Soil Contamination by Some Heavy Metals in Automotive Repair Workshops in Al-Diwaniyah Province, Iraq

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Abstract

Automobile repair workshops are significant sources of heavy metal pollution in urban environments, where used engine oils and metal-rich wastes are disposed of directly onto open soil. In Al-Diwaniyah province, Iraq, informal practices such as dumping, leaks, and spills can lead to the accumulation of potentially toxic elements in surface soils near workplaces and neighboring residential areas. This study aimed to evaluate the contamination status of surface soils in automobile repair workshops in Al-Diwaniyah by quantifying the concentrations of lead (Pb), cadmium (Cd), chromium (Cr) and zinc (Zn) and by calculating selected pollution indices. Surface soil samples (0–20 cm) were collected from 25 automobile repair workshops and 15 nearby residential sites as reference soils. Heavy metals (Pb, Cd, Cr, Zn) were determined in dried and digested samples using flame atomic absorption spectrophotometry. Descriptive statistics were computed, and differences between workshop and residential soils were tested with the Mann–Whitney U test. The geo-accumulation index (Igeo), contamination factor (CF), enrichment factor (EF) and pollution load index (PLI) were used to interpret contamination levels. Mean concentrations (mg/kg, dry weight) in workshop soils were 91.48 for Pb, 3.28 for Cd, 35.23 for Cr and 58.84 for Zn, compared with 12.32, 0.06, 16.81, and 17.41 mg/kg, respectively, in residential soils. Fold increases ranged from 1.5 for Cr to 40 for Cd, and all metals showed highly significant differences between workshop and residential soils ($p < 0.001$) with large effect sizes. Mean Igeo values indicate moderate to heavy contamination for Pb and strong to extreme contamination for Cd, while CF and EF values classified Cd as very highly enriched. The mean PLI value of 6.74 (>1) pointed to overall deterioration of soil quality in workshop areas.

Surface soil in automobile repair workshops in Al-Diwaniyah is markedly contaminated with Pb, Cd, Cr and Zn, particularly Cd, relative to residential background soils. These findings highlight the need for better management of used engine oils and workshop wastes, regular monitoring of soils in mixed residential–industrial neighborhoods, and awareness programs targeting workshop owners and workers.

Keywords: Soil contamination, Heavy metals, Workshops, Al-Diwaniyah.

Introduction

Automobile repair workshops are widely recognized as important non-point and point sources of heavy metal contamination in urban and peri-urban environments, especially in developing countries where environmental regulations and waste handling practices are often weak or poorly enforced [1, 2]. Spent engine oils, lubricants, greases, metal filings, battery scrap, and paint residues are frequently discharged directly onto open ground around repair bays, vehicle pits, and storage areas, allowing potentially toxic elements to accumulate in surface soils over time [3, 7].

Lead (Pb), cadmium (Cd), chromium (Cr) and zinc (Zn) can persist in soils for decades due to their non-biodegradable nature and strong affinity for soil particles [4]. Prolonged accumulation increases their mobility and potential for plant uptake, dust resuspension, and human exposure through ingestion, inhalation, and dermal contact [5, 6]. Elevated levels of Pb and Cd have been associated with neurotoxicity, nephrotoxicity, carcinogenicity, and adverse effects on the hematopoietic and cardiovascular systems, while Cr (especially hexavalent forms) is mutagenic and Zn at high concentrations can disrupt soil microbial and enzymatic activities [8, 9].

Several studies from Africa and Asia have documented high concentrations of heavy metals in soils surrounding auto-mechanic and vehicle repair workshops, often exceeding national and international guideline values [10, 13]. In Nigeria and Ghana, for example, Pb, Cd, Cr, Zn, and Cu levels in workshop soils were many times higher than background soils, with contamination factor (CF), geo-accumulation index (Igeo), and pollution load index (PLI) indicating moderate to extreme contamination and potential ecological risk [10, 11]. Similar patterns have been reported in soil near transport corridors, industrial facilities, and fuel stations, confirming the role of traffic- and petroleum-related activities as major contributors to heavy metal burdens in urban soils [12, 14].

In Iraq, rapid urbanization, expansion of informal service sectors, and years of infrastructural stress have led to the proliferation of small and medium automobile repair workshops within residential neighborhoods. Recent Iraqi studies have reported elevated heavy metal concentrations in roadside and urban soils, as well as in areas near refineries, cement plants, and industrial zones, using indices such as CF, Igeo, enrichment factor (EF), and PLI to characterize contamination and ecological risk [15, 18]. However, there is limited published information specifically addressing heavy metal contamination in soils of automobile repair workshops, particularly in medium-sized cities such as Al-Diwaniyah province.

Al-Diwaniyah, located in south-central Iraq, hosts numerous clustered and scattered automobile repair workshops that provide essential services for private and commercial vehicles. Many of these workshops operate on unpaved surfaces without engineered wastewater collection or hazardous waste management systems, resulting in chronic leakage and dumping of used engine oils and metal-rich wastes directly into the surrounding environment. Given the proximity of workshops to residential areas, there is concern that contaminated soil may represent a source of long-term exposure for workers, nearby residents, and children who frequently play in or pass through these spaces [16, 19].

Assessing the contamination levels of workshop soils and comparing them with nearby residential background soils is therefore critical for understanding the magnitude of environmental degradation, evaluating potential health risks, and guiding local authorities in developing mitigation strategies. Pollution indices such as Igeo, CF, EF and PLI provide a convenient way to interpret measured concentrations relative to background values and to classify contamination intensity [3, 5, 20].

The present study aimed to evaluate the contamination status of surface soils in automobile repair workshops in Al-Diwaniyah, Iraq, by: (1) determining the concentrations of Pb, Cd, Cr and Zn in workshop and residential soils; (2) comparing heavy metal levels between the two soil categories; and (3) calculating Igeo, CF, EF and PLI to interpret the degree of contamination. The findings are expected to provide baseline information for environmental monitoring and to support decision-making on waste management and land-use planning in mixed residential–industrial areas.

2. Materials and Methods

2.1. Soil sampling

A weight of 400 g of dry soil was taken to prepare the sample and placed in a suitable container of 40 surface soil samples were collected between workshops and residential areas. Twenty-five samples were collected from the top 0–20 cm of soil in active automobile repair workshops ("workshop soils") of industrial district targeting areas with visible oil stains, vehicle parking spots, repair bays and waste accumulation zones. Fifteen samples were collected from residential areas within the same city that were not directly impacted by workshop activities and were considered as control or reference soils ("residential soils"). Samples were obtained using a stainless-steel scoop, composited from several subsampling points within a small area, placed in clean polyethylene bags, labelled and transported to the laboratory for analysis.

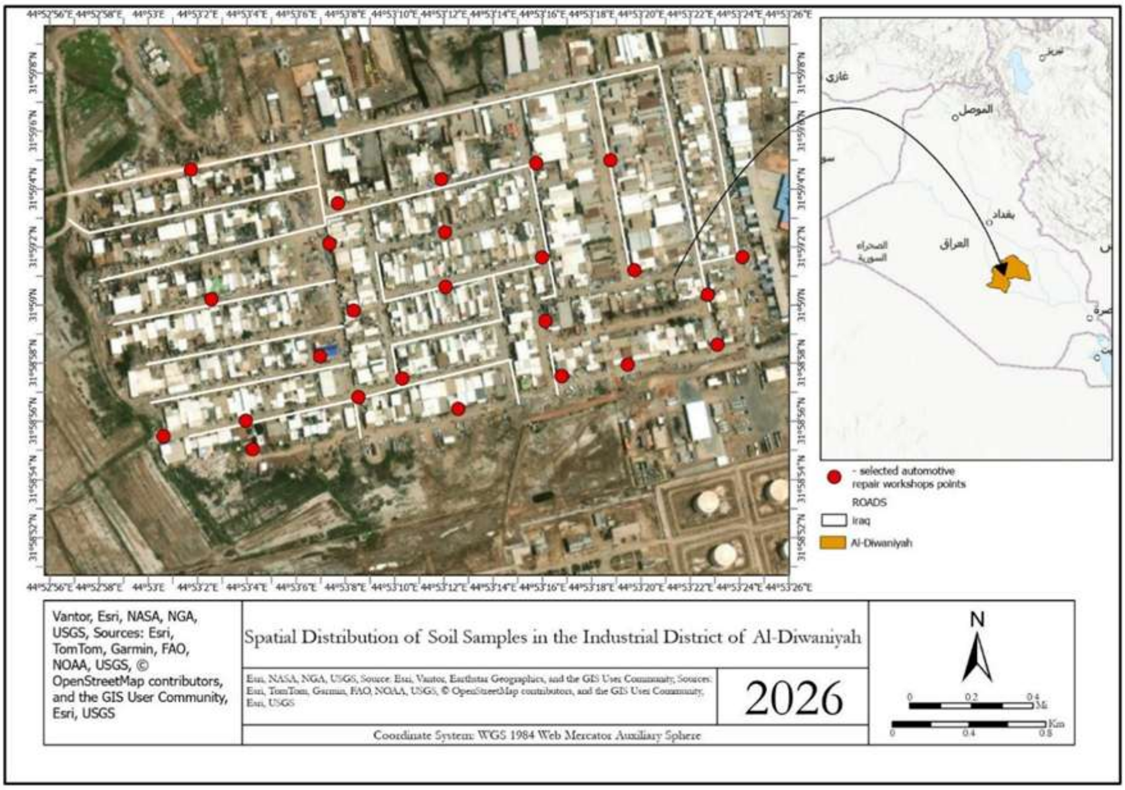

Figure 1: Study area map according to the researcher worked based on the Arc GIS Pro3.5 program.


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Image 1: Several photographs of some Automotive repair workshops by researcher.

2.2. Sample preparation and heavy metal analysis

In the laboratory, soil samples were air-dried at room temperature, gently disaggregated, and sieved through a 2 mm mesh to remove stones and debris. A representative subsample was finely ground for digestion. Heavy metals (Pb, Cd, Cr, Zn) were determined after acid digestion using a mixture of concentrated nitric acid and perchloric or hydrochloric acid following standard protocols for soil analysis [4, 6]. The resulting solutions were filtered and analyzed using flame atomic absorption spectrophotometry (AAS). Quality control measures included reagent blanks, calibration with standard solutions, and analysis of duplicate samples to ensure accuracy and precision of the measurements.

2.3. Pollution indices

To interpret the degree of soil contamination, several pollution indices were calculated using the measured heavy metal concentrations in workshop soils and the mean values of residential soils as background levels. The geo-accumulation index (Igeo) was calculated as $I_{geo}=\log_2\left(\frac{Cn}{1.5*Bn}\right)$, where C_n is the measured concentration and B_n is the background [3]. Igeo values were classified into categories ranging from unpolluted (Igeo $\leq$ 0) to extremely polluted (Igeo > 5) [3, 20].

The contamination factor (CF) was $CF=\frac{Cs}{Bn}$, where C_s is soil concentration and B_n is background. It classifies single-element contamination from low to very high, with values <1 indicating low contamination, 1–3 moderate contamination, 3–6 considerable contamination, and >6 very high contamination [5].

The enrichment factor (EF) assesses anthropogenic enrichment using a reference element like Fe:

$EF=\frac{(Cx/Cref)sample}{(Cx/Cref)background}$. It differentiates naturally from human sources [5].

The pollution load index (PLI) was computed as PLI integrates CF for multiple metals: $PLI=(CF1\times CF2\times\cdots\times CFn)^{1/n}$. It indicates overall site pollution, where PLI <1 indicates no pollution and PLI >1 denotes deterioration of soil quality [5, 20].

2.4. Statistical analysis

Descriptive statistics (mean and standard deviation) were calculated for heavy metal concentrations in workshop and residential soils. Data were tested for normality and homogeneity of variance; due to non-normal distributions, differences between workshop and residential soils were assessed using Mann–Whitney U test. The Mann-Whitney U test is a non-parametric statistical test used to compare differences between two independent groups when data does not follow a normal distribution. It ranks all observations and tests if one group tends to have higher values than the other. Fold increases in metal concentrations were computed as the ratio of workshop to residential means. Effect sizes were estimated using Cohen's d. Cohen's d is a standardized measure of effect size that quantifies the magnitude of the difference between two group means in standard deviation units. It is calculated as $d = \frac{M1-M2}{Spooled}$, where M_1 and M_2 are the means, and S_{pooled} is the pooled standard deviation, with values of 0.2, 0.5, and 0.8 commonly interpreted as small, medium, and large effects, respectively. Statistical significance was considered at $p < 0.05$. All analyses were performed using standard statistical software.

3 .Results

3.1. Heavy metal concentrations in Workshop and residential soils

Table 1 summarizes the descriptive statistics and mean concentrations of Pb, Cd, Cr and Zn in workshop and residential soils. Mean (± SD) concentrations (mg/kg, dry weight) of Pb, Cd, Cr, and Zn in workshop soils were 91.48 ± 33.57, 3.28 ± 1.30, 35.23 ± 17.49, and 58.84 ± 18.08, respectively. In contrast, the corresponding concentrations in residential soils were 12.32 ± 5.32 for Pb, 0.06 ± 0.04 for Cd, 16.81 ± 6.03 for Cr, and 17.41 ± 5.44 for Zn. Thus, workshop soils exhibited markedly elevated levels of all four heavy metals compared with residential soils.

The fold increases in mean concentrations between workshop and residential soils were approximately 8-fold for Pb, 40-fold for Cd, 1.5-fold for Cr, and 2.5-fold for Zn. The Mann–Whitney U test indicated that these differences were highly statistically significant for all metals ($p < 0.001$), reflecting strong contrasts between workshop and background conditions. Effect size estimates based on Cohen's d were large for each metal, with values of about 2.99 for Pb, 3.17 for Cd, 1.30 for Cr, and 2.86 for Zn, indicating substantial practical significance in addition to statistical significance.

Table 1: Mean concentrations (mg/kg dry weight) of heavy metals in workshops and residential soils.

Metal (mg/kg)	Workshop Soil (n=25) Mean ± SD	Residential Soil (n=15) Mean ± SD	Fold Increase	p-value	Sig.	Cohen's d	Effect Size
Pb	91.482 ± 33.566	12.315 ± 5.323	~8×	0.001	***	2.994	Large
Cd	3.284 ± 1.299	0.060 ± 0.036	>40×	0.001	***	3.171	Large
Cr	35.230 ± 17.489	16.814 ± 6.033	~1.5×	0.001	***	1.304	Large
Zn	58.844 ± 18.076	17.407 ± 5.440	~2.5×	0.001	***	2.86	Large

3.2. Soil contamination indices

The calculated pollution indices for workshop soils are presented in Table 2. Mean Igeo values for Pb, Cd, Cr, and Zn were approximately 2.27, 5.34, 0.39, and 0.59, respectively. According to the conventional classification scheme, Cr and Zn fell within the unpolluted to moderately polluted categories (Igeo < 1), Pb indicated moderate to heavy contamination (Igeo between 2 and 3), and Cd reached the severely to extremely polluted class (Igeo > 5). These results highlight Cd as the most problematic contaminant among the four metals examined.

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Table 2: Soil contamination indices for workshop soils (n=25).

Index	Pb	Cd	Cr	Zn	Interpretation Threshold
Igeo (Mean)	2.265	5.344	0.394	0.585	<0=Unpolluted. 0–1=Uncontam. Moderate. 1–2=Moderate; 2–3=Mod. -Heavy. 3–4=Heavy. 4–5=Heavy-Extreme; ≥5=Extreme
CF (Mean)	7.624	65.689	2.202	2.354	<1=Low; 1–3=Moderate; 3–6=High; >6=Very high
EF (Mean)	4.381	32.153	Reference	2.115	<2=Minimal; 2–5=Moderate; 5–20=Significant; >20=Very high
PLI (Mean)	6.74 (range: 4.518–9.994)				<1=No pollution; >1=Deterioration of soil quality

The mean contamination factor (CF) values for Pb, Cd, Cr and Zn in workshop soils were about 7.62, 65.69, 2.20, and 2.35, respectively, when using residential soil means as background. CF values greater than 6 denote very high contamination, and thus Cd again showed the highest level of contamination, followed by Pb with very high contamination and Cr and Zn with moderate contamination. Enrichment factor (EF) results, calculated relative to Cr as a reference element, yielded mean values of approximately 4.38 for Pb, 32.15 for Cd, and 2.12 for Zn. These EF values correspond to moderate enrichment for Pb, very high enrichment for Cd, and minimal to moderate enrichment for Zn, confirming that Cd is strongly enriched in workshop soils beyond natural background levels.

The mean pollution load index (PLI) value for workshop soils was 6.74, with a range from 4.52 to 9.99. Since PLI values exceeding 1 indicate overall deterioration of soil quality, the observed PLI strongly suggests considerable cumulative pollution by the four heavy metals in the sampled workshops. Collectively, the indices demonstrate that soils in automobile repair workshops in Al-Diwaniyah are heavily impacted by anthropogenic inputs of heavy metals, especially Cd and Pb.

4. Discussion

4.1. Comparison with guideline values and other studies

The present study demonstrates that surface soils in automobile repair workshops in Al-Diwaniyah, Iraq, are substantially contaminated with Pb, Cd, Cr and Zn compared with nearby residential soils. The mean concentrations of Pb and Cd in workshop soils exceeded many international guideline values for agricultural and residential soils reported by agencies such as the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), whereas Cr and Zn were closer to or moderately above typical background ranges [4, 6]. The very high CF and Ige indicate for Cd, along with a PLI far greater than 1, indicate that workshop activities have led to an advanced stage of soil degradation.

Similar patterns of heavy metal contamination have been described in auto-mechanic workshop soils in several countries. Studies from Nigeria, for example, have reported Pb, Cd, Cr and Zn concentrations in workshop soils that were several times higher than control sites, with CF and Igeo indicating moderate to extreme contamination and elevated ecological risk [10, 11]. Recent work on soils around automobile clusters in other regions has also highlighted spatial variability of heavy metal concentrations, with hotspots near vehicle servicing areas and oil storage points [1, 13]. The high fold increase

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observed for Cd in the present study (approximately 40-fold relative to residential soils) is consistent with findings that Cd, though often present at lower absolute concentrations, can show disproportionately high enrichment due to specific industrial and traffic-related inputs [11, 21].

In Iraq, previous research on roadside and urban soils in cities such as Baghdad and Basra has documented elevated levels of Pb, Cd, Cr, Zn and other metals associated with traffic emissions, industrial discharges, and legacy contamination [15, 18]. Many of these studies have used Igeo, CF, EF, and PLI to interpret contamination and have reported moderate to very high pollution, particularly for Pb and Cd [17, 18]. However, comparatively fewer studies have focused on automobile repair workshops as discrete sources of heavy metal pollution. The present findings from Al-Diwaniyah therefore add to the emerging body of evidence that small and medium-sized workshops can significantly contribute to localized hotspots of soil contamination in Iraqi cities.

4.2. Possible sources and processes

The elevated levels of Pb and Cd in workshop soils are likely linked to multiple anthropogenic sources, including the spillage and dumping of used engine oils and lubricants, wear of vehicle parts and brake linings, battery repair and disposal, welding and metal cutting operations, and historical use of lead gasoline [2, 7, 13]. These activities release fine metal-containing particles and residues that accumulate on unpaved workshop surfaces. Over time, repeated contamination events, combined with limited soil removal or remediation, result in progressively higher metal concentrations in the upper soil layer.

Chromium and Zn levels in workshop soils, while lower in relative enrichment than Pb and Cd, were still significantly higher than in residential soils. Chromium can originate from metal alloys, paints, and anticorrosive coatings, whereas Zn is commonly associated with tyre wear, galvanized components, lubricating oils, and grease additives [5, 12, 14]. Wind resuspension, water runoff, and mechanical disturbance from vehicle movement can redistribute contaminated particles within and beyond workshop boundaries, potentially affecting adjacent residential zones and roadside verges.

The high EF value for Cd (greater than 20) suggests that its presence in workshop soils is dominated by anthropogenic inputs rather than natural lithogenic sources. By contrast, the more moderate EF for Pb and Zn and the use of Cr as a reference element indicate a mix of geological background and human contributions. The strong correlation between elevated metal concentrations and the locations of mechanical pits, oil change areas, and waste dumps observed in similar studies further supports the attribution of contamination to workshop-related activities [1, 10, 11].

4.3. Environmental and health implications

From an environmental perspective, the high levels of Pb and Cd and the elevated PLI values raise concerns about the long-term sustainability of soils in and around automobile repair workshops. Contaminated soils can act as secondary sources of exposure when metals are mobilized into dust, surface runoff, or groundwater, particularly under conditions of low organic matter and weak soil structure typical of arid and semi-arid regions [4, 6]. Soil biota, including microorganisms and invertebrates, may experience toxicity, which can impair nutrient cycling and reduce soil quality and productivity.

For human populations, workshop soils represent potential exposure media for both workers and nearby residents. Workers are at risk through direct contact with contaminated soil and dust during routine activities, while residents, including children, may be exposed via hand-to-mouth behavior, inhalation of resuspended dust, or consumption of vegetables grown in contaminated patches near workshops [5, 8, 9]. Chronic exposure to Pb and Cd is particularly concerning because of their established links with neurological deficits, kidney damage, bone disorders, and carcinogenic outcomes. Although the present study did not quantify human health risk explicitly, the combination of very high CF, Igeo, EF, and PLI values for Cd and Pb suggests that detailed risk assessment and biomonitoring studies would be warranted, especially for vulnerable groups.

5. Conclusion

This study assessed heavy metal contamination in surface soils of automobile repair workshops in Al-Diwaniyah, Iraq, using Pb, Cd, Cr, and Zn as indicator elements. Workshop soils showed significantly higher concentrations of all four metals than nearby residential soils, with particularly pronounced enrichment of Cd and Pb. Pollution indices, including Igeo, CF, EF and PLI, revealed moderate to severe contamination for Pb and extreme contamination for Cd, as well as overall deterioration of soil quality in workshop areas.

The findings underline the role of small and medium-sized automobile repair workshops as important local sources of heavy metal pollution in urban environments. To mitigate environmental and potential health risks, there is a need for improved management of used engine oils and metal-containing wastes, regular monitoring of soil quality in mixed residential–industrial neighborhoods, and awareness programmes targeting workshop owners, workers, and local communities. Policy measures such as the designation of controlled industrial zones, provision of waste collection and treatment services, and enforcement of environmental regulations could contribute to reducing ongoing contamination and protecting soil resources in Al-Diwaniyah and similar settings.

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