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Analysis of Selected Heavy Metals in Indoor Dust Collected from City of Khorramabad, Iran: A Case Study

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Abstract

Background: Indoor dust as a significant source of pollution in the urban environment can cause serious ecological and health problems. Therefore, the current study has been conducted to determine the Cadmium, Chromium, Lead, and Nickel contamination in house dust in the city of Khorramabad in 2017.

Methods: A total of 80 samples of indoor dust were collected from 20 regions of the study area. After sample digestion, the content of metals was determined using the inductively coupled plasma-optical emission spectrometer (ICP-OES).

Results: Based on the results, the average contents of Cd, Cr, Pb, and Ni (mg/kg) in the analyzed dust samples were 11.34 $\pm$ 2.25, 11.81 $\pm$ 5.29, 32.08 $\pm$ 20.60, and 60.19 $\pm$ 17.90, respectively. Also, comparison of the element levels in the house dust samples with the maximum permissible concentrations (MPC) established by environmental protection agency (EPA) shows that the average levels of Cd and Ni were higher than the MPC.

Conclusions: Due to average contents of elements in the dust samples, especially Cd and Ni, were higher than the MPC; the indoor dust can cause adverse effects on human health. Therefore, control of the anthropogenic sources that cause discharge of hazardous compounds, particularly toxic heavy metals into the outdoor, indoor, and street dust, is recommended.

Keywords: Health Impacts, Heavy Metals, Indoor Dust, Khorramabad City

1. Background

Dust consists of particulate or solid matter in the form of fine powder (< 100 μm), lying on the surface of objects and/or on the ground or blown by both mechanical or natural forces (1).

Indoor air pollution with dust and other pollutants particularly toxic heavy metals may emanate from infiltration of outdoor pollutants and/or vehicle emission or through incense burning, smoking, furniture, and building material or may result from occupants' activities (2, 3). Nowadays, public health is affected by the emission of pollutants that include potentially toxic metals in the air environment (4). It should be noted that indoor dust is known as one of the important pathways of human exposure to toxic heavy metals. Therefore, due to the fact that humans spend a great extent of their time in an indoor environment and metals in the indoor dust can accumulate in human through inhalation, ingestion or dermal contact absorption, the study of indoor dust is an important way of determining the origin, distribution, and level of heavy metals (5, 6). Of course indoor dust contamination is important from the point of view that young children, especially toddlers, spend most of their time indoors and much of this time is spent in contact with floors, engaging in mouthing of hands and other objects such as toys, or the consumption of food contaminated by hands they can easily ingest indoor dusts unintentionally (1, 7).

Elements like As, Cd, Co, Ni, and Pb are the most polluting metals in the urban environment and due to their specific features such as non-biodegradable and persistent, long biological half-life and bioaccumulation potential can pose several adverse effects on human health (8, 9).

Cadmium as a non-essential element is very toxic for humans. This element, with a natural occurrence in soil, can also spread in the environment through industrials and agriculture activities as an anthropogenic origin (10). Exposure to Cd may injure the kidney. In addition, poor reproductive capacity, impaired organ function, tumors and hepatic dysfunction, as well as hypertension are known as symptoms of chronic toxicity of this element (11). It has been shown that the presence of Cd in house dust may result from natural and anthropogenic sources such as rocks and soil erosion, fossil fuel combustion and agricultural activities (12). The guideline for MPC of Cd in indoor dust set by EPA is 10.0 mg/kg (13).

Although the Cr (VI) compounds are known as human carcinogen agents, Cr (III) is essential mineral and widely distributed in human body tissues and play an important role in protein, lipid and also carbohydrate metabolism (14). Nose ulcers, irritation to the lining of the nose, shortness of breath, asthma, and also wheezing are the some adverse effects that induced through breathing the high amounts of Cr (VI) (15). The MPC of Cr in indoor dust established by EPA is 64.0 mg/kg (13). Similar to cadmium the presence of Cr in the household dust may result from natural and anthropogenic sources.

Lead is recognized as a major environmental health risk, which can promote serious adverse effects on human health, particularly young children (16). Accidental inhalation of traffic exhaust fumes, consumption of Pb contaminated foods, and also ingestion of Pb-based paint are the main pathways that humans may be exposed to this toxic element (10). The MPC of Pb in indoor dust established by EPA is 140.0 mg/kg (13). It has been shown that the presence of Pb in indoor dust samples may result from the fossil fuel combustion. Even though geological structure and agricultural practices can lead to discharge, this element into the environment (17).

Nickel in a few trace contents plays an important role in the synthesis of red blood cells and may be beneficial to activate some enzyme systems; however, it becomes adverse effects on human health when taken in higher doses (18). Exposure to a high amount of Ni for a long time and/or Ni poisoning may lead to respiratory problems, liver, heart and nervous system damage, reduction in cell growth, lung cancer, and also decrease body weight. The MPC of Ni in indoor dust established by EPA is 50.0 mg/kg (13). The presence of Ni in indoor dust is believed to be from anthropogenic sources including corrosion in automotive parts and petrochemical plants (19).

In this field the mean concentrations of Cd and Ni (mg/kg) in indoor dust samples collected from Canada were determined 4.40 and 53.60, respectively (20). In another study the mean contents of Cr and Ni in indoor dust samples collected from Muscat, Oman, were reported 34.0 mg/kg and 130.0 mg/kg, respectively (21). In addition, Chattopadhyay et al., (2013), reported that the mean concentration of Cd, Cr, and Ni (mg/kg) in household dust samples of Sydney, Australia, were 1.90, 64.30, and 15.60, respectively (22).

According to the Luo et al., (2012), hazard identification, exposure assessment, dose-response assessment, and risk characterization are the main components of health-risk assessment (HRA). Here, data compilation and evaluation of past studies helps to determine whether the particular heavy metal exposure may increase the risk of causing human adverse health effects (23).

Due to the fact that people spend more than 50% of their time in an indoor environment, indoor dust may be more hazardous to human health among various types of dust (24). Therefore, nowadays assessment of heavy metal contents in the dust from indoor environment increase rapidly (25, 26).

2. Objectives

In the present study, Cd, Cr, Pb, and Ni concentrations in different samples of houses dust in the city of Khorramabad, Iran, have been determined using ICP-OES.

3. Methods

3.1. Study Area

The city of Khorramabad, as the center of Lorestan province, is one of the medium-sized ancient cities in the western part of Iran located at an altitude of 1147 m above sea level and lies between longitudes 32°30'20" E and latitudes 21°48'16" N with an urban area about of 35 km^2 and a population of 373 416. The annual average temperature and annual average precipitation of this city are 16.1°C and 509 mm, respectively (27).

3.2. Reagents

Standard stock solutions of analyzing element ions (Sigma-Aldrich, Spain) at the content of 1000 mg/L were used to prepare all working solutions after appropriate dilution.

3.3. Sampling and Analytical Methods

In this study, during the spring season in 2017, in total 80 dust samples were collected from the residential floor, lamp covers, uncleaned windowsills, and cabinet roofs of the private households in 20 relatively large residential quarters in the city of Khorramabad using a brush and plastic spatula. Then, all collected indoor dust samples were stored in self-sealing polyethylene bags for transport and storage (28). Also, due to research limitations, dust collected from each house was mixed as one sample to avoid comparison between the samples.

In the laboratory, all samples were air-dried naturally for 14 days and then sieved through a 0.149-mm nylon mesh to remove small and refuse stones. Finally 25.0 g of the each sieved dust sample was separated according to the method introduced by Chen et al. (2014), then digested using a mixture of 3 mL concentrated nitric acid, 6 mL of concentrated perchloric acid, and 14 mL of concentrated hydrofluoric acid and diluted with 2% nitric acid to 50 mL after filtering through Whatman 542 (12, 29, 30). The concentrations of Cd, Cr, Pb, and Ni were determined using ICP-OES at the wavelengths (nm) of 226.50 for Cd, 267.716 for Cr, 220.35 for Pb, and 231.60 for Ni. In addition, the accuracy of the method was assessed based on the method described by Lin et al., (2015a) (30). The results showed good accuracy, with recovery rates (%) from 96.70 to 101.10 for Cd, from 92.60 to 99.80 for Cr, 95.40 to 102.30 for Pb, and 91.70 to 98.90 for Ni.

3.4. Statistical Analysis

The statistical analysis of the results consisted with Kolmogorov-Smirnov normality test, an ANOVA parametric test with a DMS post hoc and Duncan multiple range test for study of the variance homogeneity, independent one sample t-test for comparing the mean contents of heavy metals in the house dust samples with MPC, and the 2-tailed test of Pearson correlation to measure the degree of correlation between the studied elements in house dust.

4. Results

The mean concentration (mg/kg) of elements in the dust samples is presented in Table 1. Data in Table 1 showed that among the studied dust samples, Cd was detected in amounts ranging from 8.02 to 17.72, Cr ranged from 3.49 to 22.55, Pb ranged from 10.28 to 101.65, and Ni ranged from 25.0 to 89.47.

Based on the Pearson's correlation coefficient, positive relationships among Cd and Pb ($r = 0.566$, $P < 0.01$), between Cd and Ni ($r = 0.389$, $P < 0.01$), between Cr and Pb ($r = 0.253$, $P < 0.05$), between Cr and Ni ($r = 0.794$, $P < 0.01$), and between Pb and Ni ($r = 0.541$, $P < 0.01$) was found. It means that, when the Cd and Cr contents increased, Pb and Ni contents increased as well. In addition, when the Pb contents increased, Ni contents increased.

5. Discussion

Nowadays, due to the potential adverse health effects of toxic heavy metals, the heavy metal contamination of indoor dust derived from indoor activity and outdoor sources are known as a major environmental issue (20, 30, 31). Therefore, the current study was conducted to assess the cadmium, chromium, lead, and Nickel in different samples of the houses dust from the city of Khorramabad.

5.1. Cadmium

Long-term exposure to Cd leads to hypertension, anemia, arthritis, diabetes, hypoglycemia, headaches, cardiovascular disease, osteoporosis, kidney disease, and particularly cancer (32, 33). Based on the results, the content of Cd in dust samples with an average of 11.34 mg/kg was higher than the MPC. Meanwhile, the highest level of Cd with an average of 15.95 ± 0.45 mg/kg was found in the station with high traffic intensity. Here, it may be concluded that the sources of Cd in indoor dusts of Khorramabad mainly originated from automotive emissions and corrosion of the brake lining. However, the geological structure of the study area, particularly the existence of calcareous stones and clayey limestone, may result from the presence of Cd in the dust samples (34, 35). Concerning this, Rashed (2008) reported that the average content of Cd in the indoor dust collected from Aswan city, Egypt, was 3.72 mg/kg (4). A comparison of the Cd contents in the indoor dust samples in the study area and other selected regions are presented in Table 2.

5.2. Chromium

Chromium is used in many alloys, especially stainless steel; therefore, grinding, welding, and also polishing of stainless steel can lead to discharge of this element into the environment. Chronic exposure to Cr can cause skin irritation, circulatory, kidneys or liver damage, and nerve disorders (15, 41). In this study, Cr content in house dust samples with an average of 11.81 mg/kg was lower than the MPC. Also, the highest content of Cr with an average of 21.90 ± 0.47 mg/kg was found in the station with high traffic intensity. However, based on the results of independent samples test, no significant difference was found between heavy and low traffic intensity stations. As shown in the literature, the presence of Cr in the dust samples could be attributed to the waste incineration, combustion of fossils fuels, tyre abrasion, and engine wear. Although, the geological structure of the study area (i.e. existence of calcareous stones and clayey limestone) (35) and use of metal-containing pesticides, especially chromated copper arsenate in agricultural activities, may have been leads to the analyzed dust samples contamination to Cr (7, 15). The obtained results are against the findings of Lin et al., (2015), who reported that the values of Cr in indoor dust samples collected from Anhui rural, China, was 113.68 mg/kg (30). Compared with indoor dust from other cities, Darus et al., (2012), reported that the content of Cr in indoor dust samples collected from Shah Alam, Malaysia with an average of 16.88 were lower than the MPC (7). Also Akhter and Madany (1993) reported that against the current study, the Cr content in the house dust collected from Bahrain with an average of 144.7 mg/kg was much higher than the MPC (42).

Table 1. Heavy Metal Analysis of House Dust (mg/kg)[a]

Sampling Station	Metal Concentration ± SD			
	Cd	Cr	Pb	Ni
1	8.83 ± 0.14 ab	13.77 ± 0.64 j	23.43 ± 0.28 cd	70.55 ± 0.16 l
2	9.50 ± 0.28 b	11.70 ± 0.66 gh	23.75 ± 0.04 cd	69.50 ± 0.88 k
3	9.15 ± 0.23 ab	14.40 ± 0.32 k	16.87 ± 0.38 b	59.14 ± 0.35 h
4	8.38 ± 0.42 a	13.90 ± 0.20 jk	15.90 ± 0.28 b	62.34 ± 0.45 i
5	15.95 ± 0.45 h	10.33 ± 0.28 f	47.60 ± 0.39 h	75.85 ± 0.39 n
6	9.01 ± 0.47 ab	5.28 ± 0.17 b	11.50 ± 0.24 a	37.26 ± 0.26 c
7	8.78 ± 0.75 ab	3.90 ± 0.30 a	12.30 ± 0.25 a	25.50 ± 0.35 a
8	10.89 ± 0.16 cd	8.10 ± 0.20 d	21.50 ± 0.16 c	56.70 ± 0.32 g
9	12.63 ± 0.75 g	21.90 ± 0.47 m	42.60 ± 0.33 g	70.00 ± 0.41 k
10	11.00 ± 0.21 cd	13.76 ± 0.30 j	39.08 ± 0.29 f	76.63 ± 0.29 o
11	10.66 ± 0.66 c	6.50 ± 0.21 c	10.70 ± 0.34 a	28.15 ± 0.12 b
12	11.11 ± 0.63 cde	12.25 ± 0.35 i	14.77 ± 0.33 b	46.73 ± 0.38 e
13	12.00 ± 0.79 fg	4.04 ± 0.42 a	24.32 ± 6.06 d	41.06 ± 0.21 d
14	11.35 ± 0.75 cdef	6.45 ± 0.31 c	29.32 ± 0.46 e	41.06 ± 0.21 d
15	11.74 ± 0.92 defg	21.63 ± 0.30 m	38.55 ± 0.24 f	80.20 ± 0.23 p
16	12.38 ± 0.39 g	9.78 ± 0.33 e	101.02 ± 0.52 j	66.82± 0.35 j
17	17.07 ± 0.62 i	12.05 ± 0.16 hi	50.85 ± 4.72 i	71.46 ± 0.20 m
18	11.92 ± 0.38 efg	14.34 ± 0.32 k	51.03 ± 0.24 i	80.53 ± 0.34 p
19	12.51 ± 0.36 g	20.94 ± 0.43 l	37.44 ± 0.13 f	88.91 ± 0.43 q
20	12.03 ± 0.63 fg	11.23 ± 0.24 g	29.07 ± 0.35 e	55.42 ± 0.52 f
Min	8.02	3.49	10.28	25.00
Max	17.72	22.55	101.65	89.47
Mean	11.34	11.81	32.08	60.19
SD	2.25	5.29	20.60	17.90

[a]The letters (a, b, c, d, …) represent the significant difference between the mean concentration of metals in house dust samples that computed by One-way ANOVA (P = 0.05).

Table 2. Comparison of the Element Concentrations (mg/kg) in Indoor Dust Samples Collected from Khorramabad City and Other Selected Regions

Sample	Location	Element				Reference
		Cd	Cr	Pb	Ni	
Indoor dust	Iran	11.34	11.81	32.08	60.19	Present study
	China	-	94.60	8.40	-	(36)
	Saudi Arabia	-	-	23.0	-	(37)
	China	-	-	348.73	-	(30)
	Malaysia	-	-	31.24	-	(7)
	UK	1.95	84.30	-	43.40	(31)
	Malaysia	10.65	-	-	49.67	(38)
	UK	1.10	-	-	53.30	(3)
	Australia	2.0 - 2.50	104.0 - 202.0	-	27.0 - 49.0	(39)
	USA	-	-	-	23.6	(40)

A comparison of the obtained results with other studies is shown in Table 2.

5.3. *Lead*

Lead is a major pollutant in the urban environments that release from combustion of gasoline containing Pb, burning gas for heating, abrasion of the automobile tyres, engine wear, radiators, leaks, and spills from batteries (4, 43). In this study the mean content of Pb in dust samples with an average of 32.08 mg/kg was lower than the MPC. This can be attributed to the wide use of unleaded petroleum during the last two decades in Iran. The presence of Pb in dust samples may result from the accumulation of this element in urban bare soil due to pollution from previous decades. However, the geological structure of the study area and industrial and agricultural activities might also pose the dust samples contamination to this element. As the literature shows, the concentrations of Pb in the indoor room dust were 171.3 $\pm$ 187.0 mg/kg (4). A comparison of the obtained results with other studies is presented in Table 2.

5.4. Nickel

Nickel is representative metal of anthropogenic activities including machining, coal combustion, metallurgy and so on (22, 36, 44). Based on the results, nickel is moderately polluted in 70.0% of dust samples. Also, the Ni concentration, with an average of 60.19 mg/kg, was much higher than the MPC. As the literature shows, the source of Ni in dust is believed to be from lubricants corrosion of cars, tyre abrasion, brushing, engine wear, brake dust, and bearing metals (7, 19). Although, due to the fact that the mean content of Ni was greatly higher than background value of this element in soils (31 mg/kg) (45), Ni in dust samples may originated from natural source such as soil erosion. However, the activities of the Lorestan petrochemical complex might also pose the dust samples contamination to this element. Nickel content in the literature has been found in the range of 17.06 mg/kg to 127.25 mg/kg in indoor dust in Anhui rural, China (12). Also, Ni concentrations (mg/kg) in indoor dust collected from an industrial area in China was detected in amounts ranging from 29.60 to 67.10 (36), while Darus et al., (2012), reported that the mean concentration of Ni in indoor dust was 9.0 mg/kg (7). A comparison of our findings with other studies is shown in Table 2.

5.5. Conclusion

Based on the results of this study, the mean contents of Cd and Ni in house dust samples were higher than the MPC. Therefore, in order to reduce the potential ecological and human health risk through heavy metals, content of indoor, outdoor, and street dust control of the anthropogenic activities such as paint, industrial activities, construction activities, power generations, corrosion of automobiles parts, vehicle emissions, alloy materials, metal objects, and also fossil fuel combustion that they cause discharge of hazardous pollutants into the environment is recommended. In addition, for reduce vehicle emissions originated toxic heavy metal pollution in dusts, the use of gasoline without lead should be encouraged and vehicles with catalytic converters should be preferred.

5.6. Research Limitations

Although the research has reached its aims, there were some unavoidable limitations as described below:

1- Due to the insufficient funds, there was no possibility of conducting the study on other heavy metals such as As, Co, Cu, Fe, Hg, Mn, and Zn.

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Footnotes

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