 243.40Ωm with a depth of 4.72m and a thickness of 2.75m was interpreted as fine sand. The third layer which has resistivity value of 888.90Ωm with a depth of 13.5m and thickness of 8.73m was interpreted as medium coarse sand. This high resistivity layer could probably be hydrocarbon contaminated aquifer. The fourth layer which has a resistivity value of 2371.00Ωm with a depth of 50.65m and thickness of 37.2m was interpreted as coarse sand. This high resistivity layer could probably be hydrocarbon contaminated aquifer. The next layer with a resistivity value of 3421.00Ωm with an unknown thickness was interpreted as very coarse sand. The details of other vertical electrical soundings (VES 4-10) are shown in Table 1. This results are in agreement with those represented [14-16].

Table 6: Resistivity value, depth, thickness, and lithological 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	clay
115.00	14.20	9.56	Sand
173.00	49.80	35.60	Coarse Sand
243.00	…….	……….	Coarse Sand

Table 7: Resistivity value, depth, thickness, and lithological units for VES 6

Resistivity (Ωm)	Depth (m)	Thickness (m)	Interpreted Lithological Units
255	1.6	1.6	Top Soil
420	3.96	2.37	Sand
621	13	9.05	Sand
1441	49	36	Coarse Sand
828	…….	……….	Sand

Table 8: Resistivity value, depth, thickness, and lithological 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	Sand
888.90	13.45	8.73	Sand
2371.00	50.65	37.2	Coarse Sand
3421.00	…….	……….	Coarse Sand

Table 9: Resistivity value, depth, thickness, and lithological 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	Sand
386.00	21.00	19.04	Sand
693.00	…….	……….	Coarse Sand

Table 10: Resistivity value, depth, thickness, and lithological 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	clay
115.00	14.20	9.56	Sand
173.00	49.80	35.60	Coarse Sand
243.00	…….	……….	Coarse Sand

Table 11: Resistivity value, depth, thickness, and lithological units for VES 6

Resistivity (Ωm)	Depth (m)	Thickness (m)	Interpreted Lithological Units
255	1.6	1.6	Top Soil
420	3.96	2.37	Sand
621	13	9.05	Sand
1441	49	36	Coarse Sand
828	…….	……….	Sand

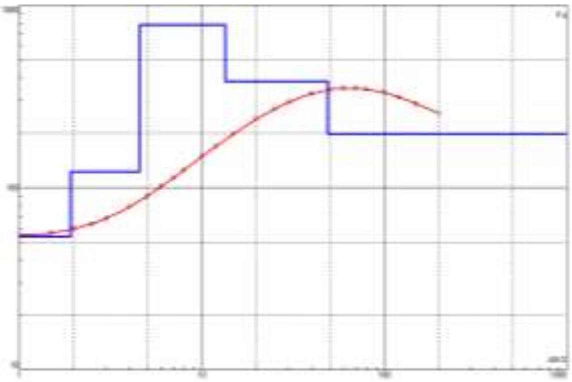


Figure 2: Computer Modeling for VES 1

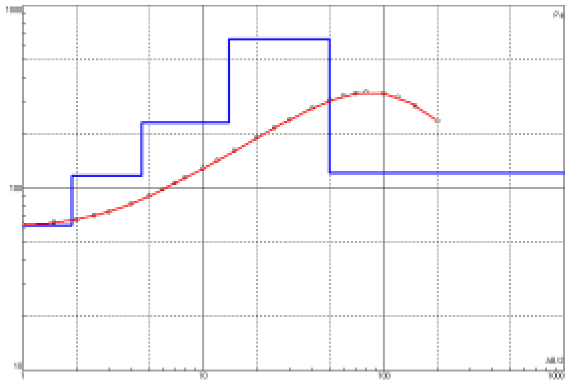


Figure 3: Computer Modeling for VES 2

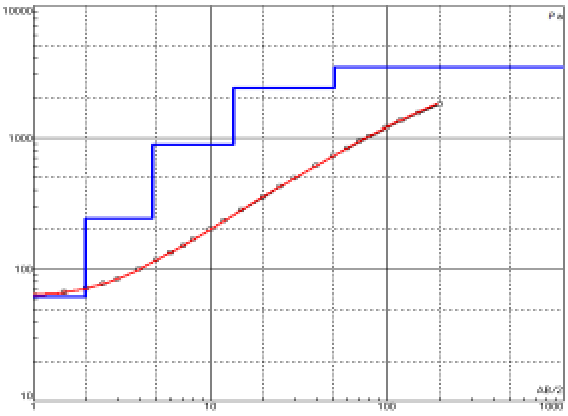
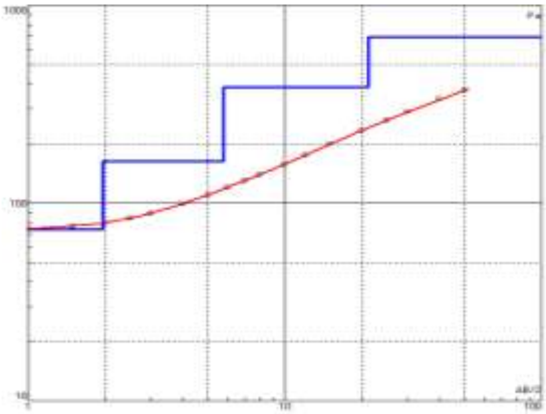


Figure 4: Computer Modeling for VES 3



Figures 5: Computer Modeling for VES 4

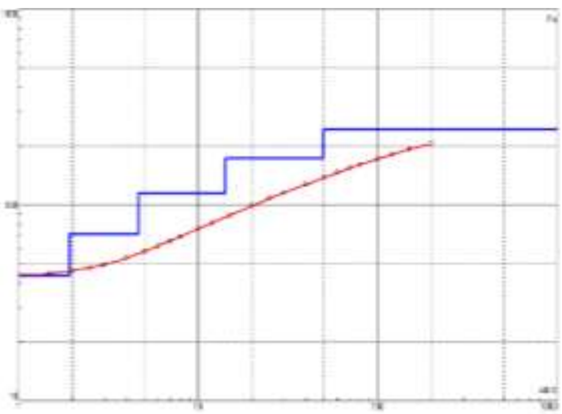
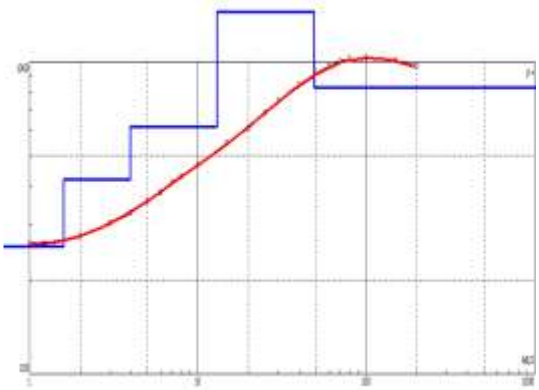


Figure 6: Computer Modeling for VES 5



Figures 7: Computer Modeling for VES 6

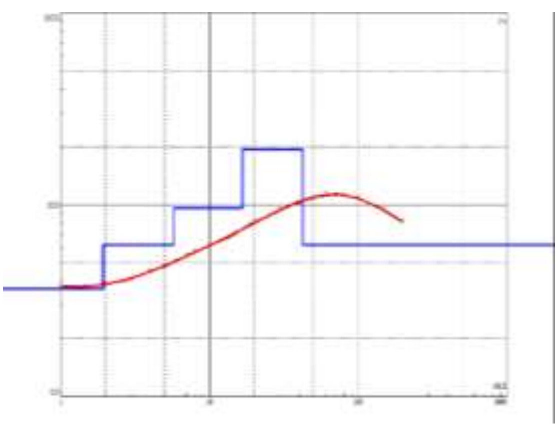


Figure 8: Computer Modeling for VES 7

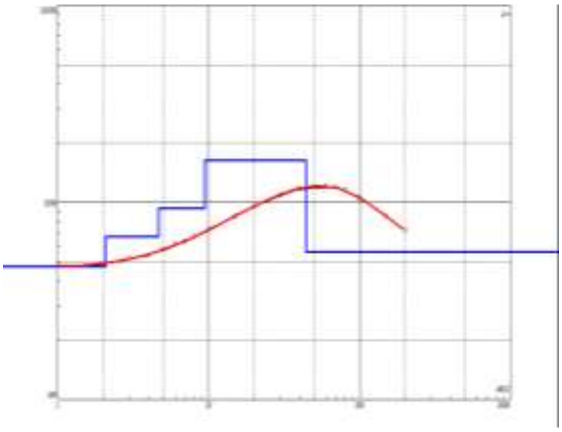


Figure 9: Computer Modeling for VES 8

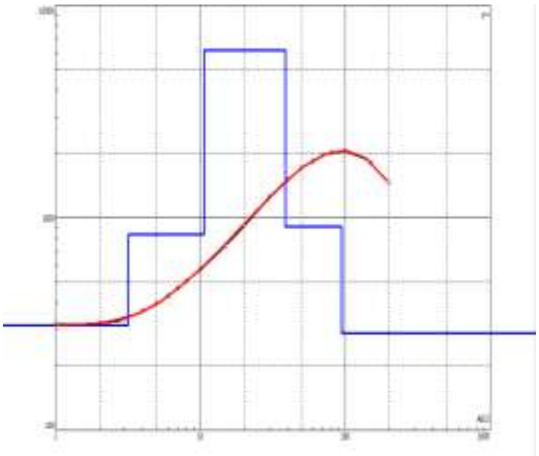


Figure 10: Computer Modeling for VES 9

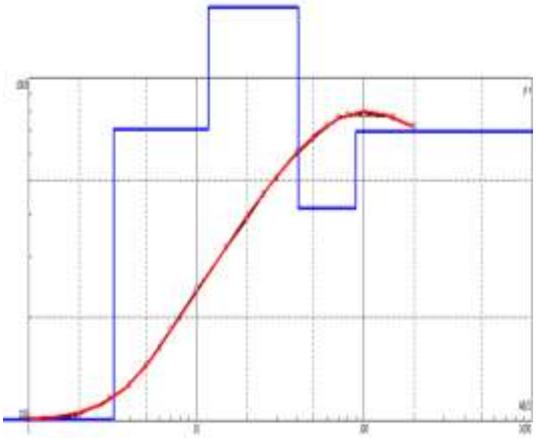


Figure 11: Computer Modeling for VES 10

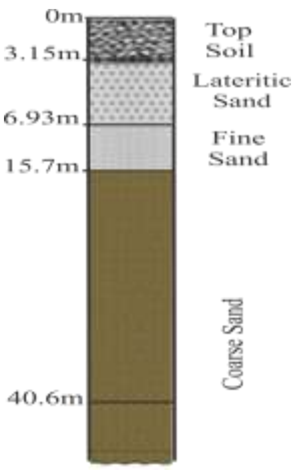


Figure 12: Geo-electric section for VES 12

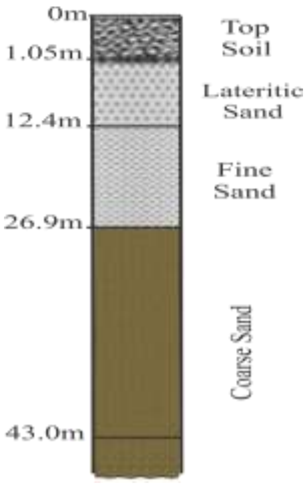


Figure 13: Geo-electric section for VES 13

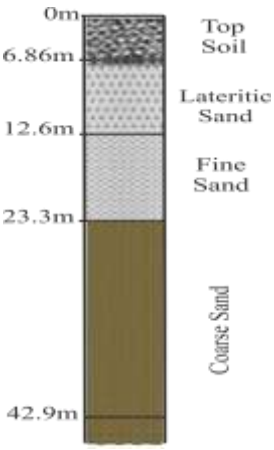


Figure 14: Geo-electric section for VES

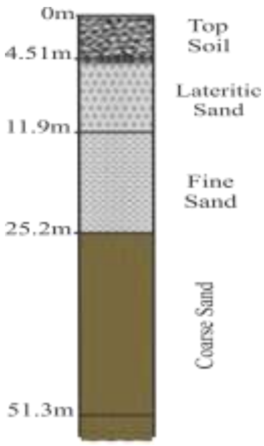


Figure 15: Geo-electric section for VES

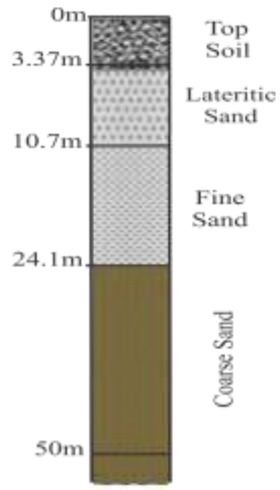


Figure 16: Geo-electric section for VES

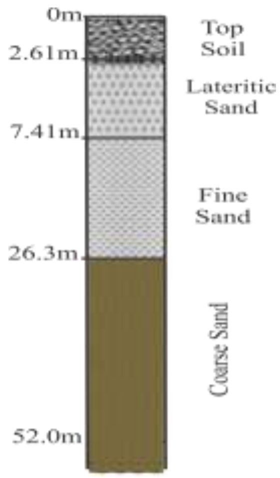


Figure 17: Geo-electric section for VES

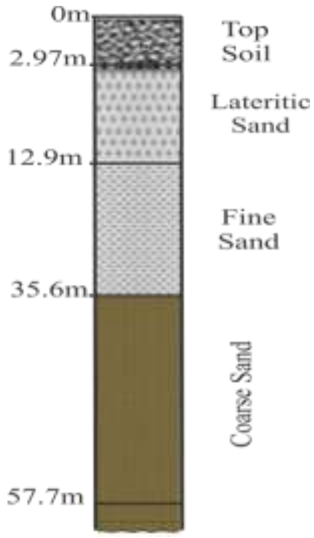


Figure 18: Geo-electric section for VES

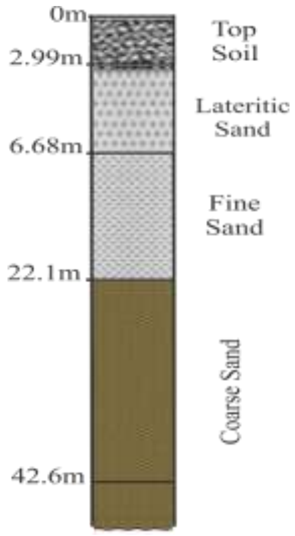


Figure 19: Geo-electric section for VES

3.2. Presentation and of 2-D Resistivity Imaging Data

The Tomograms for the 2-D resistivity imaging at various locations in Ogale Community are presented IN Fig. 20-22.

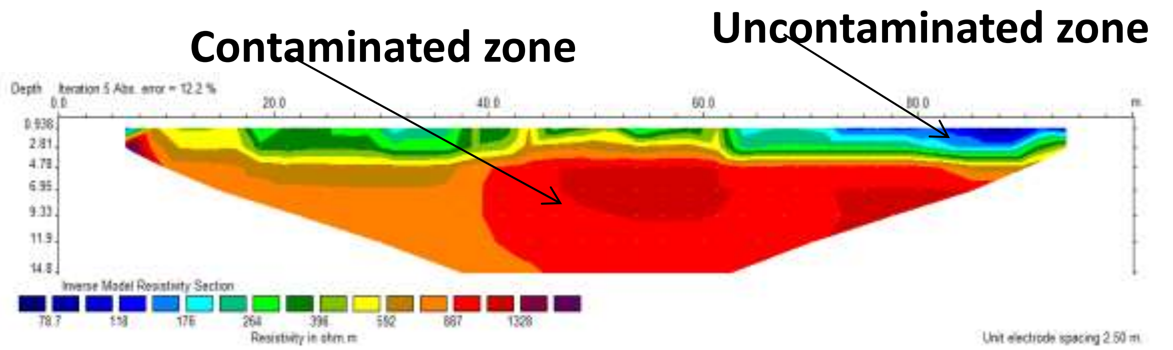


Figure 20: The geological interpretation of the inverse model resistivity section for Tomogram 1.

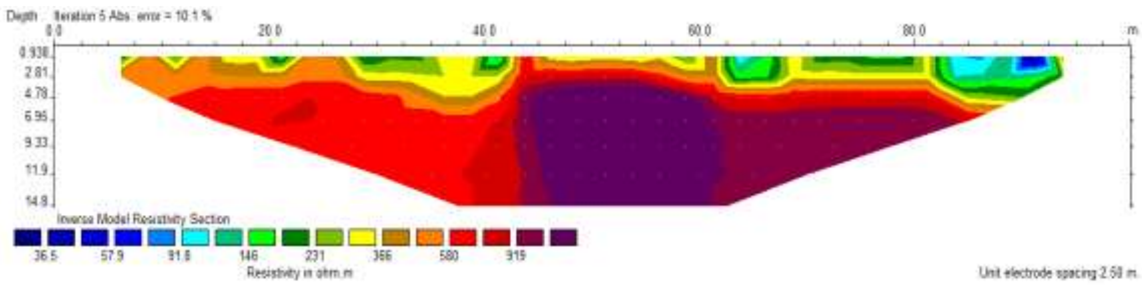


Figure 21: The geological interpretation of the inverse model resistivity section for Tomogram 2.

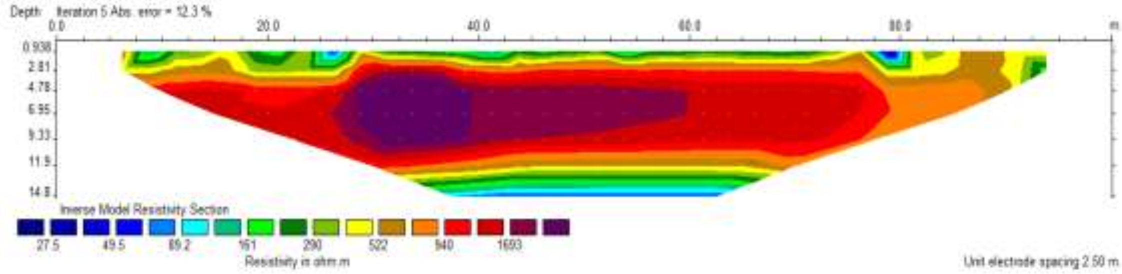


Figure 22: The geological interpretation of the inverse model resistivity section for Tomogram 3.

3.3. Geochemical Analysis of Borehole Samples

Three water samples were analyzed for heavy metals using AAS and PAH (Figure 23) using Gas Chromatograph-Flame Ionization Detector (GC-FID), in accordance with [12,13].

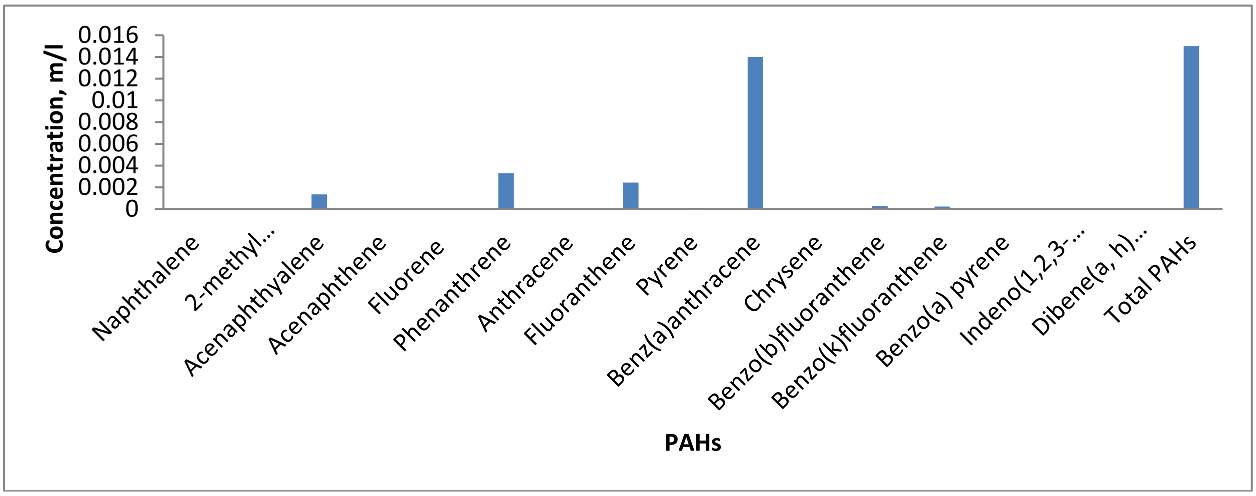


Figure 23: PAHs concentrations of boreole water from Ogale Community

Borehole one was used as control and it is 1.85km away from the resistivity sampling points. The results obtained from this borehole did not show any heavy metal and as well as hydrocarbon contamination. Borehole two is located in the resistivity sampling point, the borehole is a deep well and the result obtained from the borehole did not also show any heavy metal and well as hydrocarbon contamination. Borehole three (3) is a shallow well in the resistivity sampling point, results obtained from this well did not show any presence of heavy metals but the result indicated the presence of PAHs. The fingerprint result indicates un-weathered to fresh hydrocarbon thirteen (13) years after the spill, this could be due to the fact that the aquifer may be contaminated with hydrocarbon and that microbial activities alone cannot break down the hydrocarbons without active remediation processes, secondly the clay layer between the aquifer and the surface is too thick that nutrient and oxygen could not reach the aquifer for the microbe to be active in breaking down the contaminants. In comparison, the concentrations of the elements and PAHs in the samples were lower than the permissible limits of WHO, 2011; Karyab *et al*., 2013 for water [17,18]. This results are in agreement with those represented [19-21].

4.0. Conclusion

This work on hydrocarbon contamination in soil and groundwater of the Ogale community was carried out using electrical resistivity method, (VES) and Gas Chromatograph-Flame Ionization Detector. The results revealed the presences of hydrocarbon contaminants in soils and groundwater around the study area to a depth of 14m which is within the aquifer system in the study area. The VES delineated four subsurface layers. The electrical resistivity method used in the study further supports its application and effectiveness in identifying the vertical and lateral extent of soil and groundwater contamination from hydrocarbon spill sites. The quantitative interpretation of the 2-D resistivity imaging and geo-electric soundings has successfully helped to delineate contaminant plume produced by the oil spillage from oil pipelines within the study area. Both the 2-D imaging and vertical electrical sounding technique delineated hydrocarbon contaminant plume by their high resistivity values. This geophysical technique shows promise for application at locations of hydrocarbon contamination to help delineate the impacted area and extent of the impact. The vulnerability of the aquifer to hydrocarbon contamination may be due to high permeability, unconsolidated and poorly sorted coarse-grained sands of the vadose zone as well as shallowness of the aquifer. Furthermore, in comparison, the concentrations of the elements and PAHs in the samples were lower than the permissible limits of WHO, 2011.

Conflict of Interest

The authors declared that there is no conflict interest.

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