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Assessment of the pollution degree for some heavy elements in street dust around the shrine of Imam Hussein, Kerbala, Iraq

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ABSTRACT
Heavy element pollutions in urban street dust has caused global concern due to the potential danger to human health and the urban environment. Therefore, the present study was designed to assess street dust pollution in Kerbala, the most important city in terms of religious tourism. Samples were collected from most of the streets surrounding the Imam Hussein shrine and the concentration of elements (arsenic, lead, copper, chromium, cadmium and zinc) were measured using an atomic absorption spectrometry. The results showed that the arranging of those elements according to their concentration was as follows: Zn> Pb> Cu> Cr> As> Cd. Street dust was contaminated with a strong and serious degree according to total complex indices; integrated pollution index (IPI) and Nemerow pollution index, and that the most polluting elements to dust are cadmium and lead based on single pollution indicators enrichment factor (EF), pollution index (PI), and geo-accumulation Index (Igeo). This was attributed to the traffic density and vehicle exhausts, especially the exhausts of the numerous electricity generators inside the city. Therefore, the study recommends prohibiting the use of leaded gasoline and providing the city with a constant electric current to prevent the operation of generators and the obligation to clean the streets.

Keywords: Street dust, Nemerow pollution index, Air pollution, Heavy elements, Human health.
Article type: Research Article.

INTRODUCTION
Heavy elements contamination dust is becoming an extremely severe environmental issue in Iraq due to urbanization and the number of vehicles increased (Alhesnawi *et al.* 2019). Heavy elements are continuously released into the atmosphere, posing a serious health threat, especially in urban areas (Zgłobicki *et al.* 2018). There are several studies on heavy metals in the world (Johari *et al.* 2015; 2016; Yabanli 2016; Janbakhsh *et al.* 2018; Sattari *et al.* 2019a,b; Sattari *et al.* 2020a,b,c; Forouhar Vajargah *et al.* 2020a,b; Forouhar Vajargah *et al.* 2021a,b). Dust carries many pollutants, the most important ones are heavy elements due to its ability to absorb them on the surface of its particles (Sutherland 2003; Padoan *et al.* 2017). Street dust has, in addition to soil components, vegetable fragments, construction waste, particles from car tires and brake pads, solid soot, and a lot of industrial and natural origin materials (VanLoon & Duffy 2017). Due to the unique properties of street dust, it is considered an important indicator of the quality of the urban environment. Furthermore, the dust particles are often suspended into the air by wind or the movement of pedestrians and vehicles. As a result, people are exposed to the risk of street dust through inhalation, ingestion and skin contact (Hou *et al.* 2019; Sheikhi Alman Abad *et al.* 2021). Therefore, in recent years, the study of street dust and urban soils in densely populated cities has become a focus of public health investigators (Kamani *et al.* 2015). Kerbala is one of the most important cities for religious tourism in Iraq and for the whole world because of the shrine of Imam Hussein. The number of tourists is approximately 25 million tourists annually, and due to the crowdedness of tourists on some occasions during the year, walking on the road is the only way to reach the shrine, as well as that walking is one of the

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important rituals performed by tourists. This traffic raises the dust accumulated on both sides of the streets, which poses a threat to the health and safety of tourists and residents. Despite the importance of this city, the studies that have been conducted to assess pollution are limited and insufficient (Alhesnawi *et al.* 2019), so the aim of this study was to evaluate the degree of accumulation and possible sources of the target heavy elements in street dust depending on some indicators of pollution. Moreover, the results of this study will help us better understand how heavy elements accumulate in urban areas as a result of rapid urbanization.

MATERIALS AND METHODS

Study area

Kerbala Province is about 105 km from the capital, Baghdad, and it is the most important religious province in Iraq. The focus was on the area surrounding the Imam Hussein shrine (32°36'56.12"N and 44° 1'55.57"E) as in Fig. 1, which is a densely populated area and often suffers from traffic congestion due to narrow streets and the large number of tourists.

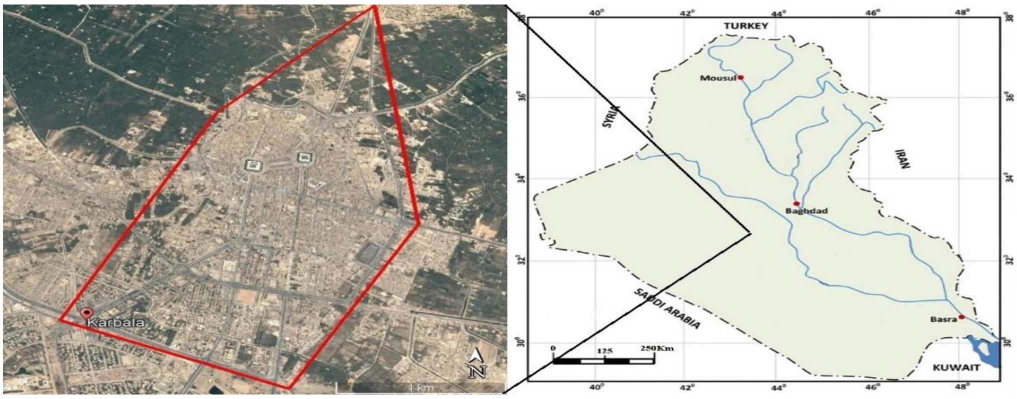

Fig. 1. Kerbala city center, the area around the shrine of Imam Hussein.

Sample collection and analysis

Thirty-six samples were collected, representing most of the streets leading to the Imam Hussein shrine and the surrounding streets, during July 2020 in dry and stable weather conditions. About 500 g of each sample was collected from both sides of the streets using a plastic brush and stored in polyethylene containers (Alhesnawi 2018). Then the samples were transferred to the laboratory and dried in an oven at 70 °C for 24 h. Samples were passed through a sieve (<63 μm) and 1 gram was taken from each sample and digested using a mixture in a 5: 1: 1 ratio of HNO_3, $HClO_4$, and H_2SO_4 respectively (Yadav & Yadav 2018). The concentrations of the elements were measured using an atomic absorption spectrometry (AAS).

Environmental pollution indices

Single indices

Single indicators are indicators used to determine the contamination of heavy elements at the individual level to determine the quality of soils and sediments (Weissmannová & Pavlovský 2017). They were applied to street dust as well. Three single indicators were used in the current study as follows:

Index of geo-accumulation (Igeo)

To calculate the Igeo, the following equation was applied (Qingjie *et al.* 2008):

$$Igeo = \frac{Cx}{1.5 \times Cref} \qquad \textbf{(1)}$$

where C_x (sample) is the heavy elements' concentration in the street dust sample and C_{ref} (background) is the concentration of elements in the background sample. Factor 1.5 is used to reduce the impact of potential changes in the background values caused by lithogenic variation in the soil. Table 3 shows the assessment criteria of Igeo.

Enrichment factor (EF)

The following equation was used to calculate the enrichment factor (Sheikhi Alman Abad *et al.* 2021):

$$EF = \frac{\frac{Cx}{Cref}(sample)}{\frac{Cx}{Cref}(Earth's\ crust)} \qquad \textbf{(2)}$$

where ((C_x/C_{ref}) $_{sample}$) represents the concentration of element Y to the iron concentration in the examined sample to know the extent of its contamination. Also ((C_x/C_{ref}) $_{Earth's\ crust}$) represents a reference concentration ratio of the element to iron in the Earth's crust (Shirani *et al.* 2020) .

The calculated EF values can be interpreted according to the criteria shown in Table 3.

Pollution index (PI)
The PI formula is as follows (Malkoc *et al.* 2010):

$$PI = \frac{Cn}{Bn} \qquad \textbf{(3)}$$

Where C_n is the elements' mean concentration in samples and B_n is the elements' background value. The pollution level for each element was determined on the basis of the classification (Hu *et al.* 2018) shown in Table 3.

Total complex indices
Three types of integrated indicators have been used for assessing heavy element pollution, which are based on the values of the individual indicators:

Pollution load index (PLI)
PLI can be calculated from the following equation (Shehu 2019):

$$PLI = \sqrt[n]{PI1 \times PI2 \times PI3 \times \ldots\ldots PIn} \qquad \textbf{(4)}$$

The terms shown in Table 3 were used to evaluate the pollution load index.

IPI Integrated pollution index (IPI)
The integrated pollution index (IPI) is calculated as the average of individual elements pollution indices (PI) as in the following equation:

$$IPI = \frac{PI1 + PI2 + PI3 \ldots\ldots PIn}{n} \qquad \textbf{(5)}$$

The IPI values were categorized into three grades (Weissmannová & Pavlovský 2017), as shown in Table 3.

Table 1. Environmental Indices classification.

Indices of pollution	Value	Categories
(EF)	EF < 2	Deficiency to minimum enrichment
	EF = 2–5	Moderate enrichment
	EF = 5–20	Significant enrichment
	EF = 20–40	Very high enrichment
	EF > 40	Extremely high enrichment
(Igeo)	Igeo ≤ 0	Unpolluted
	0 ≤ I geo < 1	Unpolluted to moderately polluted
	1 ≤ Igeo < 2	Moderately polluted
	2 ≤ Igeo < 3	Moderately polluted to highly polluted
	3 ≤ Igeo < 4	Highly polluted
	4 ≤ Igeo < 5	Highly polluted to very highly polluted
	I geo > 5	Very highly polluted >5
(PI)	PI ≤ 1	Nonpollution
	1 < PI ≤ 2	Low pollution
	2 < PI ≤ 3	Moderate pollution
	PI > 3	High pollution
(PLI)	PLI < 1	Unpolluted
	PLI = 1	Pollution baselines
	PLI > 1	Pollution
(IPI)	IPI < 1	Low polluted
	1 ≤ IPI ≤ 2	Moderate polluted
	IPI < 2	Strongly polluted
(NPI)	NPI < 0.7	Unpolluted
	0.7 ≤ NPI < 1.0	Little pollution
	1.0 ≤ NPI < 2.0	Slight pollution
	2.0 ≤ NPI < 3.0	Moderate pollution
	NPI ≥ 3.0	Serious pollution

Nemerow pollution index NPI

Use the Nemerow Pollution Index (NPI) to extensively assess the soil environmental quality (Cheng *et al.* 2007), which is defined as;

$$NPI = \frac{\sqrt{(Pimax)^2+(Piavex)^2}}{2} \quad \textbf{(6)}$$

The degree of pollution is split into five stages based on the value of PI, as indicated in Table 3 (Hu *et al.* 2018).

RESULTS

The basic descriptive statistics for the samples of street dust are shown in Table 2. The highest concentration of elemental Zn was 100.06 (mg kg^{-1}), while the lowest concentration of Cd was 2.22 (mg kg^{-1}), and the order of the elements was based on their concentration in descending order as follows: Zn> Pb> Cu> Cr> As> Cd.

Table 2. Heavy elements (mg kg^{-1}) in the street dust: average, standard deviation, minimum, and maximum.

Elements	Average	SD	Minimum	Maximum	Crust average
As	2.44	1.78	0.50	5.50	9.7
Pb	70.56	13.10	55.00	100.00	16
Cu	51.17	10.23	38.50	70.00	32
Cr	32.39	4.57	25.00	38.00	71
Cd	2.22	0.71	0.50	3.00	0.2
Zn	100.06	13.26	82.00	125.00	127

Table 3 represents the enrichment factor (EF) values and the average enrichment factor values were in the following order in descending order: Cd (39.57) > Pb (15.77) >Cu (5.73) > Cr (1.60) Zn (2.78) > As (0.87). According to the Enrichment Factor (EF) shown in Table ١, the elements were classified as follows: As, Cr (deficiency), Pb, Cu (significant enrichment), Zn (moderate enrichment), and Cd (very high enrichment).

Table 3. Comparison of heavy elements values according to Enrichment Factor (EF) index.

Elements	Average	SD	Degree of Enrichment Factor
As	0.87	0.61	Deficiency to minimum enrichment
Pb	15.77	4.41	Significant enrichment
Cu	5.73	1.64	Significant enrichment
Cr	1.60	0.20	Deficiency to minimum enrichment
Cd	39.57	13.46	Very high enrichment
Zn	2.78	0.36	Moderate enrichment

Table 4 shows the values of the geo-accumulation index (Igeo) and the criteria on the basis of which the results (Table 1) were classified, and they were as follows: As, Cr, Zn (Unpolluted), Cu (Unpolluted to moderately polluted), Pb (Moderately polluted), and Cd (Moderately polluted to highly polluted).

Table 4. Comparison of heavy elements values according to Igeo index.

Elements	Average	SD	Degree of geo-accumulation index (I geo)
As	-2.97	1.19	Unpolluted
Pb	1.54	0.25	Moderately polluted
Cu	0.06	0.28	Unpolluted to moderately polluted
Cr	-1.73	0.20	Unpolluted
Cd	2.76	0.78	Moderately polluted to highly polluted
Zn	-0.94	0.19	Unpolluted

The highest average of pollution index (IP) was for cadmium (11.11), followed by lead (4.41) in Table 5, and the results were classified according to the degrees of pollution index shown in Table ١ as follows: As, Cr, Zn (Nonpollution), Cu (Low pollution) and Pb, Cd (High polluted).

Table 5. Comparison of heavy elements values according to IP index.

Elements	Average	SD	Degree of Pollution Index (IP)
As	0.25	0.18	Nonpollution
Pb	4.41	0.82	High pollution
Cu	1.60	0.32	Low pollution
Cr	0.46	0.07	Nonpollution
Cd	11.11	3.56	High pollution
Zn	0.79	0.10	Nonpollution

The values of the total complex indices including PLI, IPI and NPI were 1.39, 3.10 and 8.16 respectively (Table 6) and the values were classified according to the degrees of each indicator (shown in Table 1) as polluted for PLI, while IPI was considered as strongly polluted and NPI as serious polluted.

Table 6. Comparison of heavy elements values according to PLI, NPI, and IPI indices.

Type of index	Average	Degree of pollution
Pollution load index (PLI)	1.39	Pollution
Integrated pollution index (IPI)	3.10	Strongly polluted
Nemerow pollution index (NPI)	8.16	Serious pollution

DISCUSSION

Based on the single pollution indicators (EF, Igeo and IP) used to assess pollution with heavy elements, the results showed that the street dust was contaminated to a high degree with cadmium and lead, and to a lesser extent with copper, while the other elements (arsenic, chromium, and zinc) were not contaminated with street dust. The analysis of the results clearly exhibited the role of anthropogenic activities on the higher concentrations of lead, cadmium, and copper. The high concentrations of these elements compared to the reference values (Table 3) threaten public health and cause multiple functional diseases for humans, especially since these elements have toxic and carcinogenic properties (Balali-Mood *et al.* 2021; Duong & Lee 2011). Vehicle and motorcycle exhaust, whose numbers have increased dramatically, are among the most important sources of pollution in the city (Alhesnawi 2021; Taghavi *et al.* 2019). In addition, the excessive use of generators as a result of power cuts within the study area release huge amounts of exhausts which are deposited close to their origin due to its collision with the surrounding buildings. Total complex indices (PLI, IPI and NPI) revealed that street dust is very polluted and dangerous. Some studies have indicated that measuring the degree of street dust pollution is very important for determining the quality of the urban environment (Hou *et al.* 2019; Kaonga *et al.* 2021; Pan *et al.* 2017). Therefore, the city center of Kerbala is considered as an environment contaminated with heavy elements and poses a potential risk to human health. This finding suggests that human activities have a major impact on the amount of dust and its contents from heavy elements in the study area. As a result, lowering heavy element levels to avoid possible hazards from these elements should be considered.

CONCLUSION

In this study, the concentration of some heavy elements (As, Pb, Cu, Cr, Cd and Zn) in street dust was investigated for the city center of Kerbala, and single and total pollution indicators were used to assess the level of pollution. The results showed that the street dust is seriously contaminated based on the total complex indices (PLI, IPI and NPI). According to the values of single pollution indicators (EF, PI, and I geo), it was found that the level of pollution of copper was low, while cadmium and lead were highly contaminated which are two very toxic elements and have negative effects on human health and the environment. Therefore, the current study recommends limiting the accumulation of street dust to prevent the process of re-suspending dust in the air, by tightening control over construction operations to prevent the accumulation of building materials and their waste in the streets. It is also necessary to reduce the emission of exhausts by relying on public transport only inside the city, as well as limiting the addition of lead in gasoline and preventing the use of generators inside the city by providing them with a continuous electric current.

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