



Source Identification and Fate of Polycyclic Aromatic Hydrocarbons in Agricultural Soils of Imo River Watershed, Imo State, Nigeria

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Abstract

Environmental contamination by Polycyclic Aromatic Hydrocarbons (PAHs) has been of great concern due to risk to human health and the ecosystem. This study was carried out to identify the sources and fate of PAH contamination in agricultural soils of Imo River Watershed, Imo State, Nigeria. A total of 8 soil samples (0-30cm) were randomly collected from different activity areas on the watershed and analyzed for the presence of the 16 US-EPA priority PAHs. The identification and quantification of the PAHs in the soil samples were carried out in accordance with EPA 8270: (GC-MSD). The results of the analysis revealed that amongst the 16 US-EPA priority PAHs, eight of them were detected in the soil samples. The total concentration of PAHs detected in the study area were Naphthalene (0.146mg/kg), Acenaphthylene (0.010mg/kg), Acenaphthene (0.210mg/kg), Phenanthrene (0.021mg/kg), Anthracene (0.041mg/kg), Flouranthene (0.130mg/kg), Pyrene (0.020mg/kg) and Benzo(b)fluoranthene (8.641mg/kg). The decreasing order for individual PAHs concentration in the soil samples within the study area were Benzo(b)Flouranthene>Acenaphthene>Naphthalene>Flouranthene>Anthracene>Phenanthrene Pyrene > Acenaphthelyn. The total PAHs concentrations recorded in the soil of Obowob zone were generally observed to be higher than Okigwe zone. This study revealed that Imo River watershed of Imo State is gradually being contaminated with PAHs from abattoirs and auto-mobile repair activities, as the results showed that the concentrations of some PAHs in the study area were beyond maximum permissible limits of 0.5mg/kg for individual PAHs and 10mg/kg for total PAHs stipulated by National Environmental Standards and Regulations Enforcement Agency (NESREA), which is an indication of anthropogenic contribution. There is need for public education on the consumption of vegetables grown in and around abattoirs and areas dominated by automobile repair activities.

Keywords: Polycyclic aromatic hydrocarbons, Soil, Physiochemical parameters

INTRODUCTION

The 16 environmentally significant PAHs are those PAH molecules that contain 2 to 7 benzene rings and are divided into two groups based on their physical, chemical, and biological characteristics (Martinez et al., 2004). The lower-molecular-weight (LMW) PAHs for example, the 2 to 3 rings of PAHs such as naphthalenes, fluorenes, phenanthrenes, and anthracenes, have significant acute toxicity to aquatic organisms. The high-molecular-weight

(HMW) PAHs, containing 4 to 7 rings, from chrysenes to coronenes, do not cause acute toxicity but are known to be carcinogenic. According to Oyo-ita et al., (2016) techniques used to differentiate pyrogenic and petrogenic sources of PAHs include examining the relative amounts of low molecular weight (LMW) and high molecular weight (HMW) compounds. LMW PAHs compounds predominate in petrogenic sources while HMW compounds predominate in pyrogenic sources, (Guo et al., 2021). Due to their low water solubility and high lipophilic nature, PAHs are

easily and rapidly absorbed by organisms and can be accumulated in aquatic organism or adsorbed onto the surface of suspended matter, get deposited on the sea floor and be passed onto the marine food chain (Oyetunji et al., 2022). Although hundreds of PAHs exist, some of the environmentally essential PAHs are: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz[*a*]anthracene, chrysene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*a*]pyrene, benzo[*ghi*]perylene, dibenz[*a,h*]anthracene, and indeno[1,2,3-*cd*]pyrene. Four isotopically labeled Polycyclicnuclear aromatic hydrocarbons (acenaphthene-*d*₁₀, phenanthrene-*d*₁₀, chrysene-*d*₁₂ and perylene-*d*₁₂), (Bingnan Ren, 2021)

PAHs can be found in tire wear debris, asphalt particles and stationary combustion sources (Srogi K., 2007). Sources of PAHs in urban atmosphere include automobiles, re-suspended soils, refineries and power plants (Omar et al., 2002; Yang et al., 2002; Dyke et al., 2003). PAHs are also widely used in commercial products, such as intermediaries in pharmaceuticals, agricultural products, photographic products, thermosetting plastics and lubricating materials. (Munyengabe, 2017) argues that PAHs also occur in large amounts in sedimentary rocks and petroleum. Additional contributions to ambient air levels arise from tobacco smoking, while the use of heating sources can increase PAH concentrations in indoor air. Natural sources such as forest fires and volcanic eruptions are less important. The fate of PAHs is determined by their physicochemical properties, especially nonpolarity and hydrophobicity which is responsible for their persistence in the environment. PAHs from fuel oils tend to be quickly adsorbed onto particles and to accumulate in sediments (Tolosa et al., 2004).

PAHs can also enter the environment through atmospheric deposits and direct releases of substances through petroleum spills and uses, municipal wastewater treatment plants, industrial discharges, storm water runoff, landfill leachate and surface runoff (Cao et al., 2010). PAHs readily attach to sediment particles, leading to high concentrations in bottom sediments of water bodies. A literature review on tire wear particles in the environment indicates that the high aromatic (HA) oils generally used in tires contain PAHs (Chen et al., 2007).

Bioavailability of PAHs in the soil is the basic process of PAH accumulation in crops, herbs and soil microorganisms. PAHs can enter plants through plant leaves or settle into the soil from the atmosphere, and then migrate, metabolize, and accumulate in plants through plant roots, thereby threatening human health through the food chain. In addition, soil, as an important environmental medium, is a storage and transfer station for PAHs in the natural environment, which bears more than 90% of the environmental load of PAHs (Ailijiang et al., 2022). The amount of PAHs entering the human body from soil is higher than that from other environmental media, such as

air and water. The impact of soil pollution on food chain has presented a challenge for many investigations and in recent years, research on PAHs has mostly focused on the distribution, analysis and determination of PAH content in crops, farmland soils and soils around cities or on the risk assessment of PAHs in the urban atmosphere in different seasons to humans. However, there are few studies on PAHs in Imo River watershed around the study area.

Research by (Olayinka et al., 2018), suggests that the adverse impact of PAHs to the environment is determined by monitoring the sediment, soil, water and air. Different upland activities in recent times has contributed significantly to environmental degradation partly due to poor waste management practices and weak enforcement in ensuring that auto mechanic operators and abattoirs are located in designated sites.

MATERIAL AND METHODS

The study area

This study was carried out along the Imo River watershed in Imo State, Nigeria. Imo River drains three States, namely Imo State, Abia State and Rivers State. Imo State, is the largest (in terms of size and length) of the rivers, it is the major river in Imo state with a large number of tributaries. Imo River being the most prominent, traverses from north to south of the state with a length of about 225 km. In its upper reach, it receives tributaries. It has its source in the Ideato North Area of Imo State near Osina. Its middle reaches flow north to south for some 80 km in the flat valley through the coastal plain lowland without receiving any significant tributaries. The Imo River drained not only Imo State but also Abia and Akwa Ibom States and empties into the Atlantic Ocean. It is joined by Aba River flowing from the North and then enters Akwa Ibom State enroute to the Ocean. The major tributary of Imo River is the Otamiri River, (Okoro et al., 2014).

Imo River is in southeastern Nigeria and flows 240 kilometers (150 mi) into the Atlantic Ocean. Its estuary is about 40 km wide with an annual discharge of 4 Km³ and 26,000 hectares of wetland. The Imo's tributaries are the Otamiri and Oramirukwa.

Sampling plan

The study area was divided into two zones: Okigwe and Obowo, each zone was further divided into four sampling sites, namely (**Figure 1**).

OKSS1=Okigwe Soil Sample 1 (Imo State Water Scheme premises)

OKSS2 =Okigwe Soil Sample 2 (Abandoned waste dump)

OKSS3= Okigwe Soil Sample 3 (River bank)

OKSSC= Okigwe Soil Sample Control (1KM from the river bank)

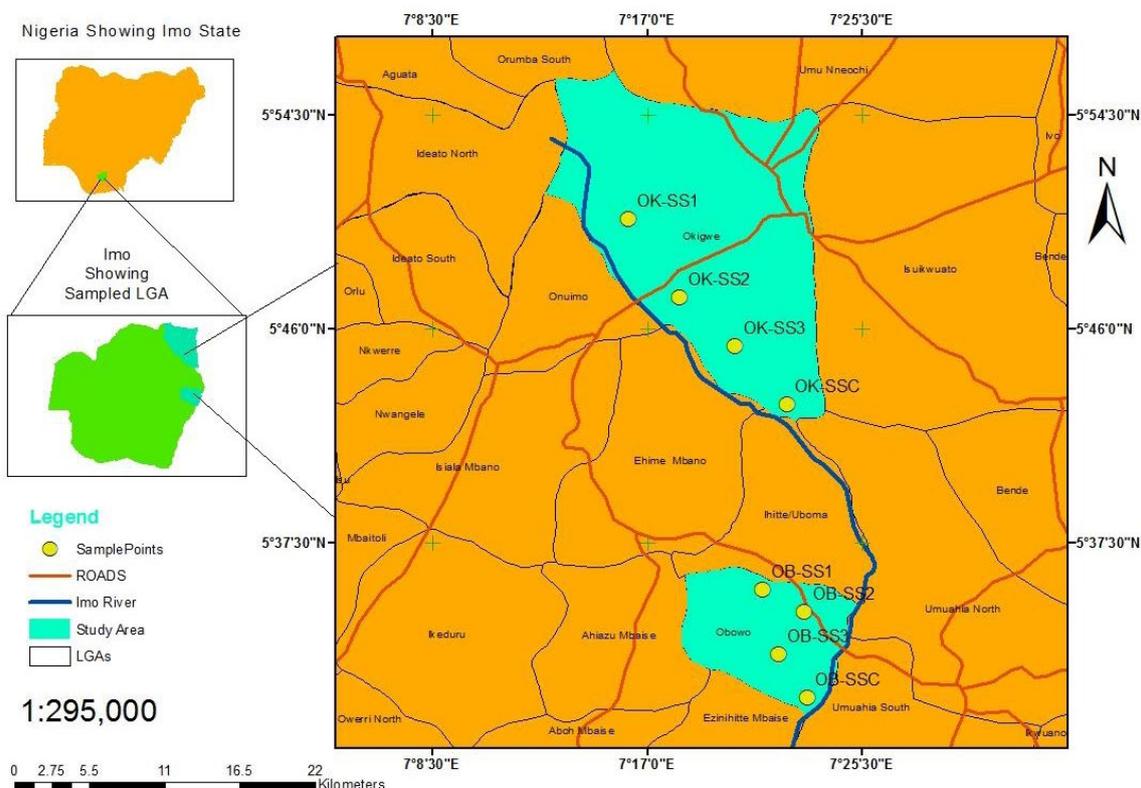


Figure 1. Map of Nigeria showing Imo State, Okigwe and Obowo Local Government areas, the study area and sampling points.

OBSS1=Obowo Soil Sample 1 (Abattoir)

OBSS2 =Obowo Soil Sample 2 (Spare Parts Market)

OBSS3= Obowo Soil Sample 3 (River bank)

OBSSC= Obowo Soil Sample Control (1KM from the river bank)

Sample collection

Soil samples were collected in triplicate into sterilized containers using a 30cm marked metal soil auger from each of the sampling points within the zones and then a control site. A total of forty eight (48) batch soil samples made into thirty two (16) different composite samples were collected for both seasons at a depth of 0-30cm (subsurface soils). This range of soil depth was chosen because it comprises surface and subsurface soils which are the first locus of input of contaminants, where they tend to accumulate on a relatively long term basis, according to (Abenchi et al., 2010) (Krishna et al., 2007) also added that pollutants normally contaminate the upper layer of the soil at a depth of 0-40cm.

Physicochemical analysis of samples

The physicochemical analysis were carried out on the soil samples to assess their impact on some physicochemical variables such as soil pH, electrical conductivity, total organic carbon, organic matter and nitrate. Soil pH was determined using the HANNA (HI83099) multi-parameter.

Soil Electrical Conductivity was determined using the Hanna Conductivity meter. Cation Exchange Capacity was obtained by the summation of the concentrations of exchangeable base cations and exchangeable acidity. The soil nitrate was determined using the HANNA (HI83099) Multi Parameter Bench Photometer and the test method was ALPHA 4500. Soil Organic Carbon and organic matter were determined by the Walkley-Black Method.

Analysis of polycyclic aromatic hydrocarbons in the soil samples

The Polycyclic aromatic hydrocarbon analysis of the soil samples collected from the study area were carried out in accordance with EPA 8270: Standard Test Method for Determination of Parent and Alkyl Polycyclic Aromatics in Sediment Pore Water Using Solid-Phase Micro-extraction and Gas Chromatography/Mass Spectrometry in Mass Selective Detection Mode, which describes the procedure for analysis of extractable Polycyclic aromatic hydrocarbon (PAH) in surface water, ground water and soil/sediment. In the case of this study, polycyclic aromatic hydrocarbons (PAHs) were detected in the soil samples by Gas Chromatography-Mass selective detector (GC-MSD).

Statistical analysis

All data collected were analyzed using Minitab statistical package (16th Edition) and boxplots which were used to represent variations in soil chemical characteristics and the concentration of PAHs in the study area (Musa et al.,

2020). Two-Way Analysis of Variance (ANOVA) was used to partition means and significant means separated using Tukey range test and 95% Confidence. Pearson correlation coefficient[®] was used to determine the possible relationship between PAHs concentrations and the physicochemical attribute.

DISCUSSION AND RESULTS

Polycyclic aromatic hydrocarbon concentration level in the soil samples

The Polycyclic Aromatic Hydrocarbons (PAHs) detected in the soil samples from the study area and their concentrations are recorded in (Table 1). The result revealed that only Naphthalene (0.146mg/kg), Acenaphthylene (0.010mg/kg), Acenaphthene (0.210mg/kg), Phenanthrene (0.021mg/kg), Anthracene (0.041mg/kg), Flouranthene (0.130mg/kg), Pyrene (0.020mg/kg) and Benzo(b)fluoranthene (8.641mg/kg) amongst the 16 EPA priority PAHs studied were detected in the eight soil samples analyzed. The individual PAH concentrations ranged from negligible to 3.1mg/kg, with Benzo (b) fluoranthene concentration level being highest among the individual PAHs across the sampling locations. The highest individual PAH concentrations were recorded in OB/SS/1.

The result revealed that there were significant variations in the level of Polycyclic Aromatic Hydrocarbons across the sampling locations. Obowo zone had the highest number of individual PAHs. The individual PAHs present in the study area were Naphthalene, Acenaphthylene, Acenaphthene, Phenanthrene, Anthracene, Flouranthene, Pyrene and Benzo (b) fluoranthene.

Physicochemical properties of soil samples analyzed in the study area

The result of the analysis is presented in (Table 2). The physicochemical parameters showed significant differences across the sampling locations ($P < 0.05$). The pH ranged from 5.50 ± 0.0 to 6.33 ± 0.05 showing that the soil samples all had low pH and their mean values varied slightly across the sampling locations. EC ranged from 128.0 ± 0.06 to $325.3 \pm 0.57 \mu\text{s}/\text{cm}$, TOC ranged from 0.02 ± 0.006 to $0.06 \pm 0.006\%$, TOM ranged from 0.030 ± 0.0006 to $0.17 \pm 0.063\%$. NO_3 ranged from 0.32 ± 0.006 to $1.15 \pm 0.006 \text{mg}/\text{kg}$.

Correlation between chemical parameters and individual PAHs

Karl Pearson's correlation (r) was used to evaluate the

Table 1. Concentration of PAHs detected in the soil samples with their mean separations across the sampling locations.

Sampling Locations	PAH Components (mg/kg)							
	NAPH	ACENATHYLN	ACE	PHTHN	ANTH	FLTHN	PY	B(b)FLTHN
OK/SS/1	$0.07 \pm 0.0006a$	$0.0 \pm 0.0b$	$0.0 \pm 0.0b$	$0.0 \pm 0.0b$	$0.0 \pm 0.0c$	$0.0 \pm 0.0c$	$0.0 \pm 0.0b$	$1.20 \pm 0.006c$
OK/SS/2	$0.0 \pm 0.0c$	$0.0 \pm 0.0b$	$0.0 \pm 0.0b$	$0.0 \pm 0.0b$	$0.0 \pm 0.0c$	$0.0 \pm 0.0c$	$0.0 \pm 0.0b$	$0.1 \pm 0.006f$
OK/SS/3	$0.0067 \pm 0.006b$	$0.0 \pm 0.0b$	$0.21 \pm 0.006a$	$0.0 \pm 0.0b$	$0.01 \pm 0.0b$	$0.11 \pm 0.0a$	$0.0 \pm 0.0b$	$1.01 \pm 0.006d$
OK/SS/C	$0.0 \pm 0.0c$	$0.0 \pm 0.0b$	$0.0 \pm 0.0b$	$0.0 \pm 0.0b$	$0.0 \pm 0.0c$	$0.0 \pm 0.0c$	$0.0 \pm 0.0b$	$0.12 \pm 0.0f$
OB/SS/1	$0.07 \pm 0.00a$	$0.01 \pm 0.0a$	$0.0 \pm 0.0b$	$0.021 \pm 0.0012a$	$0.031 \pm 0.002a$	$0.02 \pm 0.006b$	$0.02 \pm 0.06a$	$1.5 \pm 0.0b$
OB/SS/2	$0.0 \pm 0.0c$	$0.0 \pm 0.0b$	$0.0 \pm 0.0b$	$0.0 \pm 0.0b$	$0.0 \pm 0.0c$	$0.0 \pm 0.0c$	$0.0 \pm 0.0b$	$3.1 \pm 0.0006a$
OB/SS/3	$0.0 \pm 0.0c$	$0.0 \pm 0.0b$	$0.0 \pm 0.0b$	$0.0 \pm 0.0b$	$0.0 \pm 0.0c$	$0.0 \pm 0.0c$	$0.0 \pm 0.0b$	$1.20 \pm 0.006c$
OB/SS/C	$0.0 \pm 0.0c$	$0.0 \pm 0.0b$	$0.0 \pm 0.0b$	$0.0 \pm 0.0b$	$0.0 \pm 0.0c$	$0.0 \pm 0.0c$	$0.0 \pm 0.0b$	$0.41 \pm 0.006e$

NAPH= Naphthalene. ACENATHYLN = Acenaphthylene. ACE = Acenaphthene, PHTHN = Phenanthrene. ANTH= Anthracene, FLTHN = Flouranthene, PY = Pyrene and B(b)FLTHN= Benzo(b)fluoranthene. OKSSI = Okigwe Soil Sample 1, OKSS2 = Okigwe Soil Sample 2, OKSS3 = Okigwe Soil Sample 3, OKSSC = Okigwe Soil Sample Control, OB/SS/1 = Obowo Soil Sample 1, OBSS2 = Obowo Soil Sample 2, OBSS3 = Obowo Soil Sample 3, OBSSC = Obowo Soil Sample Control.

Means with different alphabets as superscript for each soil sample are significantly different while those with the same alphabets are the same.

Table 3. Correlation (r) between PAHs and physicochemical parameters measured in the soil samples.

Sampling Location	Parameters				
	NO_3 (mg/kg)	TOC (%)	pH	EC ($\mu\text{s}/\text{cm}$)	OM (%)
OK/SS/1	$1.04 \pm 0.006b$	$0.02 \pm 0.006c$	$6.10 \pm 0.006b$	$325.3 \pm 0.57a$	$0.033 \pm 0.006c$
OK/SS/2	$1.04 \pm 0.006b$	$0.06 \pm 0.006a$	$5.60 \pm 0.06ge$	$131.3 \pm 0.57g$	$0.13 \pm 0.06b$
OK/SS/3	$0.67 \pm 0.006e$	$0.06 \pm 0.006a$	$6.33 \pm 0.05a$	$128.0 \pm 0.06h$	$0.17 \pm 0.063a$
OK/SS/C	$1.02 \pm 0.0c$	$0.03 \pm 0.0006b$	$6.03 \pm 0.06c$	$219.3 \pm 0.56c$	$0.050 \pm 0.0006c$
OB/SS/1	$0.32 \pm 0.006g$	$0.02 \pm 0.006c$	$5.60 \pm 0.0e$	$263.7 \pm 0.6b$	$0.030 \pm 0.0006c$
OB/SS/2	$0.69 \pm 0.006d$	$0.03 \pm 0.0b$	$5.50 \pm 0.0f$	$140.3 \pm 0.6e$	$0.050 \pm 0.0006c$
OB/SS/3	$0.65 \pm 0.006f$	$0.031 \pm 0.0012b$	$5.60 \pm 0.10e$	$136.3 \pm 0.6f$	$0.050 \pm 0.0006c$
OB/SS/C	$1.15 \pm 0.006a$	$0.03 \pm 0.0b$	$5.80 \pm 0.006d$	$217.3 \pm 0.56d$	$0.050 \pm 0.001c$

possible relationships between the chemical parameters and individual PAHs analyzed in the study area. The correlation results are presented in **(Table 3)**, and it revealed that relationship existed between the PAH and soil chemical properties, thus PAHs availability and distribution in the study area were influenced by some physicochemical properties. The result further revealed that at $P \leq 0.001$ with a confidence level of significance of 99.9%, NAPH, ACENTHLYN, PHTHN, ANTH and B(b)FLTHN correlated positively with soil Nitrate (NO_3) with a correlation coefficient r of 0.000, 0.033, 0.008, 0.003, 0.027 respectively, also, NAPH correlated positively and averagely with Electrical Conductivity (EC) with a correlation coefficient r of 0.006 and no relationship existed between the Soil pH, total organic carbon and soil organic matter with PAHs obtained in the soil of the study area.

DISCUSSION

Sixteen PAHs recommended by the United State Environmental Protection Agencies (USEPA) were investigated in this study and only Naphthalene, Acenaphthelyn, Acenaphthene Phenanthrene, Acenaphthene, Fluoranthene, Pyrene and Benzo(b)fluoranthene were detected in the soil samples. The highest concentrations of PAHs were recorded in the soils of Obowo zone and the lowest concentrations were recorded in the soil of Okigwe zone. The highest total concentration for individual PAHs in the study area was Benzo (b) Flouranthene at 8.641mg/kg, while the least individual PAH was Acenaphthelyn at 0.010mg/kg. The decreasing order for individual PAHs concentration in the soil samples within the study area was

Benzo (b) Flouranthene > Acenaphthene > Naphthalene > Fluoranthene > Anthracene > Phenanthrene > Pyrene > Acenaphthelyn. Obowo Zone had the highest concentration levels of PAHs in the study area indicating pollution input from the abattoir and spare parts market. This may lead to PAH of the watershed, therefore polluting the water body itself and accumulating in the sediments.

Identification of PAH sources

PAHs identified in the study area are classified as petrogenic (petroleum sources) and pyrogenic (combustion sources). Petrogenic sources give off organic particulates which are characterized by a high mole fraction of low molecular weight PAHs (Munyengabe et al., 2017). Low molecular weight PAHs usually originate from petrogenic sources, (Nam et al., 2003), also suggested that high molecular weight PAHs originates from pyrogenic sources. Low molecular weight PAHs dominate petrogenic sources while pyrogenic sources are dominated by high molecular weight PAHs (Kumar et al, 2014). It is important to identify PAH sources for effective pollution control, environment risk management and health risk assessment. PAH sources can be predicted using PAH molecular weights and diagnostic ratios. The ratios of low molecular weight PAHs to high molecular weight PAHs in the environment can be used as tool to identify the sources of PAHs. Pyrolytic (pyrogenic) sources (combustion of coal, biomass or petroleum) usually indicate the ratio of < 1 while the petrogenic sources (petroleum spills) usually indicate the ratio of > 1 (Mastral et al., 2000) (Wilcke, 2000). Diagnostic ratios have been used also in several studies like (Olajire et al., 2005), (Bobak et al., 2010), (Bayowa et al., 2014), (Munyengabe et al., 2017).

Fate of PAHs in soils

The movement of PAHs in the environment depends on properties such as how easily they dissolve in water and how easily they evaporate in the air. As persistent organic pollutants (POPs), some of them are susceptible to dispersion on a global scale because in addition to having environmental persistence, they move between the atmosphere and earth's surface in repeated, temperature-driven cycles of deposition and volatilization (Adewumi et al., 2022). POPs are truly multimedia contaminants which occur in all parts of the environment: atmosphere, inland and sea water, sediments, soil and vegetation (Daley et al., 2014). They are mainly of anthropogenic origin and have only a few significant natural sources (Fetzer et al., 2000).

Table 3. Correlation (r) between PAHs and physicochemical parameters measured in the soil samples.

Parameters	PAH Components (mg/kg)							
	NAPH	ACENATHLYN	ACE	PHTHN	ANTH	FLTHN	PY	B(b) FLTHN
Ph	-0.11	-0.073	0.043	-0.037	-0.054	-0.028	0.006	-0.05
	0.465	0.632	0.778	0.806	0.72	0.852	0.966	0.744
NO3	0.719*	0.315*	0.043	0.388*	0.434*	0.209	0.169	0.327*
	0	0.033	0.776	0.008	0.003	0.164	0.263	0.027
TOC	0.016	-0.096	-0.089	-0.086	-0.049	0.024	-0.032	-0.162
	0.918	0.528	0.555	0.568	0.749	0.872	0.835	0.283
EC	0.398*	0.006	-0.196	0.053	0.071	-0.096	-0.151	-0.002
	0.006	0.967	0.192	0.724	0.641	0.524	0.317	0.987
OM	-0.105	-0.106	-0.139	-0.041	-0.036	0.011	-0.051	-0.151
	0.486	0.482	0.357	0.786	0.812	0.943	0.734	0.317

Cell Contents: Pearson correlation; P-Value. * = Significant at $P \leq 0.001$. ** = Significant at $P \leq 0.05$.

The most commonly encountered POPs are Organo chlorine pesticides, such as DDT, industrial chemicals like Polycyclic chlorinated biphenyls (PCB) and dioxins. PAHs (which are known for their strong mutagenic, carcinogenic and toxic properties) are composed of carbon and hydrogen atoms arranged in the form of fused benzene rings. There are thousands of PAHs compounds in the environment but in practice PAHs analysis is restricted to the determination of 6 to 16 PAHs as priority pollutants, while some of them, e.g. benzo (a) pyrene, chrysene, benzo (a) anthracene are considered to be potential human carcinogens. PAHs are the most toxic among the hydrocarbon families. Individual PAHs differ substantially in their physical and chemical properties (Maliszewska et al., 1998). The widespread occurrence of PAHs is largely due to their formation and release in all processes of incomplete combustion of organic materials. The last century of industrial development caused a significant increase of PAHs concentrations in the natural environment.

In terrestrial environments, soil is the primary environmental repository for semi-volatile organic compounds, such as PAHs (Zhao et al., 2022). PAHs in soil can be derived from both dry and wet deposition of PAHs from the atmosphere. Wastewater discharge and irrigation may also increase the concentration of PAHs in soil. The degree to which PAHs are retained within the soil is controlled by soil properties, such as organic matter (OM), clay content, and physicochemical properties of the contaminant (Luo et al., 2012).

Properties of polycyclic aromatic hydrocarbon (PAH) compounds

Physical and chemical properties of PAHs vary with their molecular structure (number of rings) and molecular weight. This means that, as the number of rings increases, the molecular weight also increases. They vary with high melting and boiling points, low vapor pressure, very low aqueous solubility and tend to decrease with increasing molecular weight. PAHs are generally classified as Low Molecular Weight and High Molecular Weight PAHs. According to (Wick et al., 2011), PAHs with low molecular weight are those with two or three fused benzene rings while high molecular weight PAHs are those with four or more fused benzene rings. (Pandey et al., 1997) stated that PAHs with low molecular weight easily degrade and volatilize faster than the high molecular weight PAHs. The higher the molecular weight of PAHs, the higher its hydrophobicity, toxicity, lipophilic property and the lower its solubility in water, vapor pressure, and degradability (Wick et al., 2011). Although, low molecular weight PAHs of 3-rings and high molecular weight of 5-rings dominated the study area.

Characteristics of soil physicochemical properties

The quality of any environmental medium is generally influenced by its physicochemical factors; therefore, the monitoring of these factors is imperative for both long-term and short-term environmental management of pollutant

inputs. Also, the distribution and productivity levels of organisms are largely determined by physicochemical factors in these ecosystems. Accordingly, several authors have investigated the direct effect of interactions of many frequently measured physicochemical variables on biotic residents of these ecosystems (Jonnalagadda et al., 2001). Also, (Ogbuagu et al., 2011), revealed that the physicochemical attributes of the Imo River varied based on the gradient. According to (Biswas et al., 2018), soil parameters such as pH and redox conditions largely affect adsorption and desorption of chemical contaminants in the soil. However, these sorption processes are dependent on the soil parameters aforementioned and other soil parameters. The occurrence, fate, and transport of chemical pollutants in soils are largely dependent on the properties of the soil and pollutants as well.

CONCLUSION

Soil is the major storehouse of different pollutants that are emitted from various anthropogenic activities that leads to deterioration of soil quality. Industrialization and urbanization has greatly contributed to the soil quality degradation because of the huge amount of contaminants they introduce into the surrounding environment. Abattoirs and automobile repairs activities are proven to significantly release hazardous pollutant into the soil thereby causing disruption of normal function of soil resources, polluting agricultural products as well as the food chain. As a result, the pollution of soil resource is calling for great concern especially in developing countries like Nigeria as the impact of soil pollution is found to be more hazardous for developing countries due to lack of proper consideration and management.

Of the 16 individual PAHs on the US EPA priority list that were analyzed, the individual concentrations of PAHs ranged from negligible to 3.1mg/kg. Higher values of total PAHs were generally recorded in the soil samples of Obowo zone, indicating pollution input from the abattoir and spare parts market. The high concentrations of the PAH components recorded in the soil samples can readily be linked to high level of petrogenic (petroleum sources) and pyrogenic (combustion sources) activities going on in the study area, such as the indiscriminate abattoirs located in various locations within the watershed, as well as other automobile and industrial activities. This indicates that PAH contamination in the study area may have greatly risen from these activities.

It is therefore evident from this study that abattoirs and automobile repair activities have the potential to emit huge amount of polycyclic aromatic hydrocarbons (PAHs) to soil resource.

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