An Integrated Investigation Of Hydrocarbon Pollution In Ahoada Area, Niger Delta Region, Nigeria

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Abstract

This study investigates hydrocarbon pollution in Ahoada community of the Niger Delta region of Nigeria. The study uses geographic information system (GIS) for mapping oil spill hotspots in the region. Resistivity method was used for delineating the extent of hydrocarbon pollution to a depth of 19.7m at Ahoada area of the region. Three categories of soil samples:impacted soil (IMS), remediated soil (RS) and control soil (CS) were collected and analyzed for the presence of BTEX, PAH, TPH, TOC and TOG. The concentrations of the samples from the IMS and RS were compared to that of the CS to determine the extent of pollution. The GIS mapping shows that the most polluted areas in the Niger Delta Region are Rivers, Bayelsa, and Delta states. Results of the geophysical images revealed contaminants presence to depths beyond 20m at some locations in the study area. The highest depth of contaminant travel was at Ukperede. Soil samples analysis showed that the range of concentrations of TPH in IMS at Oshie was 17.27 – 58.36 mg/kg; RS was 11.73 – 50.78 mg/kg which were higher than the concentrations of 0.68 mg/kg in the CS. PAH are more prevalent in Ukperede ranging from 54.56 - 77.54 mg/kg. BTEX concentrations ranged from 0.02 – 0.38 mg/kg for IMP, 0.01 – 2.7 mg/kg for RS against CS value of 0.01 mg/kg. Study revealed that there are characteristically high resistivity values in the samples which were corroborated by the findings from the resistivity survey. TOC was found to be higher in the IMS and RS than in the CS demonstrating that significant quantity of the hydrocarbon has undergone appreciable decomposition.

1.0 Introduction

For over five decades when oil was first discovered in Oloibri, the Niger Delta region of Nigeria, exploration and exploitation of the resource has left devastating impacts. There has been pollution of the different compartments of the environment of the area including hydrosphere, lithosphere, biosphere and the atmosphere (Anejionu et al. 2015; Elum et al. 2016; Solomon et al. 2017). Oil and gas exploration and production activities are known sources of different hydrocarbon pollutants which can persists in the environment when not remediated and can have devastating health impacts on humans and other organisms in the environment (Alboiu and Walker 2019; Carpenter 2019; Enuneku et al. 2020). A vast majority of areas located in the heart of oil and gas operations in Nigeria have experienced significant levels of oil pollution from operational incidents (Ite et al. 2013; Nriagu et al. 2016; Onyena and Sam 2020). However, recent exacerbations in oil pollution issues in the Niger Delta is attributable to the illegal operations of pipeline vandals, crude oil thieves and illegal artisanal refiners (Ezirim 2018; Yeeles and Akporiaye 2016).

The history of oil spills in the Niger Delta region dated back to some of the earliest recorded spills post-independence Nigeria in 1979 that resulted in the discharge of over 570,000 barrels of crude oil in storage at the Forcados oil terminal (Ukoli 2001). Several other high volume spills have occurred thereafter including the Funiwa-5 well blowout of 1980 that resulted in the release of over 420,000 barrels of oil into the Atlantic coast of Nigeria (Tolulope 2004). The 24 inch Ogada-Brass Pipeline spill of 1983 released some 5000 barrels of oil into the lakes and swamps of the community and from the same pipeline, in

1995 24,000 barrels of crude oil was spilled in Etieme in Nembe resulting in the pollution of limited fresh water sources and a large area of mangrove swamps (Kadafa 2012). Several other incidences of oil spills have since been reported in literature (Egberongbe et al. 2006; Kostianoy et al. 2014; Zabbey et al. 2017). The environmental and ecological impacts of oil and gas exploration and production have also been widely reported (Aigberua et al. 2017; Ejiba et al. 2016; Obida et al. 2018; Sam et al. 2017).

Even though there have been several calls and agitation for the compensation of inhabitants and remediation of the contaminated sites in the Niger Delta region, not much has been done. The adopted remediation techniques are sometimes not efficient and remnants of contaminants are sometimes in the environment even after acclaimed remediation. For example, the report of the United Nations Environment Programme (UNEP 2011) on environmental impacts assessment in Ogoni land of the Niger Delta area showed that the remediation conducted by Shell Petroleum Development Company (SPDC) using enhanced natural attenuation (RENA) was inefficient. Some of the spill locations remained sources of pollution to other areas particularly through rainwater runoffs. Similarly, the International Union for Conservation of Nature (IUCN-Panel 2013) reported the ineffectiveness of RENA and phytoremediation in polluted sites in the Niger Delta area as contaminants were found to remain in soil strata at remediated sites.

While literature abound on the level of hydrocarbon contamination of the Niger Delta area by the use of conventional intrusive water and soil sampling methods, there is paucity of it on the use of geophysical investigations for contaminants investigation in the area (Ehirim et al. 2016; Raji et al. 2016; Chima et al. 2013). The usefulness and reliability of geophysical survey methods in hydrocarbon contaminant investigation has been demonstrated in many studies (Al-weshah 2016). Its effectiveness lies in its capability to capture contaminant data in 3 dimensions and reveal contaminant presence at deeper depths. This makes it possible to see the trajectories of the dispersive and advective nature of contaminants within impacted soil matrix without the need for drilling (Atakpo 2013). For example, (Raji et al. 2018) applied 2D electrical resistivity tomography (ERT) and (VES) to delineate areas contaminated by oil spills in a coastal area in Lagos, Nigeria. The tomographic images obtained corroborated the findings from the intrusive sampling techniques. The study by (Atakpo 2013) in Burutu local government area of the Niger Delta using resistivity imaging revealed contaminant signatures at depths below 10m at the study site.

In this study, resistivity imaging method, was used for delineating the extent of hydrocarbon pollution at selected locations within Ahoada communities of the Niger Delta region. Three categories of soil samples namely, impacted soil (IMS), remediated soil (RS), and control soil (CS) were collected at different depths and analysed for the presence of petroleum hydrocarbon constituents. The constituents analysed include benzene, toluene, ethylbenzene and xylene (BTEX), Polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbon (TPH) and total oil and grease (TOG) contents. The total organic carbon contents (TOC) of the soil samples were also measured. The concentrations of the analytes in the IMS and RS were compared to those of the CS to determine the extent of pollution.

2.0 Material And Methods

2.1 Study Area

The oil-rich Niger Delta area is located on latitude 40 10’ to 60 20’ north and longitude 20 35’ east of the equator projecting towards the Gulf of Guinea on the Atlantic coast of West Africa. It is the second world largest delta with a coastline of about 450km that stretches from the coast of Ondo, Delta, Bayelsa, Rivers, Akwaibom to Cross Rivers state (Figure 1A). Covering about 70,000 km^2 wetland, the region has been described to be among the top ten wetlands and deltaic ecosystems in the world. Stagnant swamp covers approximately 8600 km2, while rivers, creeks, and estuaries cover about 2,370 km2. The mangrove swamp which is the largest swamp in Africa spans about 1900 km (Awosika 1994).

Ahoada area considered in this study has close proximity to oil and gas exploration and production facilities including pipelines. It is located in the north-west of Porthacourt, Rivers state (Figure 1B). The area lies between latitude 60 87.26N and longitude 60 38’59.9”E and comprises of Ahoada west and Ahoada east both comprising several communities. The area has a large expanse of dense rain forest vegetation. The Orashi and Sombreiro river systems drain the area through several smaller streams and channels that criss-cross the entire communities (Awosika 1994). The major occupations in the area are farming, fishing and hunting.

3.0 Methods

3.1 Spill hotspots analysis

Oil spills data covering the entire Niger delta region were collected from the National Oil spills detection and response agency (NOSDRA) which keeps a database of official oil spills in Nigeria and Shell Petroleum Development Company (SPDC), a multinational oil company that has operated in Nigeria for several decades. The data had been compiled by both Shell and NOSDRA via a process of joint investigation visits (JIV). Information on the data base which is updated as soon as another incidence occurs encompasses dates, time, causes, magnitude, and GPS coordinates of spills. The mapping of the oil spills in the entire Niger Delta was first conducted in order to identify the oil spills hotspots and select one of such areas for specific studies of samples collection and geophysical studies. Based on the hotspot map, the identification of the study area was done. In addition to the oil spill occurrence data, pipelines locations (coordinates or maps) information was obtained from SPDC and NOSDRA. The map was georeferenced to align to UTM zone 32N projection and was digitized using ArcMap 10.5. The data obtained were processed using kernel density function of the GIS to obtain the hot spot map of the study area.

3.2 Application of geophysical survey

3.2.1 Electrical resistivity method

Supersting R8/IP resistivity meter with 56 electrodes dual switch box system was used in this study to delineate contaminant sources and plumes at Oshie-Akara Olu community in Ahoada West of the Niger Delta area. The method involves the measurement of apparent electrical resistivity of subsurface materials. A component of the instrument used in the method; the resistivity meter acts as a switch box and measuring device, supplying energy to different sets of electrodes via a set sequence. Surface resistivity measurement involves subjecting current (I) into the ground via two current electrodes firmly inserted into the ground. The first electrodes act as sink (−I), allowing the passage of current into the ground, while the second serves as a return (+I) into the current injecting source, ensuring current flow within the subsurface. The resultant potential difference (V) generated due to current flow is measured via two potential electrodes, separated by a distance that corresponds to a factor (n) of the spacing (a) between individual current or potential electrodes. Measurement of a subsurface resistance to the conventional current is computed as the ratio induced ground voltage resulting from movement of current within the ground.

Dipole-dipole has different penetration depths ranging from 12m for an 80m array, 25m for a 160m array and 60m for a 400m array. In this study, profile 1-12 is located within the study area where signs of oil spills exist. Each profile was on a straight line, since the topography of the study area is flat. 4m distance was maintained to separate one profile from the other and the profile length differed based on space availability and the local surface conditions. Survey was conducted to a depth of 0 to 22.8m. The stored measurement in the terrameter was retrieved and analyzed after the survey.

For this present study, the electrode spacing was at 2m and 4m depth in order penetrate a depth of 24m at the study area.

The infiltration of water saturated stratum by oil forms immiscible plumes producing irregular shapes of different sizes thereby impacting the stratums resistivity (Raji et al. 2018). The location of the oil plumes can be predicted from the size and distribution of the anomaly of the resistivity image (tomogram) (Loke and Barker 1996; Win et al. 2011). Therefore, the interpretation of the resistivity tomograms was based on this principle.

3.2 Collection and analysis of water and soil samples

For water sampling, collection was done for borehole and hand-dug wells at the study area. Sampling bottles were first rinsed with dilute HCl (0.05m) and then rinsed with distilled water. After this, they were air-dried in an environment free from dust. Samples were collected from selected sampling locations by a composite sampling process (Tóth et al. 2016). Subsamples were taken and mixed together at each sampling area before they were transported to the laboratory for analysis.

For soil sampling, hand-held auger drill was used for the collection of samples at depths of 0-15cm, 15-30cm, and 30-45cm intervals. The locations of samples collections were based on proximity to oil pipelines within the study area and on reported contaminated sites. Soil samples from non-polluted areas and remediated soils were collected as soil concentration reference for the contaminated soils.

Composite samples were made from the samples collected at the different depths in order to obtain representative sampling of all the samples collected. Samples were air-dried and grinded until it passes through 2mm mesh to remove stones and debris. The samples were taken to the laboratory, well labelled in sterilized polythene bags for analysis.

Hydrocarbon pollutant analysis conducted on the water and soil samples are: Total Organic Carbon (TOC), Total Oil and Grease (TOG), Total Petroleum Hydrocarbon (TPH), Benzene-Toluene-Ethylbenzene-Xylene (BTEX) and the Polycyclic Aromatic Hydrocarbons (PAHs).

4.0. Results

The hotspots map of the entire Niger Delta is presented in Figure 2. The map shows areas that are more clustered, moderately clustered and less clustered with oil spills, indicating highly impacted areas, moderately impacted areas and less impacted areas respectively. Areas mostly affected are Rivers, Bayelsa and Delta states. Out of these states, Rivers state has lots of incidences of oil spills pollution and Ahoada community in the state was therefore chosen as the study area. Figure 3(a) and 3(b) shows the oil spill map by pipeline interdiction and the general oil spill hotspots in Ahoada community respectively. The hotspots vandalization areas include, Ochebeke, Idu-Ekpeye, Ukperede, Okobe, Odieke in Ahoada west, while areas like Iheke, Uduogba and Akpobo in Ahoada east are highly impacted. Communities falls within the moderately affected includes Akinima, Oshie and Onitu in Ahoada west, while places like okobe, Ogbo, Oklisame, Obulubulu and Abessa in Ahoada east are moderately affected. With regards to the general spills which consist of accidental, natural and interdiction, the hotspots areas are Ochebeke, Oshie, Idu-Ekpeye and Ebraso in the west while Ochebe and Obulubulu from the east respectively.

4.2 Analysis of the resistivity imaging method of Ahoada communities

The resistivity and IP results of the inverted sections of earth material data collected from the electrodes laid on line section 1 on the site measuring 108m from origin are as shown Figure 4. Resistivity values recorded along this transect ranged from 56 - 100000Ωm. The occurrence of various resistive bands within the fresh water resistivity range indicates the presence of freshwater groundwater system. These resistivity range signature appears to the near surface during the sampling period indicative of a very shallow water table that is reached within less than 0.1 - 0.5m from the surface. There are more resistive signatures on the surface areas towards the right of the transect 64m to 108m. This may likely indicate recent migration of a mobile dissolved and or non-aqueous resistive material towards the surface by the rising water table during the last rainy season water table rise episode. There is also a discontinuous band of resistive materials on the surfaces around 30m – 60m.

There is a very resistive plume from 15000 -100000Ωm range, 5m below the ground surface with lateral distance range from 36m – around 54m. The resistivity distribution in this line profile depicts a long term process has been creating the marked elevation observable in this profile which are very significant from the expected normal resistivity ranges of the predominant earth materials on this site which is sand, soil and fresh water. Inverse Polarization levels recorded as chargeability responses along the Line 1 transect ranged from (-83) – 306 mV/V. Aside a few centimeters below the ground surface in section from 12m – 44m, every other segment of this transect recorded chargeability above 13.9mV/V. There is a contiguous presence of hydrocarbon contaminant plume from 48m to 108m from the ground surface to lowest depth achieved by the line length ES of 19.7m. From points 0 – 52m exists a visible plume movement (1m – 14m below ground surface) towards the NS direction of the site which was the orientation of the line transect. The plume in the first 0-3m below ground surface at points 48m – 108m appear to be created from the migrating plume at 36 – 52m (4.9 – 12m below ground level) and lower depths around points 80 - 96m down the transect. These sources appear to be secondary sources as revealed from the 3D rendering of the 2D data sets.

The resistivity and IP results of the inverted sections of the study area collected from the electrodes laid on line section 2 on the site measuring 108m from origin are as shown in Figure 5. Resistivity values recorded along this transect ranged from 78 - 100000Ωm. There is the wide spread presence of resistive bands within the fresh water resistivity range indicating the presence of freshwater groundwater system intercepted encountered by the injected current. These resistivity range signature appears to the near surface during the sampling period indicative of a very shallow water table like in line1 that is reached within less than 0.3 - 0.5m from the surface. There are more resistive signatures on the surface areas towards the south of the transect 72m to 108m than there are within the same zones from 0 – 68m. This may likely indicate resent migration of a mobile dissolved and or non-aqueous resistive material towards the surface by the rising water table during the last rainy season. There is a migrating plume of resistive materials south of the transect from 4m – 18m below ground surface spanning from 8m – 68m. There appears a slight discontinuity of the resistivity elating medium along this plane from 68 - 84m. The inverse polarization readings along the Line 2 transect ranged from -75 to 232mV/V. The chargeability values were significant along these corridors on the transect (12 – 28m), (34 – 60m), and 68 – 108m) the plume created by these was more spread from the distal areas of the line southwards went 0 - 5m and even further towards the 100m – 108m points. Below these set of plumes, there is also another obvious upward moving plume from areas below 19.7m especially from 0m – 12m, 32m – 72m and 84m – 92m and 96m – 108m respectively. From these upward movements 6 corridors of upward migration is visible.

The resistivity pattern observed along the earth material matrixes depicted in Figure 6 revealed a similar resistivity signature as the first two lines described above with very clear indication of a prominent fresh water signature near the surface less than 0.3m. The resistivity ranges were between 29 – 100000Ωm with a discontinuous band of higher resistive readings above the water table from points 0m to 108m. There is a sharp resistivity discontinuity between 5.7 to 8m down the profile with 2 prominent resistivity plumes migrating from the North to south section of the transect. Surrounding these major resistivity plumes are lower resistivity smears from 5.7m down to about 20m the horizontal stretch of this resistivity plume is from 0 – 108m with the leading edge appearing to be rising to the surface under the influence of the rising groundwater system. The inverse polarization result shows a very prominent chargeability plume around 5.7 – 15m below the ground surface and stretching from 36m – 48m. The plume is vertically elevating towards the surface through a corridor which has created a smear zone between 52 – 72m. Another surface movement corridor is visible around 84 – 108m and is coming from possible secondary sources 20m below the ground surface while another corridor exists behind the point of origin (0m mark) on this transect.

The resistivity signatures recorded along this transect of Figure 7 were almost 3 folds lower than in the first 3 line readings however, a similar pattern is noticed in the resistivity profile along this transect. The range of resistivity recorded was 69 – 30749 Ohm-m with a prominent resistivity bulge at the mid-section of the line from 40m – 64m horizontally and 8m – 17m vertically. From the median point elevated resistivity smear zones migrate left and right, thinning out as they spread in both directions. The inverse polarization section of this line shows a highly significant spread of chargeability around the entire soil profile except at the median point around 48 – 60 m were the chargeability was quite reduced with negative values recorded. The presence of negative chargeability is not unusual as this phenomenon is attributable to point distribution factors of the resistive materials. Chargeability values ranged from (-367) – 222mV/V. there is evidence of upward migration of the plume from lower sources to the surface southwards of the electrode line. The surface plume is very significant around the 81m – 108m areas which areas are near the entrance to the swamp.

4.3 Hydrocarbon contaminants in water and soil samples

The results of the analysis of the hydrocarbons present in the soil samples are presented in Table 1 and 2 as well as Figure 8 respectively. Total organic carbon (TOC) and Benzene-Toluene-Ethylbenzene-Xylene (BTEX) detected in samples from both impacted and remediated areas are far below the DPR limit (Table 2). On the other hand, the polycyclic aromatic hydrocarbons (PAH) are more prevalent in the Ukperede sample, which ranges between 54.56 and 77.54 mg/kg (Figure 8) with predominant components being Naphthalene (9.3%), Fluorene (4.65%), benzo(a)pyrene (6.98%) and Benzene, 1,2,3-trimethyl- (6.98%) as shown in Table 1. These components together with other traces were found to be somewhat below the detection limit after remediation. These organic compounds are generally hydrophobic in nature due to two or more benzene rings, which make them resistant to structural degradation (Anejionu, et al, 2015). This success could be linked to the remediation technique used, probably combination of soil washing, chemical oxidation, electrokinetic, photo-oxidation, evaporation, and microbial oxidation (Polyak et al. 2018; Gitipour et al. 2018).

Table 1
PAH calibration of Ukperede

Compounds	**Retention Time (RT)**	**QI on**	**Conc (Unit)ppm**	**Response**	**Dev (min) #**	**% of Conc**
Benzene, 1,2,3-trimethyl-	5.926	105	0.03	8652	1	6.98
Naphthalene	6.263	105	0.04	12523	35	9.30
2-Methylnaphthalene	8.488	128	0.01	4034	1	2.32
Acenaphthylene	8.593	128	0.02	6820	1	4.65
Acenaphtene	10.003	142	0.02	7004	48	4.65
Fluorene	10.003	152	0.02	7004	43	4.65
Anthracene	11.937	153	0.02	6426	59	4.65
Phenanthrene	12.320	166	0.02	4773	1	4.65
Fluoranthene	13.412	178	0.02	5986	66	4.65
Pyrene	15.828	178	0.03	7491	1	6.98
Benz(a)anthracene	15.940	202	0.02	5063	1	4.65
Chrysene	20.000	202	0.02	4806	1	4.65
Benzo(b)Fluoranthene	20.667	202	0.03	7472	1	6.98
Benzo(k)Fluoranthene	24.387	228	0.02	6902	1	4.65
Benzo(a)pyrene	24.453	228	0.03	9935	27	6.98
Diben(a,h)anthracene	27.159	252	0.03	7457	1	6.98
Indeno(1,2,3-cd)pyrene	27.212	252	0.02	6796	1	4.65
Benzo(g,h,i)perylene	27.922	252	0.03	7276	1	6.98
TOTAL			0.43			100

The concentrations of TPH and oil and grease in remediated sites were significantly higher than the impacted particularly in the Oshie samples. Generally, natural attenuation, such as evaporation, photo-oxidation, and biodegradation, is expected to reduce hydrocarbons to a large extent for certain period. However, the observation noted could be attributed to the presence of recalcitrant compounds with higher molecular weight in addition to their possible toxic degradation intermediates, which are capable of inhibiting oil-degrading microorganisms (Polyak et al. 2018). This shows that hydrocarbons cannot be completely removed by biological decontamination, even after a prolonged exposure. Consequently, the results from this finding suggests high values of hydrocarbon contaminations in these sites, which exceeded the background values for petroleum hydrocarbon in rural agricultural wet lands soils of the Niger Delta region in Nigeria and regulated limits making the site unfit for agricultural purposes.

Table 2
Results of Hydrocarbon Analysis of the Soil Samples. Values are average of triplicates (TOGx103, TPHx102 and TOCx10)

	Chemical compound				
	TOG (mg/kg)	**TPH (mg/kg)**	**PAH (mg/kg)**	**BTEX (mg/kg)**	**TOC %**
Oshie IMP Soil 01	19.84	42.81	0.43	0.1	2.37
Oshie IMP Soil 02	17.96	31.97	33.53	0.38	5.14
Ukperede IMP Soil 01	16.37	41.39	54.56	0.22	4.84
Ukperede IMP Soil 02	21.75	58.36	77.54	0.14	6.04
Akinima Soil IMP 01	14.92	19.44	43.02	0.09	2.17
Akinima Soil IMP 02	15.69	17.27	6.99	0.19	4.15
Ihereke Soil IMP	16.09	46.73	5.48	0.02	3.37
Oshie RS	24.67	50.78	0.42	0.01	1.14
Ukperede RS	16.75	24.78	0.43	0.15	8.11
Akinima RS	14.86	11.73	10.65	2.7	7.18
Ihereke RS	12.71	28.42	2.4	0.38	2.74
Control Soil CS	0.27	0.68	0.49	0.01	0.318
DPR Limits	5000	5000	40	246	2

***DPR** (Department of Petroleum Resources) ***TOG** (Total Oil and Grease) *** TPH** (Total Petroleum Hydrocarbon) ***PAH** (Polycyclic Aromatic Hydrocarbon) ***BTEX** (Benzene, Toluene, Ethylbenzene and Xylene) ***TOC** (Total petroleum hydrocarbons)

5.0 Discussion

Environmental pollution remains a major challenge in many parts of the globe, particularly hydrocarbon contaminants because of their persistent nature (Anejionu et al. 2005; Ogboghodo 2004; Osuji and Onojake 2004). Pollution from oil spills impacted sites poses serious risks to ground water through the migration of contaminant; they also affect farm produce and in turn expose communities to different health issues. They are known to also severely affect the economy of a region. Understanding the extent and types of pollution is a stride towards mitigating the impacts of pollution. While individual techniques or methods can be sufficient in investigating a polluted area, the application of a combined approach can be more robust and reliable in determining the extent and characterizing contaminants.

GIS has become an essential tool in environmental studies for mapping contaminants and has been applied in such studies in many parts of the globe. GIS was applied along the Chennai Coast in India to assess the environmental sensitivity and oil spill (Kankara et al. 2016). Bayramov et al. (2018) used remote sensing and GIS to quantitatively assess and model oil pollution and predict risks and consequences to shoreline from oil platforms in the Caspian Sea (Emil Bayramov et al. 2018). Similar to these studies, our study used GIS to map hydrocarbon pollution at the Ahoada area of the Niger Delta region.

Surface geophysical investigations are paramount and applicable in the detection and delineation of chemical contaminants found in oil spill sites in exploration and production operation. Resistivity imaging is being applied increasingly in the areas of environmental studies because of recent improvements in electronics and computational power. The method was applied by geophysicists, geologist and other environmental researchers to investigate hydrocarbon pollution at different scale. The study of Benson et al. (1997) and Shevnin et al. (2005), showed that porous rocks saturated with oil spills corresponds to high resistivity signatures while mapping oil contaminated sites using 1D vertical electrical sounding (VES) to 2D resistivity tomograms in Utah County, U.S.A and Cardenas city, Mexico respectively. Raji et al. (2018), applied 2D electrical resistivity tomography (ERT) and vertical electrical sounding (VES) to map out areas contaminated by oil spills in the coastal areas of Ijegun Community of Lagos –Nigeria. The results revealed that there was presence of contaminant of different extents and shapes around the area. It was discovered that the top aquifer around Ijegun has been infiltrated by oil plumes and the contaminant plumes emanating from oil spills are yet to undergo complete degradation as at the period of the research (Raji etal. 2018). While these methods have been applied in many parts of the globe and in some parts of Nigeria for environmental pollution, they have not been widely applied by individuals or researchers for such purposes due to associated costs, but mostly by companies. However, few studies available such as" Addressing Environmental Health Problems in Ogoniland" through Implementation of United Nations Environment Program Recommendations (Yakubu 2017) and "Hydrocarbon pollution in the Niger Delta: Geographies of impacts and appraisal of lapses in extant legal framework" (Anejionu 2015) showed that there is extensive environmental pollution in the Niger Delta area. This present study supports the findings from the previous studies. In addition, this study revealed the types of hydrocarbons that are present in the study area, which can be of importance in correlating the associated diseases in the area with the location of facilities such as water wells and the types of hydrocarbon contaminants.

6.0 Conclusions

The existence of hydrocarbon compounds in sediments and surface soil in locations where natural gas flaring and oil pollution occur deserves serious attention as it can alter the ecology of the location and can have significant impacts on humans and other components of the environment. Several other sources such as wastewater, sewage and atmospheric fallouts may contribute to the increase in pollutants. Environmental pollution mainly from oil exploration and exploitation has plagued locations such as the Niger Delta region of Nigeria for over five decades since oil discovery in the area. The problem was compounded by the more recent activities of bunkering and artisanal crude oil refining thereby worsening the socio-economic developments and increasing health hazards in the area. This study reports the geophysical assessments and soil analysis to assess the impacts of hydrocarbon pollution in the Ahoada community of the Niger delta region of Nigeria. Resistivity methods which are used for oil, mineral and ground water exploration are the underpinning geophysical techniques. The geophysical survey revealed that hydrocarbon pollutants are migrating from the surface within the study area and have reached depths ranging from 1m to 21.8m BGL. Some contaminant plumes were also seen to have widths ranging from 1 to 10m. Hydrocarbons were found at the deepest depth of 24.6m at Oshie-Akara-Olu location. Soil samples' analysis showed that the range of concentrations of TPH for the IMS was 17.27 – 58.36 mg/kg; RS was 11.73 – 50.78 mg/kg which were higher than the concentrations of 0.68 mg/kg in the CS. PAH are more prevalent in the samples from Ukperede ranging from 54.56 - 77.54 mg/kg with predominant components being Naphthalene (9.30%) and the lowest was 2-Methylnaphthalene (2.31%). These components together with other traces were found to be below the detection limit after remediation. BTEX concentrations ranges from 0.02 – 0.38 mg/kg for IMS, 0.01 – 2.7 mg/kg for RS against CS value of 0.01 mg/kg. The study revealed that there are characteristically high resistivity values in the samples which was corroborated by the findings from the resistivity survey. TOG was found to be higher in the impacted and remediated area than in the control area demonstrating that significant quantity of the hydrocarbon has undergone appreciable decomposition. Results of the geophysical survey show that there are characteristically high resistivity contaminants in the study area and this was corroborated by the findings from the soil samples' analysis. TOC was found to increase significantly in the impacted and remediated area than in the control area demonstrating that significant quantity of the hydrocarbon has undergone appreciable decomposition or a degradation process.

Declarations

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Figures

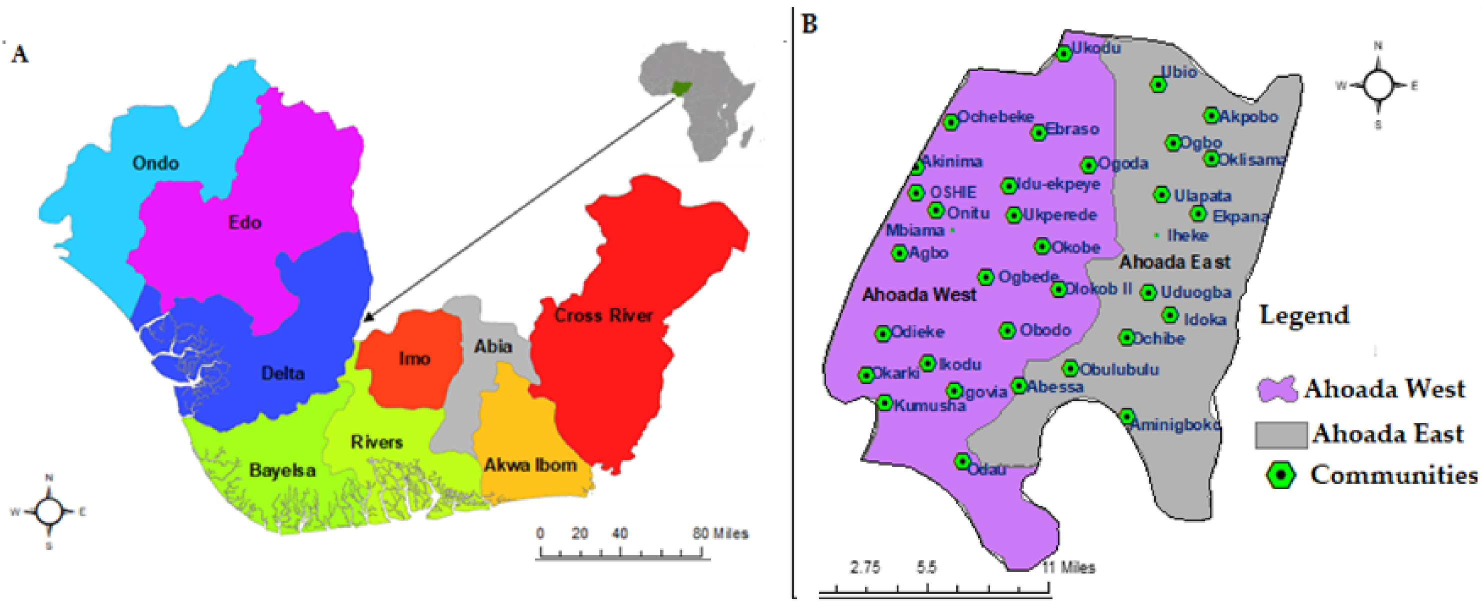

Figure 1

A-Map of Africa, Nigeria and Niger Delta B- Map of Ahoada Communities

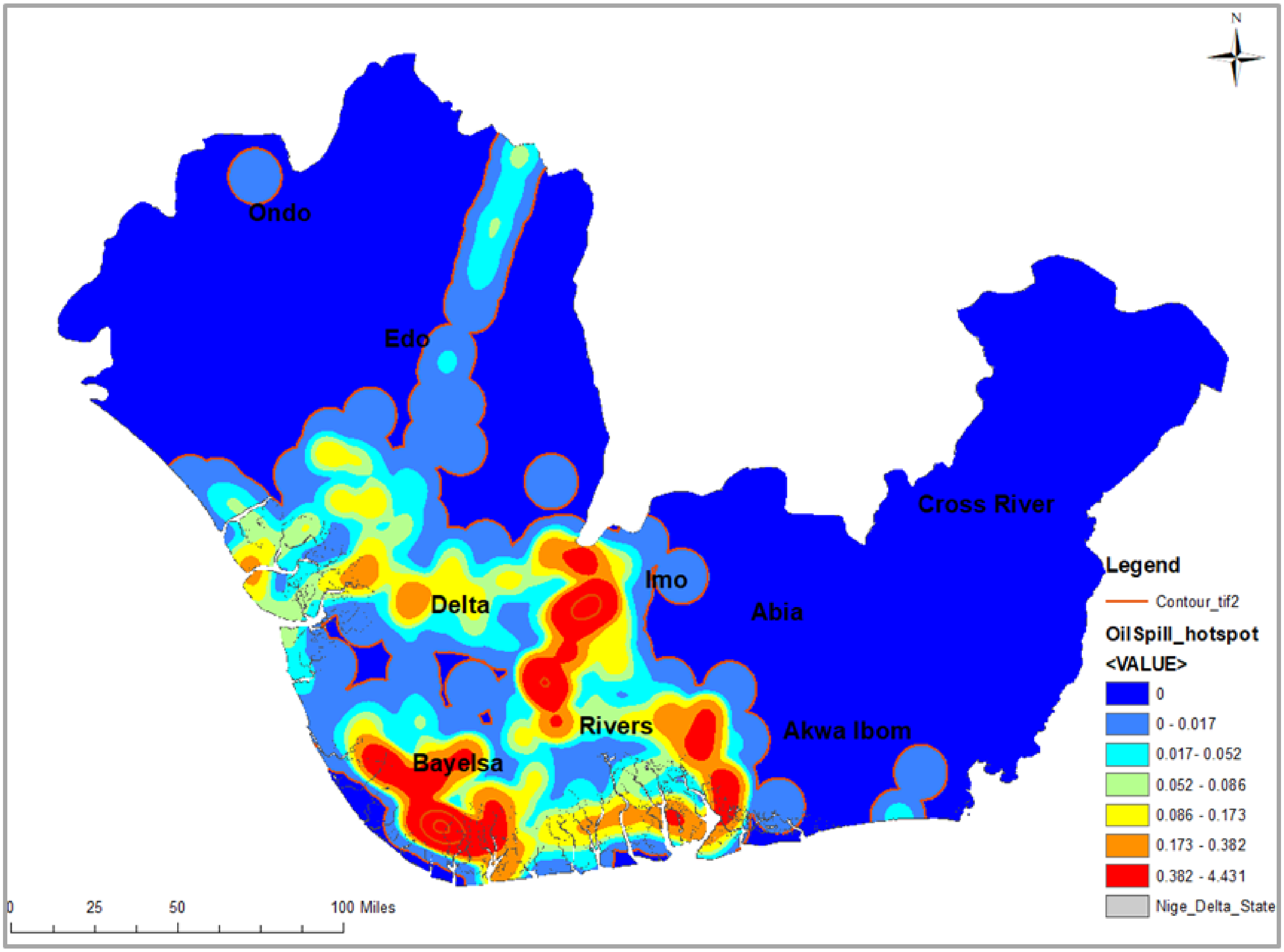

Figure 2

Oil spill hotspot map of kernel density of Niger Delta

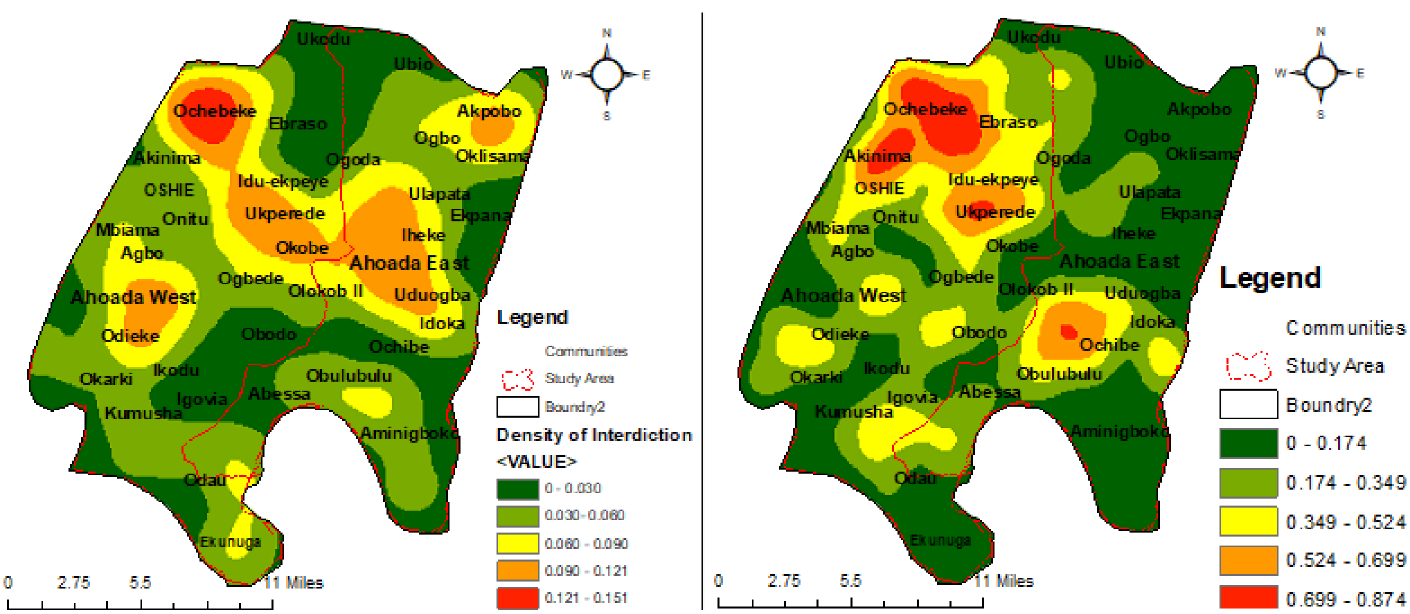

Figure 3

(a) Oil spills hotspot by interdiction

(b) General Oil spill hotspot of the Study Area

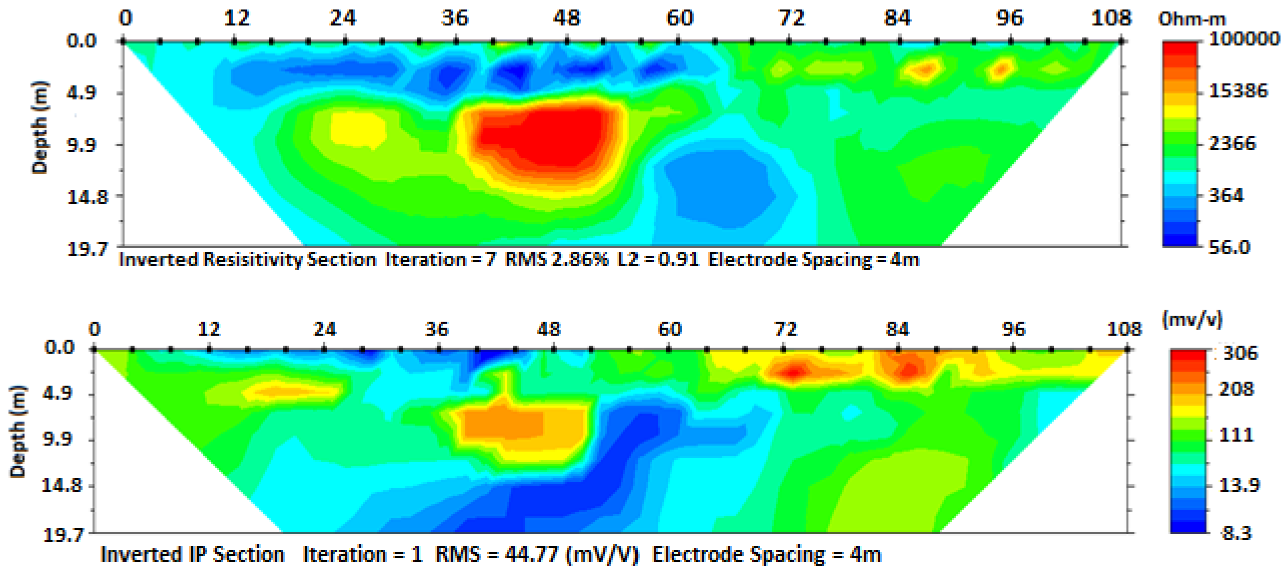

Figure 4

Resistivity and Induced Polarization of Ukperede line 1

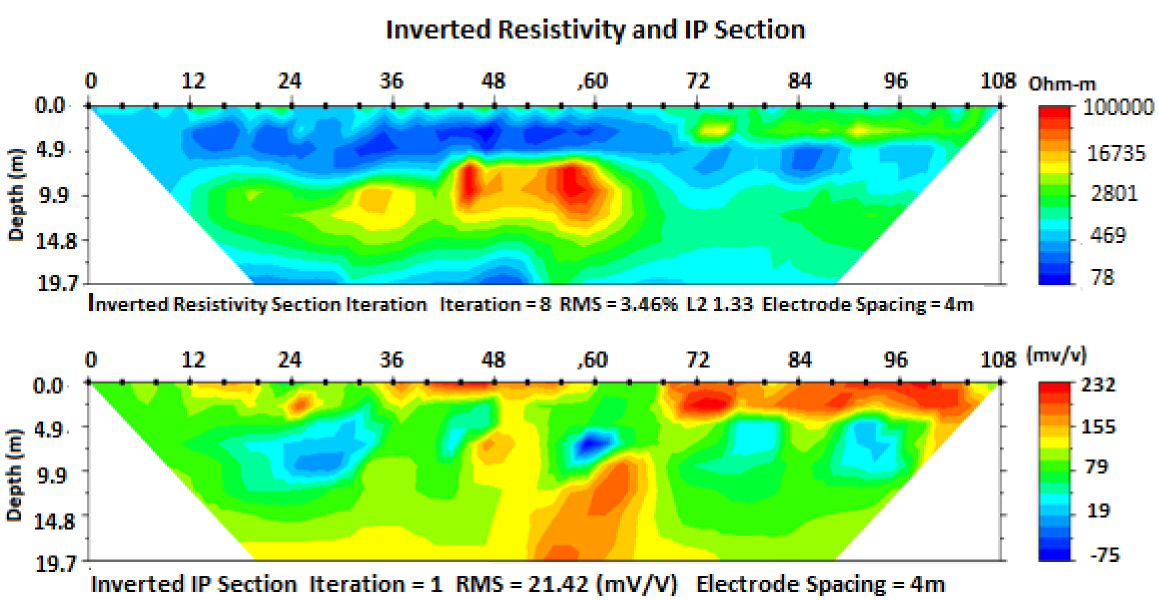

Figure 5

Resistivity and Induced Polarisation of Ukperede line 2

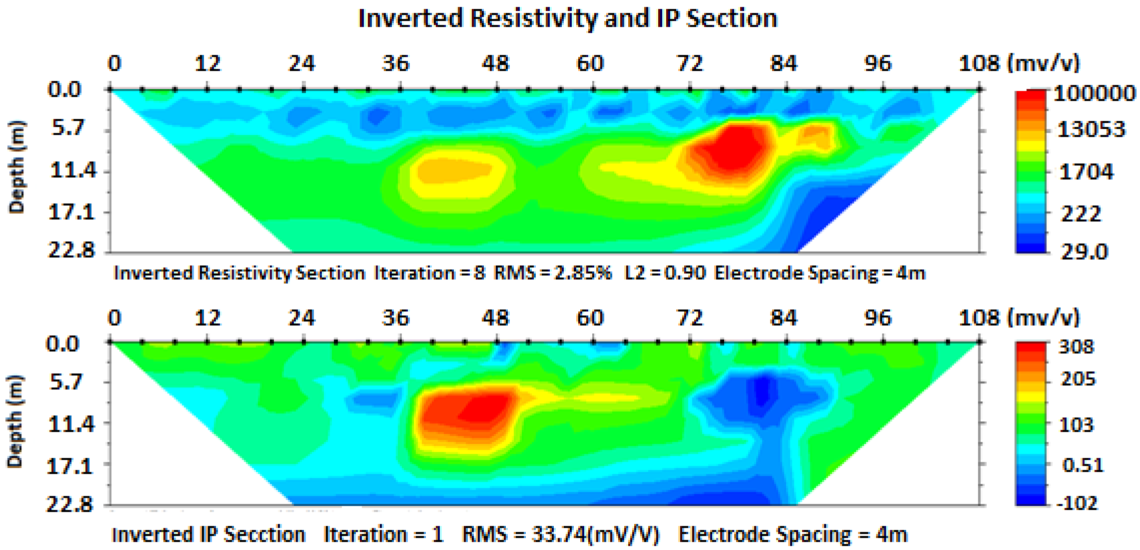

Figure 6

Resistivity and Induced Polarisation of Ukperede line 3

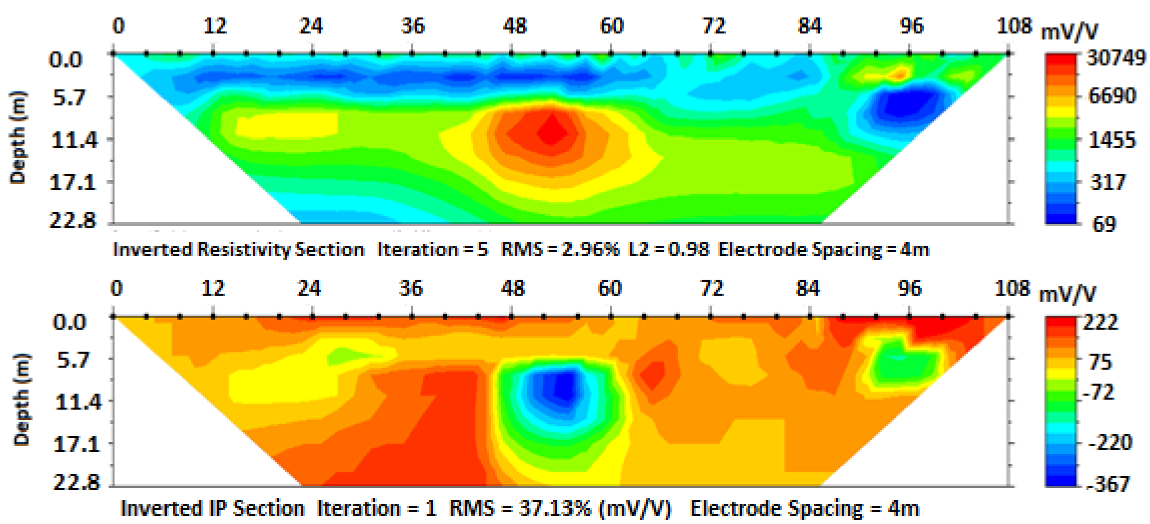

Figure 7

Resistivity and Induced Polarization of Ukperede line 4

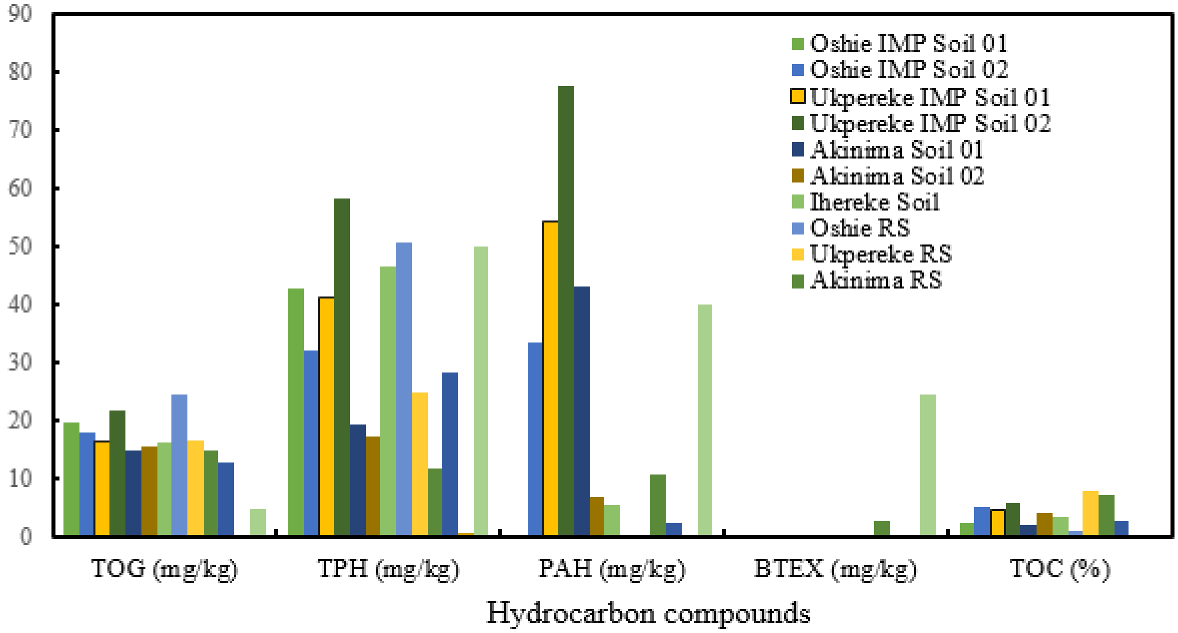

Figure 8

Summary of hydrocarbon analysis of the soil samples of Ahoada. Values are average of triplicates (TOGx103, TPHx102 and TOCx10)