**Scientific Inquiry and Review (SIR)**
**Volume 10 Issue 2, 2026**
$ISSN_{(P)}$: 2521-2427, $ISSN_{(E)}$: 2521-2435
Homepage: https://journals.umt.edu.pk/index.php/SIR


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**Academic Editor** Abdul Rauf

**DOI:** https://doi.org/10.32350/sir.102.01

**History:** Received: February 27, 2026, Revised: April 13, 2026, Accepted: May 07, 2026, Published: June 02, 2026

**Citation:** Onyenze U, Enogbe EJ, Edozie OI. Heavy metal concentrations in soil around automobile workshops in Wukari, North East Nigeria. *Sci Inq Rev.* 2026;10(2):01–14. https://doi.org/10.32350/sir.102.01



**Conflict of Interest:** Author(s) declared no conflict of interest

A publication of
The School of Science
University of Management and Technology, Lahore, Pakistan

# Heavy Metal Concentrations in Soil around Automobile Workshops in Wukari, North East Nigeria

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## ABSTRACT

An increasingly major source of heavy metal pollution in developing countries like Nigeria, where environmental regulations are poorly enforced, is automobile repair activity. In this study, soil samples were collected from different automobile workshops in Wukari Local Government in Taraba State, Nigeria to assess the heavy metal (Cr, Cu, Fe, Pb, Zn) concentration. A total of eight sampling points were analyzed using Atomic Absorption Spectrophotometry (AAS) and standard aqua regia digestion and the results were compared with the World Health Organization's (WHO) permissible limits and a control value. The study shows a significant increase in metal concentration for iron (Fe) and lead (Pb) in soils around high-traffic workshop zones. The five heavy metals, from the geo-accumulation index (Igeo), were found to be within the unpolluted to moderately polluted category. The metal with the highest Igeo value at 0.38 is lead (Pb), suggesting that the presence of lead in the soil around the selected automobile workshops was more elevated as compared to the other metals. The lowest is copper (Cu) with Igeo value of 0.04, indicating the lowest level of contamination. Although the observed values for all the metals were within WHO standard limits, the continuous deposition of these metals in the soil around automobile workshops raises concerns about long-term soil health and potential risks to surrounding communities.

## Highlights

- Heavy metals showed measurable enrichment around Wukari auto workshops.
- Lead had the highest Igeo (0.38), while copper had the lowest (0.04).

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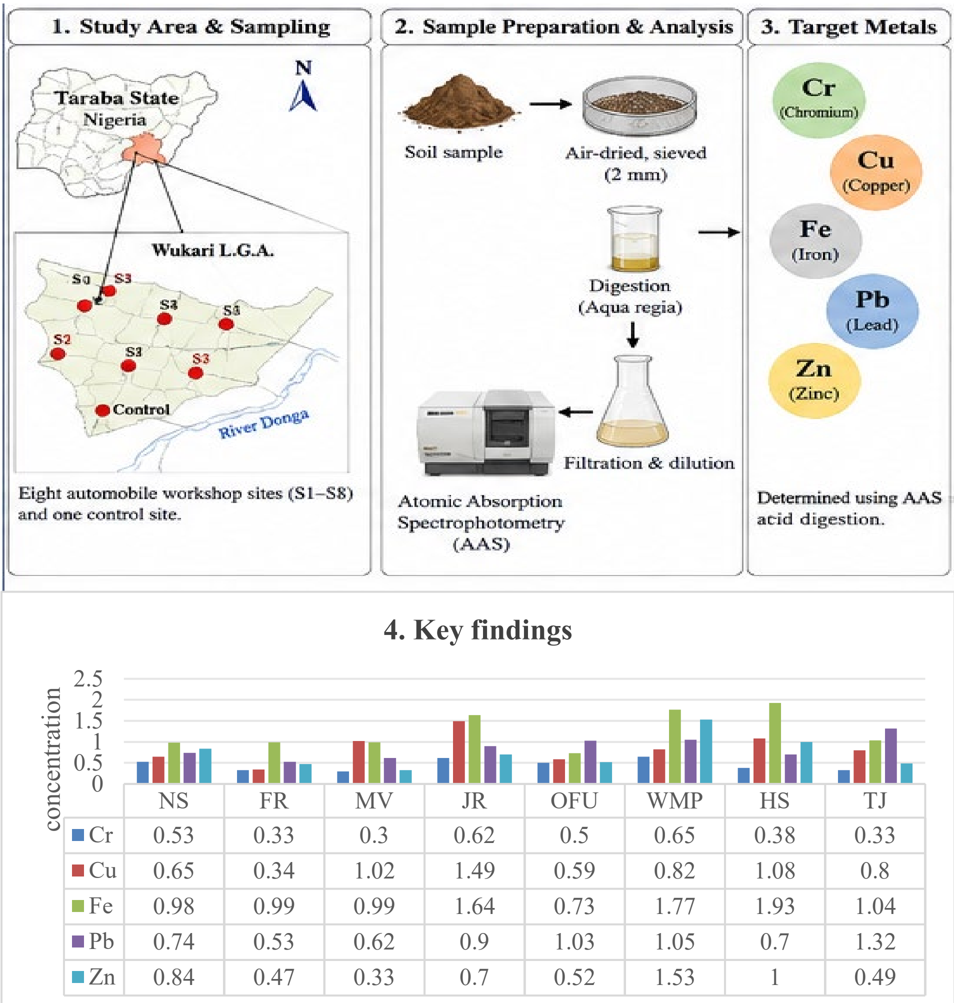
- All metals remained within WHO limits, indicating low to moderate pollution.

## GRAPHICAL ABSTRACT




| | NS | FR | MV | JR | OFU | WMP | HS | TJ |
|---|---|---|---|---|---|---|---|---|
| Cr | 0.53 | 0.33 | 0.3 | 0.62 | 0.5 | 0.65 | 0.38 | 0.33 |
| Cu | 0.65 | 0.34 | 1.02 | 1.49 | 0.59 | 0.82 | 1.08 | 0.8 |
| Fe | 0.98 | 0.99 | 0.99 | 1.64 | 0.73 | 1.77 | 1.93 | 1.04 |
| Pb | 0.74 | 0.53 | 0.62 | 0.9 | 1.03 | 1.05 | 0.7 | 1.32 |
| Zn | 0.84 | 0.47 | 0.33 | 0.7 | 0.52 | 1.53 | 1 | 0.49 |

***Keywords:*** automobile workshop, geo-accumulation index (Igeo), heavy metals, soil

## 1. INTRODUCTION

An environmental element that cannot be replaced for human and animal habitation is soil and it serves as the central source for food security and human well-being [1]. Heavy metals are environmental contaminants that are primarily introduced into the soil and the environment through anthropogenic activities, such as vehicular emissions, mine tailings, coal combustion residues, cigarette smoking, industrial discharge, leaded gasoline and paints, sewage sludge, animal manure, spillage of petrochemicals, and automobile repair operations [2, 3]. Heavy metals can be described as elements with a relatively high density (more than that of water), although they can be very toxic or harmful to humans even at low concentrations. Generally, these include elements in the periodic table with an atomic number greater than 20 or densities greater than 5g/cm$^3$ [4]. Heavy metals in the soil pose a serious risk and harzard to humans and the ecosystem through food chain, drinking of heavy metal contaminated water, or due to direct contact with the soil. Heavy metal contaminated food products pose significant health risks [5]. The consumption of heavy metal contaminated food even at trace levels can result in their accumulation in the body, leading to harmful health effects [4]. Consequently, it is a necessity to monitor human exposure to heavy metals within the food chain [5].

Automobile workshops in developing countries like Nigeria often lack adequate environmental protection which may lead to soil contamination from battery acid, used engine oil, brake fluids, metallic debris, and other automobile operations [6]. Soil contamination with heavy metals, such as lead (Pb), chromium (Cr), iron (Fe), copper (Cu), and zinc (Zn), poses serious ecological and health risks due to their toxicity, persistence, and potential for bioaccumulation [7]. While trace amounts of some metals are essential micronutrients, their elevated concentrations are harmful to plants, animals, and humans [8].

Metallurgical activities generate heavy metal pollution to contaminate the soil, presenting severe risk to the environment through multiple exposure pathways [9]. Various pathways through which heavy metals can contaminate the soil include contaminated dust particles integration, soil ingestion, and direct contact during recreational activities. The most endangered are children, particularly due to their elevated soil ingestion rates, lighter body weights, developing organs and body systems, and an increased duration of time spent in contact with contaminated soil [10].

Owing to their non-biodegradability and the potential for bioaccumulation in ecosystems and human food chains, heavy metals accumulation poses a great threat to the human population [11, 12]. A recent global report revealed that roughly 14-17% of agricultural land is polluted by one or more heavy metals at concentrations exceeding the permissible threshold [13].

Plants taking up soils containing heavy metals is a crucial step in the trophic transfer of these metals in the food chain. These metals are taken up by plants from contaminated soil and subsequently transferred to herbivorous animals along the food chain [14]. Consuming cereals contaminated with toxic heavy metals may risk human health. Heavy metals have been reported in vegetables grown with wastewater in higher concentrations, as compared to those cultivated with groundwater. Also, higher metal concentrations were found in leafy vegetables, when compared with other types of vegetables [15].

This study focuses on Wukari, a fast-growing town in Taraba State, Northeastern Nigeria, with an increasing number of automobile workshops. The study addresses a local data gap by analyzing eight automobile workshop locations in Wukari and by combining direct metal determination in comparison with control soil, the reported WHO standard values, and the geo-accumulation index. The objective is, therefore, to determine the concentrations of Cr, Cu, Fe, Pb, and Zn in soils around these eight selected automobile workshops in Wukari and estimate their degree of enrichment using Igeo (geo-accumulation index).

## 2. MATERIALS AND METHODS

### 2.1 Study Area and Sample Collection

A total of eight composite soil samples were collected from the top 0–15 cm of soil at various automobile workshop locations in Wukari (Figure 1), Holy Spirit (HS), Opposite Federal University (OFU), Takum Junction (TJ), Wukari Motor Park (WMP), Mechanic Village (MV), Jalingo Road (JR), Federal Road (FR), and New Site (NS) with the aid of a locally fabricated stainless steel depth soil auger. This equipment was thoroughly cleaned after each sampling to prevent cross-contamination. The samples were stored in clean polythene bags immediately after collection to avoid cross-contamination and transported to the laboratory.

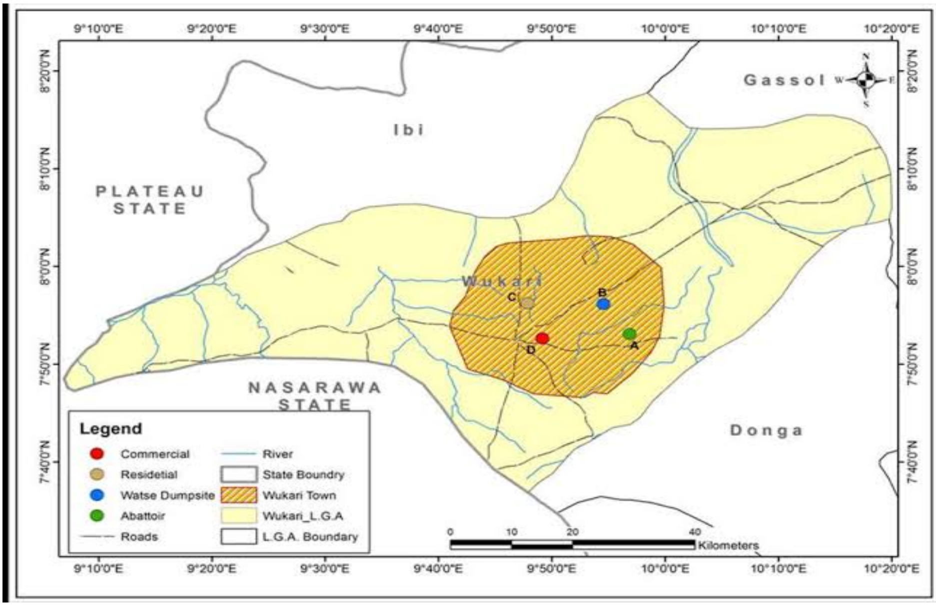



**Figure 1.** Map of Taraba State Showing Wukari Local Government Area
***Note.*** Source: Ministry of Land and Survey, Jalingo, Taraba State.

## 2.2 Sample Preparation

The soil samples were air-dried to constant weight, gently crushed, and homogenized using an acid-prewashed mortar and pestle (to reduce contamination). The homogenate was then passed through a 2 mm plastic sieve. Approx. 5 g of each soil sample was digested with 12 mL of freshly prepared aqua regia (3:1 of HCl and $HNO_3$, respectively) at 80°C for 3 h, until brown fumes ceased. Finally, they were filtered and diluted up to 100 mL with distilled water before AAS determination (Figure 2) by following the method described by the Association of Analytical Chemists (AOAC) [16].

## 2.3 Metal Analysis

The heavy metal concentration of the filtrates was tested for five (5) metals {chromium (Cr), Copper (Cu), iron (Fe), lead (Pb), and zinc (Zn)} using an Atomic Absorption Spectrophotometer (Model PG 90). The analytical wavelengths used for Cr, Cu, Fe, Pb, and Zn were 357.87, 324.75, 232.00, 228.80, and 213.86 nm, respectively. Calibration standards were prepared from certified stock solutions and calibration curves were generated for the analytes. The linearity of the calibration curves was evaluated using the coefficient of determination ($R^2$). The data were collected and compared with the WHO standards and further analyzed statistically to check the significance of chemical parameters in soil samples.

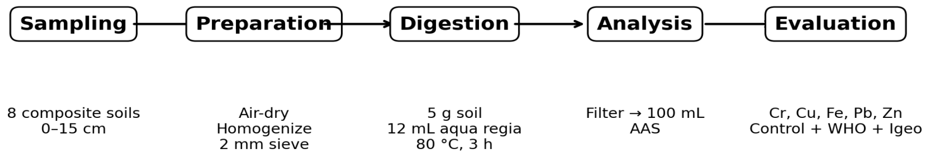



**Figure 2.** Workflow for Soil Sampling, Preparation, Digestion, and Metal Analysis

### 2.4 Statistical Analysis

Analysis of Variance (ANOVA) was used to obtain the average concentration of the data. ANOVA is a statistical technique utilized to examine differences among two or more mean values. Additionally, to assess the level of heavy metal contamination in the soil around the workshops, Igeo was used. This test was introduced by Muller [17]. The control sample soil was used as a background value for Igeo calculation. The Igeo of metal in the soil was calculated using the following equation 1,

$$Igeo = \log 2\,(Cn / 1.5Bn) \quad (1)$$

where Bn is the geochemical background value, Cn is the measured concentration of heavy metal in the sample, and Igeo is the geo-accumulation index of the metal. The constant value (1.5) comprises the background matrix correction factor due to lithological variations. The geo-accumulation index (Igeo) values are provided below in Table 1.

**Table 1.** Classification of Geo-Accumulation Index (Igeo) Values

| Igeo | Class | Terminology |
|---|---|---|
| ≤ 0 | 0 | Uncontaminated |
| 0-1 | 1 | Uncontaminated to moderately contaminated |
| 1-2 | 2 | Moderately contaminated |
| 2-3 | 3 | Moderately to heavily contaminated |
| 3-4 | 4 | Heavily contaminated |
| 4-5 | 5 | Heavily to extremely contaminated |
| >6 | 6 | Very extremely contaminated |

***Note.*** Source: Muller 1969

**2.4.1. Determination of Heavy Metal Pollution Level in the Soil.** The level of heavy metal pollution in soil can be assessed using various indices. In this study, the geo-accumulation index (Igeo) was used to evaluate and interpret the extent of contamination.

## 3. RESULTS

**Table 2.** Sampling Codes and Location Names

| Sample | Location name |
|---|---|
| HS | Holy Spirit |
| OFU | Opposite federal university |
| TJ | Takum junction |
| WMP | Wukari motor park |
| MV | Mechanic village |
| JR | Jalingo road |
| FR | Federal road |
| NS | New site |

**Table 3.** Heavy Metal Concentrations in Soils around Selected Automobile Workshops

| Sample area (mg/kg) | Cr | Cu | Fe | Pb | Zn |
|---|---|---|---|---|---|
| NS | 0.53±0.10 | 0.65±0.18 | 0.98±0.22 | 0.74±0.16 | 0.84±0.31 |
| FR | 0.33±0.23 | 0.34±0.42 | 0.99±0.28 | 0.53±0.25 | 0.47±0.46 |
| MV | 0.30±0.29 | 1.02±0.16 | 0.99±0.28 | 0.62±0.13 | 0.33±0.15 |
| JR | 0.62±0.10 | 1.49±0.30 | 1.64±0.09 | 0.9±0.10 | 0.70±0.43 |
| OFU | 0.50±0.10 | 0.59±0.44 | 0.73±0.46 | 1.03±0.42 | 0.52±0.39 |
| WMP | 0.65±0.05 | 0.82±0.19 | 1.77±0.49 | 1.05±0.18 | 1.53±0.15 |
| HS | 0.38±0.16 | 1.08±0.52 | 1.93±0.15 | 0.70±0.20 | 1.00±0.50 |
| TJ | 0.33±0.25 | 0.80±0.17 | 1.04±0.14 | 1.32±0.42 | 0.49±0.28 |

**Table 4.** Comparison of Results with the Control and WHO Standards in mg/Kg

| Metal | Result | Control | WHO Standard |
|---|---|---|---|
| Cr | 46±20 | 29±23 | 100 |
| Cu | 85±43 | 55±38 | 140 |
| Fe | 26±49 | 14±20 | 50 |
| Pb | 86±33 | 44±21 | 100 |

| | | | |
|---|---|---|---|
| Zn | 74±48 | 42±44 | 300 |

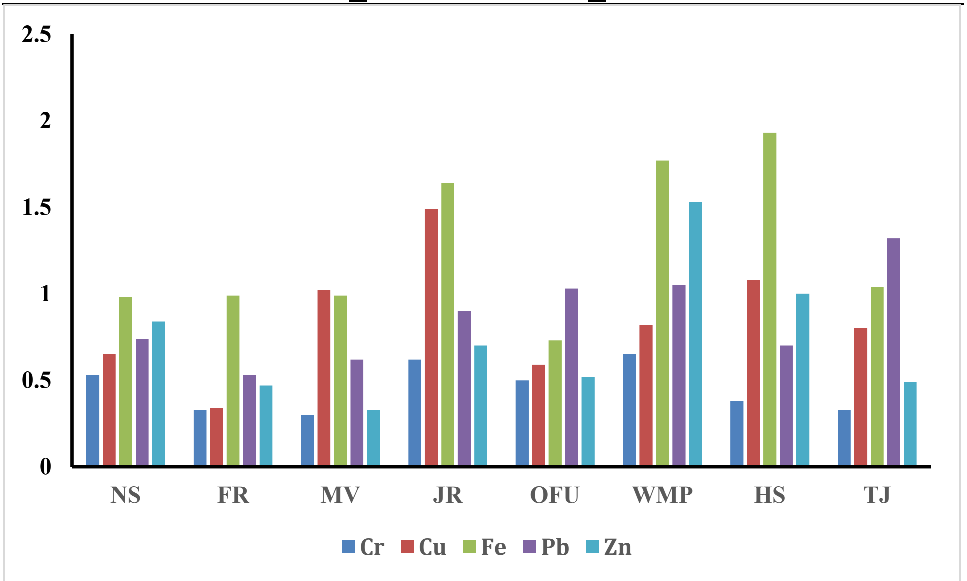



**Figure 3.** Heavy Metal Concentrations Reported for the Eight Sampling Locations

***Note.*** NS – New Site, FR – Federal Road, MV – Mechanic Village, JR – Jalingo Junction, OFU – Opposite Federal University, WMP – Wukari Motor Park, HS – Holy Spirit, TJ – Takum Junction

**Table 5.** Geo-accumulation Index (Igeo) Values

| Metal | Sample (Cn) mg/Kg | Control (Bn) mg/Kg | Igeo |
|---|---|---|---|
| Cr | 46 | 29 | 0.08 |
| Cu | 85 | 55 | 0.04 |
| Fe | 26 | 14 | 0.31 |
| Pb | 86 | 44 | 0.38 |
| Zn | 74 | 42 | 0.23 |

## 4. DISCUSSION

The results (Table 3 and Figure 3) showed that the concentrations of all five metals (iron (Fe), chromium (Cr), Copper (Cu), lead (Pb), and zinc (Zn)) were elevated in workshop soils as compared to the control, indicating anthropogenic input, primarily from automobile activities. The presence of the metals in the soil is consistent with the types of materials and wastes colligated with automobile repair activities, including batteries, paints, lubricants, and other workshop residues [3, 6, 18].

The concentration of Cr ranged from 0.30–0.65 mg/kg, with the highest value at WMP (Table 3). Though well below WHO's threshold, its presence may originate from paint pigments, brake linings, and alloys used in vehicles [18]. The elevated levels may suggest localized contamination. Alarmingly, the high concentrations could be carcinogenic [19].

Similarly, Cu concentration ranged from 0.34-1.49 mg/kg and it was the highest at JR. Cu is a common component of vehicle engines, wiring, and antifreeze, making its presence obvious in the soil [20]. Some values were observed to be three times higher as compared to the control group. The Fe concentrations found were high across all samples (0.73–1.93 mg/kg), especially at HS and WMP. Automobile activities might contribute to elevated concentrations through metal scraps and engine corrosion [3].

Pb concentration was found to be highest at TJ (1.32 mg/kg), followed by WMP (1.05 mg/kg). Pb accumulation is linked to batteries, lubricants, and exhaust emissions. Its chronic exposure poses serious health risks, especially to children [21]. Although within WHO limits, the elevated accumulation is still alarming. Pb is neurotoxic, specifically in children [19].

The concentration of Zn showed the highest variability, ranging from 0.33–1.53 mg/kg, with WMP with the highest accumulation. Zn is widely used in vehicle coatings, tires, and lubricants. Although less toxic than Pb, Zn may disrupt microbial activity and nutrient cycling if found at high concentrations [22].

The Igeo in Table 5 reported five heavy metals in soil samples. The values ranged from 0.04-0.38. The index may help determine natural enrichment *vs* enrichment caused by anthropogenic activities including mechanical repairs, oil spills, and metal scrap disposal. According to the categories in Table 1, all the five metals tested fall within the 'unpolluted to moderately polluted' category. Pb recorded the highest Igeo value of 0.38, suggesting that its presence in the soil is more elevated as compared to other metals. Whereas, Cu recorded the lowest Igeo value of 0.04, indicating the lowest level of contamination. Igeo does not suggest heavy contamination but the results suggest that the soil samples showed measurable metal enrichment in relation to the control values.

### 4.1. Conclusion

This study highlighted site-specific information of five metals (Cr, Cu, Fe, Pb, and Zn) in soils around selected automobile workshops in Wukari, Taraba State, Nigeria. The results showed that while the soils around the workshops are not heavily polluted, yet they show signs of early contamination. The low-to-moderate pollution may be attributeable to accumulation from vehicle repairs, paint spillage, battery disposal, used oil leakage, and metal waste. Although current concentrations remain below the WHO permissible limits [23], elevated levels, as compared to natural background values, highlight the need for continuous monitoring and preventive measures.

### 4.2. Implications

The study is significant as it may establish a local baseline against which the automobile workshop soils in Wukari could be compared. Soil monitoring, improved handling of used oil, battery materials, and metallic waste disposal may be recommended. Over time, if pollution sources persist, contamination level could increase further, potentially posing risks to the soil, groundwater, plants, and even human health. Future research should investigate the bioavailability and mobility of these metals and assess contamination in food crops grown in or near affected areas.

#### Author Contribution

**Onyenze Ugochukwu:** resources, software, data curation, visualization, investigation, writing-review & editing. **Enogbe Joy Emmanuel:** methodology, conceptualization, writing - original draft, project administration. **Otuokere Ifeanyi Edozie:** supervision, validation, formal analysis.

#### Conflict of Interest

The authors of the manuscript have no financial or non-financial conflict of interest in the subject matter or materials discussed in this manuscript.

#### Data Availability Statement

Data supporting the findings of this study will be made available by the corresponding author upon request.

#### Funding Details

No funding has been received for this research.

#### Generative AI Disclosure Statement

The authors did not use any type of generative artificial intelligence software for this research.

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This review article examines the role of straw-derived biochar in the remediation of soils contaminated with heavy metals. The authors analyze different preparation methods of biochar, its physicochemical properties, and its capacity to immobilize toxic metals in soil environments. The study highlights the mechanisms through which biochar reduces metal mobility and improves soil quality. The article is significant for environmental scientists and soil chemists because it presents sustainable and cost-effective strategies for mitigating heavy metal pollution in agricultural soils

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This study presents a bibliometric analysis of global research trends related to heavy metals in urban soils. Using scientific databases, the authors analyze publication trends, influential journals, countries contributing to research, and emerging themes in the field. The work identifies key research directions, including pollution sources, risk assessment, and remediation technologies. This article is valuable for researchers seeking an overview of current developments and knowledge gaps in urban soil contamination studies

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This research investigates the distribution and concentration of heavy metals in soils from auto-mechanic workshop clusters in Nsukka, Nigeria. Soil samples were analyzed to determine levels of metals such as lead, cadmium, chromium, and nickel. The study evaluates pollution indices and assesses environmental risk associated with these contaminants. The findings highlight the impact of automobile repair activities on soil quality and provide data useful for environmental monitoring and pollution control policies

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