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Analysis of Hydrocarbon Level in Kofar Ruwa Automobile Mechanic Village Soil

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Abstract: *This study investigated the level and distribution of hydrocarbon-related pollutants in soil samples collected from Kofar Ruwa Automobile Mechanic Village, Kano. Five soil samples were analyzed using Gas Chromatography–Mass Spectrometry (GC-MS) to determine the types and classes of organic contaminants present. The results revealed a total of ninety-nine (99) organic compounds classified into alkanes, phthalates, esters, solvents, polycyclic aromatic hydrocarbons (PAHs), and other organic compounds. Alkanes and phthalates were the dominant pollutants, indicating significant contamination from used engine oil, lubricants, fuels, plastics, and vehicle repair activities. Only one PAH (anthracene) was detected, suggesting limited inputs from combustion-related sources. The presence of chemical makers such as hopanes further confirmed contamination by petroleum products. Pollution indices including Total Hydrocarbon Index (THI), Total Petroleum Hydrocarbon Index (TPHI), Organic Pollution Index (OPI), and Pollution Class Index (PCI) showed elevated contamination across all sampling sites. The study concludes that soils within the Kofar Ruwa mechanic zone are significantly impacted by mixed hydrocarbon pollution, posing potential risks to soil quality, groundwater, and human health. The findings highlight the need for environmental regulation, waste-oil management, and remediation interventions within the mechanic village.*

Keywords**:** *Kofar Ruwa, Total Hydrocarbon Index, GC-MS, Automobile mechanic, Pollution Class Index*

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1.0 Introduction

Petroleum hydrocarbons are ubiquitous environmental pollutants present in soils, water bodies, and sediments (Abugu *et al*., 2023). They comprise a highly complex assemblage of numerous chemical compounds, primarily originating from fossil fuels especially crude oil which can be classified based on their molecular structures.

The quantity of crude oil and petroleum-derived products currently utilized far exceeds that of many other substances considered hazardous to ecological systems and human health (Coulon *et al*., 2014). Petroleum products such as gasoline, diesel, and lubricating oils enter the environment through accidental releases, operational discharges, or unintended outcomes of industrial, commercial, or domestic activities, a(nd improper disposal practices common in densely populated urban and peri-urban centers) resulting in both localized and widespread environmental pollution (Ekanem *et al*., 2021). Consequently, contamination is extensive due to the large number of related facilities and processes, posing significant risks to human health, water resources, ecosystems, and other environmental receptors.

Waste oil comprises a heterogeneous mixture of chemical constituents, including petroleum hydrocarbons, chlorodibenzofurans, chlorinated additives, biphenyls, aromatic compounds, aldehydes, and ketones as minor components, degradation by-products, and heavy metals introduced from engine wear and mechanical processes—mechanical wear (Balogun *et al*., 2023). Used engine oil also referred to as spent lubricant or waste engine oil is typically generated after routine maintenance activities, when lubricating oil is drained from automobile and generator engines (Eze *et al.,* 2024). The specific chemical composition of used oil varies depending on its source, duration of use, and the nature of degradation processes occurring during engine operation. Ganiyu *et al*. (2024) reported that soils contaminated with petroleum hydrocarbons derived from used engine oil exhibit significant alterations in their physicochemical properties. Soil pollution by oil promotes the accumulation of heavy metals and facilitates their subsequent transfer into plant tissues, while used engine oil readily disperses into surrounding environments and can infiltrate nearby water bodies (Amos *et al*., 2024).

An auto-mechanic village refers to a planned and designated zone where vehicle repair, servicing, and associated activities are conducted by numerous mechanics, technicians, spare-parts dealers, related enterprises and where improper handling of petroleum wastes is a common environmental concern (Kalagbor *et al*., 2024). These villages are typically established to consolidate automotive repair operations, minimize roadside workshop congestion, and enhance standardization as well as environmental oversight (Madukasi *et al*., 2024). The concept was introduced to curb the uncontrolled proliferation of automobile workshops across urban areas, with large tracts of land specifically allocated to auto-mechanics to enable effective land-use planning and environmental resource management (Nwoko *et al*., 2017). This structured approach prevents indiscriminate siting of workshops in urban and peri-urban settings, thereby reducing environmental degradation. Nevertheless, the improper disposal of spent engine oil onto soil surfaces remains a major public health and ecological concern in many developing countries (Olamide *et al*., 2024).

Onu *et al*. (2023) reported that the environmental impacts of activities within auto-mechanic villages in Nigeria have received (particularly with respect to hydrocarbon contamination in soils and associated ecological risks) relatively little scholarly attention, despite evidence that such operations generate significant quantities of petroleum-based wastes. These wastes are often produced and indiscriminately discharged by individuals who may be unaware of the potential health risks associated with exposure to these contaminants. Consequently, continuous environmental monitoring is essential to evaluate the extent, distribution, and dispersion patterns of pollutants within affected ecological zones. Kofar Ruwa automobile mechanic village is located in Kano State, where uncontrolled disposal of spent engine oil poses a substantial risk of environmental contamination, as the site represents one of the largest auto-mechanic repair hubs in Kano and northern Nigeria. This underscores the importance of assessing hydrocarbon contamination levels at the site to safeguard public health and ensure environmental protection (Silalahi *et al*., 2021).

In Kofar Ruwa Mechanic Village, Kano, continuous spillage and improper disposal of oil and fuel residues have raised concerns about possible contamination of the soil with hydrocarbons. Such contamination poses serious risks to soil health, groundwater quality, agricultural productivity, and public health due to the toxic and persistent nature of petroleum hydrocarbons. Despite the environmental importance of this issue, there is a lack of adequate data on the extent and severity of hydrocarbon pollution in the soil of this mechanic village. Without such baseline information, it is difficult to design appropriate mitigation, remediation, or policy strategies. Therefore, this study seeks to assess the level of hydrocarbon contamination in the soil of the Kofar Ruwa Mechanic Village, Kano, to evaluate the environmental implications and provide data that can support future remediation and regulatory efforts. The study is necessary due to the environmental risks posed by improper disposal of petroleum products in the Kofar Ruwa Mechanic Village, Kano. Hydrocarbon contamination threatens soil health, groundwater, and public health. Despite these risks, there is limited data on the pollution level in this area. This research will generate essential information to guide environmental management, raise awareness, and support policy development for pollution control and sustainable land use.

Ibe *et al*. (2021) identified the indiscriminate disposal of waste and used engine oil as one of the most pervasive environmental pollutants in Nigeria, with impacts comparable to crude oil contamination. They further noted that frequent handling of petroleum products such as gasoline, diesel, and lubricating oils in automobile workshops often leads to unintended and widespread soil contamination. Their ecological risk assessment of soils from abandoned sections of Orji Mechanic Village, Owerri, Nigeria, revealed detectable polycyclic aromatic hydrocarbon (PAH) contamination, with mean concentrations ranging from $1.22 \times 10^{-2} \pm 0.00$ to $5.60 \times 10^{-2} \pm 0.01$ mg/kg. Higher PAH concentrations were recorded in surface soils (0–10 cm) compared to deeper layers. The total PAH concentrations (∑PAHs) ranged from 1.58×10^{-1} to 6.71×10^{-1} mg/kg, while low-molecular-weight PAHs (∑LPAHs) varied between 7.16×10^{-3} and 1.60×10^{-1} mg/kg, and high-molecular-weight PAHs (∑HPAHs) ranged from 1.81×10^{-2} to 5.42×10^{-1} mg/kg. Notably, carcinogenic PAHs (∑Carcino-PAHs) occurred at elevated levels (5.39×10^{-1}–9.74×10^{-2} mg/kg), underscoring significant health concerns.

Source apportionment using diagnostic ratios, principal component analysis, and correlation analysis indicated predominantly pyrogenic origins of PAHs, attributed mainly to automobile repair activities within the mechanic village. Additionally, the

Benzo(a)pyrene equivalent (BePeq) values demonstrated high carcinogenic potency, particularly for sample A, while the estimated total cancer risk exceeded 1×10^{-6}, signifying a substantial carcinogenic risk associated with exposure to the contaminated soils and highlighting a serious ecological and public health concern.

Nwoko *et al*. (2017) described polycyclic aromatic hydrocarbons (PAHs) as toxic, persistent, and bioaccumulative organic pollutants mainly introduced into the environment through fossil fuel use and incomplete combustion processes. Structurally composed of two or more fused benzene rings, PAHs are hydrophobic and pose serious ecological and human health risks. Owing to these concerns, the United States Environmental Protection Agency (US EPA) has designated sixteen PAHs as priority pollutants. The authors emphasized that although automobile mechanic villages are intended to improve urban planning and environmental management by restricting indiscriminate workshop locations, improper disposal of spent engine oil remains a major public health and environmental challenge in many developing countries. Their findings revealed that only eight of the sixteen US EPA priority PAHs were detected in soil samples from the study area, with total PAH concentrations ranging from 2.564 to 21.841 mg/kg, while no PAHs were detected at the control site. Dominant compounds included dibenzo(a,h)anthracene, indeno (1,2,3-cd)pyrene, and anthracene, occurring at concentrations exceeding recommended regulatory limits. These elevated PAH levels highlight significant environmental contamination and prompted recommendations for improved waste management practices, public health education, and stricter regulatory enforcement in automobile mechanic workshops to ensure environmental sustainability.

Ahmed *et al.* (2025) attributed the growth of automobile mechanic workshops in Nigeria to the increasing demand for roadside vehicle repairs and economic pressures that favor maintenance of older vehicles over replacement. Their GC–MS analysis of mechanic garages in Azare, Bauchi State, revealed elevated concentrations of VOCs, PAHs, and aliphatic hydrocarbons across multiple sites, all exceeding WHO and USEPA permissible limits. These findings indicate significant environmental contamination and potential health risks, highlighting the need for improved waste management, continuous monitoring, and stricter regulation of workshop locations, particularly away from residential areas and water bodies.

Nyarko *et al*. (2019) investigated the effects of petroleum fuels and lubricants on soil properties in automobile mechanic workshops and garages in the Cape Coast Metropolis, Ghana. The study reported that petroleum hydrocarbons—comprising saturated, aromatic, and non-hydrocarbon compounds—are readily absorbed by soil and are persistent due to their low water solubility and complex aromatic structures. These contaminants were found to alter key soil properties, including hydrophobicity, moisture retention, permeability, porosity, microbial activity, and metal enrichment, ultimately degrading soil quality.

Soil samples collected from eight mechanic workshops and control sites showed similar particle size distributions dominated by sand, with no significant differences between contaminated and control soils. However, petroleum hydrocarbon contamination significantly influenced soil physicochemical relationships, as evidenced by strong correlations among pH, nutrients, moisture content, conductivity, and organic matter. Overall, the findings indicate that petroleum hydrocarbon pollution modifies soil properties and may negatively affect sensitive soil microorganisms.

Akomah *et al*. (2018) described auto-mechanic workshops as designated areas for vehicle repair and servicing, whose numbers have increased in developing countries such as Nigeria due to rising vehicle importation. Activities in these workshops generate substantial quantities of waste, including spent engine oil, grease, hydraulic fluids, petrol, electrolytes, sludge, and paint (Nwachukwu *et al*., 2010). Spent engine oil, commonly used as an automobile lubricant, contains high levels of polycyclic aromatic hydrocarbons (PAHs) such as naphthalene, anthracene, benzo(a)anthracene, benzo(a)pyrene, and fluoranthene (Jain *et al*., 2009), some of which are known carcinogens and pose serious environmental and health risks.

The study emphasized that improper disposal of spent engine oil leads to environmental degradation by disrupting the balance between biotic and abiotic components of the ecosystem. Continuous discharge of engine oil alters soil microbial communities, with oil-contaminated soils showing higher populations of hydrocarbon-utilizing bacteria compared to uncontaminated sites. This shift suggests both ecological disturbance and the potential use of hydrocarbon-degrading microorganisms for the bioremediation of engine-oil-contaminated environments.

Okonokhua *et al*. (2024) noted that petroleum contamination alters soil physicochemical properties depending on the soil type, initial conditions, and the contaminant's type and concentration. While some studies report increased organic carbon and reduced levels of major elements like phosphorus and potassium, others have observed elevated nitrogen and phosphorus. Petroleum products in Nigeria contain heavy metals such as copper, zinc, manganese, silicon, vanadium, molybdenum, and iron, with automobile workshops in Aba and Port Harcourt showing particularly high levels of lead, cadmium, and total petroleum hydrocarbons (TPH). These anthropogenic contaminants may pose ecological and human health risks through direct soil contact, ingestion, or via the food chain. Additionally, while most refined hydrocarbons are volatile and easily inhaled, TPH are highly lipophilic and readily absorbed through the skin and mucous membranes, except when highly viscous.

Automobile mechanic villages are hubs of vehicular repair activities that involve the frequent use and disposal of petroleum products such as engine oil, diesel, petrol, brake fluid, and grease. These activities, when not properly managed, often lead to the indiscriminate discharge of hydrocarbons into the surrounding soil, resulting in environmental degradation. Studies on hydrocarbons contamination from automobile mechanic workshop is limited. To assess the concentration and distribution of petroleum hydrocarbon contaminants in the soil of Kofar Ruwa Mechanic Village, Kano, and assess associated environmental risks and inform mitigation strategies. This study is limited to the assessment of hydrocarbon contamination in soil within the Kofar Ruwa Mechanic Village, located in Kano State, Nigeria.

2.0 Materials and Methods

2.1 Study Area

This study was conducted at Kofar Ruwa Automobile Mechanic Village, Kano State, Nigeria. Kofar Ruwa is a historic area located within the ancient city of Kano, in Kano State, Nigeria. It is one of the prominent traditional city gates of the old Kano wall, symbolizing Kano's rich cultural heritage and long-standing trade history. Historically, Kofar Ruwa served as an entry point for water carriers and traders, linking the city to external communities. It has a GPS Coordinates of Latitude: 12.0070° N and Longitude: 8.5234° E The area is a major hub for automobile repairs and spare parts sales, characterized by extensive oil and fuel spills that contaminate surrounding soils.

2.2 Sample Collection

Soil samples were collected using a grid sampling technique to ensure representativeness across the mechanic village. Five sampling points were randomly selected to cover different zones, including visible oil spill sites, vehicle parking areas, and vehicle repairing site. At each sampling location, soil samples were obtained from the upper 0–15 cm layer using a stainless-steel auger, the soil samples have the geographic coordinates as described in Table 1. All the samples are stored in a polyethene bags and transported to the laboratory for analysis.

Table 1: Sampling Point, longitude, latitude and Sample Codes

S/N	Sampling Location	longitude	latitude	Sample codes
1	Tashar Kuka Bus Station, Kofar Ruwa	8°29′53.4″E	12°01′41.5″N	MV 1
2	Tashar Kuka Bus Station, Kofar Ruwa	8°29′52.5″E	12°01′41.5″N	MV 2
3	Kofar Ruwa, Timesi	8°29′59.5″E	12°01′37.4″N	MV 3
4	Yan Alluminium, Kofar Ruwa	8°29′53.4″E	12°01′37.3″N	MV 4
5	Kofar Ruwa Bus Repair	8°29′57.4″E	12°01′37.8″N	MV 5

MV = mechanic Village

2.3 Sample Preparation

The soil samples were air-dried at ambient temperature, carefully pulverized using a mortar and pestle, and passed through a 2 mm sieve. Approximately 10.00 ± 0.05 g of each processed sample was accurately weighed into a cellulose extraction thimble for subsequent extraction.

2.3.1 Sample Extraction Procedure

The procedure was adopted by Ahmed, et al (2025), with some modification. approximately 10.00 ± 0.05 g of soil sample was transferred into a conical flask, 10 g of anhydrous sodium sulphate and the contents was Shake using mechanical shaker for 2 hours and allow to equilibrate at 4 °C overnight. The content was extracted using 100 mL of dichloromethane/acetone mixture (1:1 v/v). The mixture was shaken using a mechanical shaker for 1 minute and sonicated at 20 °C for 30 minutes. The sonication and shaking were repeated three more times. The contents were transferred to a centrifuge tube, and the tube was rinse with a dichloromethane/acetone mixture, and centrifuged at 1,850 rpm for 5 minutes. After cooling, the supernatant was filtered through Whatman No. 1 filter paper.

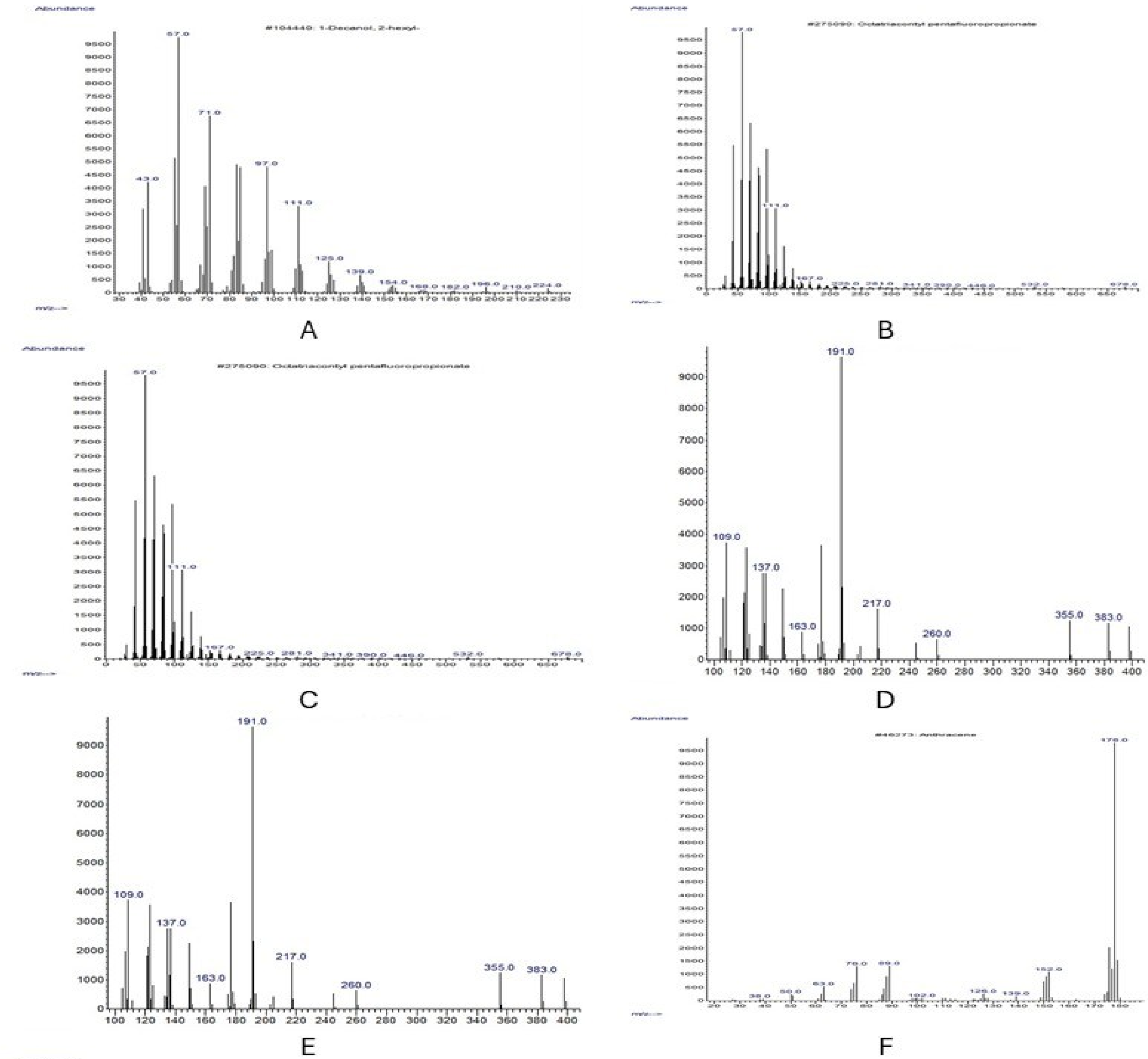
2.3.2 Cleanup and Fractionation

A silica gel column was prepared and conditioned with appropriate solvents. The extract was loaded onto the column to separate polar compounds. 50 mL of acetone was used to elute aliphatic hydrocarbons fraction while, 50 mL of dichloromethane was used for the aromatic fraction.

3.0 Result and Discussion

3.1 Result

Representative GC-MS chromatograms of the soil samples from Kofar Ruwa Mechanic Village are shown in Fig. 1. The present study analyzed the distribution of hydrocarbon-related compounds detected in five soil samples and classified them into major chemical classes including alkanes, phthalates, polycyclic aromatic hydrocarbons (PAHs), esters, solvents, and other organic compounds.



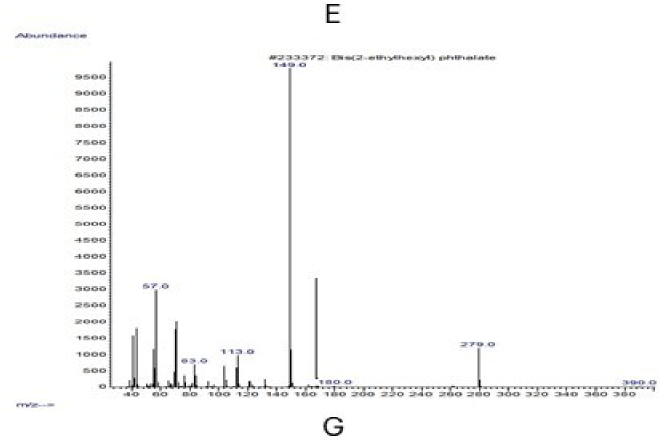


Fig. 1. Representative GC-MS chromatograms (A–G) showing the distribution of alkanes, esters, hopanes (other), solvents, PAHs, and phthalates in soils from Kofar Ruwa Automobile Mechanic Village

Table 2: Classification of compound detected in the sample

Chemical Class	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Total Compounds
Alkanes	5	6	4	4	3	22
Phthalates	1	3	1	4	2	11
PAHs	0	0	0	1	0	1
Esters	5	3	4	4	2	18
Solvents	0	0	2	2	2	6
Others	5	7	10	8	11	41

Table 3: Classification of compounds with percentages (%) area covered in the samples

Sample	Alkane	Phthalate	Solvent	PAH	Ester	Other
S1	33.01	50.52	0.00	0.00	18.03	-1.56
S2	23.08	27.73	0.00	0.00	4.11	45.08
S3	40.30	13.35	0.54	0.00	23.41	22.41
S4	14.22	29.20	0.35	1.54	0.00	54.69
S5	25.96	29.65	0.71	0.00	2.93	40.75

S1 – S5 = Indicates sample 1-5

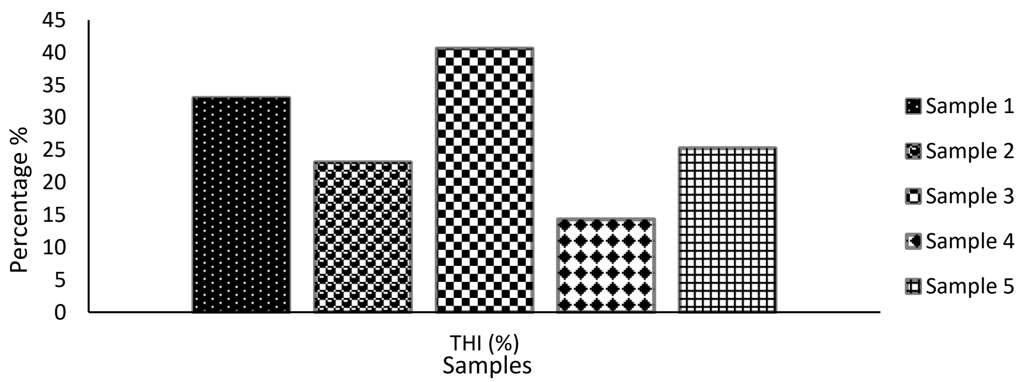


Fig. 2: Total Petroleum Hydrocarbon Index (THI)

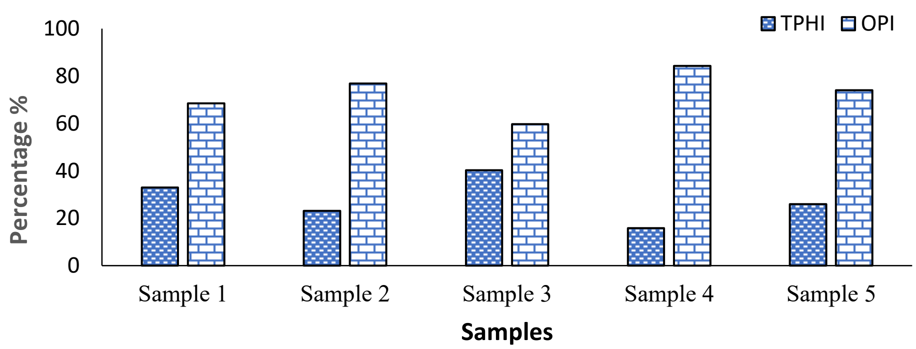


Fig. 3: A graph of Total Petroleum Hydrocarbon Index and Organic Pollution

The classification of compounds in Tables 2 and 3, along with the calculated Pollution Class Index (PCI), Total Hydrocarbon Index (THI), Total Petroleum Hydrocarbon Index (TPHI), and Organic Pollution Index (OPI), provides insight into the type and extent of organic contamination across the sampling sites. The negative value observed under 'others' in Sample 1 likely results from rounding errors or classification boundaries, and does not significantly affect the interpretation of the results.

3.2 Discussion

Table 2 presents the classification of all organic compounds detected across the five soil samples collected from the mechanic village. A total of 99 compounds were identified and grouped into six major classes: alkanes, phthalates, PAHs, esters, solvents, and others. The "others" category includes cycloalkanes, alkenes, alcohols, ketones, phenolic aromatics, organosulfur compounds, biomarkers such as hopanes and triterpenes, and halogenated hydrocarbons.

The predominance of alkanes (22 compounds) observed in the samples is consistent with contamination from lubricating oils, diesel, petrol, and other petroleum derivatives typically found in mechanic workshops, where spills and improper disposal are widespread (EPA, 2023; UNEP, 2018).

Phthalates were the next dominant group, with 11 compounds distributed across the samples. These include widely used industrial plasticizers such as diethylhexyl phthalate (DEHP) and dibutyl phthalate (DBP), typically released from PVC materials, vehicle interior components, electrical cable coatings, and plastic waste common in mechanic clusters. These compounds, commonly detected in automobile-related environments (ATSDR, 2022; Ehrampush *et al*., 2024), are of concern due to their endocrine-disrupting potential (WHO, 2021).

Esters (18 compounds) were also abundant. Many of these esters are fluorinated, long-chain fatty acid esters or succinic esters, which are common in hydraulic fluids, grease formulations, engine treatment additives, and degraded plant/wax residues. Their presence indicates both anthropogenic influence (lubricants and chemical additives) and minor biogenic input (wax esters from soil organic matter). This has been reported in soils impacted by mechanical workshops (Cristale, *et al*., 2017). Their persistence is enhanced by hydrophobicity and strong sorption to soil organic matter (Adesina *et al*., 2024).

Solvents were relatively low in all samples (six compounds total), dominated by chlorinated and fluorinated solvents (e.g., chloroform, dichlorodifluoroethane). These chemicals often originate from degreasing agents, brake-cleaning sprays, refrigerant leaks, or chemical spills in the mechanic environment (EPA, 2022).

PAHs were the least represented group, with only one PAH (anthracene) observed in Sample 4. PAHs typically arise from incomplete combustion, tire wear, and exhaust deposition (WHO, 2017). Even at low concentrations, PAHs are environmentally significant due to their carcinogenic and mutagenic properties (IARC, 2018).

The 'others' category, which includes cycloalkanes, alkenes, aromatic phenols, ketones, organosulfur compounds, and biomarkers such as hopanes and triterpenoids, highlights the chemical complexity of mechanic village soils. The presence of hopanes and triterpenoids confirms contamination from used engine oil, as these compounds are resistant to weathering and serve as diagnostic petroleum markers (Yilmaz *et al*., 2020).

The data in Table 3 presents the relative area % covered by each pollution class, giving a quantitative view of the dominant pollutant types within each sample. Sample 1 shows high phthalate contribution (50.52%), indicating dominant input from plastic waste, vehicle components, and lubricant additives, this was consistent with previous reports on plastic pollution at automobile-workshop soils (Adesina *et al*, 2024). Alkanes contribute 33.01%, reflecting strong petroleum impact. Esters contributed 18.03%, supporting the presence of lubricant and grease additives. The 'others' category, which includes cycloalkanes, alkenes, aromatic phenols, ketones, organosulfur compounds, and biomarkers such as hopanes and triterpenoids, highlights the chemical complexity of mechanic village soils. The presence of hopanes and triterpenoids confirms contamination from used engine oil, as these compounds are resistant to weathering and serve as diagnostic petroleum markers (Yilmaz *et al*., 2020

Sample 2 had a high proportion of compounds in the "others" class (45.08%) and moderate phthalates and alkanes. This pattern is typical of soil with mixed contamination sources (Ibe *et al.,* 2021). Sample 3 exhibited the highest alkane contamination (40.30%), suggesting the strongest petroleum signature among the samples. Soils containing aged petroleum residues often present such alkane dominance (EPA, 2023; Tanimu *et al*., 2019). In Sample 4, the exceptionally high "other" fraction (54.69%) included phenols, chlorinated organics, and biomarkers. The unique detection of anthracene (1.54%) suggests localized combustion residue input from welding or burning of vehicle parts (IARC, 2018). Sample 5 showed mixed contamination similar to Sample 2 but with higher phthalates (29.65%) and alkanes (25.96%). This aligns with reports that mechanic workshops act as hotspots for phthalate and hydrocarbon release (Adipah, 2019).

Across all samples, the results show that soils in mechanic villages contain complex mixtures of petroleum hydrocarbons, phthalates, solvents, and other organic pollutants. The widespread presence of alkanes confirms chronic input of used engine oil, petrol, diesel, and lubricants. Improper waste-oil disposal is a well-documented environmental issue in developing countries (Haleyur *et al*., 2016).

Phthalates were abundant across all samples. Their presence suggests that plastic waste degradation, PVC materials, lubricating oil additives, adhesives, and electrical cable coatings significantly contribute to soil contamination. Phthalates are known endocrine disruptors, and their persistence raises concerns for long-term ecological and human health risks (WHO, 2021). The dominance of esters, especially fluorinated and long-chain fatty esters, indicates contamination from grease formulations, hydraulic fluids, and engine additives. These compounds tend to bind strongly to soil, reducing biodegradability (Adipah, 2019). The detection of chlorinated and fluorinated solvents suggests the use of degreasing agents and brake cleaners in the workshop environment. These compounds can volatilize or migrate and may contribute to groundwater contamination (ATSDR, 2020). The presence of hopanes, squalene, and friedelan derivatives confirms petroleum fingerprinting and indicates that many contaminants originate from used lubricating oil, which is rich in stable biomarkers.

The limited presence of PAHs suggests that combustion residues are not the primary pollution source. Instead, contamination is predominantly caused by surface deposition of petroleum products, plastic waste, lubricants, and chemical additives typical of automotive repair activities, which is consistent with findings from mechanic villages in Nigeria and other developing regions (Ibe *et al*., 2021; Haleyur *et al*., 2016).

Overall, the results indicate that soils from Kofar Ruwa Automobile Mechanic Village are heavily impacted by mixed organic pollution, dominated by petroleum hydrocarbons and phthalate plasticizers. GC-MS analysis identified 99 compounds across five soil samples, with alkanes (22 compounds) as the most dominant petroleum-related pollutants, followed by phthalates, esters, and solvents. Only one PAH (anthracene) was detected, suggesting minimal contribution from combustion residues. Biomarkers such as hopanes confirmed the presence of used engine oil. High values of THI, TPHI, and OPI across all samples indicate extensive contamination and potential ecological and human health risks, primarily due to improper disposal of lubricants, fuels, and workshop chemical wastes.

A total of ninety-nine (99) compounds were detected and grouped into alkanes, phthalates, PAHs, esters, solvents, and other organic contaminants. Alkanes (22 compounds) were the most dominant petroleum-related pollutants, reflecting chronic contamination from diesel, petrol, lubricants, and spent engine oils. Phthalates, largely originating from plastic materials, vehicle interior components, and lubricant additives, were also abundant. Esters and solvents indicated contributions from grease formulations, hydraulic fluids, and degreasing chemicals. Only one PAH (anthracene) was detected, suggesting minimal combustion-derived pollution compared to petroleum product spills. Biomarkers such as hopanes confirmed the strong presence of used lubricating oil.

Pollution indices showed that all sample sites exhibited high Total Hydrocarbon Index (THI), Total Petroleum Hydrocarbon Index (TPHI), and Organic Pollution Index (OPI) values, confirming extensive organic pollution across the mechanic village. The overall findings demonstrate that hydrocarbon pollution in Kofar Ruwa is widespread, driven mainly by indiscriminate disposal of used engine oil, fuel leakage, plastic waste degradation, and workshop chemicals.

4.0 Conclusion

The study concludes that the soil in Kofar Ruwa Automobile Mechanic Village is significantly contaminated with hydrocarbons, primarily from petroleum derivatives, lubricants, and plastic-related chemicals. Alkanes and phthalates were the predominant pollutant groups, indicating chronic and unmanaged pollution resulting from mechanic activities. Although PAH levels were low, the presence of petroleum biomarkers and high hydrocarbon indices emphasizes considerable environmental degradation. The contamination poses risks to soil fertility, groundwater safety, ecological balance, and public health. Without intervention, pollution levels are likely to increase due to continuous mechanical operations and poor waste disposal practices. The study therefore establishes the urgent need for environmental management and regulatory actions.

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5.0 References

Abhulimhen, B. (2016). Physico-Chemical Properties of Soil Sourced from Automobile Mechanic Workshop in Ikoku Mechanic Village, Mile 3 Diobu, Port Harcourt, Rivers State, Nigeria.

Abugu, H. O., Ezugwu, A. L., & Ihedioha, J. N. (2023). Assessment of polycyclic aromatic hydrocarbon contamination of fruits, leaves, and soil within automobile repair workshops in Nsukka Metropolis. *Polycyclic Aromatic Compounds*, 43, 9, pp. 8333-8355.

Adesina, A. D., Sojinu, S. O., Aikulola, E. O., & Salako, J. O. (2024). Heavy metals and phthalates in water, soil and plant from automobile mechanic villages in Abeokuta. *Journal of the Chemical Society of Nigeria*, 49, 6, pp. 1014-1026.

Adipah, S. (2019). Introduction of petroleum hydrocarbons contaminants and its human effects. *Journal of Environmental Science and Public Health*, 3, 1, pp. 1-9.

Agency for Toxic Substances and Disease Registry (ATSDR). (2020). *Toxicological Profile for Chlorinated Solvents*. U.S. Department of Health and Human Services.

Agency for Toxic Substances and Disease Registry (ATSDR). (2022). *Toxicological Profile for Phthalates (DEHP, DBP)*. U.S. Department of Health and Human Services.

Ahmed, J., Katagum, Y. M., Nuhu, A. H., Abdulhameed, A., & Khalil, B. I. (2025). Determination of Polycyclic Aromatic Hydrocarbons and Volatile Organic Compounds in Surface Soils of Mechanic Workshops in Azare Bauchi State, Nigeria. *Fudma Journal of Sciences*, 9, 7, pp. 133-136.

Akomah, O. N., & Osayande, A. D. (2018). Evaluation of hydrocarbons level and identification of indigenous bacteria in soil from auto-mechanic workshops along Ikokwu mechanic village, Port Harcourt, Nigeria. *Journal of Applied Sciences and Environmental Management*, 22, 1, pp. 115-118.

Alabi, B. A., Aiyesanmi, F. A., & Ololade, I. A. (2019). Qualitative and Quantitative Assessment of Hydrocarbons in Soil Profiles of Auto-Mechanic Workshop: A Case Study of Akure City, Nigeria. *Polycyclic Aromatic Compounds*, 41(1), 1–14. https://doi.org/10.1080/10406638.2019.1567559

Ale, T. O. (2025). Assessment of potentially toxic elements concentration and distribution in soils at automobile mechanic workshops across different geological environments: a review. *NRIAG Journal of Astronomy and Geophysics*, 14, 1, pp. 1-24.

Amos, I. A., Edward, B. A., & Maryam, I. (2023). Quality assessment of the physicochemical properties of soils from automobile workshops and transformer installations site in Lafia, Nasarawa State. *Science World Journal*, 18, 1, pp. 20-25.

Aryee, A. A. (2016). *Levels of Polycyclic Aromatic Hydrocarbons and Heavy Metals in Surface Soil at Auto-Mechanic Workshops within the Accra Metropolis, Ghana* (Doctoral dissertation, University of Ghana).

Balogun, V. S., Ugwa, I. K., Ekpenkhio, E., & Abdulsalam, M. D. (2023). Assessment of Heavy Metal Contamination and Microbial Counts of Soils in Selected Auto-Mechanic Workshops within Benin Metropolis, Edo State, Nigeria. *Nigeria Journal of Environmental Sciences and Technology*, 7, 1, pp. 25-35.

Coulon, F., & Wu, G. (2014). Determination of petroleum hydrocarbon compounds from soils and sediments using ultrasonic extraction. In *Hydrocarbon and Lipid Microbiology Protocols: Petroleum, Hydrocarbon and Lipid Analysis* (pp. 31-46). Berlin, Heidelberg: Springer Berlin Heidelberg.

Cristale, J., Álvarez-Martín, A., Rodríguez-Cruz, S., Sánchez-Martín, M. J., & Lacorte, S. (2017). Sorption and desorption of organophosphate esters with different hydrophobicity by soils. *Environmental science and pollution research international*, 24, 36, pp. 27870–27878. https://doi.org/10.1007/s11356-017-0360-0

Ehrampush, M. H., Abouee, E., Arfaeinia, H., Soltanian, Z., Ghorbanian, M., & Ghalehaskari, S. (2024). Occurrence, distribution and risk assessment of phthalate esters in dust deposited in the outdoor environment of Yazd industrial park using Monte Carlo simulation. *Heliyon*, 10, 18, e37500. https://doi.org/10.1016/j.heliyon.2024.e37500

Ekanem, A. N., Udo, G. J., & Okori, B. S. (2021). Determination of polycyclic aromatic hydrocarbons in soil and water around automobile repair workshops within Eket metropolis in Akwa Ibom State, Nigeria using GC-MS. *Journal of Environmental Treatment Techniques*, 9, 4, pp. 819-830.

Environmental Protection Agency (EPA) (2022). *Chlorinated Solvents: Usage, Risk, and Environmental Impact*. U.S. EPA Office of Chemical Safety and Pollution Prevention.

Environmental Protection Agency (EPA) (2023). *Petroleum Hydrocarbons and Used Oil Contamination in Soil*. U.S. EPA, Washington, D.C.

Eze, V. C., Onwukeme, V. I., & Ogbuagu, J. O. (2024). Concentration, toxicity, and health risk assessment of polychlorinated biphenyls (PCBs) in top soils around Nekede auto-mechanic village, Imo State. *Arabian Journal of Geosciences*. 2024, 17(1). https://doi.org/10.1007/s12517-023-11836-w

Ganiyu, S. A., Olobadola, M. O., & Adeyemi, A. A. (2023). Concentrations and health risk appraisal of heavy metals and volatile organic compounds in soils of automobile mechanic villages in Ogun State, Nigeria. *Environmental Geochemistry and Health*, 45, 8, pp. 6407-6433.

Haleyur, N., Shahsavari, E., Mansur, A. A., Koshlaf, E., Morrison, P. D., Osborn, A. M., & Ball, A. S. (2016). Comparison of rapid solvent extraction systems for the GC–MS/MS characterization of polycyclic aromatic hydrocarbons in aged, contaminated soil. *MethodsX*, 3, pp. 364-370.

Ibe, F. C., Duru, C. E., Isiuku, B. O. & Akalazu, J. N. (2021). Ecological risk assessment of the levels of polycyclic aromatic hydrocarbons in soils of the abandoned sections of Orji Mechanic Village, Owerri, Imo State, Nigeria. *Bulletin of the National Research Centre,* 45, 18, https://doi.org/10.1186/s42269-021-00485-2.

Ikpe, E. E., Ubong, U. U., Uwanta, E., Oku, U. U., & Akpan, E. O. (2023). Investigation of petroleum hydrocarbons in soil from automobile mechanic workshops within Ikot Akpaden, Mkpat Enin LGA Akwa Ibom State Nigeria. *Chemical Science International Journal*, 32, 2, pp. 22-29.

International Agency for Research on Cancer (IARC). (2018). *Some Polycyclic Aromatic Hydrocarbons and Other Industrial Chemicals*. IARC Monographs, Vol. 92.

Kalagbor, I. A., & Ezebunwo, M. C. (2024). Risk Assessment of Some Potentially Toxic Elements Present in the Soil ofan Automobile Workshop Impacted by Waste Oil. *Nigerian Journal of Oil and Gas Technology*, 5, 1, pp. 11-28.

Lau, E. V., Gan, S., & Ng, H. K. (2010). Extraction techniques for polycyclic aromatic hydrocarbons in soils. *International Journal of Analytical Chemistry*, 2010, 1, 1, 398381. doi: 10.11 55/2010/398381.

Madukasi, E. I., & Agbazue, O. (2024). Evaluation of Physicochemical Parameters, Total Bacteria Count and some Heavy Metal Levels in Soil from Automobile Workshop Activities at Nnewi Local Government Area, Anambra State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 28, 9, pp. 2729-2736.

Nwachukwu, J. C., & Anegbode, E. F. (2024). Experimental modelling of contaminant migration of spent engine oil in a Lateritic soil within Nekede Mechanic Village. *EQA-International Journal of Environmental Quality*, 59, pp. 42-48.

Nwoko, C. O., Njoku-Tony, R. F., Nlemedim, P. U., & Ihugba, U. A. (2017). Assessment of the distribution pattern of polyaromatic hydrocarbons around Nekede Auto-mechanic Village, Imo State, Nigeria. *J Chem Environ Biol Eng*, 1, 2, pp. 27-33.

Nyarko, H. D., Okpokwasili, G. C., Joel, O. F., & Galyuon, I. A. K. (2019). Effect of petroleum fuels and lubricants on soil properties of auto-mechanic workshops and garages in Cape Coast metropolis, Ghana. *Journal of Applied Sciences and Environmental Management*, 23, 7, pp. 1287-1296.

Obini, U., Okafor, C. O., & Afiukwa, J. N. (2013). Determination of levels of polycyclic aromatic hydrocarbons in soil contaminated with spent motor Engine oil in Abakaliki Auto-Mechanic Village. *Journal of Applied Sciences and Environmental Management*, 17, 2, pp. 169-175.

Okonokhua, B. O., & Aghidi, E. A. (2024). Assessment Of Soil Physicochemical Properties And Total Petroleum Hydrocarbon Of A Three-Decade-Old Polluted Site At Evbareke, Benin City. *African Journal of Health, Safety and Environment*, 5, 1, pp. 53-61.

Olamide, A. B., & Ajayi, O. A. (2024). Assessment of polycyclic aromatic hydrocarbons in three selected auto-mechanic sites, Soil within Ijebu Igbo, Ogun State. International Journal of Multidisciplinary Research and Growth Evaluation, 5, 5, pp. 426-430.

Onu, B. (2023). Assessment of petroleum oil contamination effects on soil characteristics in farmland surrounding automobile workshops: a case study in Yenagoa, Bayelsa State, Nigeria. *Communication in Physical Sciences*, 9, 4, pp. 625-632.

Opia, C. F., & Chizoruo, I. F. (2024). Anthropogenic determination and risk assessment of total petroleum hydrocarbons of groundwater within Orji auto repair workshops, Owerri, Imo State, Nigeria. *Environmental analysis, health and toxicology*, 39.1, e2024008. https://doi.org/10.5620/eaht.2024008

Silalahi, E. T. M. E., Anita, S., & Teruna, H. Y. (2021). Comparison of extraction techniques for the determination of polycyclic aromatic hydrocarbons (PAHs) in soil. In *Journal of Physics: Conference Series* (Vol. 1819, No. 1, p. 012061). *IOP Publishi,* doi:10.1088/17426596/1819/1/012061

Tanimu, J., Michael, G. I., & James, P. A. (2019). Effects of Contamination of Soil with Used Engine Oil on Some Soil Properties and Microbial Growth in Wukari, North Eastern Nigeria. *East African Scholars Journal of Agriculture and Life Sciences*, 2, 6, pp. 358-363.

Timothy, N. M., Iyama, W. A., Egbunefu, O. C., Gbode, L. Y., Edori, O. S., Edori, E. S., ... & Ogbehi, D. (2023). Evaluation of the topsoil quality for polycyclic aromatic hydrocarbons near automobile repair facilities in Eleme, Rivers State, Nigeria. *Journal of Health, Applied Sciences and Management*, *7*(1), 132-142.

United Nations Environment Programme (UNEP) (2018). *Africa Regional Report on Used Oil Pollution*. UNEP Chemicals and Waste Branch.

United States Agency for Toxic Substances and Disease Registry. Office of Innovation and Analytics. Toxicology Section;SRC, Inc.

Vincent, F., Manu, J. M., Chessed, G., Vandi, P., Francis, S., & Norah, S. (2022). Assessment of heavy metals content in soil and groundwater within the vicinity of automobile mechanic workshops in Yola and Jimeta Towns, Adamawa State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 26, 11, pp. 1749-1755.

Wang, L., Cheng, Y., Naidu, R., & Bowman, M. (2021). The key factors for the fate and transport of petroleum hydrocarbons in soil with related in/ex situ measurement methods: an overview. *Frontiers in Environmental Science*, *9*, 756404. doi: 10.3389/fenvs.2021.756404

Wj, L., Lc, O., & Ai, H. (2024). Analyzing the Presence and Dispersion of Hydrocarbons at Mechanic Workshop Dumpsites, Port Harcourt, Rivers State, Nigeria. *Asian Journal of Environment & Ecology*, 23, 2, pp. 70-76.

World Health Organization (WHO) (2017). *Guidelines for Assessing Exposure to Polycyclic Aromatic Hydrocarbons*. WHO Press, Geneva.

World Health Organization (WHO) (2021). *Endocrine-Disrupting Chemicals and Health Risks*. WHO Press, Geneva.

Yilmaz B, Terekeci H, Sandal S, & Kelestimur F. (2020). Endocrine disrupting chemicals: exposure, effects on human health, mechanism of action, models for testing and strategies for prevention. *Rev Endocr Metab Disord.,* 21, pp. 127–147 (2020). https://doi.org/10.1007/s11154-019-09521-z

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