Assessment of health risk and geo-accumulation of toxic heavy metals in side-road dust from urban areas of Baghdad city

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ABSTRACT

INTRODUCTION Environmental contamination has become a severe problem as a result of urbanization and industrialization, particularly because of the release of heavy metals which have drawn a lot of attention due to their harmful effects, persistence, and bioaccumulation in the environment.

METHODS The present study, which was conducted from July to October 2019, provides the spatial distribution, contamination levels, and health risks assessment for four heavy metals, Pb, Zn, Cr and Ni, in the urban area within Baghdad city, depending on the type of activity and the nature of land use.

RESULTS The results show that the average value of the contamination levels for the four heavy metals were within the reference values of soil in Baghdad city. The pollution assessment indices geo-accumulation index (Igeo) and integrated pollution index (IPI), carcinogenic and non-carcinogenic health index (HI), and hazard quotient (HQ) were studied. The results of Igeo and IPI in Sheikh Omar (industrial area), Baghdad Al-Jadida (commercial area), and Sadr City (high population density) were relatively greater than in the other areas. The IPI value ranged from 1.51 in Sheikh Omar to 0.75 in Taji (agricultural area).

CONCLUSIONS The values of the health risk assessment indices (HI and HQ) indicate that the levels of the four heavy metals in the studied sites were within the safe limits (<1) and had no significant health risk for the inhabitants.

INTRODUCTION

Urban areas in the main and even minor cities represent a base for all human activities, including transportation, construction, industry, and other activities[1]. Therefore, the pollution resulting from human sources in the urban areas are more than in the other regions[2]. Numerous studies have examined the types of pollutants, their distribution, their concentrations, and the dynamics of their spread from one site to another in urban areas. Multiple techniques were utilized such as satellite images, monitoring, and surveillance stations covering the most active areas of the cities. Furthermore, mathematical models were designed to calculate the daily and seasonal measures of the most affected areas by these pollutants[3,4]. Heavy metals are among the most important pollutants that have been studied, due to their severe toxicity and their clear impact on human health[5-7]. The levels of heavy metals in the urban environment are more than in other areas, which is due to different human activities that are concentrated there such as transport, mining, industry, use of pesticides, dyes and batteries, which are the essential sources of pollution of heavy metals[8,9]. Many previous studies were conducted to determine the spread of heavy metals in Baghdad and other Iraqi cities. Al Obaidy and Al Mashhadi[10] investigated the levels of eight heavy metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn) in the urban areas of Baghdad city for different land use (industrial, commercial and residential areas). Sultan et al.[11] and Haleem et al.[12] found high concentrations of heavy metals in dust samples carried in the dust storms that swept Baghdad city during repeated days of the year. While Essa and Al-Jibury[13] detected four heavy metals (Cd, Pb, Zn and Ni) in the most crowded squares in Baghdad (Outer Karada, Al-Saadoon, Nidhal and Palestine streets); the findings indicated that the levels of the calculated pollution indices (geo-accumulation index, pollution index, carcinogenic and non-carcinogenic risks) for the heavy metals in the anthropogenic and side-road soils were affected by the emitted gasses from the vehicles' exhausts and their fly ash[13]. The spread of heavy metals in this pattern and these concentrations may cause serious health problems for all exposed people especially pedestrians, workers, road sellers, and drivers who spend eight hours or more in the streets and are exposed to these pollutants by inhalation, ingestion, or direct skin contact[14-16].

The two main objectives of this study were: 1) Evaluation of the concentrations of heavy metals on main side roads of the urban areas of Baghdad city and calculation of pollution indices such as geo-accumulation index (Igeo) and Integrated Pollution Index (IPI); 2) Assessment of the human health risk through chronic exposure to contaminated soil with heavy metals by calculating average daily dose (ADD), non-carcinogenic risk assessment, and carcinogenic risk assessment.

METHODS

Description of the study area

Baghdad city is the capital of Iraq and is located in the middle of the country. The Tigris River divides the city into two main areas, the west side (Al-Karkh) and the east side (Al-Rusafa). Baghdad is the largest and most populous city in Iraq, with about 8 million people in an area of 1000 km^2 with a complex network of conventional and highway transport routes. Baghdad is characterized as a flat plain surrounded by low hills in its Northern and Northeastern parts. The land uses are varied, covering agricultural, industrial, commercial and residential use. It is expected that the soil nature will be different from one site to another depending on the type of activity.

Samples collection

A total of 110 dust samples were collected from the side roads of 22 areas within Baghdad city from July to October 2019, with five samples per site as shown in Supplementary file Figure 1. Samples were collected from the main roads of each area in which cars, trucks, motorcycles and buses are the main modes of transportation. We expected to find marked differences in the nature of pollutants and their concentrations in each selected site depending on the type of activity carried out in each area, such as commercial, industrial, agricultural, or residential.

All dust samples were collected from the main roads in urban areas with heavy traffic. Side-road dust samples trowel of up to 500 g were collected with a plastic brush and trowel from each location and were placed in self-sealed plastic bags and labeled with all the required information such as sample size, date of collection, location, and season. The samples were then taken to the laboratory (Soil and Water Laboratory, Environment Research Center, University of Technology)[17]. The collected dust samples were dried at ambient temperature and sieved through 2 mm mesh and stored in clean plastic bags for analysis.

Heavy metal concentrations were determined by taking 5 g of each sieved soil sample and mixed with 25 mL of concentrated HNO_3, then placed on a hot plate for one hour[18]. The remainder of the mixture was filtered through 0.45 Millipore filter paper to a volume of 10 mL using a volumetric flask with deionized water. The concentrations of the heavy metals were analyzed using a flame atomic absorption spectrophotometer (FAAS, Shimadzu AA- 6200, Japan).

Quality control

All dust samples were tested in duplicate including filter blanks and Standard reference substances.

Chemical materials used for digestion and analysis have been supplied from Sigma Aldrich, USA. All measuring devices and equipment were calibrated by the Central Organization for Standardization and Quality Control (COSQC), Iraq.

Pollution assessment

The pollution levels of the heavy metals in the side-road dust samples were determined by calculating the Igeo and IPI indices. To calculate the Igeo index, the reference values of the heavy metals Pb, Zn, Cr and Ni were taken from the baseline values of Baghdad soils[13], which are 36.31 mg/kg, 56.23 mg/kg, 12.9 mg/kg, and 123.03 mg/kg, respectively. All background values were used from uncontaminated soil samples which were collected from 50 cm depth to avoid soil surface contamination[19,20].

Geo-accumulation index (Igeo)

Geo-accumulation index which was mainly developed by Muller[21] in the 1960s as the most valued tool to quantify heavy metal contamination levels in sediments (Supplementary file Table 1). Later, this method was used to determine the heavy metal contamination in soil and dust samples.

The (Igeo) is calculated from the equation:

$$Igeo= log2\times C/(1.5\times B) \qquad (1)$$

where C represents the measured concentration of the heavy metal and B represents the background value for the same metal in the soil.

Integrated pollution index (IPI)

The second index, that was applied to assess the contamination of urban soil, was the integrated pollution index (IPI), which is determined at each polluted site[22]. The IPI for each heavy metal was calculated from the equation:

$$IPI= Ci/Bi \qquad (2)$$

where Ci represents the element's concentration, while Bi is the background value of each element at the same study site. The integrated pollution index (IPI) represents the mean, and was calculated from the equation:

$IPI= (IP1+IP2+IP3+\cdots IPn)/n$ (3)

The IPI was rated as IPI≤1 for the lowest level

Table 1. Heavy metal concentrations (mg/kg) and geo-accumulation index of heavy metals in 22 side-road dust samples collected from selected areas of Baghdad city

No.	Sampling site	Site description	Concentration (mg/kg)				Geo-accumulation index			
			Cr	Ni	Pb	Zn	Cr	Ni	Pb	Zn
1	Al-Sa'adoon	Heavy traffic	290	125	89	112	0.127	-0.008	-0.180	0.020
2	Sheikh Omar	Industrial	310	155	115	105	0.158	0.082	-0.017	0.000
3	Al Kefah	Commercial	260	122	112	89	0.070	-0.022	-0.080	-0.070
4	Adhamiyah	Commercial	270	112	95	75	0.096	-0.060	-0.148	-0.148
5	Sha'ab	Moderate population residential	245	98	78	83	0.056	-0.119	-0.107	-0.102
6	Sadr City	High population residential	255	114	89	84	0.074	-0.050	-0.180	-0.096
7	Al Ghadeer	Moderate population residential	215	89	76	74	0.000	-0.161	-0.229	-0.152
8	Baghdad Al-Jadida	Commercial	288	125	89	102	0.123	-0.008	-0.180	-0.013
9	Sina'a	Commercial	243	102	82	116	0.053	-0.096	-0.211	0.041
10	Al-Jadriya	Low population residential	277	95	114	112	0.107	-0.127	-0.060	0.020
11	Karadah	Commercial	295	109	122	122	0.136	-0.071	-0.039	0.064
12	Za'franiya	Agricultural	198	77	66	78	-0.036	-0.219	-0.306	-0.130
13	Kadhimiya	Commercial	287	101	86	113	0.123	-0.101	-0.191	0.029
14	Taji	Agricultural	187	85	75	88	0.061	-0.176	-0.251	-0.080
15	Mansour	Low population residential	288	115	84	102	0.127	-0.045	-0.210	-0.013
16	Hayy Al-Jami'a	Low population residential	145	88	89	78	-0.235	-0.161	-0.180	-0.129
17	Ghazaliya	Low population residential	165	93	81	75	-0.115	-0.137	-0.217	-0.148
18	Safarat Complex	Low population residential	288	89	79	112	0.123	-0.161	-0.228	0.020
19	Abu Ghraib	Agricultural	198	78	77	85	-0.036	-0.213	-0.239	-0.090
20	Dora	Moderate population residential	230	140	71	104	0.025	0.037	-0.274	-0.004
21	Al-Saydiya	Moderate population residential	220	120	55	98	0.008	-0.027	-0.386	-0.030
22	Baya'a	Commercial	288	142	112	116	0.123	0.045	-0.416	0.042
	Mean		247.4	107.9	96.5	88.0				
	SD		45.57	20.78	16.98	15.53				
	Range		145–310	77–155	74–122	55–122				

of contamination, 1<IPI≤2 for a moderate level of contamination, 2<IPI≤5 for a high level of contamination, and IPI>5 for an extreme level of contamination[23].

Health risk assessment

According to the accredited methodology of the risk assessment by the Environmental Protection Agency of the United States (US EPA, 1989), we evaluated the health risks based on the concentration of heavy metals in the study area, depending on the average daily dose (ADD) (mg/kg/day) of only the inhalation exposure pathways, using the following formula[24,25]:

$$ADD= (C\times Rinh\times EF\times ED)/(PEF\times BW\times AT) \qquad (4)$$

where ADD represents the average daily exposure value of metals through inhalation (mg/kg/day), and Supplementary file Table 2 shows the exposure factors with EPA guidelines. The standards of EPA were adopted in this study.

The American model (USEPA, 1989) was adopted to calculate the health risks assessment of road dust for both adults and children, because there is no local model for this type of exposure. The effect of road dust on adults is expected to be greater than on children due to exposure hours, and the respiratory effect of heavy airborne elements as a result of dust in the streets is expected to be greater than its ingestion effect. The non-carcinogenic effect was calculated for four heavy metals (Pb, Zn, Cd and Ni), while the carcinogenic effect was determined for two elements (Cr and Ni).

Non-carcinogenic risk assessment

The non-carcinogenic risk assessment can be calculated for the studied metals by dividing the average daily dose (ADD) by a particular reference dose (RFD), as in the following formula:

$$HQ=ADD/RFD \qquad (5)$$

while the HI represents the sum of the HQ for the four studied metals:

Table 2. Pollution index of heavy metals in side-road dust samples of all studied areas in Baghdad city

No.	Sampling site	Cr	Ni	Pb	Zn	Integrated pollution index
1	Al-Sa'adoon	1.34	1.47	0.00	1.60	1.103
2	Sheikh Omar	1.44	1.82	1.29	1.50	1.513
3	Al Kefah	1.20	1.43	1.26	1.27	0.000
4	Adhamiyah	1.25	1.31	1.06	1.07	1.173
5	Sha'ab	1.14	1.15	0.87	1.18	1.085
6	Sadr City	1.19	1.34	0.00	1.20	0.933
7	Al Ghadeer	0.00	1.04	0.85	1.05	0.735
8	Baghdad Al-Jadida	1.34	1.47	0.00	1.45	1.065
9	Sina'a	1.13	1.20	0.96	1.65	1.235
10	Al-Jadriya	1.29	1.12	1.28	1.60	1.323
11	Karadah	1.37	1.28	1.37	1.74	1.440
12	Za'franiya	0.92	0.91	0.74	1.11	0.919
13	Kadhimiya	1.33	1.19	0.97	1.61	1.275
14	Taji	0.87	0.00	0.88	1.25	0.750
15	Mansour	1.34	1.35	0.99	1.45	1.282
16	Hayy Al-Jami'a	0.67	1.03	1.04	1.11	0.963
17	Ghazaliya	0.77	1.09	0.95	1.07	0.969
18	Safarat Complex	1.34	1.04	0.92	1.60	1.225
19	Abu Ghraib	0.92	0.92	0.91	1.21	0.990
20	Dora	1.07	1.64	0.83	1.48	1.255
21	Al-Saydiya	1.02	1.41	0.64	1.40	1.118
22	Baya'a	1.34	1.67	1.31	1.65	1.493

$HI=\sum_{(i=1)}^{4} HQi$ (6)

The threshold values adopted to determine exposure severity[26,27] are: H≤1 non-significant risk for non-carcinogenic; and H>1 significant risk for non-carcinogenic.

Carcinogenic risk assessment

The lifetime average daily dose (LADD) for inhalation exposure routes for Cr and Ni was applied to evaluate the carcinogenic risk depending on the IARC classification list. To calculate the carcinogenic risk for the two metals, we used the following formula:

$$LADD=\frac{C\times EF}{AT}\times\left(\frac{R\,inh\,child\times ED\,child}{BWchild}\times\frac{R\,inh\,adult\times ED\,adult}{BWadult}\right) \quad (7)$$

where all the factors are annotated in Supplementary file Table 2. The lifetime cancer risk can be calculated using:

$R=LADD/SF$ (8)

where SF value ranges from 10^{-6} to 10^{-4}.

RESULTS

Concentrations of Pb, Zn, Ni and Cr have been determined in the side-road dust samples from 22 areas within Baghdad city for different land-use areas (industrial, commercial, and residential). The maximum, minimum, and mean of total heavy metal concentrations are shown in Table 1. The distribution pattern of the four toxic metals (Cr, Ni, Pb and Zn) followed the same distribution in all sites whether industrial, commercial, or residential. It is possible that the high concentrations of toxic metals in soil samples on the side road in urban areas may be due to the leakage of heavy-duty fuel, as well as the wear of the tyres, motors and brakes, battery wastes and engine emissions may add high amounts of heavy metals to the dust.

Contamination indices

Geo-accumulation index

The maximum, minimum, and mean values of Igeo were calculated for each study site and given in Table 1. All Igeo values of the study samples were <1, which refer to uncontaminated soil. The Igeo values of the four metals were as follows: Zn ranged from 0.042 in Baya'a to -0.152 in Al-Ghadeer, Pb ranged from -0.0165 in Sheikh Omar to -0.416 in Baya'a, Ni values ranged from 0.082 Sheikh Omar to -0.219 Za'franiya, while Cr values ranged from 0.158 in Sheikh Omar to -0.235 in Hayy Al-Jami'a. The Igeo indicates a logarithmic relationship to measure the degree of soil contamination, and thus the minus sign for any value expresses the absence of influence of pollution sources in the soil. This reflects the non-participation of the geological source of contamination of those soils with heavy metals and the concentrations of these metals from anthropogenic activities. The range of the four heavy metals in Iraqi soils were Pb range 20–45 mg/kg, Ni range 40–100 mg/kg, Cr range 4–810 mg/kg with a mean value 180 mg/kg, while for Zn the range was 20–117 mg/kg with mean 56 mg/kg. In Equation (1), we adopted a background value from the soils, at a depth of 50 cm in urban areas of Baghdad city, to avoid the large variation in the index of geo-accumulation. It is important to note that the mean values of the four heavy metals in the Baghdad soils were: Pb, 36.31 mg/kg; Zn, 56.23 mg/kg; Cr, 12.9 mg/kg; and Ni, 123.03 mg/kg. Most of the metal concentrations were within the normal range of their distribution in Iraqi soils, except for Ni, its concentration was slightly higher than the background.

Pollution index (PI)

The values of the pollution index for each metal (Cr, Ni, Pb and Zn) in the side-road soils for different areas of Baghdad city are given in Table 2. The pollution index values for Cr ranged from 0.0 in the Al-Ghadeer to 1.44 in Sheikh Omar, while for Ni, the values ranged from 0.0 in Al-Taji to 1.82 in the Sheikh Omar area, whereas for the Pb, the values ranged from 0.0 to 1.9, and for the Zn, the values ranged 1.05–1.74 in the Karradah. It is worth noting that all the pollution factor values were within the second level of contamination (1≤PI<3). Contamination from low to moderate, and the highest pollution index was recorded in the Sheikh Omar and Baya'a sites due to the presence of industrial activity for the maintenance of vehicles and diesel engines, as well as heavy traffic during the hours of the day.

Health risk assessment

The present study showed high health risks for adults through the inhalation route than for children, which can be associated with high exposure duration and inhalation rate of adults than in children.

Non-carcinogenic risk

Tables 3 and 4 present the HQ and HI values for non-carcinogenic health risks for tested metals. For adults and children, the poising metals take the following order (Cr > Pb > Ni > Zn). The highest value for HI for the adults was 0.0028 while the least value was 0.0013. The highest value for HI for the children was 0.001 while the least value was 0.0007. From the above results, we notice that HQ< 1, so all data are <1, with the safe level USEPA indicating low health risks from road dust in the studied areas.

Carcinogenic risk

Carcinogenic risk can be defined as the probability of developing any type of cancer in a person from lifetime exposure to carcinogenic hazards[16]. In this study, the cancer risk for Ni and Cr was assessed by calculating the lifetime average daily dose (LADD) for the inhalation exposure route and the results are given in Table 5. The highest values for RCr (1.08) and RNi (540.02) were recorded in the Sheikh Omar site, while the lowest values for RCr (0.05) were recorded in the Hayy-Al-Jamia site, and for RNi (271.75) for the Abu Ghraib site.

Table 3. HQs and HIs from heavy metals given with their concentrations and reference dose in the studied sites' soils (adults)

No.	Sample site	ADD_{Cr} ($\times 10^{-8}$)	HQ_{Cr}	ADD_{Ni} ($\times 10^{-8}$)	HQ_{Ni} ($\times 10^{-6}$)	ADD_{Pb} ($\times 10^{-8}$)	HQ_{Pb} ($\times 10^{-6}$)	ADD_{Zn} ($\times 10^{-8}$)	HQ_{Zn} ($\times 10^{-8}$)	HI
1	Al-Sa'adoon	7.78	0.0025	3.350	1.34	2.38	6.80	3.01	8.60	0.0026
2	Sheikh Omar	8.32	0.0027	4.159	1.66	3.08	8.80	2.80	8.05	0.0028
3	Al Kefah	6.97	0.0023	3.274	1.31	3.01	8.50	2.38	6.82	0.0023
4	Adhamiyah	7.24	0.0024	3.010	1.20	2.55	7.20	2.01	5.75	0.0024
5	Sha'ab	6.57	0.0021	2.630	1.05	2.10	5.90	2.20	6.36	0.0022
6	Sadr City	6.84	0.0022	3.050	1.20	2.40	6.80	2.25	6.40	0.0023
7	Al Ghadeer	5.80	0.0019	2.380	0.96	2.04	5.80	1.98	5.67	0.0019
8	Baghdad Al-Jadida	7.73	0.0020	3.350	1.34	2.38	6.80	2.73	7.80	0.0026
9	Sina'a	6.52	0.0021	2.740	1.09	2.20	6.28	3.10	8.90	0.0022
10	Al-Jadriya	7.40	0.0024	2.549	1.02	3.06	8.74	3.00	8.60	0.0025
11	Karadah	7.92	0.0026	2.925	1.17	3.27	9.30	3.27	9.35	0.0026
12	Za'franiya	5.31	0.0030	2.066	0.83	1.77	5.06	2.09	5.98	0.0017
13	Kadhimiya	7.70	0.0025	2.710	1.08	2.30	6.50	3.03	8.66	0.0025
14	Taji	5.02	0.0016	2.280	9.12	2.01	5.70	2.36	6.70	0.0016
15	Mansour	7.73	0.0025	3.086	1.23	2.25	6.44	2.73	7.80	0.0025
16	Hayy Al-Jami'a	3.89	0.0012	2.300	0.94	2.38	6.82	2.09	5.98	0.0013
17	Ghazaliya	4.43	0.0014	2.490	1.00	2.17	6.21	2.01	5.75	0.0015
18	Safarat Complex	7.73	0.0025	2.380	0.95	2.12	6.05	3.01	8.60	0.0026
19	Abu Ghraib	5.31	0.0017	2.090	0.84	2.07	5.90	2.28	6.50	0.0018
20	Dora	6.17	0.0020	3.750	0.15	1.90	5.44	2.79	7.97	0.0021
21	Al-Saydiya	5.90	0.0019	3.220	0.13	1.48	4.21	2.63	7.50	0.0020
22	Baya'a	7.73	0.0025	3.810	0.16	3.01	8.58	3.11	8.80	0.0026

Table 4. HQs and HIs from heavy metals given with their concentrations and reference dose in the studied sites' soils (children)

No.	Sample site	ADD_{Cr} ($\times 10^{-8}$)	HQ_{Cr}	ADD_{Ni} ($\times 10^{-8}$)	HQ_{Ni} ($\times 10^{-7}$)	ADD_{Pb} ($\times 10^{-8}$)	HQ_{Pb} ($\times 10^{-6}$)	ADD_{Zn} ($\times 10^{-8}$)	HQ_{Zn} ($\times 10^{-8}$)	HI
1	Al-Sa'adoon	3.45	0.0012	1.48	5.95	1.05	3.02	1.30	3.80	0.0012
2	Sheikh Omar	3.68	0.0012	1.84	7.37	1.36	3.91	1.20	3.56	0.0013
3	Al Kefah	3.09	0.0010	1.45	5.80	1.33	3.81	1.06	3.03	0.0010
4	Adhamiyah	3.21	0.0011	1.33	5.33	1.13	3.23	8.90	2.54	0.0010
5	Sha'ab	2.91	0.0010	1.16	4.66	9.28	2.65	9.87	2.82	0.0009
6	Sadr City	3.03	0.0010	1.35	5.42	1.05	3.02	9.99	2.85	0.0010
7	Al Ghadeer	2.55	0.0010	1.06	4.23	9.04	2.58	8.80	2.51	0.0009
8	Baghdad Al-Jadida	3.42	0.0010	1.49	5.95	1.05	3.02	1.21	3.46	0.0011
9	Sina'a	2.89	0.0016	1.21	4.85	9.75	2.78	1.38	3.94	0.0001
10	Al-Jadriya	3.29	0.0010	1.13	4.52	1.35	3.87	1.33	3.80	0.0010
11	Karadah	3.51	0.0010	1.29	5.18	1.45	4.14	1.45	4.14	0.0010
12	Za'franiya	2.35	0.0007	9.16	3.66	7.85	2.24	9.28	2.65	0.0007
13	Kadhimiya	3.41	0.0010	1.20	4.81	1.02	2.92	1.34	3.84	0.0010

Continued

Table 4. Continued

No.	Sample site	ADD_{Cr} ($\times10^{-8}$)	HQ_{Cr}	ADD_{Ni} ($\times10^{-8}$)	HQ_{Ni} ($\times10^{-7}$)	ADD_{Pb} ($\times10^{-8}$)	HQ_{Pb} ($\times10^{-6}$)	ADD_{Zn} ($\times10^{-8}$)	HQ_{Zn} ($\times10^{-8}$)	HI
14	Taji	2.22	0.0010	1.01	4.04	8.92	2.55	1.05	2.99	0.0007
15	Mansour	3.42	0.0010	1.36	5.47	9.99	2.85	1.21	3.46	0.0010
16	Hayy Al-Jami'a	1.73	0.0005	1.04	4.18	1.05	3.03	9.28	2.65	0.0005
17	Ghazaliya	1.96	0.0007	1.10	4.42	9.63	2.75	8.92	2.55	0.0006
18	Safarat Complex	3.43	0.0017	1.05	4.23	9.39	2.68	1.33	3.81	0.0010
19	Abu Ghraib	2.35	0.0008	9.28	3.71	9.16	2.61	1.01	2.89	0.0007
20	Dora	2.73	0.0010	1.66	6.60	8.44	2.41	1.23	3.53	0.0009
21	Al-Saydiya	2.62	0.0009	1.42	5.71	6.54	1.87	1.17	3.30	0.0008
22	Baya'a	3.43	0.0017	1.69	6.75	1.33	3.81	1.38	3.94	0.0010

Table 5. Carcinogenic risks for metal elements in soil collected from areas of Baghdad city

No.	Sample site	Cr	$LADD_{Cr}$	R_{Cr}	Ni	$LADD_{Ni}$	R_{Ni}
1	Al-Sa'adoon	290	42.536	1.0127	125	18.339	435.502
2	Sheikh Omar	310	45.469	1.0826	155	22.731	540.022
3	Al Kefah	260	38.136	0.9080	122	17.896	425.050
4	Adhamiyah	270	39.602	0.9429	112	16.426	390.209
5	Sha'ab	245	35.935	0.8556	98	14.371	341.433
6	Sadr City	255	37.402	0.8905	114	16.728	397.177
7	Al Ghadeer	215	31.535	0.7508	89	13.052	310.077
8	Baghdad Al-Jadida	288	42.243	1.0057	125	18.335	435.502
9	Sina'a	243	35.642	0.8486	102	14.961	355.369
10	Al-Jadriya	277	40.629	0.9673	95	13.938	330.981
11	Karadah	295	43.269	1.0302	109	15.987	379.757
12	Za'franiya	198	29.042	0.6914	77	11.294	268.269
13	Kadhimiya	287	42.096	1.0022	101	14.814	351.885
14	Taji	187	27.428	0.6530	85	12.467	296.141
15	Mansour	288	42.243	1.0057	115	16.867	400.661
16	Hayy Al-Jami'a	145	21.268	0.5063	88	12.907	306.593
17	Ghazaliya	165	24.201	0.5762	93	13.640	324.013
18	Safarat Complex	288	42.243	1.0057	89	13.054	310.077
19	Abu Ghraib	198	29.042	0.6914	78	11.440	271.753
20	Dora	230	33.735	0.8032	140	20.534	487.762
21	Al-Saydiya	220	32.268	0.7683	120	17.601	418.082
22	Baya'a	288	42.243	1.0057	142	20.828	494.730

DISCUSSION

Our results reveal that the Sheikh Omar site recorded the highest mean value of heavy metal concentration and Hayy Al-Jami'a recorded the lowest mean value. This is due to the nature of the land use and the overpopulation of each area; Sheikh Omar is located in the center of Baghdad city, with high industrial activity, high populated area and heavy traffic, thus all these reasons may explain the higher concentrations of the heavy metals. In contrast, Hayy Al-Jami'a is a residential neighborhood and shopping area with weaker traffic.

Lead concentration in Iraqi soils varies depending on the parent rock and weathering erosion; lead (as Pb2+) forms carbonates, joined in clay metals like Fe and Mn oxides and in organic matter[28]. In Mesopotamia, the highest concentration of Pb is recorded in mid Euphrates and further south toward the marshland. Lead records high rates in Iraqi soils (urban and rural) because it is added to engine fuel to reduce the octane number; this is the main source of soil pollution of this toxic metal[29]. Zinc concentrations are also correlated to parent rock more than to pedogenic processes. Its concentrations increase significantly in arid regions and in saline-alkaline soils[30,31]. Zinc is replaceable with Mg^{2+} in silicate and has good mobility in acid oxidizing soils[32]. Urban soil contamination by Zn is closely associated with industries and the use of composted materials, fertilizers, and pesticides. Zn also results from mechanical abrasion of vehicles, fuel spills, and abrasion of brass alloy[32,33]. Other reasons associated with the addition of Zn to the urban soils is fertilizing, traffic, vehicle emissions, and tyre abrasion[31-33]. The results of the present study are in agreement with many previous studies that measured toxic metals in Baghdad soils[34]. Chromium highest level was recorded in the arid and semi-arid areas, reaching 2400 mg/kg. Chromium exists as Cr^{3+} in many soils, has slow mobility except in very acid environments, and its compounds have high stability in soil[31]. Usually, the parent rock determines its concentration in soil. In the North of Iraq (mountainous area), Cr concentrations are higher than the background value mainly due to the composition of the source rocks[29].

The observed concentrations were higher than the world average value (180 mg/kg); this may be due to its slow mobility in soil, so it will stay in the upper surface, but, at depth, its concentration is low (12.9 mg/kg). The Cr average value (247.36 mg/kg) is greater than that of chromium in the rural soil (17.33 mg/kg), about 14.27 times.

Nickel (Ni) is a well mobilized metal and precipitated with Fe and Mn oxides, or organically attached in soil, this explains the presence of high concentrations of Ni in the deep soil. The Ni presence in soil is strongly determined by climate and parent rock components. Its levels are high in arid and semi-arid regions, especially in saline-alkaline soils; in urban areas Ni is added to the soil as a result of continuous human activities, because it is widely used in electroplating and battery manufacturing[30,31].

Limitations

This study naturally has inherent limitations, primarily related to the small number of soil samples for assessment, which may inhibit the generalizability of the results.

CONCLUSIONS

Road dust is a source of many dangerous pollutants for residents of urban areas, due to its high toxicity and wide exposure by inhalation, ingestion, or by skin penetration. In this study, we determined the concentrations of four toxic metals (Cr, Zn, Ni and Pb) in road dust from 22 sites of Baghdad city with different land uses. Pollution rates with the four toxic metals were characterized as being moderate to low in all sites of the capital. Despite the low to moderate pollution rate, it gave high toxicity indicators for exposed people, this may be due to the synergy of more than one type of pollutant in the severe or high toxicity, and that heavy dust-borne toxic metals are not the only ones responsible for the toxicity.

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CONFLICTS OF INTEREST

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DATA AVAILABILITY

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