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Geochemical Assessment of Hydrocarbon Contaminated Site in Central Niger Delta, Nigeria

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ABSTRACT

Hydrocarbon contamination results in environmental degradation and adversely affects health and socioeconomic standards of life globally and the Niger Delta in particular. This study assessed soil pollution and contamination levels of a Total Petroleum Hydrocarbon (TPH) impacted site at Otuasega in Ogbia Local Government Area of Bayelsa State, Nigeria. Geochemical analysis of soil samples for TPH was performed using gas chromatography (flame ionization detection) (GC-FID) and TPH divided into different carbon fractions in terms of the aliphatic and aromatic compounds and also according to their equivalent carbon number (EC). Soil type, particle size and size distribution were obtained by sieve analysis. Results showed that the soil type is generally composed of sand/clayey sand at proportions of 16-32 % fines and 68-84% sand to depth of over 30 cm. Chromatograms indicate predominance of the C15-C21 carbon fractions, the soils TPH concentrations generally increase with depth, having a minimum of 17,457.00 ppm at 0 – 15 cm and a maximum of 163,609.50 ppm at 15 cm - 30 cm. These concentrations are enormously higher than the target value of 50 ppm for Department of Petroleum Resources, (DPR) and intervention values of 300 ppm for Shell Petroleum Development Company, (SPDC) and 500 ppm for Environmental Guidelines and Standards for Petroleum Industry in Nigeria, (EGASPIN 2002) for TPH in soils of Niger Delta. A collective cooperation by respective authorities is paramount to achieve a sustainable management of oil pollution in the area.

Keywords: Hydrocarbon Contamination, Soil Pollution, Environmental Degradation, TPH Concentrations, Geochemical Analysis, Gas Chromatography

INTRODUCTION

Commencing with the early days of petroleum operations in the region which dates back to the

1950's, there have been several cases of oil spills resulting from failure of pipes and storage tanks due to corrosion and vandalization, equipment failure and human errors with numerous damaging consequences to both the socio-economic and biophysical environmental components of the Niger Delta. (Tse and Nwankwo, 2013). These in turn have undermined the chances of achieving a sustainable development in this region. The Niger Delta region is located along Atlantic Coast of Southern Nigeria and has a coastline covering roughly 450 kilometers making it the second largest river delta in the world (Badejo, Folarin and Anwanane, 2014). Soils contaminated by hydrocarbon create prevalent environmental problems due to their adverse effects. It is crucial assessing areas of contamination, remediating and monitoring clean-ups and also final quality evaluation of the remediated soil. Total Petroleum Hydrocarbon TPH are significant toxic contaminants of the environment and harmful to human, (Paula, Lurdes, Jose and Cristina, 2012).

According to Tse and Nwankwo (2013), Total petroleum hydrocarbon describes numerous group of chemicals from crude oil, it is the quantifiable volume of petroleum-based hydrocarbon in the environment. TPH is a measure of sum of hydrocarbon entirety in a given sample of a hydrocarbon contaminated medium of the environment. TPH can occur as dissolved form in water, sorbed on solids, form part of the soil gas and also as singular liquid phase called non-aqueous phase liquid (NAPL).

Gas chromatography-flame ionization detection (GC-FID) is a majorly used analytical technique for separating, identifying and quantifying of compounds in their vapour state. The popularity of gas chromatography is totally centered on a high sensitivity, selectivity and resolution in combination with a good precision and accuracy in wide dynamic concentration range (Okop and Ekop, 2012). Alinnor, Ogukwe and Nwagbo, (2014) have reported using GC-FID to ascertain levels of TPH in groundwater and soils of oil spill area in selected localities of Rivers State, Niger Delta - Nigeria. Crude oil spillage contamination of soil samples from Ikot Abasi and Ikot Ada Udo in Akwa Ibom State, Niger Delta region of Nigeria were investigated and evaluated using GC-FID (Okop and Ekpo, 2012).

Study have been carried out by Nwankwoala and Mzaga (2017), on hydrocarbon impacted sites in areas of Eastern Niger Delta of Nigeria to determine consequence of pollution on the characteristics physical properties of soils, assess contamination levels and toxicity, evaluate contaminant migratory pathway and groundwater flow direction. Sustainability cannot be achieved in the midst of frequent oil spills and subsequent environmental pollution and degradation. This

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study is therefore carried out with the aim to assess the level of contamination of TPH impacted site, determine the result of contamination on properties of soils, identify different types and fraction of hydrocarbon contaminant, evaluate the predominant contaminant present in the soil as well as establish the importance of oil spill prevention, control, timely and efficient oil spill emergency response and suggest sustainable pollution management options.

Location of Study Area

The location of study is in Bayelsa State which is a part of the Niger Delta. The Niger Delta is an extensive province spanning over 100's of kilometers and extending from Equatorial Guinea and parts of Cameroon down to Nigeria (Short and Stauble, 1967). It contains extensive lowlands and rugged terrain of marshy landscape and large mangroves of a typical tropical rain forest region. Geopolitically the region covers about nine states in Nigeria, namely; Bayelsa, Abia, Delta, Imo, Rivers, Edo, Cross-River, Akwa-Ibom and Ondo State, Figure 1.

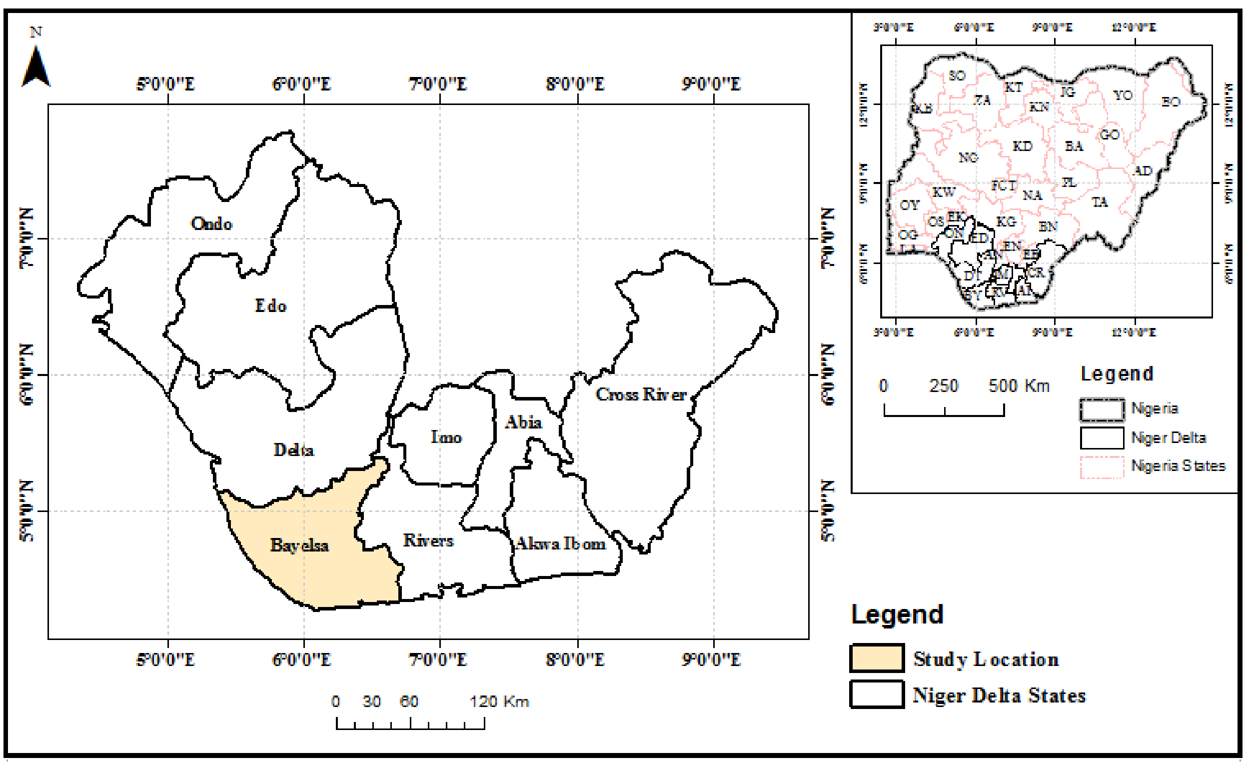

Figure 1 Showing States in the Niger Delta and Outlining the Study Location.

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The study area is in Ogbia Local Government of Bayelsa State and the primary towns are Ebelibri, Otuasega, Elebele and Imiringi. Ogbia LGA falls within the coordinates Latitudes 4^0 38’ 59.99” N and Longitude 6^0 15’ 60.00” E, with an area of 695 km^2 and major population of inhabitants with occupation of fishing and farming. It is the local government of Oloibiri, where the oil was first discovered and mined in Nigeria.

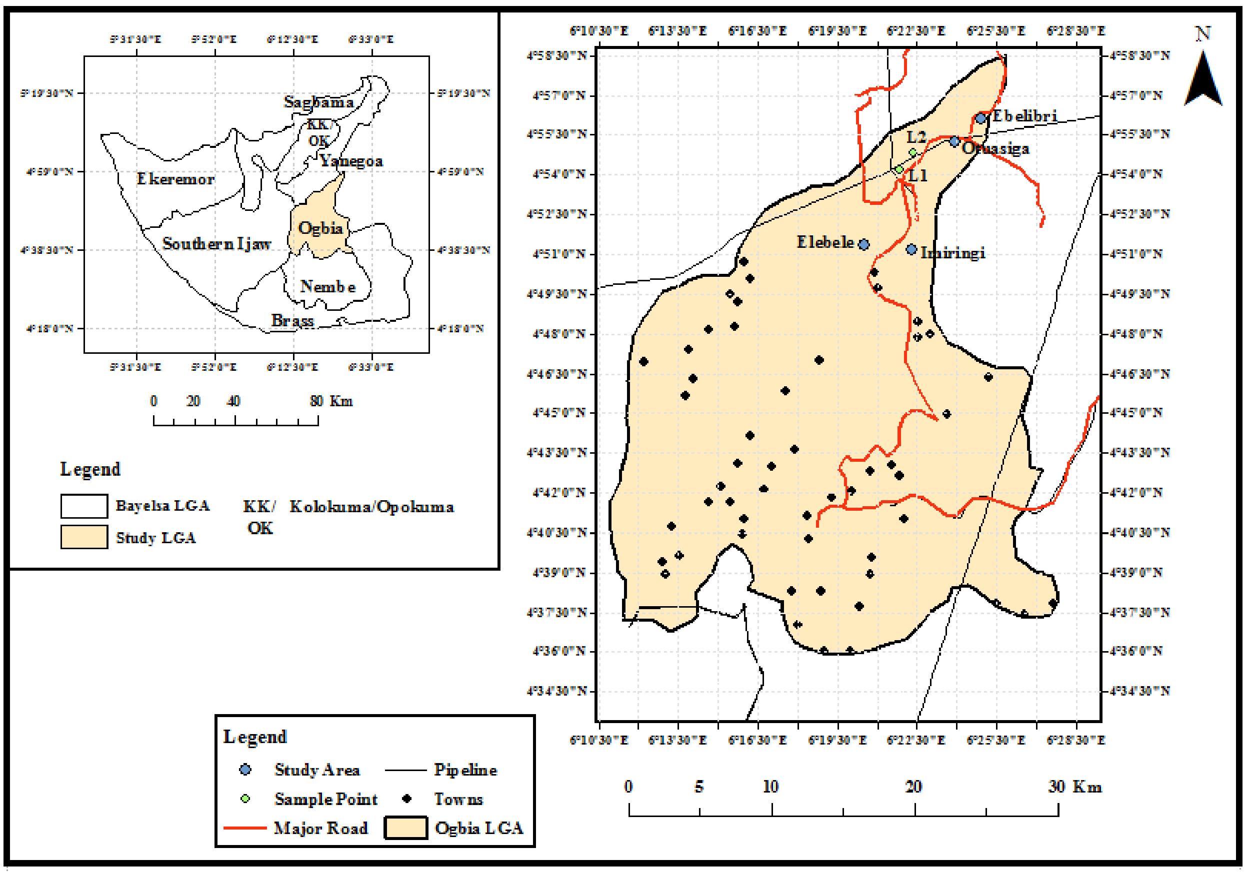

Figure 2 Showing Study Area and Sampling Points.

Geology of the Study Area

Ogbia and its localities has a geology of the Niger Delta region with a stratigraphy comprising of the Benin, Agbada and Akata formations, (Short and Stauble, 1967). Benin formation extends crossways the entire Delta from Benin – Onitsha in north to beyond the current coastline of Nigeria. The formation comprises of enormous, highly porous, fresh water continental sandstone with local thin shale interbedded which is reflected emanating from braided watercourse source. The sands and sandstone of the Benin formation are generally coarse to medium to fine grained, and are poorly sorted. This is the youngest formation in Niger Delta. The Agbada formation comprises of a cyclic upward coarsening regressive sequence developed from disturbance and abandonment. These sequences are composed of alternating shale, siltstone and sandstone. The alternation of sandstone, siltstones, and shale are results of differentiated sinking disparity in supply of sediments and Delta depositional axes shifts that cause local transgression and regression. The geologic age of Agbada formation ranges from Eocene to recent. It is the deepest formation and made up of marine shale, clays and silts that underlie the deltaic sequence. The depositional environments is typically marine, therefore, it is the source rock i.e. where hydrocarbon is generated before migrating to Agbada formation. The maximum thickness is believed to be over 20,000 ft. in some parts across the Delta. Akata formation seems to be continuous but diachronous with the outcropping Imo shale. The formation ranges in angle from Miocene to recent (Doust and Omatsola 1990).

MATERIALS AND METHODS

Two (2) study holes (Location 1 and 2) were bored and a total of four (4) soil/sediment samples collected at potential contaminated site. Portable Global Positioning System (GPS) device where used to get location and position of sample points. Soils were sampled with hand augers at depths of 0–15 cm and 15cm–30cm each per sampling point. After collection, the soil samples were kept in clean plastic bags and labelled as Samples A, B, C and D. Ice-packed cooler was then used to store the samples in transit for laboratory analysis. These samples were analyzed and compared with a control sample to assess the level of contamination of the study area.

Two laboratory techniques/types of analysis were performed on the samples. Sieve analysis (particle size distribution) technique was first applied in this study. Basic sieve properties of the retrieved contaminated soils were carried out to have an idea of the lithology and their permeability estimated. Determination of hydrocarbon contamination of the site, by soil analysis for TPH concentration was the second technique used in this study. This was done using gas chromatography (GC-FID).

RESULTS AND DISCUSSION

Site Characterization

The spill site has a gentle sloped terrain; Location 1 (L1) is a complete dry land area while the southern part of Location 2 (L2) is swampy with a small stream flowing eastwards. The stream area contained scanty distribution of plants while

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the rest of the spill site was mostly dried up from effects of crude oil on soil. Plant cover in the affected sites is very minimal in comparison to the unaffected area. The presence of stream in the L2 gave an insight of the hydrogeology of the area. It shows presence of a shallow water table and an unconfined aquifer in the area, thereby increasing the chances of groundwater pollution.

Sieve Properties of the Soil

Sieve properties of the retrieved soils were carried out to have an idea of the lithology and estimate the permeability of the affected soils, this was done by using different sets of sieves with diameters of 0.075 mm, 0.150mm, 0.425mm, 1mm and 2mm. From general observation and sieve analysis of the sample soils gotten, it showed that the soil types in the location site were sand/clayey sand. The results obtained as shown in Table 1 below indicates that all soil samples compose of predominantly medium grained sand particles with the top of the soils between depths of 0 – 15 cm containing relatively more clay than samples taken at depths 15 cm – 30 cm where the proportion of clay slightly decreases.

Table 1 Sieve Properties of Soil Samples

Sample Location	Sample Depth (cm)	Mass of dry sample (g)		Sieve Diameter					% Sand	% Clay and Silt
				2	1	0.425	0.150	0.075		
1	0 -15	87.5	Mass retained	0.3	2.5	27.3	56.7	59.2	68	32
			Mass passing	87.2	84.7	58.2	31.8	28.3		
			% Passing	97	96	66	36	32		
	15 - 30	78.2	Mass retained	3.1	10	30.8	20.1	1.5	84	16
			Mass passing	75.1	65.1	34.8	14.2	12.7		
			% Passing	96	83	45	18	16		
2	0 -15	60	Mass retained	0	5.8	31.3	45.6	47.7	79.5	20.5
			Mass passing	60	54.2	22.9	14.4	12.3		
			% Passing	100	90	38	24	20		
	15 - 30	83.5	Mass retained	2.1	6.2	31.2	28.1	2.8		16
			Mass passing	81.4	75.4	44	15.9	13.3		

			% Passing	97	90	53	19	16	84	

Table 1 shows that the predominant component of the soil is sand and therefore having moderate to high pore space with high porosity and relatively good for easy spread of fluid in contact. This makes infiltration and percolation of fluids quite easy and implies a high pollutant spread property and high contamination rate of the soil in the study area.

Total Petroleum Hydrocarbon (TPH) Concentration

Geochemical analysis done on the soil samples helped to determine the different hydrocarbon present, their constituents and quantity present. Two types of hydrocarbon were tested for in the soils which are the aliphatic (saturated) hydrocarbons and the aromatic hydrocarbons, the sum of both gave the total petroleum hydrocarbon concentration of the soil samples collected and this helped to know the degree of contamination of soil in the spill site.

From results of geochemical analysis done, the distribution of Total Saturated (Aliphatic) Hydrocarbon (TSH) components of the crude in the soil samples collected shows a similar trend with very slight differences. Generally the chromatograms indicates least significance of the lightest fractions (nC4-nC9) and heaviest fractions (nC30-nC39) of the aliphatic hydrocarbons, while having most concentration of the lighter fractions of the aliphatic hydrocarbon components (nC15-nC21), Figure 3a and 3b. The concentrations of fractions are higher at depths of 15 to 30 cm and lower at 0 to 15 cm depths, showing increased accumulation of the crude with depth, Table 2. This could be from percolation of the crude to deeper depths attributed to the soils highly porous and permeable nature. It can also be due to the actions of microbial activities in the soils resulting to biodegradation and breaking down of the heavier components at the surface into lighter ones that easily percolates into the soils. The TSH concentration is highest in L2 at depths of 15 cm to 30 cm (151,163.00 ppm) and lowest in L1 at depths of 0 to 15 cm (16,765.90 ppm), Table 2. Figure 3a, shows the profile of hydrocarbons fractions in the soil samples. The chromatographs displays a range from C10 to C39. The C10 to C39 hydrocarbon chains are semi-volatiles and C6 to C9 are the volatiles. The chromatograms for the abundance and distribution of the Total Aromatic Hydrocarbon (TAH) components of the soil samples obtained from L1 and L2 are presented in Figure 4a and 4b. The aromatic hydrocarbon components of the soils also show similar trends of distribution, but having the highest concentration in L2 at depths 15 to 30 cm

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(15,225.20 ppm) and lowest concentration in L1 at depths of 0 to 15 cm (691.10 ppm), Table 2.

Table 2 Sample Locations with THS and TAH Concentrations of Soil Samples

SAMPLE LOCATION	DEPTH	TSH (ppm)	TAH (ppm)
1	0 – 15	691.10	16,765.90
	15 – 30	12,446.50	151,163.00
2	0 – 15	5590.21	23,746.40
	15 – 30	15,225.20	101,150.00

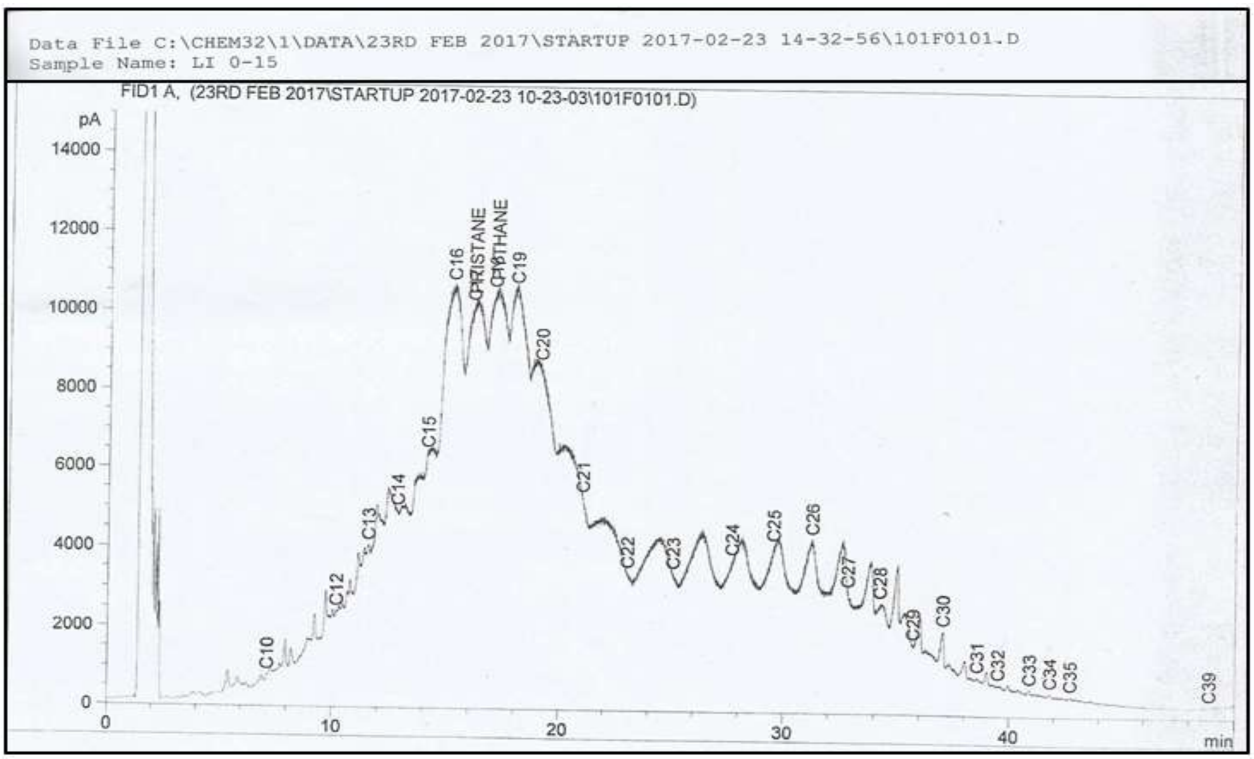
The soil samples TPH concentrations increases from surface to depths. Sample B has the highest value of 163,609.50 ppm followed by Sample D with a concentration of 116,375.20 ppm. Sample C has 29,336.60 ppm and Sample A has the lowest concentration value of 17,457.00 ppm, Table 3.

Table 3 Sample points coordinates and respective TPH Concentrations

Location	Sample ID	Latitude (N)	Longitude (E)	Depth (cm)	TPH (ppm)
1	**A**	04^0 54′ 7.2″	06^0 21′ 50.4″	0 – 15	17,457.00
	B	04^0 54′ 7.2″	06^0 21′ 50.4″	15 – 30	163,609.50
2	**C**	04^0 54′ 46.8″	06^0 22′ 58.8″	0 – 15	29,336.60
	D	04^0 54′ 46.8″	06^0 22′ 58.8″	15 – 30	116,375.20
EGASPIN Intervention Limits					500.00
Shell Petroleum Development Company (SPDC) Intervention Limits					300.00

Department of Petroleum Resources (DPR) Limits in Soils	50.00

Table 3 shows the coordinates of collected samples and the total hydrocarbon content in the soils and compared with the DPR limits and Shell E.I.A control sample value of the unaffected soil in the study area. It is observed that the concentrations of the TPH in all samples collected are enormously high beyond the regulatory agency's targets of 50 ppm (DPR) and intervention values of and 500 ppm (EGASPIN 2002) and 300 ppm (SPDC) respectively. The least value of 17,457 ppm (Sample A) at L1 (0 – 15 cm) which is 58 times the targets of SPDC intervention value of 300ppm and 349 times the DPR limits indicates an extremely high level of hydrocarbon contamination in the soils.



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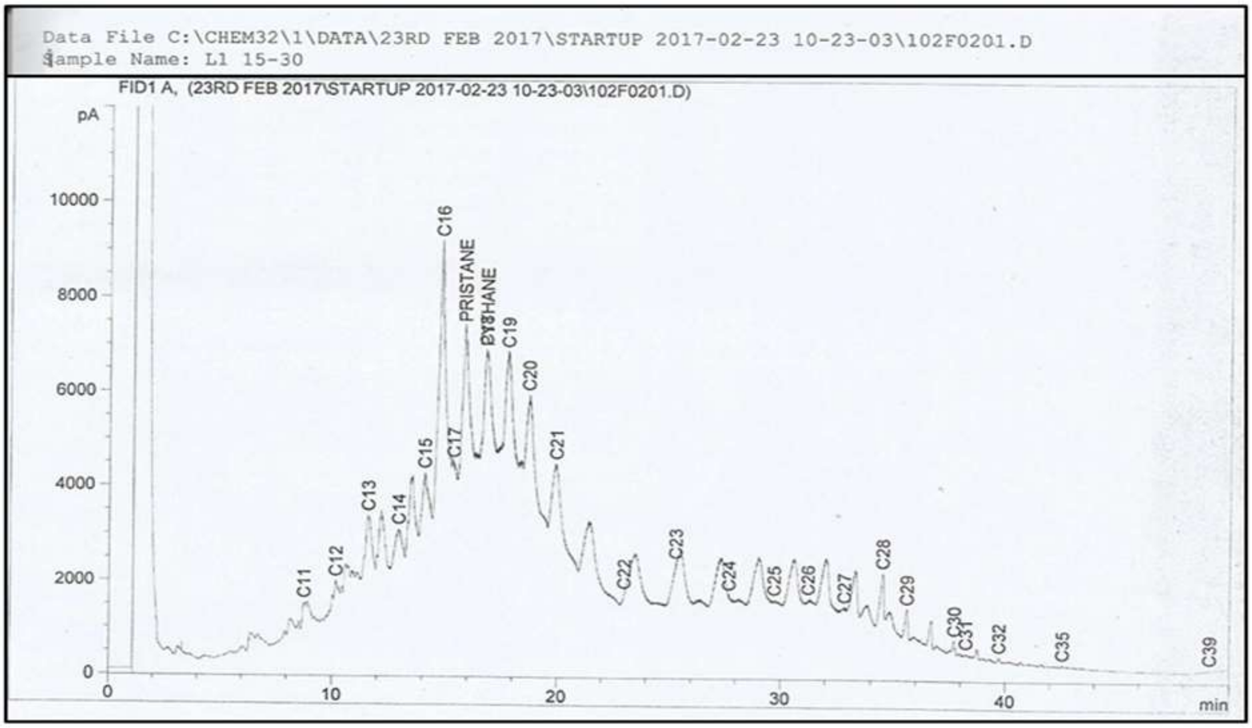
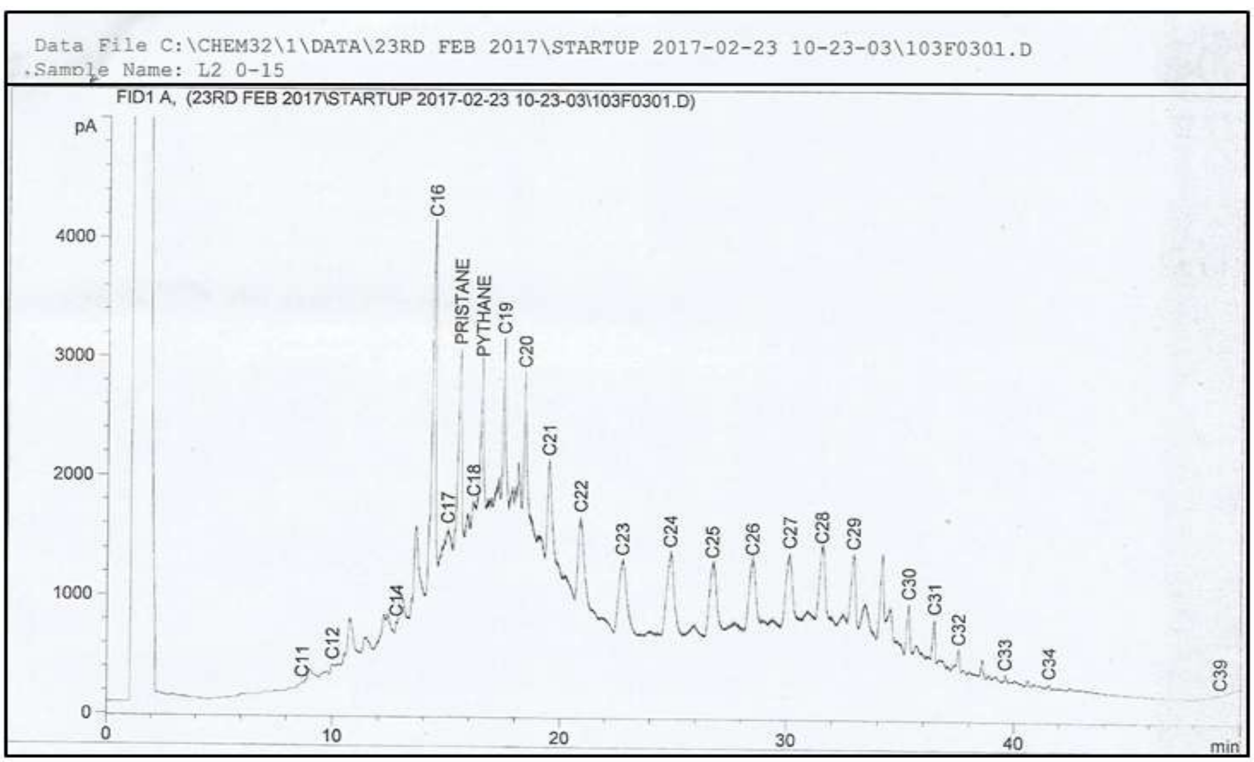


Figure 3a Chromatograms of Aliphatic Hydrocarbon components in soil samples from Location 1



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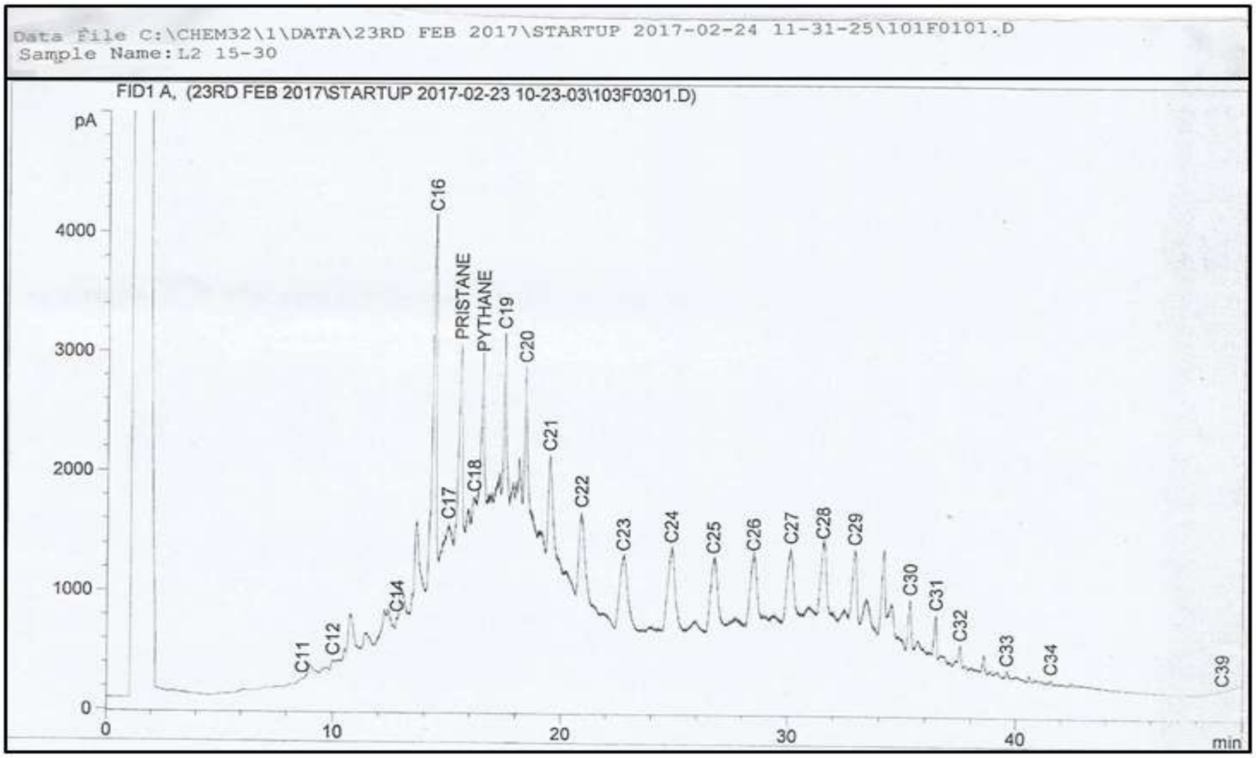

Figure 3b Chromatograms of Aliphatic Hydrocarbon components in soil samples from Location 2

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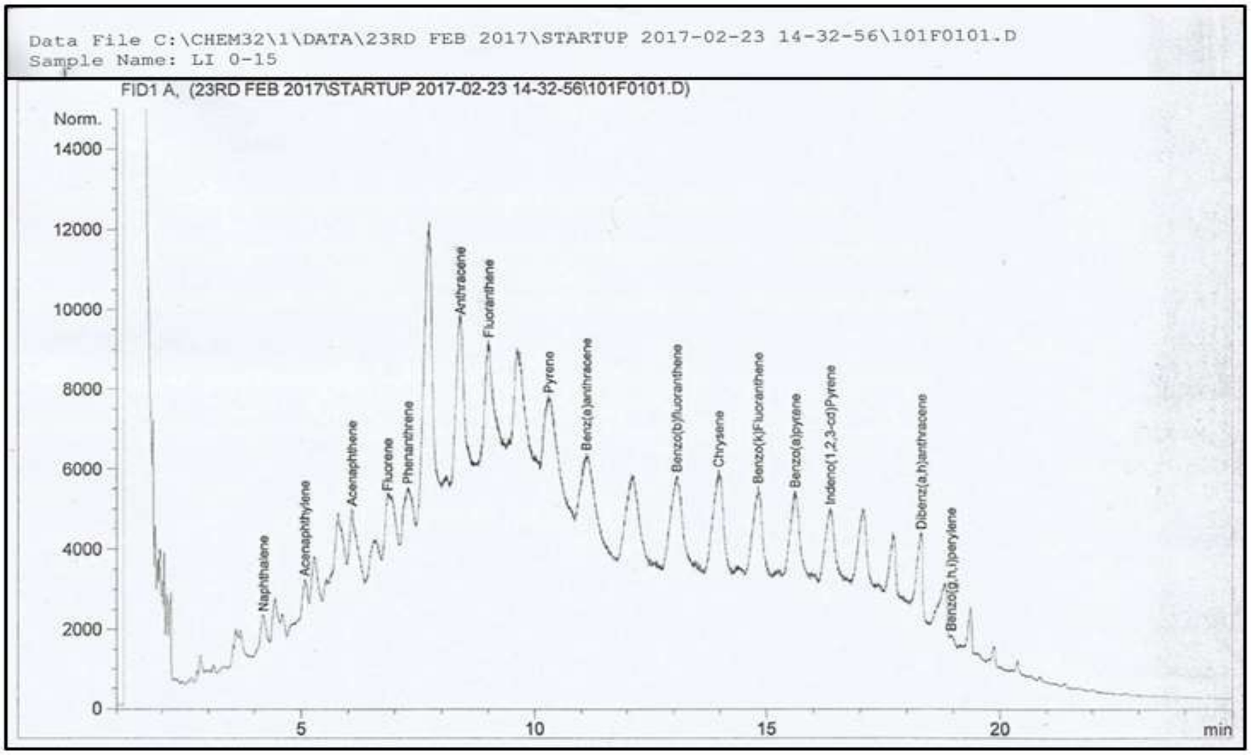

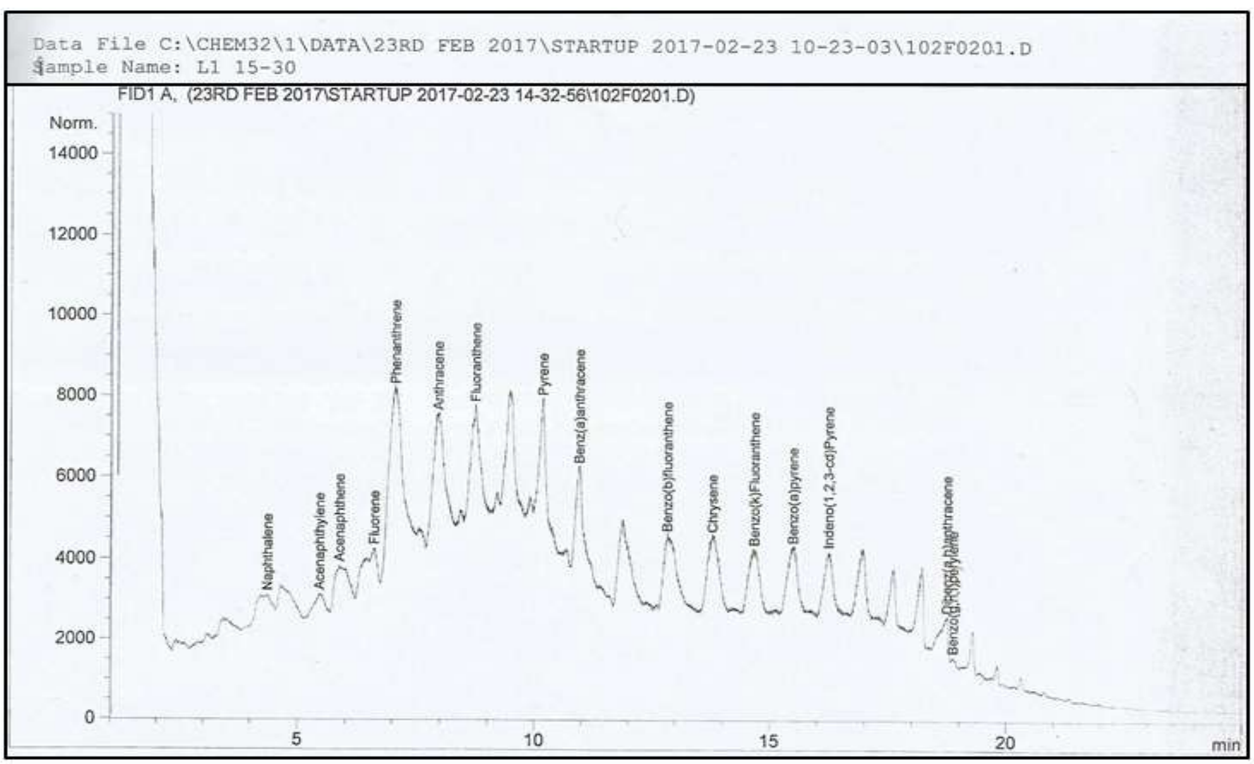

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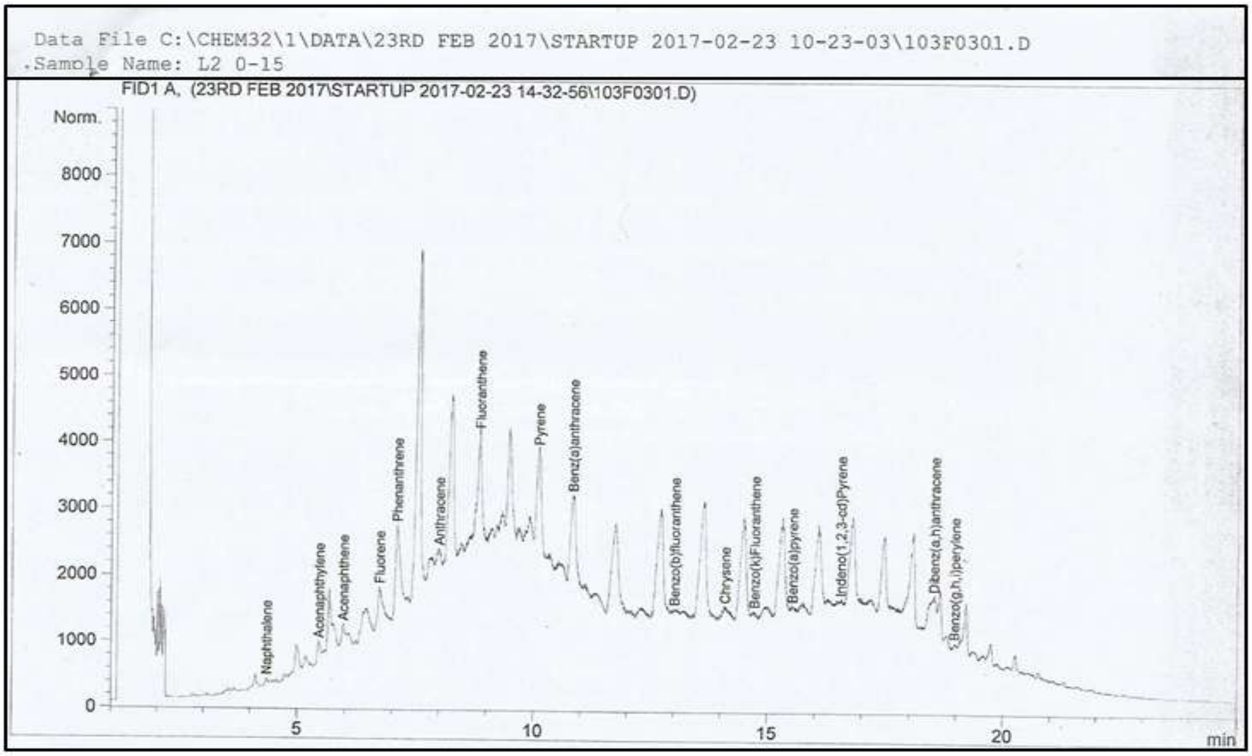
Figure 4a Chromatograms of Aromatic Hydrocarbon components in soil samples from Location 1



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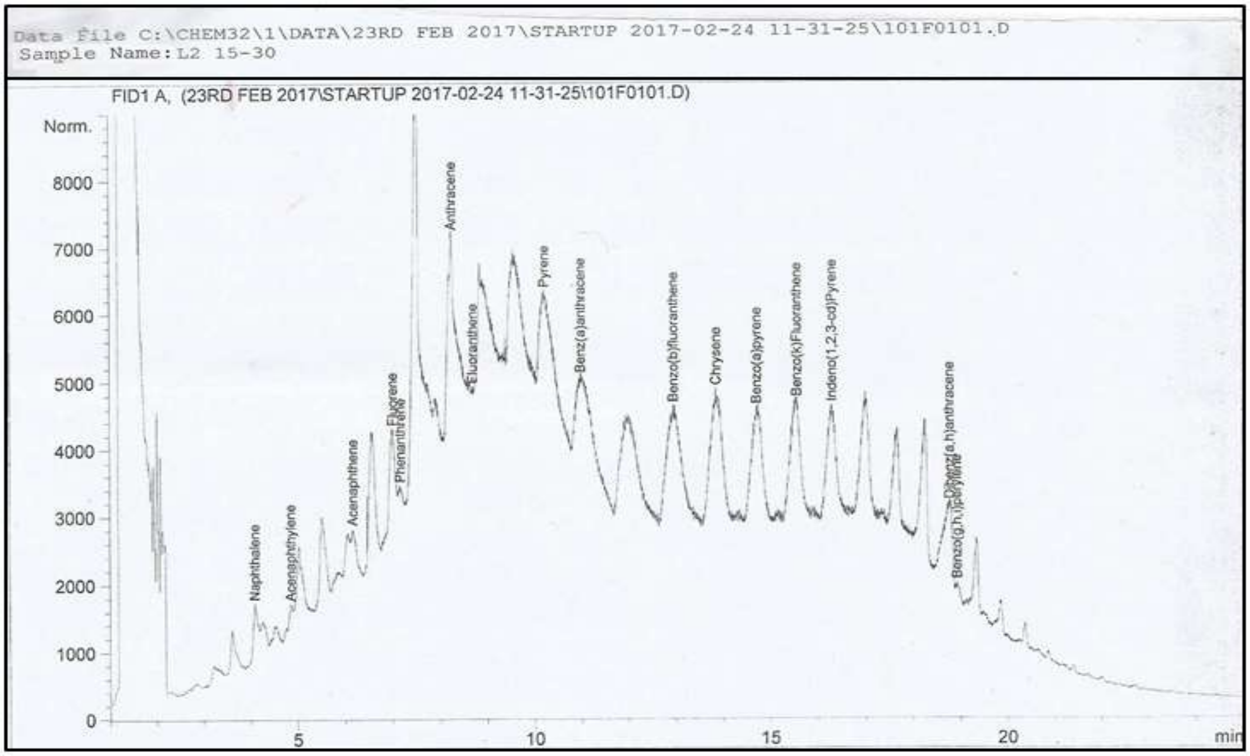

Figure 4b Chromatograms of Aromatic Hydrocarbon components in soil samples from Location 2

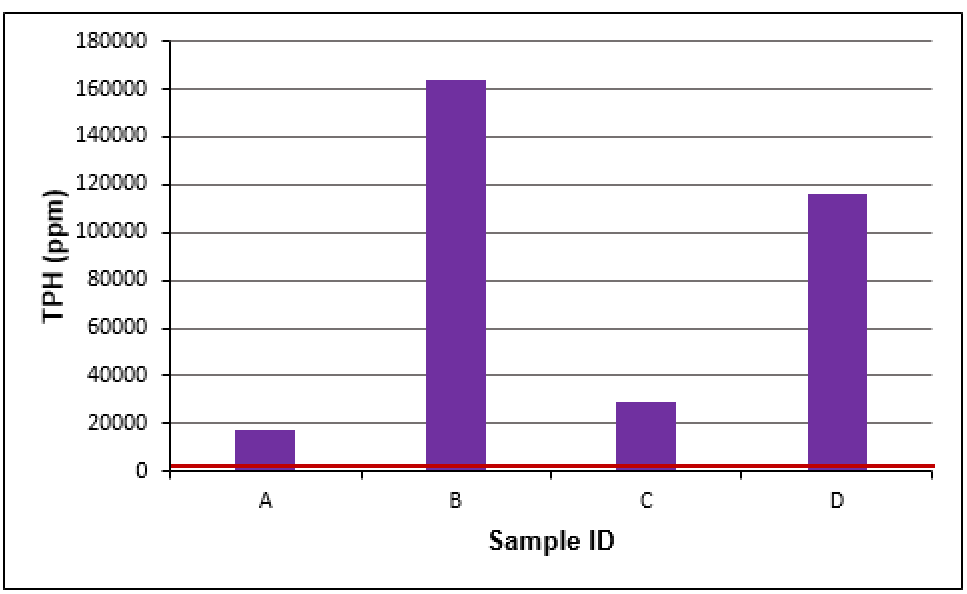

Figure 5 TPH concentration of soil samples and the indicative maximum regulatory limit in Nigeria (EGASPIN 2002) represented by the red line.

CONCLUSION

The field study, sampling and sieve properties of the soils shows the predominant types as sand and clayey sand having a high porosity and moderately permeable. The soil properties aids infiltration and percolation of fluids, thereby favoring pollutant spread and high contamination rate of the soils in the study area. The results gotten from characterization and analysis of TPH fractions in the soil indicates that the area contains enormously high hydrocarbon contaminant concentrations. Hence, findings from this study calls for the need for a collective cooperation by the government agencies and other relevant authorities for a better oil spill management system. Major considerations should be geared towards a proper proactive spill prevention, control and emergency response strategy rather than a reactive approach. In doing this, the issues of oil spill pollution and environmental degradation would be curbed thus, moving towards attaining a sustainable environment in the Niger Delta region and Nigeria at large.

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