

An Assessment of Heavy Metal Pollution in Roadside Dust: A Case Study from Basrah Governorate, Southern Iraq

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Received: 09 May 2025

Received in revised form: 05 August 2025

Accepted: 02 October 2025

Available online: 01 October 2026

Abstract

This study assessed the extent and sources of heavy metal contamination in Roadside dust across Basrah Governorate, a major hub for petroleum production in southern Iraq. Samples were collected from six strategic industrial and urban locations. Concentrations of nickel (Ni), lead (Pb), cadmium (Cd), and chromium (Cr) were quantified, and pollution was evaluated using the geoaccumulation index (I_{geo}) and contamination factor (CF). Results indicate exceptionally high cadmium (Cd) contamination at the Al-Shuaiba industrial site ($I_{geo} = 5.49$; $CF = 67.93$), identifying it as a significant pollution hotspot. A distinct urban pollution pattern was also observed, with elevated lead (Pb) concentrations at the high-traffic Sa'ad Square site ($I_{geo} = 2.22$). Source apportionment via Pearson correlation supported these findings, revealing a strong, statistically significant positive correlation among Ni, Cd, and Cr ($p < 0.005$), suggesting a common industrial origin. Conversely, Pb showed no significant correlation with the other metals, corroborating its primary association with vehicular emissions. Notably, Ni contamination was minimal, and Cr levels remained consistently low, suggesting their lesser contribution to the overall pollution load in the studied area. In conclusion, this study identifies a dual-front environmental challenge in Basrah, necessitating the implementation of source-specific remediation and management strategies targeting both severe industrial cadmium emissions and widespread urban lead pollution.

Keywords:

Heavy metals, Roadside dust, soil contamination, pollution, geochemical index.

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1. Introduction

Environmental pollution represents one of the most significant contemporary challenges, directly threatening key pillars of human well-being such as food security and public health (Food and Agriculture Organization, 2018). Its severity has markedly increased since the Industrial Revolution, becoming a central concern across vital sectors, including health, agriculture, and industry (Al-Sarrafi, 2009). In this context, soil serves as the fundamental substrate supporting agricultural and urban landscapes and is the primary medium for most human activities (Adhikari and Hartemink, 2016). Soil pollution often originates from mining, industrial activities, improper product use, and natural heavy metal concentrations intensified by mining and pesticide application (Al-Saad et al.,

2007). Recent studies have continued to highlight these challenges across southern Iraq, emphasizing the need for ongoing regional environmental assessments (Al-Taie and Al-Khafaji, 2023).

A pollutant is defined as any foreign substance that causes harm to the environment or its living inhabitants (Siddiq et al., 2012). Pollution effectively occurs when the introduction of these substances disrupts an ecosystem's ability to maintain its dynamic equilibrium, thereby hindering the sustainability of life within it. Recent studies and a scientific review have confirmed that chemical pollution has surpassed safe planetary limits, threatening the stability of global ecosystems (Persson et al., 2022). Furthermore, the interactions between pollutants and the environment are complex; air pollutants, for instance, can contribute to the acidification of soil and water, thereby

degrading their quality and capacity to support life (Manisalidis et al., 2020).

More specifically, air pollution by fine particulate matter and dust is a serious environmental issue in urban areas. These particles are emitted from vehicle exhaust, industrial processes, and construction activities and may contain chemical compounds and heavy metals that pose a risk to human health upon inhalation (WHO, 2021). This challenge is exacerbated by rapid urban growth, the absence of environmental planning, and climatic factors such as drought and wind (EPA, 2022). Particles ranging from 2.5 to 10 micrometers in size are particularly dangerous, as they can penetrate the respiratory system and enter the bloodstream, worsening cardiovascular and respiratory diseases (European Environment Agency, 2023).

The intensity of a pollutant's impact depends on multiple factors, including its type, environmental concentration, and the duration of exposure (Castro-Gonzalez et al., 2017). This is particularly relevant to Basra, a major industrial and oil hub in southern Iraq, whose environment makes it susceptible to heavy metal accumulation in the soil and atmosphere (Jalal, 2020). Accordingly, this research aims to assess the concentrations of several heavy metals (chromium, nickel, lead, and cadmium) by analyzing roadside dust samples from selected areas of the Basra governorate. This makes the study of its geochemical environment an endeavor of both scientific and practical importance.

2. Research Area

Basrah, with an area of approximately 19,070 km² (Central Statistical Organization, 2023), is situated between 46.7° E and 48.6° E longitude and 29.5° N and 31.3° N latitude (GADM, 2022). The area contains numerous oil fields, petrochemical facilities, fertilizer factories, and energy production facilities. The research region includes some Quaternary and recent sediments, primarily clay, silt, sand, and gravel (Al-Khafaji et al., 2010). The samples were collected from six stations: Al-Shuaiba, Al-Zubair, Al-Faw, Sa'ad Square, Al-Garma, and Al-Tanumah (Fig. 1).

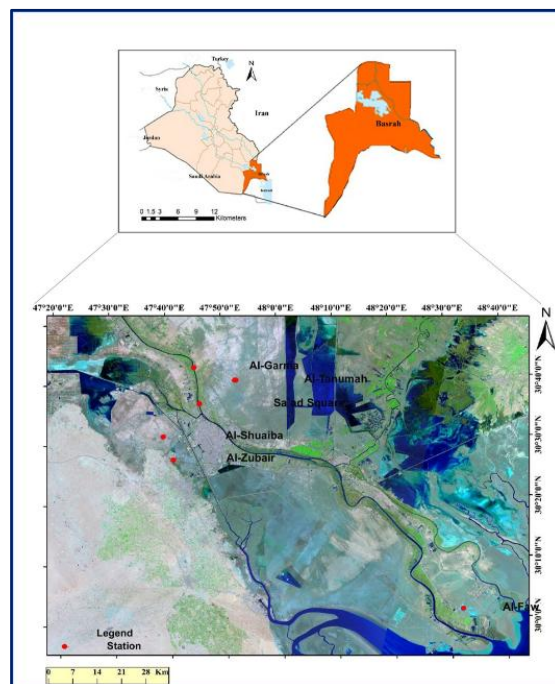


Fig. 1: Sample stations in the research area.

3. Procedures

A. Collecting and preparing samples

Roadside dust samples were collected in August 2021 from six sites across the Basrah Governorate: Al-Garma, Al-Tanumah, Sa'ad Square, Al-Shuaiba, Al-Zubair, and Al-Faw (Fig. 1). These locations were selected to represent a cross-section of local environments, including high-traffic roads, open areas, and mixed residential-commercial zones. At each site, approximately 250 g of surface dust was collected with a stainless-steel shovel and sealed in a labeled polyethylene bag. Before analysis, samples were processed in the lab by first manually removing visible debris (e.g., cigarette butts, glass, plastic). The cleaned samples were then air-dried to a constant weight at room temperature. Finally, each sample was thoroughly homogenized before being sieved with a ceramic mortar and pestle to obtain a fine, uniform powder for chemical analysis.

At Basrah City's Al-Wasal Science Center for Environmental Assessment, trace elements were analyzed using ICP-OES (iCAPTM PRO, Thermo Fisher Scientific, USA) with calibration performed using a multi-element standard solution (Carl Roth, Art. No. 2650.1, Lot 782085). Method detection limits (MDLs) were 0.5 ppm for Ni, 1.7 ppm for Pb, 0.1 ppm for Cd, and 0.4 ppm for Cr. Analytical accuracy was validated by analyzing certified

reference materials (CRMs), with recovery rates from 90% to 105%. Analytical precision was assessed by repeated measurements (triplicates) of selected samples. The relative standard deviation (RSD) was consistently below 5% for most measurements, though it was higher for concentrations approaching the method detection limit, which is typical for trace analysis.

B. Assessment of pollution levels

The contamination factor (CF) (Pecky, 2004) or pollution index (PI) (Faiz et al., 2009) was used to show the concentration level of heavy metals in the soil, and the geoaccumulation index (Igeo) (Muller, 1969) was utilized to evaluate the accumulation of elements in the soil. The following formulas are shown below:

$$CF = (C_n/B_n)$$

$$I_{geo} = \log_2 (C_n / 1.5B_n)$$

Where C_n represents the measured concentration of the studied metal in the roadside dust samples. B_n represents the geochemical background value of an element. For this study, the average elemental abundance in the Earth's crust, documented in the CRC Handbook of Chemistry and Physics (Lide, 2004), served as a proxy for natural background concentrations. The constant 1.5 is a correction factor that accounts for potential natural fluctuations in background values, thereby minimizing the misclassification of minor natural enrichments as anthropogenic contamination (Pan et al., 2017).

Tables 1 and 2, following Muller (1969) and Pekey et al. (2004), present the standard Igeo and CF values for heavy metals.

Table 1: Concentration factors (Pekey et al., 2004).

Category	Description
CF	Pollution Level
$CFI < 1$	Little
$1 \leq CFI < 3$	Reasonable
$3 \leq CFI < 6$	Great
$CFI \geq 6$	Very Great

Table 2: Geoaccumulation index (Muller, 1969).

Category	Description
Igeo is equal to or less than 0	Almost uncontaminated
Igeo is between 0 and 1	Undirty to medium dirty
Igeo is between 1 and 2	Medium polluted
Igeo is between 2 and 3	Medium toward high dirty
Igeo is between 3 and 4	High polluted
Igeo is between 4 and 5	Highly toward exceedingly dirty
Igeo is equal to or more than 5	Exceedingly polluted

4. Results and Discussion

According to Kabata-Pendias and Pendias (1992), nickel is considered a human toxicant and often leads to respiratory diseases. Nickel concentrations at the Shuaiba station reached 247.03 ppm (Table 3); this severe level of contamination is directly related to the oil and gas exploitation sites there. As shown in Table 3 and Fig. 2, soil nickel levels ranged from 22.104 ppm (at Al-Faw station) to 247.03 ppm (at Al-Shuaiba station). Concentrations at three stations, Al-Shuaiba (247.03 ppm), Sa'ad Square (106.29 ppm), and Al-Zubair (91.55 ppm), exceeded 84 ppm, the normal concentration for uncontaminated soil (Kabata- Pendias, 2011). These levels were also higher at the Zubair station (91.55 ppm). Fayad et al. (2013) indicated that battery production, fuel combustion, and household cleaning products such as bleach and soap are significant contributors to nickel accumulation in urban soil. Table 3 and Fig. 2 show that lead concentrations ranged from approximately 10.16 ppm (at Al-Tanuma station) to 97.81 ppm (at Sa'ad Square station). This exceeds the natural limit for lead in soil (14 ppm). Vehicle emissions are a major source of lead in urban soils, as lead enters the environment through a variety of personal activities, including mining, smelting, and manufacturing (Li et al., 2009).

Montagne et al. (2007) demonstrated that lead-containing dust particles from roads, after short atmospheric residence times, contribute to lead accumulation on soil surfaces in the proximity to highways. Clausen et al. (2004) showed that cadmium levels in soil exceeded the global average of 0.15 ppm for uncontaminated soil. Table 3 and Fig. 2 show that cadmium ranges from 0.02 ppm (Al-Tanumah station) to 10.2 ppm (Al-Shuaiba station). These elevated levels, exceeding 0.5 ppm, may be attributed to human activity (CSO, 2014). Monitoring soil cadmium levels in the research area is essential, particularly where concentrations are high, given its accumulation in the human body and delayed toxicity from prolonged exposure (Certini et al., 2013). Due to human activities, including the use of solid waste and sewage, as well as industrial and agricultural processes, cadmium levels in the soil have risen above the natural limits of the element's concentration (Facchinelli et al., 2001). In addition, Giaccio et al. (2012) showed that cadmium is

utilized in electrical coatings, paints, and dyes in a variety of sectors.

Chromium concentrations ranged from 0.6 ppm at the Al-Tanumah station to 141.68 ppm at the Al-Shuaiba station (Table 3 and Fig. 2). The concentration at Al-Shuaiba exceeds the normal limit of 120 ppm (Kabata-Pendias, 2011), which indicates a significant localized source of contamination. In contrast, values at all other study sites were well below this limit (Table 3). Due to the strong binding of chromium (Cr^{3+}) to oxide surfaces, it is typically found in soils rich in metal oxides, especially iron oxides (such as goethite and hematite) and manganese oxides. Also, due to its similar size to iron (Fe^{3+}), it can replace iron atoms within the mineral's crystal structure, leading to its immobilization (Kabata-Pendias, 2011). The low chromium concentrations in the study area are mainly attributed to the naturally low geogenic background of chromium in the parent materials of Basrah, as well as the physicochemical properties of the street dust matrix, which is generally dominated by non-cohesive and coarse particles with limited capacity to retain heavy metals compared to clay-rich natural soils (Alloway, 2013). Sandy soils retain little $\text{Cr}(\text{III})$ due to low surface area and minimal cation exchange capacity; the region's clay minerals and their source composition further constrains overall chromium levels (Kabata-Pendias, 2011). These findings align with Al-Khafaji et al. (2010), who also reported low Cr levels in Basrah soils.

Table 3: The heavy metal concentrations (in ppm) within the soil at the study stations.

Station Name	Statistics	Ni	Pb	Cd	Cr
Al-Garma	1	63.11	22.6	0.24	30.97
	2	63.1	22.8	0.26	30.99
	3	63.13	22.4	0.22	30.95
	Mean	63.11	22.6	0.24	30.97
	SD	0.02	0.2	0.02	0.02
Al-Tanumah	1	28.17	10.16	0.020*	0.6
	2	28.15	10.2	0.023*	0.65
	3	28.19	10.12	0.017*	0.55
	Mean	28.17	10.16	0.02	0.6
	SD	0.02	0.04	0.003	0.05
Sa'ad Square	1	106.29	97.81	0.29	22.23
	2	106.3	97.85	0.27	22.24
	3	106.28	97.77	0.31	22.23
	Mean	106.29	97.81	0.29	22.23
	SD	0.01	0.04	0.02	0.01
Al-Shuaiba	1	247.03	59.42	10.19	141.68
	2	249	60.42	10.26	142.68
	3	245.06	58.4	10.14	140.68
	Mean	247.03	59.41	10.2	141.68

Al-Zubair	SD	1.97	1.01	0.06	1
	1	91.55	64.73	0.91	34.65
	2	92.55	65.73	0.92	35.65
	3	90.55	63.73	0.9	33.65
	Mean	91.55	64.73	0.91	34.65
Al-Faw	SD	1	1	0.01	1
	1	22.1	21.06	0.090*	2.59
	2	23.1	21.03	0.100*	2.61
	3	21.1	21.09	0.080*	2.57
	Mean	22.1	21.06	0.09	2.59
Method Detection Limit (MDL)	SD	1	0.03	0.01	0.02
		0.5	1.7	0.1	0.4

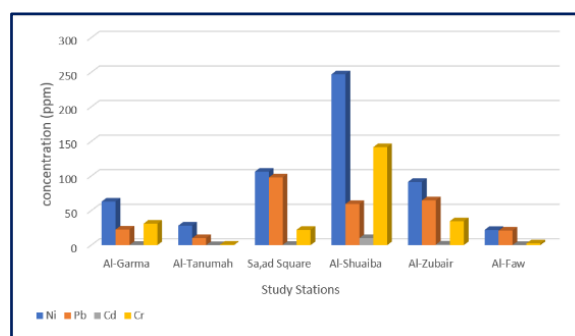


Fig. 2: Heavy metal content at the study stations.

It is acknowledged that several measurements of cadmium (Cd) at Al-Tanumah and Al-Faw stations registered below the formal method detection limit (MDL) of 0.1 ppm. These readings, however, were consistently above the instrument detection limit (IDL) of 0.001 ppm, representing quantifiable instrumental responses. They are reported herein to demonstrate the reproducibility of the analysis at these trace concentrations, with the understanding that they are associated with greater analytical uncertainty than levels above the MDL.

To investigate the potential origins of the heavy metals, a Pearson correlation analysis was performed (Table 4). While these findings should be interpreted with caution due to the limited sample size ($n=6$), the results revealed a strong, positive, and statistically significant relationship between Ni, Cr, and Cd, as seen in the Ni-Cr ($r = 0.968$, $p = 0.001$), Ni-Cd ($r = 0.933$, $p = 0.003$), and Cr-Cd ($r = 0.976$, $p < 0.001$) pairings. This tight grouping suggests a potential common origin from activities such as oil and gas processing or industrial waste (EPA, 2020; WHO, 2021). In contrast, lead (Pb) did not correlate significantly with any of the other metals ($p > 0.05$). The lack of correlation may indicate that lead pollution stems from a different

source and is primarily caused by traffic-related emissions from vehicles (WHO, 2021).

Table 4: Pearson Correlation Coefficients (r) for Heavy Metal Concentrations in roadside dust.

Heavy Metals	Statistic	Ni	Pb	Cd	Cr
Ni	Pearson Correlation	1	0.541	0.933**	0.968**
	p-value		0.134	0.003	0.001
Pb	Pearson Correlation	0.541	1	0.236	0.329
	p-value	0.134		0.326	0.262
Cd	Pearson Correlation	0.933**	0.236	1	0.976**
	p-value	0.003	0.326		< 0.001
Cr	Pearson Correlation	0.968**	0.329	0.976**	1
	p-value	0.001	0.262	< 0.001	

**. Correlation is significant at the 0.01 level (1-tailed). The critical value for r with df = 4 is 0.917.

Despite being a known environmental hazard due to its potential to bioaccumulate, chromium showed very little accumulation in the roadside dust of Basrah in our study. This was confirmed by the geoaccumulation index, which showed consistently low values at all sites. All six locations fell into the 'uncontaminated' class ($I_{geo} \leq 0$). Even at its highest concentration at the Al-Shuaiba industrial site, the I_{geo} value was 0.32 (Table 5). This overall lack of significant accumulation strongly suggests that chromium has poor mobility in the soils of this region, a finding consistent with its tendency to become immobilized under the kinds of moderate redox conditions reported by Clausen et al. (2004).

Analysis of the Geoaccumulation Index (I_{geo}) revealed distinct spatial patterns of contamination across the study area, suggesting different pollution sources (Table 5, Fig. 3). The most alarming finding was the severe and highly localized contamination by cadmium (Cd) at the Al-Shuaiba industrial site. With an I_{geo} value of 5.49, this location is classified as heavily to extremely polluted, which strongly points to a specific industrial point source.

Lead (Pb) and, to a lesser extent, nickel (Ni), also showed notable contamination at specific sites. Lead pollution was most significant at Sa'ad Square, a high-traffic area, with an I_{geo} value of 2.22 ('moderately to heavily polluted'). Significant lead contamination was also found at Al-Zubair ($I_{geo} = 1.62$) and Al-Shuaiba ($I_{geo} = 1.5$).

In contrast, nickel (Ni) contamination was far less widespread than initially suggested, and was primarily confined to the Al-Shuaiba station, which had an I_{geo} value of 0.97 ('uncontaminated to

moderately polluted'). All other stations showed no signs of nickel pollution, with negative I_{geo} values. Therefore, the primary heavy metal concerns identified by the I_{geo} analysis are the extreme cadmium enrichment at Al-Shuaiba and the significant lead pollution at traffic and industrial sites, making these the elements of greatest environmental concern in the study area.

Table 5: The geochemical accumulation index values (I_{geo}) at the study stations.

Station No.	Station Name	Geochemical accumulation index (I_{geo})			
		Ni	Pb	Cd	Cr
1	Al-Garma	-1	0.11	0.09	-2.86
2	Al-Tanumah	-2.18	-1.05	-4.49	-8.55
3	Sa'ad Square	-0.25	2.22	0.35	-3.33
4	Al-Shuaiba	0.97	1.5	5.49	-0.32
5	Al-Zubair	-0.44	1.62	2.01	-3.1
6	Al-Faw	-2.52	0	-1.58	-6.34
Range		-2.52-0.97	-1.05-2.22	-4.49-5.49	-0.32-8.55
Average		-0.90	0.73	0.31	-4.08
Background value (Bn)		84	14	0.15	120

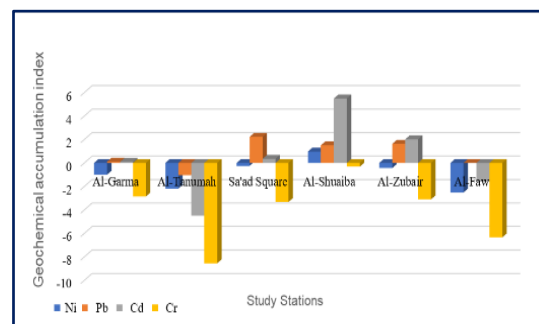


Fig. 3: The geochemical accumulation index (I_{geo}) distribution across the study stations.

The Contamination Factor (CF) analysis effectively distinguished between highly localized industrial pollution and more widespread urban pollution sources (Table 6, Fig. 4). Al-Shuaiba was confirmed as the primary industrial pollution source, with 'very high' contamination by cadmium (CF = 67.93). Significant cadmium contamination was observed in Al-Zubair, with a contamination factor of 6.06. The urban pollution signature was most evident at Sa'ad Square, which had the highest lead contamination level (CF = 6.98, 'very high contamination'), likely due to heavy traffic. Nickel contamination was generally low to moderate across most industrial and urban sites. In contrast, chromium levels were consistently low, with a CF value never exceeding 1.18, indicating minimal contamination from this element.

The overall enrichment hierarchy in the region, based on average CF values, was Cd (13.04) > Pb (3.28) > Ni (1.10) > Cr (0.32), highlighting the severe impact of industrial activities on cadmium levels in the environment. Chromium (Cr), with a CF consistently below 1 at most sites, was not associated with a significant pollution signature. This clear distinction between sources explains the overall enrichment hierarchy in the region (Cd > Pb > Ni > Cr) and highlights the critical impact of targeted industrial and vehicular emissions.

Table 6: Concentration factor (CF) values for the study stations.

Station No.	Station Name	Concentration Factor (CF)			
		Ni	Pb	Cd	Cr
1	Al-Garma	0.75	1.61	1.6	0.25
2	Al-Tanumah	0.33	0.72	0.13	0.005
3	Sa'ad Square	1.26	6.98	1.93	0.18
4	Al-Shuaiba	2.94	4.24	67.93	1.18
5	Al-Zubair	1.08	4.62	6.06	0.28
6	Al-Faw	0.26	1.50	0.6	0.02
Range		0.26-2.94	0.72-6.98	0.13-67.93	0.005-1.18
Average		1.10	3.28	13.04	0.32
Background value (Bn)		84	14	0.15	120

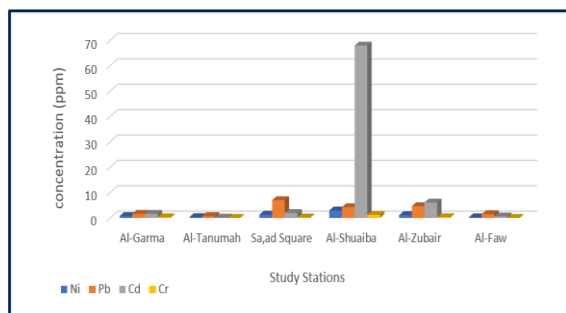


Fig. 4: Distribution of heavy metal concentration factors (CF) at the study stations.

To expand on the scientific context, the results of the current study were compared with average heavy metal concentrations reported from several local Iraqi studies and international studies, revealing significant differences that reflect variations in local environmental conditions and pollution sources (Table 7).

Table 7: A comparison of mean heavy metal concentrations (ppm) in roadside dust from the present study with other local and international studies.

References	Studied Area	Heavy metals (ppm)			
		Ni	Pb	Cd	Cr
Al-Khafaji and Jaafar (2023)	Iraq (Al-Zubair in Basrah)	23.21	19	0.32	34.5
Jalal (2020)	(Basrah) Iraq	374.3	64.96	0.17	980

Al-Sudani et al. (2021)	Iraq (Al-Anbar)	155.33	10.55	14.62	117.4
Al-Sarafi (2009)	Iraq (Al-Shuaiba in Basrah)	24.1	7.6	2.9	26.4
Zhao et al. (2020)	Southeast China (Xiamen, Fujian)	52	202	1.33	143
Tang et al. (2022)	Southeast China (Guangdong)	34.4	150	0.73	150
Al-Obaidy and Al-Mashhadi (2013)	Iraq (Baghdad)	86.76	87.06	0.29	23.09
Present Study	Iraq (Al-Basrah)	93.04	45.96	1.96	38.79

The average nickel (Ni) concentration was 93.04 ppm. This value was considerably higher than levels reported in other Basrah studies by Al-Khafaji and Jaafar (2023) and Al-Sarafi (2009), and comparable to the concentration found in Baghdad by Al-Obaidi and Al-Mashhadi (2013). However, it was significantly lower than the exceptionally high values recorded by Jalal (2020) in Basrah and Al-Sudani et al. (2021) in Al-Anbar. This suggests that the primary sources of pollution are likely anthropogenic, resulting from the oil industry and heavy traffic emissions.

The lead (Pb) concentration, at 45.96 ppm, was higher than in some local areas but still significantly lower than the levels recorded in major industrial cities by Tang et al. (2022), Zhao et al. (2020), Jalal (2020), or Al-Obaidi and Al-Mashhadi (2013). This indicates localized urban pollution, likely from vehicle emissions, such as tire wear and legacy leaded gasoline.

The cadmium concentration in the current study, 1.96 ppm, was notably higher than that in most other cited Iraqi studies, including Al-Khafaji and Jaafar (2023), Jalal (2020), and Al-Obaidi and Al-Mashhadi (2013). The value, however, was comparable to that reported by Al-Sarafi (2009) in Al-Shuaiba's industrial area and significantly lower than that found by Al-Sudani et al. (2021). This suggests contamination from a range of sources, including industrial sources such as electroplating and battery manufacturing.

The chromium (Cr) concentration was 38.79 ppm, which was relatively moderate. Unlike other metals, this value is consistent with regional background levels reported by Al-Khafaji and

Jaafar (2023). This suggests that chromium levels are more significantly influenced by widespread contamination and the characteristics of the region's soils, rather than by specific, high-intensity industrial sources such as tanneries or paint facilities.

Thus, heavy metal pollution in the study area can be classified as moderate to high. Overall, the contamination in the region indicates a complex, multi-source environmental problem caused by the combined effects of the oil industry, traffic, and agricultural practices, underscoring the need for targeted environmental management.

5. Conclusion

The study results show that heavy metal concentrations varied significantly across the different sites. The highest levels of nickel, cadmium, and chromium were consistently found at the Shuaiba Industrial Station, attributed to nearby oil fields, gas flaring, and oil spills. The highest lead concentration was also recorded at Sa'ad Square. Urban centers such as Sa'ad Square and Zubair were subsequently classified as highly polluted sites, where pollution is primarily associated with heavy vehicular traffic. In contrast, the Tanuma and Al-Faw stations showed minimal pollution due to their distance from these major sources. Pollution indices (CF and Igeo) confirmed these spatial patterns, showing that overall pollution levels varied significantly from low to very high in specific areas. Shuaiba stands out in these indices due to high to severe cadmium pollution levels from industrial and petroleum-related activities. Contrary to initial assessments, the geochemical accumulation index indicated that nickel accumulation was minimal. In contrast, heavy lead accumulation was primarily associated with the Sa'ad Square site, which has heavy traffic, while chromium showed minimal accumulation at all sites.

Furthermore, statistical analysis showed strong and significant correlation among nickel, cadmium, and chromium, while lead (Pb) showed no significant correlation with the other metals. However, these findings are preliminary due to the limited number of samples (n=6). With this caveat in mind, the correlation suggests that these elements may originate from shared sources, likely related to industrial and other human activities in the region, while lead contamination stems from a different source.

In conclusion, these results highlight the importance of monitoring these metals as environmental indicators. They also call for more detailed studies employing a larger sampling size to statistically validate these preliminary findings, accurately identify pollution sources, and develop effective strategies to mitigate the harmful impacts of both heavy industrial cadmium contamination and widespread urban lead contamination on the environment and public health.

6. Acknowledgements

The authors express their gratitude to the Department of Geology at the University of Basrah for their ongoing assistance. We are particularly grateful to the Al-Wasal Scientific Laboratory for Environmental Analysis in Basrah, southern Iraq, for their assistance in the laboratory analysis. We sincerely thank the editor and reviewers for their time and work in making the necessary revisions to the paper.

7. Conflict of Interest

The authors declare that none of their personal or financial conflicts could have influenced the work presented in this study.

8. Funding Statement

This research received no external funding.

9. Author contributions:

Iqbal O. Al-Taie: Conceptualization, Methodology, Validation, Investigation, Data curation, writing – original draft, Visualization, Project administration.

Hanan A. Darweesh: Methodology, Visualization, Project administration, Writing, Review, and Editing.

Yasmin I. Al Fraji: Conceptualization, Methodology, Writing review, and Editing.

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تقييم تلوث الغبار بالعناصر الثقيلة من جوانب الطريق: دراسة حالة من محافظة البصرة،

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تاريخ الاستلام: 09 أيار 2025 تاريخ المراجعة: 05 آب 2025 تاريخ القبول: 02 تشرين الأول 2025

تاريخ النشر الإلكتروني: 01 تشرين الأول 2026

الملخص

أُجريت هذه الدراسة لتقييم مدى ومصادر تلوث المعادن الثقيلة في غبار الطرق في محافظة البصرة، وهي مركز رئيسي لإنتاج النفط في جنوب العراق. جُمعت العينات من ستة مواقع صناعية وحضرية استراتيجية. خُددت تراكيز النيكل (Ni) والرصاص (Pb) والكاديوم (Cd) والكروم (Cr)، وقُتِم التلوث باستخدام مؤشر التراكم الجيولوجي (Igeo) وعامل التلوث (CF). تشير نتائج الدراسة إلى تلوث مرتفع للغاية بالكاديوم (Cd) في موقع الشعبة الصناعي ($I_{geo} = 5.49$; $CF = 67.93$)، مما يجعله نقطة تلوث رئيسية. كما لوحظ نمط تلوث حضري يتميز بارتفاع تراكيز الرصاص (Pb) في موقع ساحة سعد ذي الحركة المرورية الكثيفة ($I_{geo} = 2.22$). دعم تحليل توزيع المصادر عبر معامل ارتباط بيرسون هذه النتائج، كاشفاً عن ارتباط إيجابي قوي ذي دلالة إحصائية بين النيكل والكاديوم والكروم ($p < 0.005$)، مما يشير إلى الأصل الصناعي المشترك. في المقابل، لم يُظهر الرصاص أي ارتباط ذي دلالة إحصائية مع المعادن الأخرى، مما يؤكد ارتباطه الأساسي بانبعاثات المركبات. والجدير بالذكر أن التلوث بالنيكل كان ضئيلاً، بينما ظلت مستويات الكروم منخفضة باستمرار، مما يشير إلى انخفاض مساهمتهما في إجمالي حمل التلوث في المنطقة المدروسة. وفي الختام، تُحدد هذه الدراسة تحدياً بيئياً مزدوجاً في البصرة، مما يستلزم تطبيق استراتيجيات معالجة وإدارة خاصة بالمصدر تستهدف كلاً من انبعاثات الكاديوم الصناعية الشديدة وتلوث الرصاص الحضري واسع الانتشار..

الكلمات المفتاحية:

المعادن الثقيلة، غبار جوانب الطريق، تلوث التربة، التلوث، المعامل الجيوكيميائي.

DOI: [10.33899/injes.v26i4.56161](https://doi.org/10.33899/injes.v26i4.56161), ©Authors, 2026, College of Science, University of Mosul.

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