A Comparison between Concentrations of Heavy Metals in Indoor and Outdoor Dust in Haditha City, Western Iraq

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Abstract

The aim of this study is to determine the levels of selected heavy metals (cadmium, chromium, copper, lead and zinc) in indoor and outdoor dust and to make a comparison among them at 50 different locations in Haditha city, Al-anbar Governorate, from October to November, 2021. Dust samples from the indoor and outdoor in different locations (homes, schools, mosques and offices) were collected using a brush and a plastic hand shovel .The concentrations of the heavy metals selected in the indoor samples of dust were dominated by Zn with a concentration of 130.95 ± 123mg kg -1 followed by Pb > Cr > Cu and Cd with concentration of 91.83 ± 32, 50.65 ± 7.34, 26.64 ± 10.09 and 8.17 ± 0.98 mg kg -1, respectively. While the order of heavy metals in outdoor was Zn > Pb > Cr > Cu and Cd. The ratios of indoor and outdoor concentrations generally varied significantly from one place to another and from one metal to another. The originality of the metals can be explained through their concentrations ratios. The results showed that soil, street dust and house building have a prominent role in the concentration formed in the indoor and outdoor dust that is resulted most likely from the emissions of automobiles.

Keywords: Heavy metals; AAS; Indoor and Outdoor dust; Haditha

1. Introduction

It is especially vital to research human exposure to urban dust due to the presence of industrial and commercial operations, as well as easy access to facilities such as transportation, energy, water, entertainment, and healthcare. As a result, there is a lot of resource consumption and trash production, which could lead to the release of dangerous atmospheric dust [1].Hazardous compounds in urban dust can induce cancer and other non-cancer-related harmful consequences in people and other organisms when they come into contact with them by skin contact, inhalation, or ingestion. The presence of heavy metals in urban dust and soils is a good indicator of environmental contamination [2].Heavy metals are non-degradable, toxic, mutagenic, and carcinogenic materials. They have negative health impacts such as harm to the neurological system, cardiovascular mortality, delayed growth development, and asthma as a prevalent type of indoor floor dust pollution [3].Furthermore, heavy metal complexes are defined as metals with a density greater than 5.0 g/cm3, and contain 45 elements such as zinc (Zn), manganese (Mn), iron (Fe), mercury (Hg), copper (Cu), cadmium (Cd), and lead (Pb) [4]. The concentration and toxicity of urban dust in the atmosphere are affected by their location, source type, and proximity to sources, physico-chemical composition, and season. The concentration of hazardous metals in urban dust is about two to three times than that of hazardous metal concentrations in urban soils [5]. Heavy metals are found in both natural and anthropogenic sources in urban dust; nevertheless, anthropogenic activities (urbanization, industrialization, automobile traffic, biomass burning, and construction) resulted in significant enrichment of these metals. Heavy metal contamination in urban dust (both outdoor and indoor) is common. As a result, identifying and evaluating polluted regions for the presence of heavy metal is critical [2].The indoor and outdoor air qualities are closely linked, since air can be exchanged through doors, windows, and ventilation systems [6].The indoor environment has become a significant source of pollution exposure in the home (trace element, tobacco smoke, etc) Doyi et al. [7], Cheng et al. [8] indicate that footwear could bring outdoor dust which contains heavy metals indoors, and the dispersed particles could drift thoroughly in the house. Furthermore, building materials, wall paints, fuel combustion in heating and cooking, rubber products, smoking, plastic materials, electronic equipment, cutlery, and metals-composed jewelry are all main sources of dust containing heavy metals in household [9]. The aim of this study is to determine the levels of selected heavy metals (cadmium, chromium, copper, lead and zinc) in indoor and outdoor dust and through a comparison among them at 50 different locations in Haditha city.

2. Materials and Methods

Study Area Description

Haditha city is located in the western of Iraq, 240 km from Baghdad to the northwest, Fig1. This farming town is situated on the Euphrates River at 34°08′23″N 42°22′41″E. beside Al-Qadisiyyah lake, which is an artificial lake formed by the building of Haditha Dam, the biggest hydroelectric facility in the country. In this study, there are few small industries factories (stone, plastic, power plant and mechanical, electrical activities). The climate of Haditha city is arid to semi- arid. The average annual precipitation, Temperature and evaporation are 131mm, 370C and 234 mm, respectively [10].

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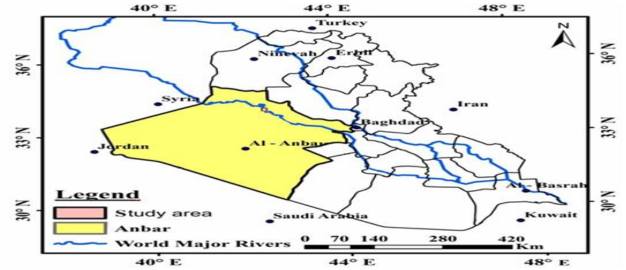

Fig.1. Locations map of Haditha city.

Sample Collection and Analysis

A total of fifty dust samples (indoor and outdoor) were taken from the study area from different locations (homes, schools, mosques and offices) in Haditha center, west Iraq, during two months (October to November, 2021) (Fig.2). A polyethylene brush and a plastic hand shovel were used to collect the samples. Twenty five of the samples were taken from the indoor areas, including the surfaces of furniture such as desks, chairs, sills of windows, lockers, and bookshelves. As for the outdoor areas, twenty-five samples were collected from the areas surrounding the sites from which the indoor samples were taken.

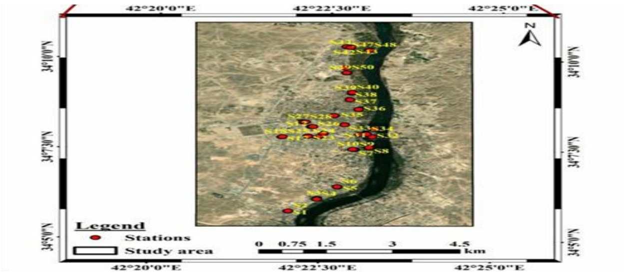

Fig.2. Locations of the sampled in indoor and outdoor in Haditha city.

The dust samples were put individually in sealable plastic bags, till to analysis in the laboratory. The equipment used for collecting the samples were cleaned after each sampling, and gloves were worn during all sampling and laboratory procedures, for preparing, all samples were put into oven and dried at 80C˚for 24 h, and then sifted using stainless steel sieves 53 µm to remove the hairs and other visible extraneous particles. A beaker was used to digest one gram of each dust sample separately with the employment of aqua regia (3:1 HCl and HNO3), and 30 ml of the aqua regia was added to each of the samples in the 150 ml beaker. A hot plate was employed to heat the samples for 2.5 h at 90C˚. After being digested, the mixture was cooled and then filtered into a volumetric flask of 50 mL, making it up to the mark with distilled water. An atomic absorption spectrophotometer (Model AA-Phoenix-986, American), that was joined to burner of air-acetylene flame, was employed to determine the concentrations of Zn, Pb, Cu, Cd and Cr in the samples digested. Standard solutions of the metals under study were used to calibrate the equipment.

3. Results

Heavy Metals in Outdoor and Indoor Dust

The concentrations of Cd, Cr, Cu, Pb, and Zn and descriptive statistics in the collected dust from fifty sites representing outdoor and indoor dusts in Haditha city are listed in Table 1.TABLE 1. Heavy metals' mean concentrations in outdoor and indoor dust in various sites in Haditha city, mg/kg

	Outdoor Indoor									
Heavy metals	Cd	Cr	Cu	Pb	Zn	Cd	Cr	Cu	Pb	Zn
Mean	7.83	48.08	22.54	96.30	139.99	8.17	50.65	26.64	91.83	130.95
Minimum	4.40	36.87	15.98	51.24	55.15	6.30	36.50	15.87	61.40	55.35
Maximum	9.70	60.40	33.80	222.75	618.15	10.00	60.70	62.65	179.50	635.01
Standard deviation	1.24	5.78	4.85	36.45	127.10	0.98	7.34	10.09	32.48	123.19
indoor/outdoor	1.04	1.05	1.18	0.95	0.94					

The ranges of Zn, Pb, Cr, Cu and Cd in outdoor dust samples were 55.15 to 618.15, 51.24 to 222.75, 36.87 to 60.40, 15.98 to 33.80 and 4.40 to 9.70 mg kg -1 with means 139.99, 96.30, 48.08, 22.54, 7.83 mg kg -1 respectively. While in indoor dust samples, the ranges of Zn, Pb, Cr, Cu and Cd were55.35 to 635.01, 61.40 to179.50, 36.50 to 60.70, 15.87 to 62.65, and 6.30 to10.00 mg kg-1 with means 130.95, 91.83, 50.65, 26.64, 8.17mg kg_1 respectively. The results proved that Zn mean concentration in indoor and outdoor samples was higher than other heavy metals, while Cd mean concentration was the lowest, as shown in Figures 3, 4.

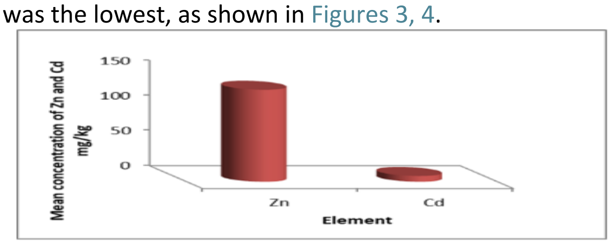

Fig .3. The mean concentrations of heavy metal Zn and Cd in indoor dust

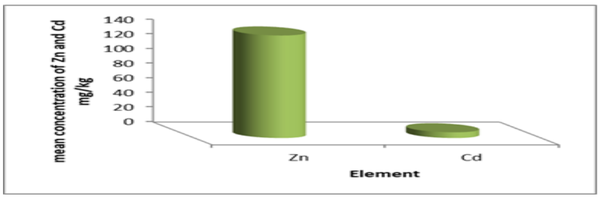

Fig .4. The mean concentrations of heavy metal Zn and Cd in outdoor dust

Generally, the high concentration of Zn is most likely due to the fact that Zn is an essential element and also many industries use it, including paints, cement, pesticides, pharmaceutical waste, batteries and accumulators, fluorescent lamps, office supply trash, building waste, metallurgical slag, galvanic waste, sewage sludge, and waste incinerator ash [11]. In addition to lubricating lubricants, as well as motor vehicle tires, wear brake linings [12].

The difference in the concentrations of heavy metals in the study area can be attributed mainly to human activities, in addition to the effects caused by natural sources. In this study, when comparing our results of all mean concentrations with many previous studies, the results show that some significant differences is arise. In the outdoor dust, the mean concentrations of Cd were recorded higher concentration than that in Babylon area, while the mean concentrations of Cu, Cr, Pb, Zn recorded are lesser than that in the same area [13].Globally, the mean concentrations of Cr, Cu recorded in our study were lesser than the mean concentrations recorded in Jordon, Saudi Arabia, Mexico and China cities [14-17], as shown in Table 2.

Table 2. The mean concentrations of heavy metals in outdoor dust from Haditha city, Iraq and other cities.

mean Concentrations (mg/kg)						
City	Cd	Cr	Cu	Pb	Zn	Reference
Riyadh, Saudi Arabia	0.07		42.20	4.57	62.40	Alotaibi et al.(2022)
Al-Karak city, Jordan		51.7	57.4	52.7		Al-Madanat et al.(2017)
city of Mexico		51.4	99.7	128.2	280.7	Aguilera et al.(2021)
China	164.6	136.9	196.7	2215.0	5867.0	Cao et al.(2020)
Haditha city	7.83	48.08	22.54	96.30	139.99	The current study

The mean concentration of Pb in the indoor dust samples, recorded is higher than that resulted in Al-Fallujah and Ramadi cities, while the mean concentration of Cu, Cr recorded is lesser than that in these cities Dulaimi [18, 19]. Globally, the mean concentrations of Cd recorded in our study were higher than the mean concentrations recorded in Egypt ,Saudi Arabia,Iran and China [8, 9, 17, 20].While the mean concentration of Cu recorded in our study is lesser than that reported in the same areas [8, 9, 14, 17, 20],as shown in Table 3 below.

Table 3. The heavy metals' mean concentrations of in indoor dust from Haditha city, Iraq and other cities.

mean Concentrations (mg/kg)						
City	Cd	Cr	Cu	Pb	Zn	Reference
Kafr El-Sheikh, Egypt	0.27	33.4	46.1	24.8	257	Jadoon et al.(2021)
Riyadh, Saudi Arabia	0.08		59.20	4.99	94.10	Alotaibi et al.(2022)
Al-Karak city, Jordan		72.5	90.4	51.9		Al-Madanat et al.(2017)
Bushehr, Iran	5.31	143.20	186.09	209.0	567.18	Hashemi et al.(2020)
Chengdu, China	2.37	82.7	161	123	675	Cheng et al.(2018)
Haditha city, Iraq	8.17	50.65	26.64	91.83	130.95	The current study

Due to no guidelines for heavy metals in dust are available, the comparisons have been done with soil guidelines for metals in many previous studies [21, 22]. The Canadian Soil Quality Guidelines (CSQG) provided by the Canadian Council of Ministers of the Environment (CCME) was employed to compare the outcomes. The standard values of Cd, Cr, Cu, Pb and Zn mentioned by CSQG were 10, 64, 63,140 and 200 respectively (CCME, 2014). The results of our study showed that the average concentrations of Cd, Cr, Cu, Pb and Zn in the outdoor and indoor dust samples are lower than the values mentioned in the guidelines of CSQG. This proves that the heavy metals' concentrations in the study areas do not constitute any pollution to these areas.

Correlation Matrix Analysis among the Metals in Outdoor and Indoor samples of Dust

The correlation matrix analysis of concentrations of Cd, Cr, Cu, Pb, and Zn in the outdoor and indoor dust in Haditha city are listed in Table 4.The obtained results showed that there is a positive significant correlation between Pb and Cu in outdoor dust. This correlation indicates the common origin or source of both metals. While the significant negative correlation between copper and chromium in outdoor dust reflects the different origin or source of both metals. Generally, the results of the correlation matrix analysis of the concentrations of heavy metals in the indoor dust showed positive significant correlations between Cd-Cu, Cu-Pb, and Cu -Zn and Pb -Zn. These correlations reflect the common source for these metals.Cu -Zn and Pb -Zn. These correlations reflect the common source for these metals.

TABLE 4. Correlation Coefficients for metals in outdoor and indoor samples of dust, marked correlations are significant at $P < 0.05$.

	Outdoor Indoor									
	Cd	Cr	Cu	Pb	Zn	Cd	Cr	Cu	Pb	Zn
Cd	1.00					1.00				
Cr	0.01	1.00				-0.25	1.00			
Cu	0.15	-0.53	1.00			0.53	0.05	1.00		
Pb	0.18	-0.30	0.58	1.00		0.11	0.20	0.53	1.00	
Zn	-0.03	0.08	0.21	-0.01	1.00	0.29	0.27	0.40	0.51	1.00

Comparison of Metal Concentrations among Indoor and Outdoor Dusts

The indoor/outdoor concentration ratio, analysis of variance (ANOVA), and regression analysis were employed to compare the heavy metal concentrations in outdoor and indoor samples of dust in Haditha city. The calculated mean ratio for Cadmium in indoor and outdoor dust is 1.04 (Table 1), a reference for the emission of Cadmium from indoor reason. The reported ratio for indoor–outdoor dust for Riyadh is 1.14 [17], indicating that the main contributors to indoor Cadmium are indoor sources, and that conforms to the findings of the current study. The means ratio of Copper in indoor–outdoor dust is 1.18 (Table 1). The Cu higher concentrations in house samples in comparison to the concentrations in the street dust show that Copper could be generated from an internal source. The ratio is slightly lower than the values of 1.4, 1.57 reported for Riyadh and Al-Karak Cities [14, 17]. The mean ratio for zinc in indoor–outdoor dust is 0.94 (Table 1). In comparison to the concentrations in indoor dust, the Zn higher concentrations in outdoor dust suggest that Zn pollution is caused by an external source. The reported indoor–outdoor ratio for Riyadh city is 1.5 [17], indicating that indoor sources are the main contributors to outdoor Zinc, which is contrary the findings of our results. The mean ratio of lead in indoor and outdoor is 0.95 (Table 1), showing that in the indoor environment, lead pollution could be attributed more to the outdoor sources than the internal sources. This value is almost similar to the stated value for Al-Karak city (0.98) [14] which conforms to the current findings. The ratio of 1.09 reported by Alotaibi et al. [17] is contrary to the current findings. The ratio between the indoor–outdoor mean levels of chromium is 1.05 (Table 1), an indication of 1.4 [14] which conforms to the current findings. The ANOVA results of the concentrations of heavy metals in indoor and outdoor dusts in the study area are listed in Table 5.

TABLE 5. Levels of significance among the metals' concentrations in indoor and outdoor samples of dust by employing one factor repeated measures ANOVA analysis

Heavy Metals	F	p
Cd	9.23	0.006
Cr	3.77	0.06
Cu	7.05	0.01
Pb	1.29	0.27
Zn	9.71	0.005

In current study, the results of ANOVA showed significant differences at $p \leq 0.05$ between the concentrations of Cu, Cd and Zn in the indoor dust and outdoor dust. This result indicates the different sources of releasing these heavy metals in the inner dust compared to the outer dust. There are insignificant differences at $p \leq 0.05$ between the concentrations of Cr and Pb. This result suggests that Cr and Pb are generated from common origins.

The regression analysis was employed to analyze the relationship between metal concentration in outdoor dust as independent variable, and metal concentration in indoor dust as a dependent variable. Two-dimensional scatterplots visualize a relation between the metal concentration in indoor dust and in outdoor dust. The scatterplots between Cd, Cu, and Zn in indoor dust and Cd, Cu, and Zn in outdoor dust are shown in Figures 5, 6, and 7.The Figures show that the concentrations of Cd, Cu and Zn in the indoor dust increase with the increase in the concentrations of these metals in the outdoor dust.

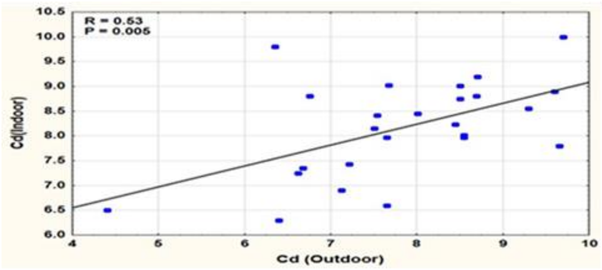

Fig.5. Scatterplot of Cd concentration in in indoor dust and outdoor dust

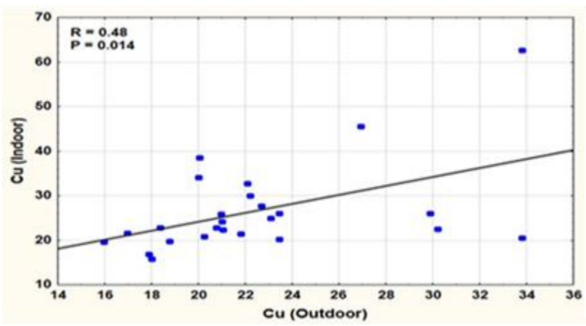

Fig.6. Scatterplot of Cu concentration in in indoor dust and outdoor dust

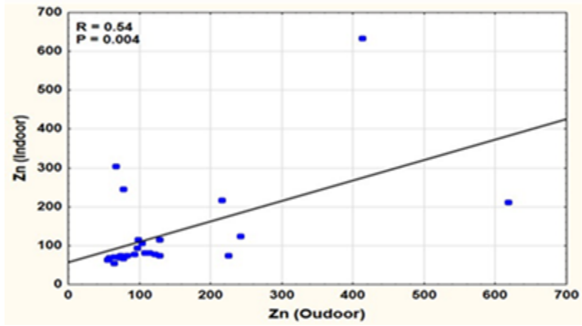

Fig.7. Scatterplot of Zn concentration in in indoor dust and outdoor dust

4. Conclusions

The current study was accomplished to determine and compare the levels of some selected heavy metals in indoor and outdoor samples of dust. Our results showed that the mean concentration of Zn in indoor and outdoor samples was higher than other heavy metals, while the mean concentration of Cd was the lowest. As the results clarified, the order of the heavy metals' concentration in the sites examined was Zn > Pb > Cr > Cu > Cd As in the outdoor area and Zn > Pb > Cr > Cu > Cd As in the indoor area. The study revealed some noticeable positive correlations observed between the indoor and outdoor dust concerning the heavy metals. These relationships indicate that those metals come from the common origin or source. The mean concentrations' ratio of the indoor–outdoor samples showed that Cd, Cr and Cu are caused by internal sources, while lead and zinc are caused by external sources. The outcomes of the regression analysis of heavy metals in the indoor and outdoor dust in the investigated area proved that the the concentrations increase of copper, cadmium and zinc in the outer dust leads to the increase of the concentrations of those metals in the indoor samples of dust.

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Highlights

Indoor and outdoor locations have different levels of metals in the dust.

The metal correlations point to unique sources in various environments.

The mean concentrations ratio for the heavy metals indicates internal and external sources

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