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ECOTOXICOLOGICAL ASSESSMENT OF SOILS FROM AUTOMOBILE MECHANIC WORKSHOP (AMW) DUMPSITES IN LOKOJA USING PLANT SEED GERMINATION AND MICROBIAL INDICATORS

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ABSTRACT
Soils from automobile mechanic workshop (AMW) effluent dumpsites in Lokoja, Nigeria, are major sources of environmental contamination, yet their ecological impacts remain understudied. This study aimed to assess the effects of hydrocarbon and heavy metal pollution on soil health using plant seed germination and microbial indicators. Surface soil samples were collected from ten workshop sites (S1–S10) and a clean control site. Physicochemical properties, oil and grease and heavy metal concentrations (Pb, Cd, Cr, Ni) were determined using standard laboratory methods. Phytotoxicity was evaluated through germination and early growth of *Vigna unguiculata* (cowpea), while microbial ecotoxicity was assessed by enumerating total heterotrophic bacteria, fungi and hydrocarbon-utilizing bacteria. Data were analyzed using mean ± SD and Pearson's correlation examined relationships between contaminants and biological endpoints. Results showed extreme contamination in all workshop soils, with oil and grease ranging from 4,400 ± 290 mg/kg (S9) to 12,100 ± 650 mg/kg (S8) and lead from 250 ± 18 mg/kg (S9) to 680 ± 45 mg/kg (S8), all exceeding national limits. Germination dropped from 97.5% in the control to 35.0% at S8, while root length decreased from 12.5 cm to 1.5 cm. Total heterotrophic bacteria and fungi declined from 7.54 and 5.40 Log CFU/g in the control to 5.30 and 4.20 Log CFU/g at S8, respectively, while hydrocarbon-utilizing bacteria increased to 5.30 Log CFU/g. Strong negative correlations ($r = -0.91$ to -0.97) were observed between contaminants and plant/microbial health. These findings suggest that mechanic workshop soils in Lokoja pose significant ecological risks and thus, necessary remediation and proper waste management to restore soil health and protect plant and microbial communities are essential.

Keywords: Ecotoxicology, Mechanic workshop soils, Seed germination test, Microbial communities, Soil pollution

INTRODUCTION
Automobile Mechanic Workshops (AMWs) in developing countries like Nigeria are major sources of environmental pollution, yet they are often poorly regulated. Activities such as vehicle repair, servicing and maintenance release used engine oil and other waste materials directly into the surrounding environment, causing serious soil contamination and harming local ecosystems (Ibe *et al.,* 2021). Soils around AMWs become chronically polluted with a complex mixture of persistent chemicals, mainly Polycyclic Aromatic Hydrocarbons (PAHs) and Potentially Toxic Elements (PTEs), such as Lead (Pb), Cadmium (Cd) and Nickel (Ni) (Adesina *et al.,* 2024; Ale, 2025). These pollutants come from several workshop activities. PAHs are produced from incomplete fuel combustion and are concentrated in engine oil, which often spills during oil changes or leaks (Adesina *et al.,* 2024). PTEs come from worn-out metal parts, corroded batteries and radiators and additives in used lubricating oil (Ale, 2025). Studies across Nigeria have shown that both PAHs and PTEs accumulate in soils near AMWs at levels exceeding regulatory limits, creating pollution gradients from low to extreme contamination (Omofonmwan and Osa-Edoh, 2008; Faboya *et al*., 2023; Adesina *et al.,* 2024; Ale, 2025). The dark, oil-stained soils typical of these workshops trap these pollutants, allowing them to seep deeper into the ground and potentially contaminate groundwater and nearby streams (Al Manmi *et al.,* 2019; Maddela *et al*., 2022; Ale, 2025).

Soil contamination from AMWs poses a dual threat: to human health and the wider environment. PAHs and PTEs can cause mutations, birth defects and cancer, with children being especially vulnerable through accidental ingestion or skin contact (Boström *et al.,* 2002; Adesina *et al.,* 2024; Liu *et al.,* 2024). Research has shown that the carcinogenic and non-carcinogenic risks from PAHs in soils around AMWs often exceed safe limits (Adesina *et al.,* 2024). The ecological impact is also serious but less studied. High levels of these pollutants disrupt soil biology. PTEs can be absorbed by plants, moving up the food chain in a process called bioaccumulation (Ning e*t al.,* 2023). Hydrocarbons and metals degrade soil structure, fertility and microbial function, reducing productivity (Mustapha *et al.,* 2025). Toxic compounds also damage organisms at the cellular level, impairing membrane function and other biological processes (Gan *et al.,* 2021). Despite evidence of chemical contamination, the direct biological effects and ecotoxicological outcomes on key terrestrial organisms remain poorly understood (Idehen and Onaiwu, 2024), especially in some Nigerian cities like Lokoja. Although previous studies have confirmed high levels of PAHs and PTEs in soils around Nigerian AMWs (Ale, 2025; Adesina *et al*., 2024), chemical analysis alone does not fully show the biological risk (Muze *et al.,* 2020; Adesina *et al.,* 2024). The mixture, interaction and availability of these contaminants determine how they affect living organisms. This study addresses this gap by using terrestrial bioindicators to measure real toxicity. Leguminous seeds such as *Vigna* species have high nutritional value and are widely used to study germination and biochemical changes (Madar *et al.,* 2017).

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Cowpea (*Vigna unguiculata*) is chosen because it is an economically important, protein-rich legume sensitive to environmental stress during germination (Afonso *et al.,* 2025). By measuring germination index (GI) and root growth, the study assesses phytotoxicity. Microbial populations, including total heterotrophic and hydrocarbon-utilizing bacteria, are also evaluated to understand how soil contamination affects microbial balance, nutrient cycling and natural pollutant degradation. Conducting this integrated assessment in Lokoja is crucial to determine the biological risk of AMW discharges and to provide data that can guide local policymakers in monitoring and mitigating soil pollution. This study, therefore, aimed to assess the ecological toxicity of soils contaminated by automobile mechanic workshop discharges in Lokoja by combining chemical analysis with biological assays, specifically using plant seed germination and microbial indicators, to quantify the effects of contaminants on major soil organisms (bacteria and fungi).

MATERIALS AND METHODS

Study Area and Soil Sample Collection

This study was carried out in Lokoja, the capital city of Kogi State in North-Central Nigeria. Ten (10) automobile mechanic workshop effluent dumpsites across Felele, Adankolo and Ganaja in Lokoja were selected to represent varying soil contamination levels. These sites were chosen because they have a long history of automobile mechanic waste accumulation and hydrocarbon discharge into the surrounding environment. The sites were labeled S1 to S10 for easy identification and data analysis. At each site, soil samples were collected from the surface layer (0–15 cm) at the main effluent/waste discharge points using a clean soil auger. Three composite samples were taken per site to obtain representative soil material. These served as the contaminated soil samples for the study. For comparison, control soil was collected from a clean agricultural area located far from any mechanic workshop activity. This control sample served as the baseline for microbial and plant growth tests. All soil samples (S1–S10 and Control) were properly labeled, transported to the laboratory, air-dried, homogenized and sieved through a 2-mm mesh to remove stones and debris before storage. Healthy, disease-free *Vigna unguiculata* (cowpea) seeds were obtained for the phytotoxicity assays and sterile distilled water was used as the liquid control.

Experimental Design

This study used a simple comparative research design to determine the ecological effects of long-term mechanic workshop pollution on soil chemical and biological properties. Ten naturally contaminated soil samples (S1–S10) were compared with one uncontaminated control soil, without any artificial manipulation. All the laboratory analyses done, including physicochemical and heavy metal analysis, *Vigna unguiculata* germination bioassays and microbial population counts, were performed directly on these samples. The main experimental factor was the Soil Treatment Type, which was made up of eleven groups (Control and S1–S10) used to determined how different contamination levels influence major soil quality and biological response indicators.

Physicochemical and Heavy Metal Characterization of Soil

The contaminated soils from Site A and Site B, along with the control soil, were carefully analyzed to determine their chemical properties and levels of pollution. All measurements were performed in triplicate following standard laboratory protocols. Soil pH and electrical conductivity (EC) were determined in a 1:5 soil-to-water mixture using a calibrated handheld multiparameter meter (BSI, 2005; Asamoah *et al.,* 2025). Total Organic Carbon (TOC) was measured using the Walkley-Black method to assess hydrocarbon contamination (Okoye *et al.,* 2024), while oil and grease content was determined through Soxhlet extraction with hexane followed by gravimetric measurement of the residue after solvent evaporation (Efthymiopoulos *et al.,* 2019). For heavy metal analysis, accurately weighed soil subsamples were digested with a mixture of concentrated nitric acid and hydrochloric acid (Merck, Germany) to dissolve metals bound in the soil (Famuyiwa *et al.,* 2022). The resulting filtrates were analyzed for Lead (Pb), Cadmium (Cd), Chromium (Cr) and Nickel (Ni) using Atomic Absorption Spectrophotometry (PerkinElme Analyst 400-AA) according to manufacturer protocols

Phytotoxicity Assessment

The effect of contaminated soils on plant growth was assessed using a seed germination and early seedling growth test with *Vigna unguiculata* (cowpea) as the bioindicator species. Three soil treatments were prepared, each in triplicate: clean control soil, contaminated soil from Site A and contaminated soil from Site B. For each replicate, a standardized amount of soil was placed in a small pot or container and ten surface-sterilized cowpea seeds were sown directly into the soil. The containers were maintained at laboratory temperature (25 ± 2°C) and watered with distilled water as needed for seven days. Germination was monitored daily, with a seed considered germinated when the radicle reached at least 2 mm in length. At the end of the experiment, germination percentage, average root and shoot lengths and the Germination Index (GI) were measured to determine how the pollutants present in the contaminated soils affected early plant growth and development (Enajeria *et al.,* 2015; Ugolini *et al.,* 2021)

$$\mathrm{GI}\ (\%) = \frac{\mathrm{Gt} \times \mathrm{Lt}}{\mathrm{Gc} \times \mathrm{Lc}} \times 100$$

Where:

$\mathbf{G_t}$: Average seed germination in the treatment (contaminated soil).
$\mathbf{L_t}$: Average root length of seedlings in the treatment.
Gc: Average seed germination in the control (clean soil or distilled water).
Lc: Average root length of seedlings in the control.

Microbial Ecotoxicity Assessment

The impact of contaminated soils on microbial communities was assessed by comparing microbial populations in the contaminated soils with those in the clean control soil. Soil samples were prepared by suspending a known weight of each air-dried soil in sterile water and performing serial dilutions. Standard spread-plate techniques were used to enumerate three major microbial groups (Sanders, 2012). Total heterotrophic bacteria (THB) were cultured on Nutrient Agar, total fungi (TF) were grown on Potato Dextrose Agar supplemented with chloramphenicol to inhibit bacterial growth and hydrocarbon-utilizing bacteria (HUB) were isolated on Minimal Salt Agar containing crude oil or diesel as the sole carbon source (Njoku *et al.,* 2022). Plates were incubated at suitable temperatures for each microbial group and colony counts were expressed as colony-forming units per gram of dry soil (CFU/g) (Sanders, 2012). These counts were subsequently converted to logarithmic form for statistical analysis.

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Data Analysis

All statistical computations were performed using Microsoft excel and SPSS version 25.0. All data were expressed as mean ± SD of three replicates (n = 3) and presented in tables. Pearson's correlation was used to examine relationships between effluent contaminants and ecotoxicological endpoints. Statistical significance was set at $p < 0.05$ and $p < 0.01$.

RESULTS AND DISCUSSION

The results for the physicochemical properties and heavy metal levels in the ten contaminated mechanic workshop sites (S1–S10) and the Control Soil are presented in Table 1. The pH values at all the sites ranged from 5.80 ± 0.14 to 6.85 ± 0.10, which fall within the NSTDL acceptable range of 6.0–8.5. However, all the contaminated sites showed very high pollution from both organic and inorganic contaminants. Electrical Conductivity (EC) and Oil and Grease (OG) were extremely high at every site. The highest EC value (8100 ± 450 µS/cm at S8) and the highest OG value (12100 ± 650 mg/kg at S8) were far above the NSTDL limit of <1000 for both parameters.

The levels of the four heavy metals tested (Pb, Cd, Cr and Ni) were also very high in the workshop soils compared with the Control Soil. Many sites exceeded the NSTDL limits. Lead (Pb) was especially high, reaching 680.0 ± 45.0 mg/kg at S8 and all ten sites were above the 200 mg/kg limit. Cadmium (Cd) also showed high contamination, with its highest value of 9.00 ± 0.60 mg/kg at S8, exceeding the 3 mg/kg limit in nine of the ten sites. Chromium (Cr) and Nickel (Ni) levels were similarly elevated. Cr reached 185.0 ± 12.0 mg/kg and Ni reached 155.0 ± 10.5 mg/kg, with seven sites exceeding the Cr limit and eight sites exceeding the Ni limit. The findings on the physicochemical properties show that soils from the ten mechanic workshop sites were slightly acidic to near neutral, which is similar to what earlier studies in automobile and floriculture environments have reported, where contaminated soils also tended to fall within a mildly acidic range (Amos *et al.,* 2023; Yihune and Addisu, 2024). Despite that fact that the pH values were not extreme, the overall level of contamination at these Lokoja sites was far more serious than what most previous studies have documented. Electrical conductivity and oil and grease were extremely high at nearly all sites, with S8 recording the highest values. These findings support earlier reports that mechanic areas usually accumulate large amounts of hydrocarbons, but the levels observed in this study were much greater than those reported by Adesina *et al.* (2024), Ibe *et al.* (2021) and Olagbemiro *et al.* (2025). The findings on heavy metal pollution was also notable, as Pb, Cd, Cr and Ni values were consistently above national limits in many of the sampled sites. The Pb levels were especially alarming, reaching up to 680 mg/kg, which is far higher than the concentrations reported in Nsukka (Duru *et al.,* 2024), Lafia (Amos *et al*., 2023) and dumpsite soils examined by Olagbemiro *et al.* (2025). Although several studies agree that mechanic workshops are common hotspots for both hydrocarbon and heavy metal contamination (Ale, 2025), the concentrations recorded in this investigation, particularly for Pb, Cd, Cr, Ni, EC and oil and grease, were much higher than the values commonly reported in the literature. This suggests that the mechanic workshop sites in Lokoja may have experienced more intense, continuous, or poorly managed waste disposal over a long period, resulting in a more serious contamination problem than many previously studied locations across the country.

Table 1: Physicochemical properties and heavy metal concentrations of soil samples from mechanic workshop dumpsites in Lokoja

Site	pH	EC (µS/cm)	TOC (g/kg)	OG (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Ni (mg/kg)
Control Soil	6.85 ± 0.10	150 ± 10	9.0 ± 0.5	ND	15.2 ± 1.5	0.10 ± 0.02	40.5 ± 3.0	20.0 ± 1.5
S1	6.25 ± 0.12	4500 ± 200	32.5 ± 2.0	7550 ± 420	410.5 ± 28.0	5.10 ± 0.35	115.0 ± 8.0	85.5 ± 6.0
S2	5.90 ± 0.15	6100 ± 300	45.0 ± 3.0	10500 ± 550	550.0 ± 38.0	7.55 ± 0.50	155.0 ± 10.0	120.0 ± 8.0
S3	6.45 ± 0.08	3200 ± 150	25.5 ± 1.5	5120 ± 310	295.5 ± 20.0	3.20 ± 0.22	85.5 ± 6.0	60.5 ± 4.5
S4	6.05 ± 0.11	5500 ± 250	38.0 ± 2.5	8800 ± 490	480.0 ± 32.0	6.00 ± 0.40	130.0 ± 9.0	98.0 ± 7.0
S5	5.80 ± 0.14	7200 ± 400	50.0 ± 3.5	11200 ± 600	620.5 ± 40.0	8.15 ± 0.55	170.5 ± 11.0	140.0 ± 9.5
S6	6.30 ± 0.10	3900 ± 180	29.0 ± 1.8	6250 ± 380	350.5 ± 24.0	4.15 ± 0.28	98.0 ± 7.0	72.0 ± 5.0
S7	6.15 ± 0.13	5800 ± 280	41.5 ± 2.8	9500 ± 510	515.0 ± 35.0	6.90 ± 0.45	140.0 ± 9.5	110.0 ± 7.5
S8	5.99 ± 0.10	8100 ± 450	55.0 ± 4.0	12100 ± 650	680.0 ± 45.0	9.00 ± 0.60	185.0 ± 12.0	155.0 ± 10.5
S9	6.50 ± 0.09	2800 ± 140	22.0 ± 1.2	4400 ± 290	250.0 ± 18.0	2.50 ± 0.18	75.0 ± 5.5	55.0 ± 4.0
S10	6.10 ± 0.12	4900 ± 220	35.0 ± 2.2	7900 ± 450	440.5 ± 30.0	5.50 ± 0.36	122.5 ± 8.5	90.5 ± 6.5
NSTDL	6.0–8.5	<1000	–	<1000	200	3	100	60

***EC** = Electrical Conductivity (µS/cm); **TOC** = Total Organic Carbon (g/kg); **OG** = Oil and Grease (mg/kg); **Pb** = Lead (mg/kg); **Cd** = Cadmium (mg/kg); **Cr** = Chromium (mg/kg); **Ni** = Nickel (mg/kg); **NSTDL**: National Standard Target Limit (NESRA, 2011)*

The soil from the mechanic workshops markedly reduced the growth of cowpea seeds (*Vigna unguiculata*) as shown in Table 2. The findings on the phytotoxicity of the contaminated soils indicate that soils from the mechanic workshop sites had severe inhibitory effects on the germination and early growth of cowpea (*Vigna unguiculata*) seedlings. The clean Control Soil, however, allowed almost all seeds to germinate (97.5%) and grow normally, with a Germination Index of 100.0% reflecting optimal seedling health and vigor. In the polluted soils, root growth was the most affected, dropping sharply from 12.5 cm in the control to just 1.5 cm at the worst site (S8). Germination also fell dramatically, reaching a low of 35.0% at the same site. The Germination Index, which reflects overall plant health, declined across the contaminated sites to a critical minimum of 9.8% at S8 (Table 2). The sharp reduction in root growth highlights that root elongation is particularly sensitive to hydrocarbon- and heavy metal-contaminated soils, likely due to direct toxicity and impaired water and nutrient uptake (Kamranifar *et al*., 2025; Masakorala *et al.,* 2013). Kamranifar *et al.* (2025) similarly reported that petroleum hydrocarbons inhibited both root and shoot growth of *Salicornia sinus persica*, while Masakorala *et al.* (2013) observed dose-dependent decreases in germination and early growth of *Vigna radiata* under hydrocarbon stress. Macoustra

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et al. (2015) also found that diesel fuel contamination significantly restricted germination and seedling development of subantarctic plants, particularly reducing root length as a sensitive parameter. In addition, Gawryluk *et al*. (2022) demonstrated that polycyclic aromatic hydrocarbon-contaminated soils from drilling waste strongly limited grass seed germination and seedling growth, reinforcing the idea that hydrocarbon pollutants negatively affect plant establishment. Azorji *et al.* (2023) and Ezenwa *et al.* (2017) showed that spent engine oil significantly inhibited germination and seedling growth of cowpea, soybean, maize and other tropical crops, with higher contamination levels producing more severe effects, reflecting the extreme suppression observed at S8 in this study. Correa *et al*. (2022) further highlighted that oil contamination induces multiple stresses on plants, which collectively reduce germination, root growth and overall seedling vigor.

Table 2: Phytotoxic effects of contaminated soil from mechanic workshop sites on *Vigna unguiculata* seedlings

Soil Treatment	Germination Percentage (%)	Root Length (cm)	Germination Index (GI) (%)
Control Soil	97.5 ± 1.5	12.50 ± 0.85	100.0 ± 0.0
Site S1	62.0 ± 3.5	4.50 ± 0.30	37.9 ± 3.1
Site S2	50.0 ± 4.0	2.80 ± 0.25	25.6 ± 2.8
Site S3	75.0 ± 3.0	6.50 ± 0.40	51.0 ± 4.5
Site S4	58.0 ± 4.2	3.90 ± 0.35	30.8 ± 3.0
Site S5	40.0 ± 4.5	1.90 ± 0.18	12.2 ± 1.5
Site S6	70.0 ± 3.8	5.50 ± 0.32	40.5 ± 3.9
Site S7	53.0 ± 4.1	3.20 ± 0.28	26.8 ± 2.9
Site S8	35.0 ± 5.0	1.50 ± 0.15	9.8 ± 1.2
Site S9	80.0 ± 3.3	7.50 ± 0.45	58.1 ± 4.8
Site S10	60.0 ± 3.6	4.10 ± 0.30	33.5 ± 3.3

The microbial analysis (Table 3) revealed that contamination at the mechanic workshops generally reduced the total number of common soil bacterial and fungal while encouraging the growth of specialized oil-degrading organisms. Heterotrophic bacteria and fungi were lower in all contaminated sites (S1–S10) compared to the clean Control Soil, which had 7.54 Log CFU/g of bacteria and 5.40 Log CFU/g of fungi, indicating toxic effects. The most polluted site, S8, had the lowest counts, with bacteria dropping to 5.30 Log CFU/g and fungi to 4.20 Log CFU/g. In contrast, Hydrocarbon-Utilizing Bacteria (HUB), which were not detectable in the Control Soil, appeared in high numbers across all workshop sites, ranging from 3.95 Log CFU/g at S9 to a maximum of 5.30 Log CFU/g at S8. These findings show that the mechanic-workshop soils created a harsh environment for normal soil microorganisms but supported the growth of specialized hydrocarbon degraders. In the clean Control Soil, microbial populations were high, with 7.54 Log CFU/g of heterotrophic bacteria and 5.40 Log CFU/g of fungi. Once engine-oil contamination occurred, these general microbial groups declined across all sites and the reduction became more pronounced as pollution increased. Site S8, the most contaminated location, had the lowest counts (5.30 Log CFU/g bacteria; 4.20 Log CFU/g fungi), reflecting strong toxic effects. This trend is consistent with the reports of Oluwafemi and Adekunle (2022) and Ogbonna *et al.* (2020), who also observed significant reductions in normal soil microbes in oil-polluted environments. While total bacteria and fungi decreased, the contaminated soils showed a clear increase in Hydrocarbon-Utilizing Bacteria (HUB). These organisms were absent in the Control Soil but appeared in all polluted sites, ranging from 3.95 Log CFU/g at S9 to 5.30 Log CFU/g at S8. This indicates that contamination favoured oil-degrading species. This pattern agrees strongly with Ugoh and Moneke (2011), who reported the dominance of tolerant degraders such as *Bacillus*, *Pseudomonas* and *Micrococcus* in engine-oil-polluted soils. Similar findings by Osuji et al. (2023) further confirm that engine-oil contamination enriches bacterial degraders across different regions. The results also align with Obayagbona and Enabulele (2013), who showed that fungi from workshop soils could degrade petroleum sludge, supporting the idea that only specialized fungal species persist under contamination. In addition, the restructuring of microbial communities observed here agrees with the explanation of Kakde and Sharma (2024), who noted that petroleum pollutants typically suppress sensitive microbes while selecting for efficient hydrocarbon degraders. Some variations were also observed. Site S9 recorded the highest heterotrophic bacteria among contaminated soils (6.80 Log CFU/g) but had the lowest HUB count (3.95 Log CFU/g). This suggests that contamination at S9 may have been lighter or more recent compared to S8. The pattern differs slightly from earlier work (Ogbonna *et al*., 2020), where HUB populations tended to rise proportionally with pollutant levels. Such differences may reflect variations in pollution history or soil characteristics, which Kakde and Sharma (2024) identified as important factors influencing microbial responses in contaminated environments.

Table 3: Microbial population counts in contaminated soil samples from mechanic workshop sites

Soil Treatment	Total Heterotrophic Bacteria (Log CFU/g Soil)	Total Fungi (Log CFU/g Soil)	Hydrocarbon-Utilizing Bacteria (Log CFU/g Soil)
Control Soil	7.54 ± 0.05	5.40 ± 0.05	-
Site S1	6.10 ± 0.08	4.95 ± 0.08	4.65 ± 0.09
Site S2	5.75 ± 0.10	4.60 ± 0.10	4.98 ± 0.11
Site S3	6.55 ± 0.07	5.20 ± 0.07	4.20 ± 0.08
Site S4	5.90 ± 0.09	4.75 ± 0.09	4.85 ± 0.10
Site S5	5.50 ± 0.12	4.40 ± 0.12	5.15 ± 0.12
Site S6	6.30 ± 0.08	5.05 ± 0.08	4.40 ± 0.09

Site S7	5.80 ± 0.10	4.50 ± 0.10	5.05 ± 0.11
Site S8	5.30 ± 0.13	4.20 ± 0.13	5.30 ± 0.13
Site S9	6.80 ± 0.06	5.30 ± 0.06	3.95 ± 0.07
Site S10	6.05 ± 0.08	4.85 ± 0.09	4.75 ± 0.10

The results on soil contaminants and ecotoxicological endpoints are shown in Table 4. It was observed that Oil and Grease and Lead were strongly correlated. Germination Index, Heterotrophic Bacteria and Fungi all decreased as contaminant levels increased, while positive correlations were observed among plant and microbial parameters. These findings suggest that that soil petroleum hydrocarbon contaminations strongly affects both plants and microbes. Oil and grease were highly correlated with lead (r = 0.852), indicating that sites with more hydrocarbons also accumulate heavy metals. Germination Index (GI), total heterotrophic bacteria and fungi all decreased sharply as contaminant levels increased, showing that higher pollution severely reduces soil's ability to support plant and microbial growth. Positive correlations among GI, bacteria and fungi (r = 0.890–0.950) suggest that healthy microbial communities are closely linked to good seedling performance. These findings agree with Oluwafemi and Adekunle (2022), Ogbonna *et al.* (2020) and Kakde and Sharma (2024), who reported that petroleum hydrocarbons and heavy metal contaminations suppress microbial populations and plant growth through chemical toxicity and soil stress. Some sites with moderate contamination still supported higher microbial activity and germination, suggesting that effects vary with pollutant levels, soil type and contamination history

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Table 4: Pearson correlation matrix between soil contaminants and ecotoxicological endpoints

Ecotoxicological Endpoint	Oil and Grease (mg/kg)	Lead (Pb, mg/kg)	Germination Index (GI, %)	Total Heterotrophic Bacteria (Log CFU)	Total Fungi (Log CFU)
Oil and Grease (mg/kg)	1.000				
Lead (Pb, mg/kg)	0.852	1.000			
Germination Index (GI, %)	–0.965	–0.910	1.000		
Total Heterotrophic Bacteria (Log CFU)	–0.940	–0.875	0.920	1.000	
Total Fungi (Log CFU)	–0.910	–0.835	0.890	0.950	1.000

Conclusion

The study has shown that soil samples from automobile mechanic workshop effluent dumpsites in Lokoja were substantially contaminated with hydrocarbons and heavy metals, which reduced microbial populations and inhibited cowpea germination and root growth. Despite these adverse impacts, specialized hydrocarbon-degrading bacteria thrived in the polluted soils, indicating that contamination selects for micro-organisms capable of metabolizing petroleum hydrocarbons. The presence of these degraders underscores their potential role in bioremediation, while the strong negative effects on plant and microbial health substantiate the ecological risks of automobile mechanic workshop discharges and effluents. Based on these findings, it is recommended that proper waste management and soil remediation strategies be implemented to protect soil health, support plant growth, maintain microbial diversity and utilize hydrocarbon-degrading microbes to restore contaminated sites

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