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Research Article

Impact of Soils Contaminated by Automobile Servicing Waste on Seed Germination and Seedling Development in Lokoja, Kogi State

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ABSTRACT

Soil contamination from automobile servicing activities is a persistent environmental problem in many Nigerian cities, yet its implications for soil quality and early crop establishment remain poorly understood. This study assessed the physicochemical properties, heavy metal levels and their effects on seed germination and seedling development in soils collected from automobile mechanic workshops in Lokoja, Kogi State. Composite soil samples were analysed using standard laboratory procedures and maize, beans and tomato seeds were tested in germination assays. Data were evaluated using one-way ANOVA, Tukey's HSD test and Pearson correlation analysis. Contaminated soils showed significantly elevated pH, electrical conductivity, organic matter, nitrogen, phosphorus and potassium compared with controls ($p < 0.05$). Heavy metals, particularly Pb (85 ± 3.0 mg/kg) and Cd (3.2 ± 0.2 mg/kg) exceeded FAO/WHO limits. Germination percentage, seedling vigour, radicle length and plumule length were markedly reduced in contaminated soils, with tomato showing the highest sensitivity. Strong positive correlations were observed among all metals ($r = 0.84$–0.95), while growth parameters were strongly negatively correlated with metal concentrations (–0.70 to –0.88). This study further emphasizes that automobile-servicing waste severely degrades soil quality and suppresses early plant development. It recommends improved workshop waste management, routine soil monitoring and the application of phytoremediation or bioremediation techniques to restore contaminated sites.

Keywords: Automobile waste; Bioremediation; Heavy metals; Phytoremediation; Soil contamination

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INTRODUCTION

Soil pollution caused by automobile activities has become a growing environmental concern in many developing countries. In Nigerian cities, the use of vehicle, motorbike and generator (power-plants) remains on the rise causing the expansion of automobile servicing centers, which operates mostly without proper environmental controls (Nduka *et al.,* 2019). These automobile servicing centers or workshops carry out several activities, such as engine servicing, oil change, washing of greasy parts and disposal of used components, that release harmful chemicals into the surrounding soil (Oloruntoba and Ogunbunmi, 2020; Ganiyu *et al.,* 2024; Memba *et al.,* 2025). Due to inadequate enforcement of waste-management rules, mechanics often dump used engine oil, fuel residues and other contaminants directly onto the soil, contributing to widespread environmental pollution (Okebalama *et al.,* 2024). Over the years, these practices turn the many automobile mechanic workshop areas into long-term pollution systems with significant public health risks (Okebalama *et al.,* 2024).

Soils contaminated by automobile servicing activities and related wastes often contain persistent organic pollutants, particularly polycyclic aromatic hydrocarbons (PAHs). The primary sources of these pollutants, particularly polycyclic aromatic hydrocarbons (PAHs), include the improper disposal of used engine oil, accidental fuel leakage during storage or handling and the incomplete or partial combustion of petroleum products during vehicle operation (Adesina *et al.,* 2024). In addition to PAHs compounds, soils from automobile servicing centers and waste sites often contain elevated levels of potentially toxic elements (PTEs) such as lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni). These metals mainly originate from corroded vehicle parts, battery acid spills, metallic brake dust, and chemical additives in lubricating oils (Ale, 2025; Babagana *et al.,* 2025). Studies in Nigeria have reported that soils from automobile servicing sites contain significant levels of polycyclic aromatic hydrocarbons (PAHs) and potentially toxic elements (PTEs) such as lead, cadmium, chromium and nickel, often exceeding both national and international safety limits (Faboya*et al.,* 2023; Adesina *et al*., 2024; Ikeh*et al.,* 2025). These contaminants are persistent in the soil for many years and, during rainfall, can leach into groundwater or be carried into drainage channels, increasing their ecotoxicity (Al-Manmi *et al.,* 2019; Maddela *et al.,* 2022; Amos *et al.,* 2023; Adesina *et al*., 2024; Ale, 2025), highlighting the need for continuous monitoring of urban sites exposed to vehicle-related activities (Babagana *et al.,* 2025). The accumulation of recalcitrant hydrocarbons and heavy metals in soil creates harmful effects on both biological and chemical soil functions. PAHs and heavy metals interfere with living cells by damaging DNA, disrupting membranes and interfering with enzyme activity (Gan *et al.,* 2021). According to Chen *et al*. (2024), soil microbes, which play a crucial role in breaking down organic matter and recycling nutrients, are often the first to be affected by environmental changes or contamination. A reduction in microbial diversity and activity weakens soil fertility and slows down natural processes that help the soil recover from pollution (Dixit *et al.,* 2024; Mustapha *et al.,* 2025).

Plants are highly sensitive to contaminated soils, with seed germination being one of the most critical stages affected. In soils polluted with polycyclic aromatic hydrocarbons (PAHs), water absorption by seeds can be reduced because hydrocarbons block soil pores, limiting moisture availability (Gawryluk *et al.,* 2022). Similarly, heavy metals such as lead, cadmium, chromium and nickel can penetrate germinating seeds and interfere with essential physiological processes, including respiration, enzyme activity and hormone regulation (Ning *et al.,* 2023; Adesina *et al.,* 2024). These effects may cause delayed germination, poor radicle and plumule development, or even complete failure of the seeds to sprout. Even when seedlings survive, their growth is often slow, uneven and weak, reducing overall plant performance. This situation is particularly concerning in areas of Kogi State, North-Central Nigeria, where many small-scale farmers grow staple crops close to automobile servicing centers or waste sites, increasing the risk of soil contamination. Furthermore, heavy metals absorbed by plants can accumulate in edible fruits or grains, creating a serious public health risk (Atikpo *et al.,* 2021). Continuous consumption of crops grown in contaminated soils may lead to the buildup of heavy metals in humans, potentially causing chronic illnesses, organ damage and developmental problems in children (Chen *et al.,* 2024).

Although soils from automobile servicing dumpsites in Nigeria have been reported to contain high levels of polycyclic aromatic hydrocarbons (PAHs) and heavy metals (Adesina *et al.,* 2024; Ale, 2025), their direct effects on plant growth had been poorly studied. Chemical analyses alone have been unable to show how these contaminated soils influenced plants, particularly when multiple pollutants were present and could interact to produce stronger combined effects (Muze *et al.,* 2020). This study therefore examined the effects of soils from automobile servicing dumpsites on the early growth of maize (*Zea mays*), beans (*Vigna unguiculata*), and tomatoes (*Solanum lycopersicum*). These crops were selected because they are widely grown and consumed in Lokoja, form a major part of local diets and their seeds and seedlings respond visibly to changes in soil quality, making them reliable indicators of soil contamination.

MATERIALS AND METHODS

Study Area

This study was conducted in Lokoja, the capital city of Kogi State in North-Central Nigeria, strategically located at the confluence of the Niger and Benue Rivers (Latitude 7°49′ N, Longitude 6°44′ E) (Obayomi *et al*., 2023) (Figure 1). Lokoja experiences a Tropical Wet and Dry climate (Aw under the Köppen classification): characterized by distinct wet and dry seasons. Annual rainfall ranges between 1000 mm and 1500 mm, while mean temperatures average around 27°C (Ayuba and Tijani, 2021). The high rainfall during the wet season, coupled with elevated temperatures, enhances the leaching and mobility of contaminants in soils, increasing the risk of environmental pollution (Nouhou *et al*., 2025).

The study specifically focused on three areas within Lokoja: Felele, Adankolo and Ganaja (Figure 1). These locations were selected due to their high density of automobile workshops and frequent soil disturbances, which increase the potential for heavy metal and hydrocarbon contamination. Felele and Adankolo are largely residential and semi-urban areas, where waste from workshops can easily mix with soil used for small-scale urban agriculture. Ganaja, in contrast, hosts a major metal and electronic waste dumpsite, receiving mixed metal residues from automotive and industrial activities. The Ganaja dumpsite represents one of the largest repositories of metallic and industrial waste in the city, making it particularly relevant for studies on soil and water contamination. Lokoja's terrain is generally hilly, with elevations ranging from 30 to 400 meters above sea level. The area has historically faced flooding, particularly during extreme rainfall events in 2012, 2021 and 2024. These floods increase the transport of contaminants from workshop sites and dumpsites to surrounding soils, water bodies and residential areas, further exacerbating environmental and public health risks (Nouhou *et al*., 2025). The soils in these areas are highly susceptible to contamination from both point sources, such as workshops and non-point sources, including runoff during heavy rains (Ayuba and Tijani, 2021).

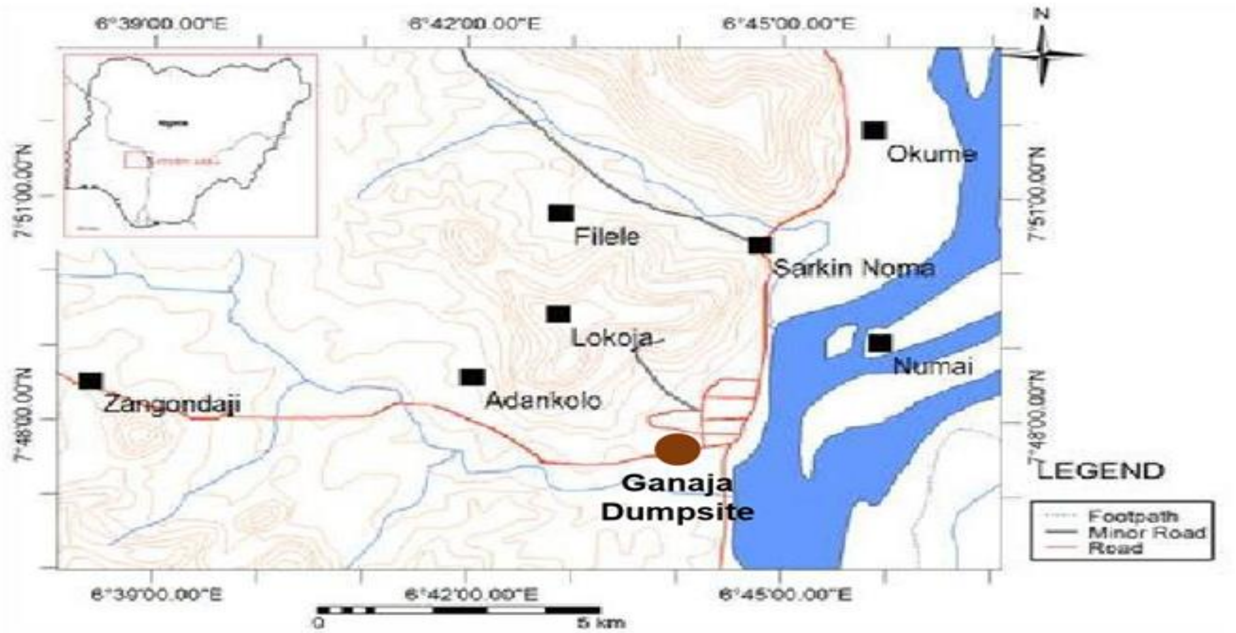

Figure 1: Map of Nigeria showing and Lokoja, the study area

Collection of Samples

The materials employed in this study included soil samples, crop seeds, analytical-grade reagents and standard laboratory equipment required for physicochemical and heavy metal analysis. Soil samples were obtained from the topsoil layer (0–20 cm) of automobile servicing workshop sites within Lokoja. The topsoil was used because they were reported to hold the highest amount of contaminants (Oguntimehin and Ipinmoroti, 2008). Sampling was carried out at three major mechanic areas in Lokoja: Felele, Ganaja and Adankolo, between May and July 2025. At each location, a total of five soil samples were collected using a clean stainless-steel trowel to prevent cross-contamination. The samples from each location were then mixed together to form one composite sample that represents the pollution level of that area. Control soil samples were also collected from clean agricultural land located more than 500 meters away from any mechanic or vehicle-related activity to ensure that they were not influenced by human contamination. All samples were placed in labeled polyethylene bags and transported in insulated cool boxes to protect their original condition. In the laboratory, the soil samples were air-dried for 72 hours, mixed thoroughly and sieved through a 2-mm mesh to remove stones, plant materials and other unwanted particles, following standard soil preparation procedures (Nathan *et al.,* 2012). The seeds of maize (*Zea mays*), beans (*Vigna unguiculata*), and tomato (*Solanum lycopersicum*) used for the germination and early seedling assays were sourced from Lokoja main markets. Seeds used for the bioassay were obtained separately and carefully sorted to remove broken or unhealthy seeds so that only good-quality seeds were used for the germination and growth tests. Only healthy, uniform and intact seeds were selected to enhance experimental reliability, following internationally recognized seed quality guidelines (ISTA, 2019). Analytical-grade chemicals were utilized throughout the laboratory analyses.

Physicochemical Properties of Soil samples

Physicochemical analyses of the contaminated and control soils were conducted using standard procedures. Soil pH and electrical conductivity (EC) were measured in a 1:2.5 soil–water suspension using calibrated digital meters (Sparks *et al.,* 1996). Organic matter content was determined by the Walkley–Black wet oxidation method (Walkley and Black, 1934). Moisture content was obtained by oven-drying soil samples at 105 °C to constant weight. Total nitrogen was quantified using the Kjeldahl digestion method (Lu, 2000). Available phosphorus was determined using the Bray-1 extraction followed by colorimetric measurement, as reported by Elbasiouny *et al*. (2020). Exchangeable potassium was extracted with ammonium acetate and quantified using a flame photometer, as described by Kenyanya *et al.,* (2013). Cation exchange capacity (CEC) was determined using the sodium acetate saturation method and displaced sodium ions were quantified via flame atomic absorption spectrophotometry (Peris *et al.,* 2008).

Heavy Metal Concentrations of Soil Samples

Heavy metal concentrations of the soil samples were analysed using standard laboratory procedures, following methods previously reported by Ojiego *et al.* (2022). The samples were first air-dried and sieved (<2 mm). Thereafter, one gram of each soil sample was digested using the wet-oxidation acid digestion method described by Allen *et al*. (1986). A mixture of concentrated nitric acid (HNO_3) and perchloric acid ($HClO_4$) was added to the soil and the mixture was heated on a digestion block until a clear solution formed. After cooling, the digest was filtered through Whatman No. 42 filter paper and made up to a known volume with distilled water. Lead (Pb), cadmium (Cd), chromium (Cr), zinc (Zn), copper (Cu), and nickel (Ni) were quantified using an Atomic Absorption Spectrophotometer (AAS) (Buck Scientific model 211VGP). Calibration curves were prepared from standard solutions and blanks were analysed to compensate for background interference. All analyses were performed in triplicates, and mean values were recorded

Effects of Automobile-Mechanic Contaminated Soil on Seedling Growth

The effect of automobile-mechanic contaminated soil on seed germination and seedling growth was evaluated under controlled laboratory conditions. Both contaminated and control soils were air-dried, homogenised and sieved before use. Clean plastic pots were filled with 500 g of soil per pot and 10 healthy, uniform seeds were sown in each pot. All treatments were set up in triplicates to ensure reliability. The pots were placed on a laboratory bench under natural light and room temperature. Soil moisture was maintained near field capacity by applying 20 mL of distilled water to each pot every two days. This ensured that observed differences in seedling performance were due to soil conditions rather than water stress. Germination was monitored daily for 10 days. A seed was considered germinated once the radicle became visibly extended. Germination percentage, mean germination time (MGT), germination rate index (GRI) and seedling vigour index (SVI) were calculated to assess germination performance (Šerá, 2023). After ten days, seedlings were gently removed and washed to remove soil. Radicle and plumule lengths were measured using a ruler. Growth inhibition in contaminated soil was expressed as a percentage relative to the control. The stress tolerance index (STI) was also calculated to determine crop tolerance to contamination (Šerá, 2023).

Data Analysis

All data were expressed as mean ± standard deviation (n = 3). Differences between contaminated and control soils, as well as among crop species, were assessed using one-way Analysis of Variance (ANOVA) and means were separated using Tukey's Honestly Significant Difference (HSD) test at 5% level of probability. Pearson correlation analysis was conducted to evaluate relationships between heavy metal concentrations in soil and seed germination or seedling growth parameters. All statistical analyses were performed using SPSS version 25.

RESULTS AND DISCUSSION

Results of physicochemical analysis of soils from automobile mechanic sites in Lokoja are presented in Table 1. Results revealed higher values in contaminated soils compared with controls. Soil pH in contaminated sites (7.95 ± 0.05) exceeded that of controls (6.70 ± 0.03) but remained within the FAO recommended range of 6–8. Electrical conductivity was elevated in contaminated soils (325 ± 7.0 µS/cm) relative to controls (115 ± 4.5 µS/cm), yet below the FAO threshold of 400 µS/cm. Organic matter (5.0 ± 0.2% vs. 2.5 ± 0.1%), moisture content (17.5 ± 1.2% vs. 10.5 ± 0.8%), total nitrogen (0.38 ± 0.02% vs. 0.18 ± 0.01%), available phosphorus (28.0 ± 1.5 mg/kg vs. 12.5 ± 1.2 mg/kg) and potassium (150 ± 7.5 mg/kg vs. 90 ± 5.2 mg/kg) were all higher in contaminated soils than controls. All differences were statistically significant ($p < 0.05$). The physicochemical properties of soils from the automobile mechanic sites in Lokoja showed clear and consistent changes when compared with the control soils. These changes suggest long-term effects from continuous deposits of spent oil, petroleum products, metal fragments and other workshop wastes. The contaminated soils had a higher pH (7.95 ± 0.05) than the controls (6.70 ± 0.03). This alkaline shift agrees with the findings of Erhunmwunse *et al.* (2016) and Abhulimhen (2016): who reported similar increases caused by alkaline hydrocarbons and metal oxides in mechanic sites. However, it disagrees with the acidic pH values reported by Nwakife *et al.* (2022) in Minna, which may be due to differences in soil type, geology, or waste composition. Electrical conductivity was also much higher in the contaminated soils (325 ± 7.0 µS/cm) than in the controls (115 ± 4.5 µS/cm), indicating an increase in dissolved ions. This pattern is similar to reports by Amos *et al.* (2023) and Ganiyu *et al.* (2024), who linked high EC values to metal-rich effluents and degraded petroleum wastes in mechanic environments.

Organic matter content in the contaminated soils (5.0 ± 0.2%) was double that of the controls (2.5 ± 0.1%), which agrees with the work of Igborgbor *et al.* (2022) and Erhunmwunse *et al*. (2016). This increase reflects the buildup of oil-based residues that do not decompose easily. The same residues also contributed to the higher moisture content recorded in the contaminated soils (17.5 ± 1.2% vs. 10.5 ± 0.8%) as oily films reduce evaporation and alter soil pore spaces, a pattern also noted by Amos *et al.* (2023). Total nitrogen levels were higher in the contaminated soils (0.38 ± 0.02%) than in the controls (0.18 ± 0.01%) and this aligns with findings by Abhulimhen (2016) who linked nitrogen increases to nitrogen-rich lubricants and the breakdown of organic pollutants. Phosphorus levels also more than doubled in the contaminated soils (28.0 ± 1.5 mg/kg) compared to the controls (12.5 ± 1.2 mg/kg), supporting the observations of Nwakife *et al.* (2022) and likely resulting from phosphate-based detergents and metal treatment agents used in vehicle repair. Potassium levels followed the same pattern, rising from 90 ± 5.2 mg/kg in the controls to 150 ± 7.5 mg/kg in the contaminated soils, a trend similar to that reported by Ganiyu *et al.* (2024) and linked to particles from brake linings, metal components and burnt residues**.**

Table 1: Physicochemical properties of automobile servicing waste contaminated soils in Lokoja, Nigeria

Parameter	Mechanic Soil	Control Soil	FAOLimit
pH	7.95 ± 0.05^b	6.70 ± 0.03^a	6–8
Electrical Conductivity (µS/cm)	325 ± 7.0^b	115 ± 4.5^a	< 400
Organic Matter (%)	5.0 ± 0.2^b	2.5 ± 0.1^a	2–5
Moisture Content (%)	17.5 ± 1.2^b	10.5 ± 0.8^a	10–20
Nitrogen (%)	0.38 ± 0.02^b	0.18 ± 0.01^a	0.2–0.5
Phosphorus (mg/kg)	28.0 ± 1.5^b	12.5 ± 1.2^a	10–30
Potassium (mg/kg)	150 ± 7.5^b	90 ± 5.2^a	100–200

Values are presented as mean ± standard deviation (n = 3). Means within the same row followed by different superscripts are significantly different at p < 0.05.

Similarly, the results showed that soils from automobile mechanic sites in Lokoja were significantly contaminated compared with control soils ($p < 0.05$) (Table 2). Lead (Pb) had the highest concentration, reaching 85 ± 3.0 mg/kg, above the FAO limit of 50 mg/kg. This contamination is likely from leaded fuel, lubricants and vehicle wear. This finding is in agreement with the report of Utang *et al.* (2013), who studied heavy metal accumulation in urban soils of Obio/Akpor LGA and the work of Eludoyinand Ogbe (2017), who assessed Pb contamination in pawpaw near automobile workshops in Port Harcourt. Cadmium (Cd) slightly exceeded its threshold at 3.2 ± 0.2 mg/kg. Batteries, metal plating and waste oils may be the sources. This finding is consistent with the report of Adelekan and Abegunde (2011), who investigated soil and groundwater contamination in Ibadan mechanic villages and the work of Anegbe *et al.* (2018) who studied heavy metal distribution around auto repair workshops in Oghara.

Chromium (Cr), zinc (Zn), copper (Cu), and nickel (Ni) were all below FAO limits but higher than concentrations in control soils. This indicates anthropogenic contributions, possibly from vehicle maintenance and metal wear. Similar patterns have been observed in Ibadan, Benue and Imo States. This finding agrees with the reports of Adelekan and Abegunde (2011), who studied mechanic villages in Ibadan, Mfam *et al.* (2023), who examined soils in Benue State workshops and Diagi *et al.* (2023), who assessed soils in Nekede and Orji, Imo State.The elevated Pb levels in Lokoja soils are consistent with observations

from Nsukka. This finding is in agreement with the report of Duru *et al.* (2024), who analysed heavy metal spatial variability in soils from auto-mechanic workshop clusters.

Moderately elevated levels of Zn and Cu were observed, which agrees with reports from soils near mechanic villages in Abeokuta (Olayinka and Oludare, 2016) and from mechanic workshops in Zaria (Garba *et al*., 2013). These metals likely originate from lubricants and corrosion of metal parts. Chromium and nickel showed the lowest concentrations, suggesting minor contributions from engine components. This finding is in line with the work of Liu *et al*. (2024), who assessed heavy metal contamination near an automobile industry in Jiaxing, China. Lead and cadmium tend to bind strongly to soils, whereas zinc and nickel are more mobile. This behaviour poses potential environmental and health risks. This finding aligns with Ale (2025), who reviewed potentially toxic element accumulation in soils across different geological environments. On a global scale, Pb remains the dominant pollutant in soils near automobile activities. Levels in Lokoja are lower than those reported near automobile factories in China. This finding is consistent with Liu *et al.* (2024), who reported extreme Pb and Cd accumulation in soils surrounding Chinese automobile industries.

Table 2: Heavy metal concentrations in automobile servicing waste contaminated soils from Lokoja, Nigeria (mg/kg)

Metal	Mechanic Soil	Control Soil	FAO Limit
Lead (Pb)	85 ± 3.0^{b}	5.2 ± 0.4^{a}	50
Cadmium (Cd)	3.2 ± 0.2^{b}	0.11 ± 0.01^{a}	3
Chromium (Cr)	20 ± 0.8^{b}	0.9 ± 0.08^{a}	100
Zinc (Zn)	105 ± 3.5^{b}	23.4 ± 1.1^{a}	300
Copper (Cu)	35 ± 2.0^{b}	6.8 ± 0.5^{a}	100
Nickel (Ni)	12 ± 0.5^{b}	1.7 ± 0.1^{a}	50

Values are presented as mean ± standard deviation (n = 3); Means within the same row followed by different superscripts are significantly different at $p < 0.05$.

Seed germination declined in contaminated soils: maize (62 ± 4%), beans (55 ± 3%), and tomato (47 ± 3%) compared with the control (92 ± 3%) (Table 3). Mean germination time (MGT) increased in contaminated soils; maize (3.7 ± 0.2 days), beans (4.2 ± 0.3 days), and tomato (5.0 ± 0.3 days), relative to the control (2.4 ± 0.2 days). Both the germination rate index (GRI) and seedling vigor index (SVI) were lower in contaminated soils, with tomato showing the strongest reduction (GRI: 4.5 ± 0.2; SVI: 96 ± 9) compared with the control (GRI: 12.9 ± 0.5; SVI: 470 ± 35). Radicle lengths declined to 2.1 ± 0.2 cm (maize), 1.7 ± 0.1 cm (beans), and 0.8 ± 0.1 cm (tomato), versus 3.8 ± 0.3 cm in the control. Plumule lengths also decreased to 3.3 ± 0.3 cm, 3.0 ± 0.2 cm, and 1.7 ± 0.1 cm, respectively, compared with 5.3 ± 0.3 cm in the control. Radicle inhibition ranged from 55.0% (maize) to 68.4% (tomato), while plumule inhibition ranged from 47.0% to 52.0%; no inhibition occurred in the control. Stress tolerance index (STI) values for radicle and plumule were all below 1.0, confirming reduced tolerance under contamination. These results show that contaminated soil substantially suppressed germination and early seedling growth. The reduced germination, particularly in tomato, agrees with Azorji *et al*. (2023), who reported delayed sprouting in crops grown in spent-oil-polluted soils. Similar reductions in vigor and germination have been described by Ezenwa *et al.* (2017). The decline in GRI and SVI supports earlier findings by Olayinka *et al.* (2012), who showed that spent oil limits seedling energy availability. The poor radicle and plumule development observed here agrees with the reports of Okebalama *et al.* (2024) and Afsharnia and Moosavi (2021), who linked petroleum-derived pollutants to suppressed root growth. The low tolerance indices (<1.0) observed are consistent with the studies of Zia *et al.* (2022) and Alzway *et al.* (2025), who found reduced resilience of seedlings in oil- and metal-contaminated soils. The growth inhibitions recorded in this study in line with the findings of Sagaya *et al.* (2023) and Azorji *et al*. (2024). The strong suppressive effect of heavy metals corresponds with results from Bae *et al.* (2016), Yang *et al.* (2004), Yao *et al.* (2021), and Yáñez-Espinosa *et al*. (2020), who reported delayed germination and reduced seedling growth in metal-stressed species.

Strong positive correlations were observed among all heavy metals, with values ranging from 0.84 to 0.95 (Table 4). The correlation analysis showed that all the heavy metals were strongly and positively related (r = 0.84–0.95), indicating that they likely originated from similar sources such as used engine oil, metal scraps and fuel residues commonly found in mechanic workshops. This clustering pattern agrees with findings by Okebalama *et al*. (2024), who also reported tightly linked metal concentrations around auto-mechanic sites due to shared contamination pathways. Heavy metals showed strong negative correlations with radicle length, plumule length and germination percentage (–0.70 to –0.88): suggesting that increasing metal load consistently suppressed early seedling development. This supports earlier observations by Bae *et al.* (2016): who found that Pb, Cd, Zn and Cu significantly inhibited root elongation and reduced germination due to oxidative stress and enzyme disruption. The strong positive correlation between radicle and plumule lengths (r = 0.93): as well as their positive association with germination percentage (r = 0.89–0.91): further indicates that once germination is impaired, subsequent growth stages are also affected.

Table 3: Effects of automobile-mechanic contaminated soil on germination and early seedling growth of maize, beans and tomato seed samples from Lokoja, Kogi State

Parameter	Maize	Beans	Tomato	Control
Seed Germination (%)	62 ± 4^{b}	55 ± 3^{c}	47 ± 3^{d}	92 ± 3^{a}
MGT (days)	3.7 ± 0.2^{b}	4.2 ± 0.3^{c}	5.0 ± 0.3^{d}	2.4 ± 0.2^{a}
GRI	7.9 ± 0.4^{b}	6.1 ± 0.3^{c}	4.5 ± 0.2^{d}	12.9 ± 0.5^{a}
SVI	221 ± 18^{b}	160 ± 14^{c}	96 ± 9^{d}	470 ± 35^{a}
Radicle Length (cm)	2.1 ± 0.2^{b}	1.7 ± 0.1^{c}	0.8 ± 0.1^{d}	3.8 ± 0.3^{a}
Plumule Length (cm)	3.3 ± 0.3^{b}	3.0 ± 0.2^{c}	1.7 ± 0.1^{d}	5.3 ± 0.3^{a}
Radicle Inhibition (%)	55.0 ± 2.9^{b}	55.3 ± 2.7^{b}	68.4 ± 3.2^{c}	0^{a}
Plumule Inhibition (%)	47.0 ± 2.4^{b}	49.0 ± 2.5^{b}	52.0 ± 2.7^{c}	0^{a}
Radicle STI	0.43 ± 0.03^{b}	0.45 ± 0.02^{b}	0.34 ± 0.03^{c}	1.00^{a}
Plumule STI	0.52 ± 0.02^{b}	0.51 ± 0.02^{b}	0.48 ± 0.02^{c}	1.00^{a}

MGT – Mean Germination Time (days); GRI – Germination Rate Index; SVI – Seedling Vigour Index; STI – Stress Tolerance Index; Values represent mean ± SD (n = 3). Means with different superscripts (^{a}, ^{b}) across rows differ significantly at p < 0.05 based on one-way ANOVA followed by Tukey's HSD test.

Table 4: Pearson correlation matrix between heavy metals and seed growth parameters in automobile mechanic workshop soils from Lokoja, Kogu State

Parameter	Pb	Cd	Cr	Zn	Cu	Radicle Length	Plumule Length
Pb	—						
Cd	0.92	—					
Cr	0.87	0.85	—				
Zn	0.95	0.90	0.88	—			
Cu	0.89	0.87	0.84	0.91	—		
Radicle Length	–0.81	–0.76	–0.72	–0.85	–0.79	—	
Plumule Length	–0.79	–0.74	–0.70	–0.82	–0.77	0.93	—
Germination %	–0.83	–0.80	–0.76	–0.88	–0.82	0.89	0.91

Pb = Lead; Cd = Cadmium; Cr = Chromium; Zn = Zinc; Cu = Copper; Radicle Length = root length; Plumule Length = shoot length; Germination % = percentage of seeds germinated.

CONCLUSION

This study has shown that soils from automobile-mechanic workshops in Lokoja contained elevated concentrations of heavy metals and petroleum-derived pollutants, which significantly altered key physicochemical properties. Lead and cadmium exceeded international safety limits, confirming substantial contamination risk. Plant bioassays further showed that these soils markedly reduced seed germination and early seedling growth of maize, beans and tomato, with tomato exhibiting the greatest sensitivity. The strong negative effects on germination parameters and seedling vigor indicated that heavy metal accumulation was the primary constraint on plant development. The findings of this study have important environmental and agricultural implications. The high levels of heavy metals and petroleum residues in soils near automobile workshops can reduce crop productivity, impair food safety and pose potential health risks to communities relying on these soils for cultivation. These results highlight the need for regulatory oversight and the implementation of sustainable waste management practices in such areas. Future studies should consider a broader range of crops, longer-term field trials and assessment of cumulative ecological and health impacts.

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. SSRN. https://doi.org/10.2139/ssrn.3490585

Adelekan, B. A.and Abegunde, K. D. (2011). Heavy metals contamination of soil and groundwater at automobile mechanic villages in Ibadan, Nigeria. *International Journal of the Physical Sciences, 6*(5): 1045–1058. https://doi.org/10.5897/IJPS10.495.

Adesina, O. A., Fakayode, O. A., Lala, M. A., Adewale, A. J. and Sonibare, J. A. (2024). Levels of polycyclic aromatic hydrocarbon in the soil around typical automobile repair workshops in Nigeria. *F1000Research,* **12**: 861. https://doi.org/10.12688/f1000research.134682.3

Afsharnia, F. and Moosavi, S. A. (2021). Effects of diesel-engine exhaust emissions on seed germination and seedling growth of Brassicaceae family using digital image analysis. *Journal of Environmental Health Science and Engineering,* **19**(2): 1887–1900. https://doi.org/10.1007/s40201-021-00742-6.

Al Manmi, D. A. M., Abdullah, T. O., Al-Jaf, P. M. and Al-Ansari, N. (2019). Soil and groundwater pollution assessment and delineation of intensity risk map in Sulaymaniyah City, NE of Iraq. *Water,* **11**(10): 2158. https://doi.org/10.3390/w11102158.

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): 1–24. https://doi.org/10.1080/20909977.2025.2500886.

Alzway, A. A. A., Mansour, G. A. H., Ahire, K. D. and Attitalla, I. H. (2025). Impact of light crude oil contamination on seed germination and seedling growth in *Zea mays* L. *Research in Ecology,* **7**(4): 20-31. https://journals.bilpubgroup.com/index.php/re.

Amos, I. A., Edward, B. A. and 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): 20–25. https://www.scienceworldjournal.org.

Anegbe, B., Okuo, J. M., Atenaga, M., Ighodaro, A., Emina, A. and Oladejo, N. A. (2018). Distribution and speciation of heavy metals in soils around some selected auto repair workshops in Oghara, Delta State, Nigeria. *International Journal of Environment, Agriculture and Biotechnology (IJEAB):* **3**(2): 574–584. https://doi.org/10.22161/ijeab/3.2.35.

Atikpo, E., Okonofua, E. S., Uwadia, N. O. and Michael, A. (2021). Health risks connected with ingestion of vegetables harvested from heavy metals contaminated farms in Western Nigeria. *Heliyon,* **7**(8): e07716. https://doi.org/10.1016/j.heliyon.2021.e07716.

Ayuba, R.and Tijani, M. N. (2021). Hydrochemical characterization of groundwater in Lokoja, North-Central Nigeria. *Sustainable Water Resources Management,* **7**: 61.

Azorji, J. N., Dike, K. S., Obi, A. U., Ngumah, M. O., Nwachukwu, M. O. and Nnanabu, I. E. (2024). A preliminary study on the effects of E-Safe treatment of crude oil impacted soil on microbial load, seed germinationand morphological indices in cowpea seedlings. *Global Scientific and Academic Research Journal of Multidisciplinary Studies,* **1**: 165. https://gsarpublishers.com/journals-gsarjms-home/.

Azorji, J. N., Udebuani, A. C., Nwachukwu, M. O., Ijeoma, O. R., Duru, C. M. and Nwachukwu, C. U. (2023). Effects of spent engine oil on germination and early seedling establishment of arable crops. *Asian Journal of Applied Sciences,* **16**(1): 16–22. https://doi.org/10.3923/ajaps.2023.16.22.

Babagana, M., Abubakar, F., Bakari, A. and Ibrahim, A. (2025). Assessment of heavy metal concentrations and the pollution level in dust samples around the vicinity of motor parks in the Kaduna Metropolis, Northwestern Nigeria. *Sahel Journal of Life Sciences,* **3**(3): 31–45. https://doi.org/10.33003/sajols-2025-0303-31

Bae, J., Benoit, D. L. and Watson, A. K. (2016). Effect of heavy metals on seed germination and seedling growth of common ragweed and roadside ground cover legumes. *Environmental Pollution,* **213**: 112–118. https://doi.org/10.1016/j.envpol.2015.11.041.

Chen, Q., Song, Y., An, Y., Lu, Y. and Zhong, G. (2024). Soil microorganisms: Their role in enhancing crop nutrition and health. *Diversity,* **16**(12): 734. https://doi.org/10.3390/d16120734.

Cuput, E. L., Mensah, L., Bentil, E., Amponsah, V. and Agbekey, B. K. (2024). Heavy metal contamination from fuel station run-off and carwash wastewater: An assessment of ecological risk and experimental treatment. *Heliyon,* **10**(7): e29167. https://doi.org/10.1016/j.heliyon.2024.e29167.

Diagi, E. B., Okorondu, J. N., Susan, I. A., Chinonye, V. E., Edokpa, D. O., Acholonu, C. and Edeh, S. (2023). Assessment of heavy metal contamination of soil in mechanic workshops at Nekede and Orji, Owerri Zone, Imo State, Nigeria. *Journal of Scientific Research and Reports,* **29**(7): 8–16. https://doi.org/10.9734/jsrr/2023/v29i71755.

Dixit, M., Ghoshal, D., Meena, A. L., Ghasal, P. C., Rai, A. K., Choudhary, J. and Dutta, D. (2024). Changes in soil microbial diversity under present land degradation scenario. *Total Environment Advances,* **10**: 200104. https://doi.org/10.1016/j.teadva.2024.200104.

Duru, S. C., Echiegu, E. A., Anyadike, C. C., Alaneme, G. U. and Okechukwu, M. E. (2024). Spatial variability of heavy metals concentrations in soil of auto-mechanic workshop clusters in Nsukka, Nigeria. *Scientific Reports,* **14**(1): 9681. https://doi.org/10.1038/s41598-024-60044-3.

Elbasiouny, H., Elbehiry, F., El-Ramady, H. and Brevik, E. C. (2020). Phosphorus availability and potential environmental risk assessment in alkaline soils. *Agriculture,* **10**(5): 172. https://doi.org/10.3390/agriculture10050172.

Eludoyin, O. S. and Ogbe, O. M. (2017). Assessment of heavy metal concentrations in pawpaw (*Carica papaya* Linn.) around automobile workshops in Port Harcourt Metropolis, Rivers State, Nigeria. *Journal of Health and Pollution,* **7**(14): 48–61. https://doi.org/10.5696/2156-9614-7.14.48.

Erhunmwunse, N. O., Ainerua, M. O., Ewere, E. E. and Ogboghodo, I. B. (2016). Physicochemical analysis of automobile waste oil on soil quality in Benin City, Nigeria. *African Scientist,* **17**(2): 97–105. https://www.niseb.org/afs.

Ezenwa, N. J., Adieze, I. E. and Aririatu, L. N. (2017). Effects of used engine oil polluted-soil on seeds' germination and seedlings' growth characteristics of some tropical crops. *International Journal of Environment, Agriculture and Biotechnology,* **2**(2): 812–818. https://doi.org/10.22161/ijeab/2.2.32.

FAO/WHO. (2004). *Regulation of the Minister of the Environment No. 12 of 2 April 2004 on maximum limits for dangerous substances in soil and groundwater*. Food and Agriculture Organization. https://faolex.fao.org/docs/pdf/est97999E.pdf.

Ganiyu, S. A., Olurin, O., Olobadola, M. O. and Onakoya, O. I. (2024). Assessment of thermal and physicochemical properties of mechanic village soils derived from two different geological formations in Ogun State, Nigeria. *Journal of Taibah University for Science,* **18**(1): 2400777. https://doi.org/10.1080/16583655.2024.24007777.

Garba, N. N., Yamusa, Y. A., Isma'ila, A., Habiba, S. A., Garba, Z. N., Musa, Y. and Kasim, S. A. (2013). Heavy metal concentration in soil of some mechanic workshops of Zaria, Nigeria. *International Journal of Physical Sciences,* **8**(44): 2029–2034. https://doi.org/10.5897/IJPS2013.4034.

Gawryluk, A., Stępniowska, A. and Lipińska, H. (2022). Effect of soil contamination with polycyclic aromatic hydrocarbons from drilling waste on germination and growth of lawn grasses. *Ecotoxicology and Environmental Safety,* **236**: 113492. https://doi.org/10.1016/j.ecoenv.2022.113492.

Igborgbor, J. C., Imarhiagbe, E. E., Okolafor, F. I. and Ekhaise, F. O. (2022). Physicochemical and microbial properties of soil samples collected from auto-mechanic workshop, Orubor-Agbor, Delta State, Nigeria. *Arid Zone Journal of Basic and Applied Research*, **1**(5): 148–157. https://doi.org/10.55639/607.1423.

Ikeh, O. A., Ejidike, L. C., Ofoelo, S. E. and Igwilo, M. O. (2025). Investigation of poly aromatic hydrocarbons and heavy metals in soils of selected auto mechanic workshops in Nimo, Njikoka, Anambra State, Nigeria. *Asian Soil Research Journal,* **9**(2): 115–121. https://doi.org/10.9734/asrj/2025/v9i2184.

International Seed Testing Association (ISTA) (2019). *ISTA method validation reports: Proposals for the International Rules for Seed Testing, 2019 edition*. ISTA. https://www.seedtest.org/api/rm/U985J868T5X2SNK/ista-method-validation-reports-2019.pdf.

Kenyanya, O., Jackson, M. and Harun, M. (2013). Determination of potassium levels in intensive subsistence agricultural soils in Nyamira County, Kenya. *International Journal of Agriculture and Forestry,* **3**(7): 294–302. https://doi.org/10.5923/j.ijaf.20130307.06.

Liu, T., Ni, S. Y. and Wang, Z. (2024). Contamination and health risk assessment of heavy metals in soil surrounding an automobile industry factory in Jiaxing, China. *Frontiers in Environmental Science,* **12:** 1362366. https://doi.org/10.3389/fenvs.2024.1362366.

Lu, R. K. (2000).*Analysis method of soil agricultural chemistry.* China Agricultural Science and Technology Press.

Maddela, N. R., Ramakrishnan, B., Kakarla, D., Venkateswarlu, K. and Megharaj, M. (2022). Major contaminants of emerging concern in soils: A perspective on potential health risks. *RSC Advances,* **12**(20): 12396–12415. https://doi.org/10.1039/d1ra09072k.

Memba, I. N., Ebong, C. U., Angaye, W. T. and Christopher, E. (2025). Assessment of the impact of auto-mechanic workshop on groundwater quality in Central Business District, Oxbow Lake, Swali, Bayelsa State, Nigeria. *Scholars International Journal of Chemistry and Material Sciences,* **8**(2): 28-32. https://doi.org/10.36348/sijcms.2025.v08i02.0022.

Mfam, A. N., Aguoru, C. U., Ogbonna, I. O., Okoh, T., Olasan, J. O. and Mfam, N. N. (2023). Heavy metals contamination in soils at automobile workshops in Benue State, Nigeria. *International Journal of Recent Research in Life Sciences,* **10**(4): 9–18. https://doi.org/10.5281/zenodo.8414242.

Mustapha, L. S., Obayomi, O. V. and Obayomi, K. S. (2025). A comprehensive review on potential heavy metals in the environment: Persistence, bioaccumulation, ecotoxicologyand agricultural impacts. *Ecological Frontiers*. Advance online publication. https://www.sciencedirect.com/science/article/pii/S2950509725001789.

Muze, N. E., Opara, A. I., Ibe, F. C. and Njoku, O. C. (2020). Assessment of the geo-environmental effects of activities of auto-mechanic workshops at Alaoji Aba and Elekahia Port Harcourt, Niger Delta, Nigeria. *Environmental Analysis Health and Toxicology,* **35**(2): e2020005. https://doi.org/10.5620/eaht.e2020005.

Nathan, M. V., Stecker, J. A. and Sun, Y. (2012). *Soil testing in Missouri: A guide for conducting soil tests in Missouri* (Revised ed.; EC923). University of Missouri Extension, Division of Plant Sciences, College of Agriculture, Food and Natural Resources.

Nduka, J. K., Kelle, H. I., Ogoko, E. C. and Okafor, P. C. (2019). Review of environmental and public health impact of automobile wastes and automobile transportation in Nigeria. In I. Uher (Ed.): *Environmental factors affecting human health*. *IntechOpen*. https://doi.org/10.5772/intechopen.884911.

Ning, Q., Shao, B., Huang, X., He, M., Tian, L. and Lin, Y. (2023). Bioaccumulation, biomagnifications and ecological risk of trace metals in the ecosystem around oilfield production area: A case study in Shengli Oilfield. *Environmental Monitoring and Assessment,* **196**(1): 87. https://doi.org/10.1007/s10661-023-12251-.

Nouhou, Y. D., Otache, M. Y., Illiassou, S. A., Okunola, O. H., Okhimamhe, A. A. and Nguyen, T. T. (2025). Flood risk assessment and zoning for Niamey and Lokoja metropolises in Niger and Nigeria. *Hydrology,* **12**(1): 17. https://doi.org/10.3390/hydrology12010017.

Nwakife, C. N., Esther, U., Musah, M., Morah, E. J., Inobeme, A. and Andrew, A. (2022). Determination of the physicochemical properties and some heavy metals in soils around selected automobile workshops in Minna, Nigeria*. African Journal of Environment and Natural Science Research,* **5**(1): 69–81. https://doi.org/10.52589/AJENSR8OHFOZ9U.

Obayomi, A., Popoola, A., Medayese, S. and Wahab, B. (2023). Examining liveability in the informal community of Kabawa, Nigeria. *Town and Regional Planning*, **82**: 18–33. https://doi.org/10.38140/trp.v82i.5661.

Oguntimehin, I. and Ipinmoroti, K. E. (2008). Profile of heavy metals from automobile workshops in Akure, Nigeria. *Journal of Environmental Science and Technology,* **1**(1): 19–26.

Ojiego, B. O., Ilo, O. P., Okolo, J. C., Igborgbor, J. C., Ishaku, T., Abdullahi, S. A., Gadzama, I. M. K. and Bolorunduro, P. (2022). Concentrations of heavy metals in soil samples from dumpsites located at Kuje and Kwali area councils, Abuja, Nigeria*. Journal of Materials and Environmental Sciences,* **13(**9): 1037–1046. http://www.jmaterenvironsci.com.

Okebalama, C. B., Onwurah, C. L., Jidere, C. M. and Okolo, C. C. (2024). Disposal of spent oil into soils around auto parts markets impacts heavy metal concentrations and poses a potential ecological risk. *Environmental Systems Research,* **13***: 15*. https://doi.org/10.1186/s40068-024-00315-4.

Okebalama, C. B., Onwurah, C. L., Jidere, C. M. and Okolo, C. C. (2024). Disposal of spent oil into soils around auto parts markets impacts heavy metal concentrations and poses a potential ecological risk. *Environmental Systems Research,* **13**, Article 15. https://doi.org/10.1186/s40068-024-00315-2.

Olayinka, B. U., Arinde, O. O. and Etejere, E. O. (2012). Effects of spent engine oil on seedling germination of groundnut (*Arachis hypogaea* L.). *Journal of Science, Technology, Mathematics and Education (JOSTMED):* **8**(2): 25–32.

Olayinka, O. O. and Oludare, H. A. (2016). Concentration of heavy metals in the soils near some mechanic villages in Abeokuta Metropolis, Ogun State, Nigeria. *Journal of Advances in Chemistry,* **8**(3): 1667–1679. https://doi.org/10.24297/jac.v8i3.4048.

Oloruntoba, E. O. and Ogunbunmi, T. O. (2020). Impact of informal automobile mechanic workshops activities on groundwater quality in Ibadan, Nigeria. *Journal of Water Resource and Protection,* **12**(7): 571–586. https://doi.org/10.4236/jwarp.2020.127036.

Peris, M., Recatala, L., Mico, C., Sanchez, R.and Sanchez, J. (2008). Increasing the knowledge of heavy metal contents and sources in agricultural soils of the European Mediterranean region. *Water, Airand Soil Pollution,* **192**, 25–37. https://doi.org/10.1007/s11270-008-9638-8.

Sagaya, A., Abdulrahaman, A. A., Oluwanisola, P. O. and Tsoho, S. B. (2023). Effects of soil pollution on the germination, growth, fruiting and leaf anatomy of *Abelmoschus caillei* (A. Chev.) StevelsMalvaceae. *Science World Journal,* **18**(1): 64–69http://www.scienceworldjournal.org.

Šerá, B. (2023). Methodological contribution on seed germination and seedling initial growth tests in wild plants. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca,* **51**(2):13164. https://doi.org/10.15835/nbha51213164.

Sparks, D. L., Page, A. L., Helmke, P. A., Loeppert, R. H., Soltanpour, P. N., Tabatabai, M. A., Johnston, C. T. and Sumner, M. E. (Eds.). (1996). *Methods of soil analysis: Part 3. Chemical methods* (SSSA Book Series). Soil

Science Society of America. https://doi.org/10.2136/sssabookser5.3.

Utang, P. B., Eludoyin, O. and Ijekeye, C. L. (2013). Impacts of automobile workshops on heavy metals concentrations of urban soils in Obio/Akpor LGA, Rivers State, Nigeria. *African Journal of Agricultural Research,* **8**(26): 3476–3482. https://doi.org/10.5897/AJAR2013.6753.

Walkley, A.and Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science,* **37**(1): 29–38.

Yáñez-Espinosa, L., Briones-Gallardo, R., Flores, J. and Álvarez Del Castillo, E. (2020). Effect of heavy metals on seed germination and seedling development of *Nama aff. stenophylla* collected on the slope of a mine tailing dump. *International Journal of Phytoremediation,* **22**(14): 1448–1461. https://doi.org/10.1080/15226514.2020.1781782.

Yang, Z. Y., Chen, F. H., Yuan, J. G., Zheng, Z. W.and Wong, M. H. (2004). Responses of *Sesbania rostrata* and *S. cannabina* to Pb, Zn, Cu and Cd toxicities. *Journal of Environmental Sciences (China):* **16**(4): 670–673.

Yao, L., Wang, J., Li, B., Meng, Y., Ma, X., Si, E., Yang, K., Shang, X. and Wang, H. (2021). Influences of heavy metals and salt on seed germination and seedling characteristics of halophyte *Halogeton glomeratus*. *Bulletin of Environmental Contamination and Toxicology,* **106**(3): 545–556. https://doi.org/10.1007/s00128-021-03130-w.

Zia, Y., Iqbal, M. Z. and Shafiq, M. (2022). The effects of automobile motor workshop wastewater on seedling growth of kidney bean and mung bean crops under abiotic stress. *Journal of Plant Development,* **29**: 133–140. https://doi.org/10.47743/jpd.2022.29.1.881.