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Assessment of Hydrocarbons in Soil along Crude Oil Pipeline Route in Rivers State, Nigeria

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Abstract:
The spillage of crude oil from the network of pipelines in the Niger Delta has been a source of concern. As a result, it became necessary to assess the extent of soil contamination along a pipeline route in Rivers State. The concentrations of TPH, PAHs and BTEX in soil along crude oil pipeline route were investigated. The pipelines are located in Idu communities, near Port Harcourt, Rivers State, Nigeria. Sampling of soils was done at two depths (0 – 15 cm and 15 – 30 cm) quarterly (January, April, July and October) at ten (10) stations and one control point, established at 1.5 km from the sampling stations. TPH, PAHs and BTEX in soils were analyzed using the GC-FID and Headspace respectively. The results obtained revealed that the soil was strongly contaminated with TPH and PAHs while BTEX was not detected. The concentrations (mg/kg) of TPH (371.83, 368.34, 353.00, 326.38 and320.84, 349.75, 303.39, 327.93) and PAHs (18.09, 25.94, 17.38, 17.96 and 12.10, 19.35, 12.86, 16.61) obtained in surface and subsurface soils respectively were not significantly different ($p>0.05$) across the four quarters of the year. However, there was significant difference ($p<0.05$) across the sampling stations. The degree of hydrocarbons contamination of soil was SS 7 > SS 8 > SS 10 > SS 6 > SS 5 > SS 4 > SS 9 > SS 1 > SS 3 > SS 2. The TPH and PAH concentrations obtained in soil exceeded their respective target values of the DPR in oil spilled soil nevertheless, below their respective intervention limits.

Keywords: *Crude oil pipelines, pollution, soil, groundwater, TPH, PAHs, BTEX*

1. Introduction

There is no contradiction that crude oil is in high demand around the world. The economies of numerous nations including Kuwait, UAE, Libya, Ecuador, Saudi Arabia, Qatar, Nigeria, etc, rely on oil income to fuel their economic development (Bhattacharyya and Adon, 2010). The current world petrol consumption is estimated at 99.5 million barrels per day (SRWE, 2018). In the United States of America for example, approximately 20 million barrels of oil were consumed daily in 2003 (Parry and Darmstadter, 2003). In 2018, the country's daily petrol consumption was estimated at 20.5 million barrels indicating a 5 million barrel increase in consumption within the period (USEIA, 2019). In Australia, daily consumption of petrol is estimated at 1.1 million barrels (CEIC, 2019). According to Europe's Energy Portal (2018), China, Japan and India consumed daily; 13 million, 4 million and 5 million barrels of petrol respectively. In Africa, Nigeria and Algeria are among the highest consumers of petrol with daily consumption of 500 and 420 thousand barrels respectively. These records indicate that crude oil is a necessary part of the modern world. Speight (Speight, 1999), observed that the world's economy is highly dependent on crude oil and its products for energy production and widespread use has led to enormous releases of contaminants and pollutants into the environment. Pipelines are critical oil and gas infrastructure in the sense that they are used to convey unrefined petroleum and oil based commodities from creation stages and processing plants to capacity terminals (depots).Globally, oil and natural gas pipelines are the two general sorts of energy pipelines. Inside the oil pipeline network, there are both unrefined lines and refined products lines (Arosanyin, 2005). Nnah and Owei (2005), noted that petroleum pipelines are fundamental methods of transportation and are frameworks of

exceptionally specific nature. However, Ogwu (2011), argued that unlike other modes of transportation such as roads, pipelines do not improve access for individuals in networks through which they pass, rather they force imperatives on connections and when found near houses, are potential risks to life. Jia*et al.* (2019), in alignment, posited that transporting hazardous substances through miles-long using pipelines although has become popular across the globe in recent decades, the odds of basic mishaps because of pipeline failures have expanded. The reasons for pipelines failures are either deliberate (like vandalism or harm) or unexpected (like gadget/material disappointment/failure and corrosion) damages (Morillo*et al*., 2007; White *et al*., 2019; Ajao*et al*., 2018). The average life span of oil pipeline is between 20 and 30 years. However, Adebayo (2018), noted that some pipelines in the Nigerian oil fields are over 30 years old. Omofonwan and Odia (2009), averred that aged and corroding pipelines is very common in many oil exploration fields in the Niger Delta region of Nigeria. The vast majority of the pipelines are networked through the streams, springs, marshes and farmland in the Niger Delta, a habitat that is wetland delicate, and exceptionally touchy to stretch(Ogwu, 2011; Ogon, 2006). For example, the Shell Petroleum Development Company's 95 km trunk line is networked from Nembe Creek field to Cawthorne Channel field running through thirty five communities and crosswise about sixty rivers and creeks of different proportions across its course (Ogwu, 2011). According to Achebe *et al*. (2012), a large number of the oil pipelines in the Niger Delta area were installed in the 1960s and 1970's. As at the year 2000, pipelines older than 20 years constituted 73% of all pipelines while those over 30 years old accounted for 41% of the total network length (Achebe *et al*., 2012). Credibility of pipelines below 20 years in use was about 46% whereas those above 30 years was about 25%. Achebe *et al*. (2012), maintained that the old age of the pipelines in Nigeria makes them prone to failures. Failed pipelines leak petroleum into the environment resulting in contamination and pollution.

Globally, hydrocarbons pollution of different matrices of the environment has been documented. For example, Pathak *et al*. (2011), investigated the effect of petroleum oil on soils located in the area of Jaipur, India. The soil samples collected were analysed using the GC-MS technique in determining the load of TPH in both contaminated and non-contaminated sites. The results showed that the chemical content for Petroleum Contaminated Soil-1 (PCS-1) and Petroleum Contaminated Soil-2 (PSC-2) were 11149 mg/kg and 14244 mg/kg respectively whereas 700 mg/kg and 614 mg/kg respectively were recorded for uncontaminated soils, indicating anthropogenic source of pollution in the area. Iturbe*et al.* (2004), investigated the load of hydrocarbons in soil around a refinery in Mexico, and reported that main source of contamination of soil was from pipelines, and old storage tanks in addition to the land disposal of untreated hydrocarbon sediments derived from the cleaning of storage tanks in the area. Gworek*et al.* (2018), assessed the ecological risk of soil contaminated by the activities of a petrochemical industry in Warsaw, Poland, using a multi-stage Triad procedure. The results showed that the permissible contamination levels of benzene, ethylbenzene and toluene (among the nine analyzed VOCs) and anthracene, benzopyrene and total PAHs (among the eleven PAHs examined) were exceeded in some of the soil plots studied, compared to the EPA and Dutch intervention standards. The authors revealed that the presence of pollutants have lowered the biodiversity indices and consequently, deteriorated the soil quality of the study area. They recommended that appropriate remediation techniques be employed to clean up the soil. In another study, Pinedo*et al*. (2013), analyzed the levels of TPH, PAHs and BTEX in 62 samples collected from different oil and gas facilities in Netherlands, and found out that TPH and PAH concentrations were above the Netherlands target values for contaminated sites and were mainly found in medium and heavy oil products such as diesel and heavy oil. According to them, unacceptable BTEX concentrations were obtained in soils contaminated with gasoline and kerosene. Okop and Ekpo (2012), investigated soil contamination due to crude oil spillage in Ikot Ada Udo in Akwa Ibom State, Nigeria. The results showed that total petroleum hydrocarbon levels for topsoil, subsoil and soils at greater depths ranged from 9 - 289 mg/kg, 8 - 318 mg/kg and 7 - 163 mg/kg respectively. The smallest level of hydrocarbon was recorded in the deepest level of soil while greatest degree occurred in the middle soil level. In comparison with the reference sites, the results revealed higher load of total petroleum hydrocarbon. They concluded that it is necessary to have a complete and sustainable environmental monitoring system and remediation. For decades, it has been known that contaminated air, soil and water due to hydrocarbon and heavy metals can affect humans causing environmental health risks (Humoud, 2017; Certini*et al*., 2013). A number of studies have been carried out on the human diseases caused by exposure to hydrocarbon contaminated soil, water, air and food crops. Ordinioha and Brisibe (2013); Osman (1997); Campbell *et al*. (1993), reported that the influence of hydrocarbon contamination on human health can affect both physical and mental health resulting in genetic disorder, heart disease, headaches, throat irritation and itchy eyes, infertility, cancer, lumbar pain, migraine, dermatitis, etc. PAHs (especially the heavy molecular weight) are of principal concern due to their intractable, staying power, bioaccumulation and potential to cause cancer (Igwo*et al*., 2010; Castorena-Torres *et al*., 2008; Xue and Warshawsky, 2005). USEPA (2002), identified a list of 16 PAHs as priority pollutants to be controlled due to the effects they might have on the human health and the environment. These include Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthene, Anthracene, Fluoranthene, Pyrene, Chrysene, Benzo(a)anthracene, Benzo(k)fluoranthene, Benzo(a)pyrene, Benzo (j) fluoranthene, Indeno (123-cd) pyrene, Dibenz (ah)anthracene, Benzo (ghi) perylene. On the other hand, BTEX are defined priority pollutants by USEPA (2002). They represent a threat to human health and ecosystems because of their toxicity (ATSDR, 2004). These are some justifications why hydrocarbons such as TPH, BTEX and PAHs should be monitored in our fragile environments.

2. Materials and Methods

2.1. The Study Area

This study was carried out in Idu (Lat5°15'0.64'N, Long 6°35'43.68'E) communities in Ogba/Egbema/Ndoni Local Government Area of Rivers State, Nigeria. Geographically, Idu Communities are located about 60km Northwest of Port

Harcourt, Rivers State.The communities within the study area are IduObosi-Uku and IduOsobile. The area is characterized by streams and floodplain. The vegetation type is typical of freshwater with diverse and rich floristic composition. The climate is tropical with rainy season between the Months of April and October and dry season between the Months of November and March. Temperature range in the area is between 25^{0}C and 32^{0}C. Farming and fishing are the major occupation of the people. The major water body in the area is the Orashi River. The general language spoken in the communities is Ogba**.** The communities are blessed with land resources that the dwellers utilize for farming activities. The two communities play host to two international oil companies. There are farms in and around the area. The inhabitants are people of different income class. Besides oil and gas activities in the area, there are other visible businesses owned by artisans and petty traders in the two communities. The general settlement pattern is dispersed with some linear characteristics identifiable in the location of houses along access roads and internal streets. Fig. 1is the map of Nigeria showing the Local Government Area (Ogba/Egbema/Ndoni) in Rivers State where the study was carried out.

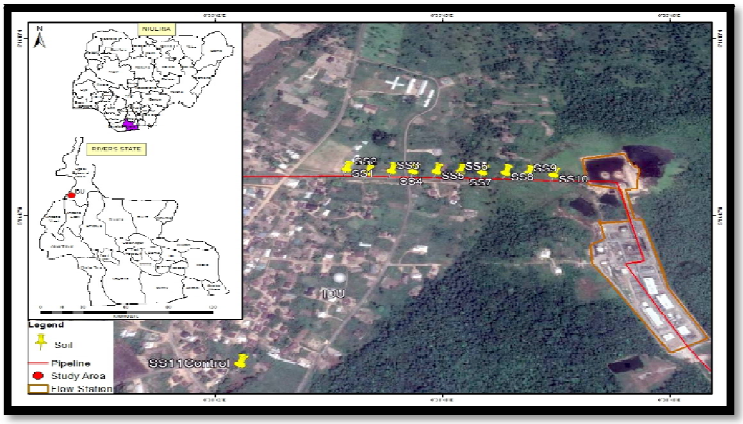

Figure 1: The Map of Nigeria Showing the Local Government Area (Ogba/Egbema/Ndoni) in Rivers State Where the Study Was Carried Out

2.2. Collection of Soil Samples

Soil samples were collected from ten stations quarterly for one year (twelve months). The samples were collected precisely on the 2nd January, 2019, 2nd April, 2019, 2nd July, 2019 and 2nd October, 2019 respectively. Soil samples were also collected at 1.5 km away from the pipeline route quarterly as control. A total of eighty-eight (88) soil samples were collected across the study stations and control. Soils were collected at two depths (0-15 cm and 15 – 30 cm depths) at each sampling station using the soil Auger. The collection of samples was done by taking 2-3 auger borings of soil at each sampling station with a Dutch Auger and bulked together to make a composite sample. At each quarterly sampling, the samples were collected in properly labeled foil plates and taken to the laboratory for analysis. In the laboratory, the soil samples were analysed for TPH, PAHs and BTEX content.

2.3. Chemical Analysis

The method measures individual and total concentrations of extractable volatile, aliphatic, aromatic and petroleum hydrocarbons components in soil samples using Headspace/Purge and trap gas chromatography mass spectrometry after liquid-liquid/soxhlet extraction as well as mixed hydrocarbon solvent (n-hexane and dichloromethane). The extract was then concentrated using a rotary evaporator, clean up in a glass packed silica-gel and sodium sulphate column and then fractionated. The fractions were eluted into their individual components using n-hexane for aliphatic hydrocarbon and dichloromethane for aromatic hydrocarbons.

2.4. Statistical Analysis

Means, standard deviations and Analysis of Variance (ANOVA) as well as Duncan multiple range test of hydrocarbons in soil were calculated. Pollution load index (PLI) was used to assess the presence and degree of TPH, PAH and BTEX contamination of soil.

The PLI is obtained using [58] approach as follows:

$$PLI = [CF1 \times CF2 \times CF3 \times \ldots\ldots \times C\ n]\ 1/n \qquad \text{Equation 1;}$$

where, CF= contamination factor; and n = specific number of contaminants studied.

2.5. Quality Assurance and Control

Quality assurance/quality control was an integral part of the research work. Basically, the quality assurance and control programme ensured that the integrity of the samples collected was not compromised. Specifically, we ensured that;

- Contamination of samples was avoided by use of clean sampling materials;
- The auger was cleaned after each sampling to avoid cross-site contamination
- Samples were collected in foil plates, correctly labeled and preserved;
- Field and equipment blanks were collected as appropriate.

PARAMETER	Target Values (DPR, 2018) (mg/Kg)	Intervention Values (DPR, 2018) (mg/Kg)
TPH (mg/Kg)	50	5000
PAH (mg/Kg)	1	40
BTEX (mg/Kg)	-	-

Table 1: Environmental Guidelines and Standards for Soil for the Petroleum Industry in Nigeria (EGASPIN) (2018 Revised)
Source: [15]

3. Results and Discussion

3.1. Results

Total petroleum hydrocarbon was generally high across the study stations in all the quarters of the year (QI, Q2, Q3 and Q4) (January, April, July and October) in both surface and subsurface soils (Table 2 and Fig. 2). PAH concentrations were detected in all the study stations both in surface and subsurface soils in Q1, Q2, Q3 and Q4 (Fig. 3). BTEX concentrations recorded in surface and subsurface soils were below equipment detection limit of 0.001 mg/kg in both study and control stations across the four quarters of the year (Table 2).

Parameters	Study Stations (0 – 15 cm)											
	1st Quarter			2nd Quarter			3rd Quarter			4th Quarter		
	Range	Mean ± SD	Control	Range	Mean ± SD	Control	Range	Mean ± SD	Control	Range	Mean ± SD	Control
TPH (mg/Kg)	134.99-561.22	371.83±157.188^{a}	126.00	94.99-610.21	368.34±184.422^{ab}	107.20	135.14-687.32	353.00±171.17^{ab}	135.38	111.38-735.41	326.38±178.165^{a}	113.29
PAH (mg/Kg)	6.75-28.06	18.09±8.641^{a}	5.06	6.70-37.20	25.94±10.051^{ab}	9.08	5.39-37.93	17.38±10.233^{ab}	9.12	8.34-34.95	17.96±10.131^{ab}	8.35
BTEX (mg/Kg)	<0.001	<0.001±0.001^{a}	<0.001	<0.001	<0.001±0.001^{a}	<0.001	<0.001	<0.001±0.001^{a}	<0.001	<0.001	<0.001±0.001^{a}	<0.001
STUDY STATIONS (15 – 30 cm)												
TPH (mg/Kg)	107.81-532,14	320.84±164.664^{a}	111.00	89.11-582.13	349.75±188.644^{ab}	99.27	111.28-631.25	303.39±153.89^{a}	118.17	129.30-713.72	327.93±158.986^{a}	96.39
PAH (mg/Kg)	3.04-21.87	12.10±6.923^{a}	3.02	4.21-27.92	19.35±8.166^{a}	8.13	3.12-24.81	12.86±7.723^{a}	5.01	7.33-32.87	16.61±9.930^{a}	7.98
BTEX (mg/Kg)	<0.001	<0.01±0.001^{a}	<0.001	<0.001	<0.001±0.001^{a}	<0.001	<0.001	<0.001±0.001^{a}	<0.001	<0.001	<0.001±0.001^{a}	<0.001

Table 2: Summary of Hydrocarbons Characteristics of Soil in the Study Area
Mean ± S.D across the Columns with Different Superscript Were Significantly Different At 5% with A>B>C. Mean Separation Done by Duncan Multiple Range Test

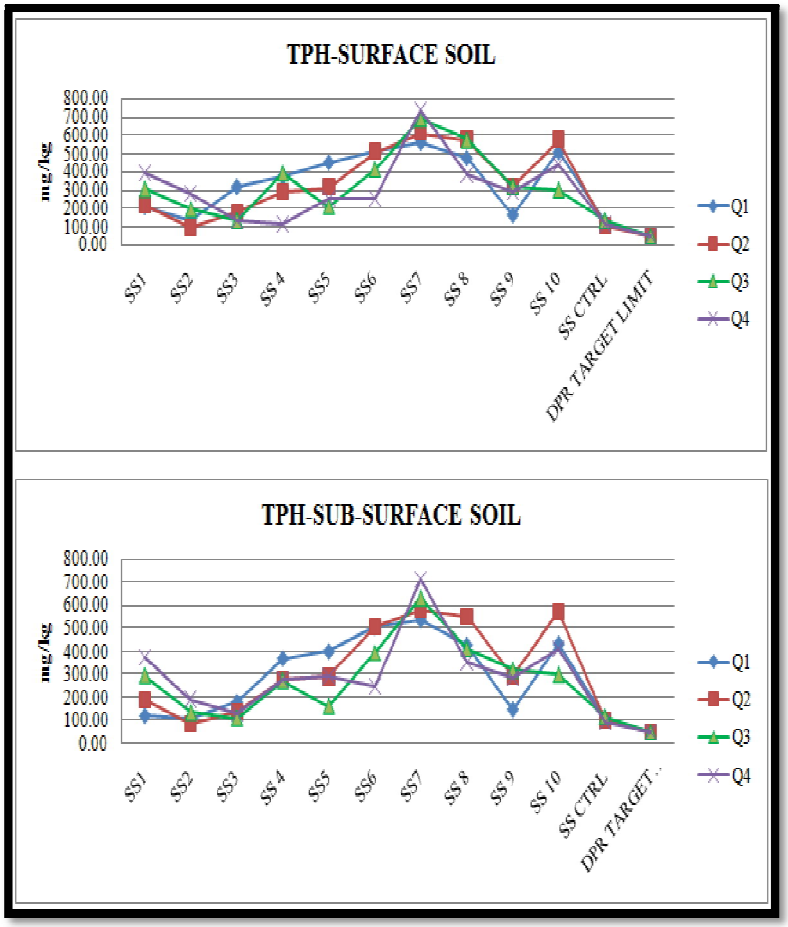

Figure 2: Total Petroleum Hydrocarbons Concentrations across Study Stations in Surface and Subsurface Soils in the Study Area in January, April, July and October, 2019

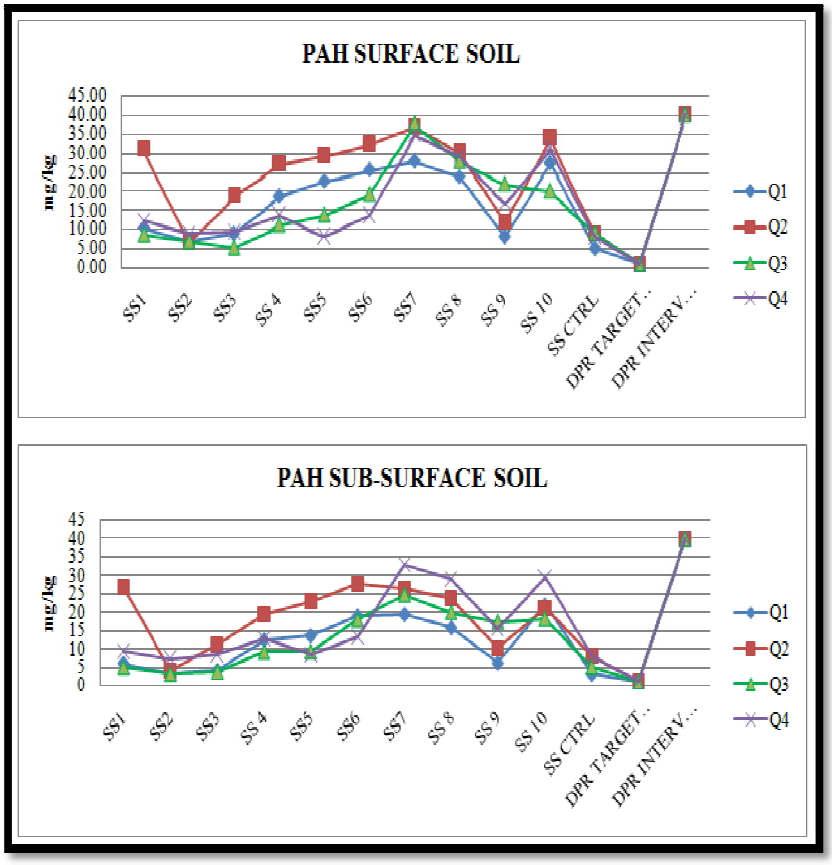

Figure 3: PAH Concentrations across Study Stations in Surface and Subsurface Soils in the Study Area in January, April, July and October, 2019

Study Stations	Parameters			
	Total Hydrocarbon Conc. (TPH + PAH + BTEX)	CF	DC	PLI
SS1	554.78	2.31	30.16	3.11
SS2	318.83	1.33		
SS3	347.15	1.44		
SS4	624.02	2.6		
SS5	626.49	2.61		
SS6	877.85	3.65		
SS7	1323.71	5.5		
SS8	985.62	4.5		
SS9	561.49	2.33		
SS10	934.46	3.9		
SSCTR	240.622	1		

Table 3: Hydrocarbons Contamination and Pollution Load Index of Soil in the Study Area

3.2. Discussion

The comparisons made in this study were based on concentrations of the control (reference) soils, as well as target and intervention values of the Department of Petroleum Resources (DPR) as enshrined in Environmental Guidelines and Standards for Soil for the Petroleum Industry in Nigeria (EGASPIN) (2018 Revised).

3.2.1.Total Hydrocarbon Petroleum (TPH)

The mean concentrations obtained were 371.83 mg/kg, 368.34 mg/kg, 353.00 mg/kg, 326.38 mg/kg, and 320.84 mg/kg, 349.75 mg/kg, 303.39 mg/kg, 327.93 mg/kg in surface and subsurface soils in Q1, Q2, Q3 and Q4 respectively (Fig. 2). TPH concentrations decreased as depth increased, which could be attributed to the physical properties (especially porosity and permeability) of soil in the study area. This finding is in agreement with similar studies conducted earlier by Sari *et al*. (2018) in Indonesia, Iwegbue*et al*. (2003) in Nigeria; O'Reilly *et al*. (2001), in America, who reported that soil with low or moderate permeability has low potential for hydrocarbon migration. The TPH values recorded were generally higher than 126 mg/kg, 107.20 mg/kg, 135.38 mg/kg, 113.29 mg/kg, and 111.00 mg/kg, 99.27 mg/kg, 118.17 mg/kg, and 96.39 mg/kg obtained in surface and subsurface soils at the control points in Q1, Q2, Q3 and Q4 (January, April, July and October) respectively. This observation indicates anthropogenic source of contamination of soil with hydrocarbons in the study area

Moreover, the TPH concentrations obtained were not significantly different ($p>0.05$) across the four quarters of the year (January, April, July and October). However, there was significant difference ($p<0.05$) in TPH load across the sampling stations. This suggested that anthropogenic activities in the study area might have influenced the sampling stations differently. For example, TPH levels obtained were generally highest at sampling station 7 (SS 7), followed by sampling station 10 (SS 10). This observation suggests that the pipeline might be leaking at these points. The suspected pipeline leakage could be attributed to pressure on the connecting branches as these two sampling stations were close to the flow station in the area. Pipeline transportation of crude oil from pump or flow station generates pressure, and loses force over time and distance. Klass (1986), had noted earlier that pressure wave may occur in pipeline transporting product if the velocity of the flowing liquid suddenly changes.

Besides, the suspected leakage could be attributed to corrosion due to the old age of the pipeline. Previously, Omofonwan and Odia (2009), in their study noted that aged and corroding pipeline is very common in many oil exploration fields in the Niger Delta region. The average life span of oil pipeline is between 20 and 30 years. Conversely, the pipelines in the study area were installed in the 1970's, indicating that they are over 30 years old. This observation agreed with Adebayo (2018), who noted that some pipelines in the Nigerian oil fields are over 30 years old. The concentrations of TPH obtained in soil across the sampling stations including 735.41 mg/kg recorded at study station 7, exceeded the Department of Petroleum Resources (DPR) target value of 50 mg/kg for oil spilled site in Nigeria. This is an indication that all the sites were strongly contaminated with hydrocarbons. Hydrocarbon polluted soil affects crops yield and can threaten regional food security and public health. In agreement with the finding in this study, Benson and Odinwa (2010), in their earlier research found out that cassava planted in hydrocarbon polluted soil recorded low yield while land degradation reduced productivity and contributed to low efficiency of the farmers. Similarly, Inoni*et al*. (2006), in their study reported that soil polluted with hydrocarbons reduced crop yield, land productivity, farm income and overall local economy. The findings in this study were comparable to the results reported by Okop and Ekpo (2012); Iwegbue and Nwajei (2008); Onianwa (1995); Adekambi (1989).However, the concentrations obtained were lower than the values reported by Iwegbue*et al*. (2007), in Nigeria, Iturb*et al*. (2004); Saari*et al*. (2007),in Finland. Although the TPH concentrations obtained in this study exceeded the Department of Petroleum Resources (DPR) target value of 50 mg/kg for a spilled site in Nigeria, it is far below 5000 mg/kg intervention value.

3.2.2. Polycyclic Aromatic Hydrocarbon (PAHs)

The soil was generally contaminated with PAHs. Among the 16 PAH components listed as criteria pollutants that were investigated in this study, Naphthalene (Nap) had the lowest concentration across the sampling stations. The low concentrations recorded for 2 – ring PAHs could be due to their high volatility. Anthrancene (Ant), phenanthren (Phen) and fluorine (Flu) were abundant in all the sampling stations however, higher in SS1, SS2, SS3, SS4, SS5, SS6, SS8, SS9 than SS7 and SS10. Whereas among the 4 – 6 ring PAHs investigated, prominent among them were benzo (a) pyrene, benzo (k) fluoranthene, benzo (b) fluoranthene, fluoranthene, pyrene, indenol [1,2,3 – cd] pyrene, benzo [ghi] perylene, dibenzo [a,h] anthrancene, chrysene and benzo (a) anthrancene. The order of dominance for 3 – ring PAHs was Ant >Phen> Flu >acy, while for 4 – 6 ring PAHs, the order was B(a)P > B(k)P > B(b)F > Flt >Pyr> IP > B(g,h,i)P > DB(ah)A > Cry > B(a)A. The result showed that Ant, Phen, B(a)P and B(k)F were among the predominant contributors of PAHs in the study area. This finding is in agreement with Lie *et al*. (2017); Ma and Zhou (2011); Lors*et al*. (2012), who reported in their studies that Phe and BbF are among the predominant PAHs in soil. The other most abundant components among the heavy molecular weight PAHs obtained were B(a)P, B(k)P, B(b)F, Flt and B(g,h,i)P which are typical tracers for fossil fuel combustion (Lie *et al*. 2017). This was expected because oil and gas exploration is the predominant anthropogenic activities in the study area.

Furthermore, the trend observed in the distribution of PAHs in both surface and subsurface soils indicated a common origin suspected to be petrogenic. The total PAH mean concentrations obtained were 18.09 mg/kg, 25.94 mg/kg, 17.38 mg/kg, 17.96 mg/kg in surface soil, and 12.10 mg/kg, 19.35 mg/kg, 12.86 mg/kg, 16.61 mg/kg in subsurface soil in Q1, Q2, Q3, and Q4 respectively. The result obtained showed that the concentrations of total PAHs decreased as depth increased. This observation can be attributed to the low mobility of PAHs in soil (Li *et al*., 2010; Wang *et al*., 2001). In a previous study conducted by Cornelissen *et al*. (2005), they observed that PAHs accumulated in the topsoil and had very low vertical migration rate because of its strong sorption towards soil organic matter (SOM) and any other absorbing materials. The total PAHs load obtained at the control point were 5.05 mg/kg, 9.08 mg/kg, 9.12 mg/kg, 8.35 mg/kg in surface soil, and 3.02 mg/kg, 8.13 mg/kg, 5.01 mg/kg, 7.98 mg/kg in subsurface soil in Q1, Q2, Q3, and Q4. Although these values were lower in comparison to the values obtained across the sampling stations, it obviously showed that PAHs were common pollutants in the study area. The higher concentrations obtained at the sampling stations indicated anthropogenic influence attributable to the oil and gas activities in the area. The values obtained were comparable to mean values of 16.19 mg/kg, 11.93 mg/kg, 18.00 mg/kg, 18.4 mg/kg reported by Kim *et al*. (2018); Morillo*et al*. (2007); Van *et al*. (2014); Bradley *et al*. (1994), in UK and USA respectively however, higher than 0.03979 mg/kg, 0.035 mg/kg reported by Emoyan*et al*. (2011); Echem*et al* (2019), and lower than 3830 mg/kg, 896.784 mg/kg, and 86.3 mg/kg reported in Niger Delta by Nwaichi*et al*. (2014); Osu and Okoro (2012); and in India by Sarma*et al* (2016) respectively. Although the TPAH concentrations obtained in this study exceeded the Department of Petroleum Resources (DPR) target value of 1 mg/kg for a spilled site in Nigeria, it is below the 40 mg/kg intervention value.

3.2.3. Benzene, Toluene, Ethylbenzene and Xylene (BTEX)

BTEX concentrations recorded in surface and subsurface soils were below equipment detection limit of 0.001 mg/kg in both study and control stations across the four quarters of the year (January, April, July and October). This finding can be attributed to their volatility, which is in agreement with the previous studies conducted by Echem*et al*. (2019), in Gokana; Duan and Li (2017), in China. Benzene, toluene, ethyl benzene and xylene are classified as priority pollutants regulated by many environmental organizations around the world including USEPA and DPR.Prolonged exposure to high concentration of BTEX is toxic and can have mild to severe effects on health including damages to kidneys, nervous system, liver, eyes, and exacerbation of respiratory conditions (PTL, 2016).

3.3. Degree of Contamination (DCI) and Pollution Load Index of Soil

Hydrocarbons contamination of soil across the sampling stations was highest at SS 7 with contamination factor of 5.50. The order of contamination was SS 7 > SS 8 > SS 10 > SS 6 > SS 5 > SS 4 > SS 9 > SS 1 > SS 3 > SS 2. The degree of hydrocarbons contamination (30.16) and pollution load (3.11) indices recorded indicated that the soils were highly contaminated nevertheless, with moderate pollution load. The hydrocarbons pollution load showed a localized pattern, evidenced by higher concentrations of TPH and PAH obtained at sampling station 7 than other stations.

4. Summary and Conclusion

This study has established that leaking underground petroleum facilities including pipelines has the potential of exposing man to high load of hydrocarbons via food chain. The concentrations of TPH and PAH obtained in soil exceeded their respective target values of 50 mg/kg and 1 mg/kg stipulated by the Department of Petroleum Resource (DPR) in oil spilled soil but below their respective intervention values of 5000 mg/kg and 40 mg/kg. This implies that the study sites may not require remediation. Nevertheless, a program such as pipeline integrity test should be implemented by the oil and gas operators in the area. This will identify leakages and if timely repaired, the soil could recover through natural attenuation. Periodic monitoring of pipelines and other underground petroleum facilities such as flow and service stations in Niger Delta region of Nigeria is strongly recommended for healthy environment.

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