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Determination and Analysis of Heavy Metals Concentration in Indoor Dust Samples in Building Material Factories in Sulaymaniyah Governorate, Iraq

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ABSTRACT

The purpose of this study is to determine and analyze the concentrations of heavy metals such as cooper (Cu), lead (Pb), chromium (Cr), cadmium (Cd), mercury (Hg), and arsenic (As) in indoor dust samples in 9 types of building material factories: Cement, gypsum, gypsum board, red brick, concrete block, tile, marble, behaton (paving slabs), and stone crusher in 28 various factory locations in Sulaymaniyah governorate-Iraqi Kurdistan by using X-ray fluorescence (XRF) spectroscopy technique. Standard levels of heavy metals in dust samples vary depending on the country, organization, and specific guidelines being referenced. There is no universal standard, but regulatory bodies such as the world health organization (WHO), the U.S. environmental protection agency (EPA), and the European union (EU) have set recommended limits for heavy metal concentrations in dust, soil, and airborne particulates, such as (Pb) 50-500 ppm, (Cd) 1-10 ppm, (As) 5-50 ppm, and (Cr) 10-100 ppm. In this study, the cement factory exhibited the highest levels of Cu (156.50 ± 16.26 ppm), Pb (89.90 ± 1.41 ppm), Cr (52.30 ± 4.95), Cd (59.40 ± 3.54 ppm), Hg (6.85 ± 0.24 ppm), and as (40.40 ± 3.54 ppm). In contrast, gypsum board factories consistently displayed the lowest concentrations of most of heavy metals, with Cu, Pb, Cr, Cd, Hg, and as values at 23.60 ± 0.30 ppm, 1.75 ± 0.93 ppm, 0.64 ± 0.13 ppm,1.39 ± 0.25 ppm, 0.20 ± 0.01 ppm, and 1.80 ± 0.22 ppm, respectively. Other factory types showed varying degrees of contamination. In comparison with studies reported elsewhere, the concentration levels of cadmium (Cd) and mercury (Hg) in our study were greater. These findings highlight significant disparities in heavy metal concentrations across industrial activities, emphasizing the need for targeted environmental monitoring and mitigation strategies to manage industrial pollution effectively.

Keywords: Building material factories, XRF, indoor dust, heavy metals, Sulaymaniyah governorate.

INTRODUCTION

Indoor dust plays a crucial role in the indoor environment, as it gathers particles originating from both inside and outside sources. This common material serves as a repository for numerous contaminants, including heavy metals, which can present serious health risks to humans. Heavy metals are metallic elements characterized by their high density (Shi and Wang, 2021).

The international agency for research on cancer (IARC) classified aluminum (Al), cobalt (Co), copper (Cu), iron (Fe), nickel (Ni) and zinc (Zn) as non-carcinogenic elements, whereas arsenic (As), cadmium (Cd), chromium (Cr) and lead (Pb) are classified as both carcinogenic and non-carcinogenic elements (Sanborn *et al.*, 2002).

The heavy metals Cr, As, Cd, and Pb represent ubiquitous environmental pollutants causing adverse health effects, including cancers. They are toxic even at low levels and can accumulate in living organisms. Due to their persistent nature and potential for bioaccumulation, these metals pose a significant health risk, particularly in indoor environments where human exposure can be continuous and prolonged (Sable *et al.*, 2024).

Numerous factors, including soil, outdoor air, consumer goods, building materials, and human activity, contribute to the presence of heavy metals in indoor dust. Vehicle emissions, industrial operations, and naturally occurring geological formations are the primary outdoor sources (Sun *et al.*, 2023; Hussein, 2023).

Upon infiltration, these particles settle and mix with indoor sources such as paint, electronic devices, furniture, and cleaning products (Chu *et al.*, 2023).

Additionally, human activities, including smoking, cooking, and the use of cosmetics, contribute to the accumulation of heavy metals within indoor spaces (Wang *et al.*, 2023).

Geographical location, building type, and the lifestyle choices of the occupants can all have a substantial impact on the kinds and quantities of heavy metals found in dust. Because these metals can be absorbed through skin contact, inhalation, and ingestion, their presence in indoor dust poses a serious risk to public health. Children should be particularly concerned about this since their frequent hand-to-mouth behavior makes them more susceptible to exposure (Pelfrêne and Douay, 2018; Hussein, 2023).

While exposure to mercury mostly affects the central nervous system, exposure to cadmium can cause kidney damage, bone loss, and an increased risk of cancer. These metals' general health hazards emphasize the necessity of routine monitoring and initiatives to lessen their presence in indoor environments (Nordberg *et al*., 2022).

A number of variables, including the age and construction materials of buildings, the surrounding environment, and human behavior, influence the spread of heavy metals in indoor dust. For instance, lead levels in indoor dust are typically greater in older buildings with lead-based paints (Menrath *et al.*, 2015; Hussein, 2013).

In a similar vein, homes close to highways or industrial regions are more likely to have higher levels of heavy metals because of outside pollution. How heavy metals are stored and transported inside indoor environments is also influenced by the size, surface area, and chemical makeup of dust particles (Wang *et al.*, 2020; Aladdin, *et al*., 2022).

A variety of regulatory frameworks and standards have been developed to reduce exposure to heavy metals in indoor dust, in recognition of the health risks they bring. For example, the environmental protection agency (EPA) of the United States has set particular thresholds for lead dust in residential areas (Jin *et al.*, 2020).

Mitigation measures involve regular cleaning with high-efficiency particulate air (HEPA) filters, limiting the use of products containing heavy metals, and enhancing ventilation systems to reduce the buildup of indoor pollutants (Braun *et al.*, 2021).

Because hazardous metals can be released during industrial operations in building material plants, heavy metal pollution in indoor dust poses a serious risk to occupational health. Workers are more likely to inhale, consume, and come into touch with these toxins due to the enclosed nature of these workplaces. Comprehensive research on the level of heavy metal contamination, its sources, and its possible health effects is lacking, despite the substantial risk associated with these environments. This study aims to fill these gaps by evaluating heavy metal concentrations and exposure risks in the indoor dust of building material factories in Sulaymaniyah governorate, Iraq.

MATERIALS AND METHODS

Study area

The study was conducted in 28 building material factories in Ranya, Chamchamal, Kalar, Penjwen, Dokan districts and Tanjaro, Bazian, and the industrial area in Sulaymaniyah (Sulaimani) district located in Sulaymaniyah governorate Fig. (1). Sulaymaniyah is a governorate located in the northeastern part of Iraq, within the Iraqi Kurdistan region, specifically in its southeastern area. Sulaymaniyah city, situated at the heart of the governorate, is located at coordinates (35° 33′ 14.99″ N) and (45° 26′ 58.68″ E), with an elevation of 864 meters above sea level (Hussein *et al*., 2013).

These areas are home to a high concentration of building material factories, including those producing cement, red brick, gypsum, gypsum board, tile, marble, concrete blocks, behaton (paving slabs), and stone crushers. Industrial activities in these regions have grown considerably in recent decades, driven by rapid urbanization and infrastructure development. As a result, the factories release large quantities of dust containing various heavy metals, which can accumulate indoors and pose health risks to workers and nearby residents. Sulaymaniyah governorate has a semi-arid climate, with hot summers and mild winters, which may affect the dispersion and settling of dust (Majid, 2016; Ismail *et al*., 2020).

The study area was selected due to the high concentration of industrial activities and its potential implications for environmental pollution and public health. Sampling locations were defined according to GPS coordination (Table 1).

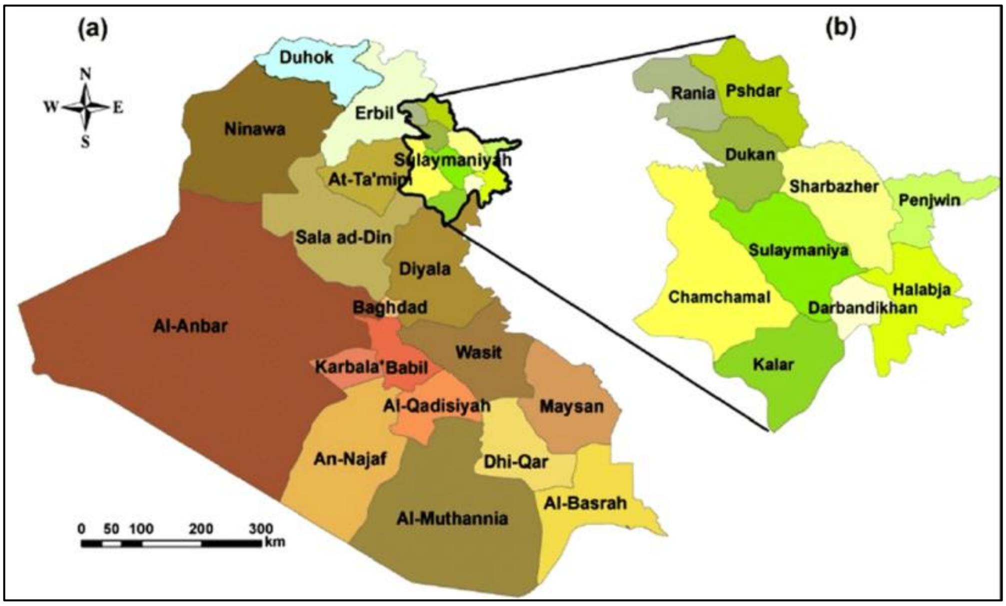

Fig. 1: (a) Map of Iraq. (b) Location study of Sulaymaniyah governorate.

Table 1: GPS coordinates for the locations of factories dust samples collection.

No.	Factories	Locations	GPS Coordinates	
			Latitude (N)	Longitude (E)
1	Cement 1	Bazian	35° 63' 52.36"	45° 09' 78.51"
2	Cement 2	Tanjaro	35° 29' 00.36"	45° 25' 34.50"
3	Gypsum 1	Bazian	35° 71' 23.12"	45° 19' 44.50"
4	Gypsum 2	Bazian	35° 77' 32.34"	45° 23' 70.41"
5	Gypsum 3	Bazian	35° 68' 35.46"	45° 12' 50.32"
6	Gypsum 4	Tanjaro	35° 24' 32.26"	45° 21' 64.09"
7	Gypsum 5	Tanjaro	35° 21' 15.24"	45° 19' 54.40"
8	Gypsum Board 1	Industrial Area / Sulaymaniyah	35° 33' 59.58"	45° 23' 12.33"
9	Gypsum Board 2	Industrial Area / Sulaymaniyah	35° 33' 73.18"	45° 23' 43.53"
10	Gypsum Board 3	Industrial Area / Sulaymaniyah	35° 33' 89.23"	45° 23' 76.50"
11	Red Brick 1	Bazian	35° 56' 10.58"	45° 43' 21.33"
12	Red Brick 2	Bazian	35° 58' 23.48"	45° 44' 02.35"
13	Concrete Block 1	Ranya	36° 25' 65.25"	44° 88' 27.89"
14	Concrete Block 2	Chamchamal	35° 53' 11.01"	44° 82' 71.91"
15	Concrete Block 3	Kalar	34° 63' 12.63"	45° 31' 76.62"
16	Concrete Block 4	Penjwen	35° 62' 22.08"	45° 94' 88.45"
17	Concrete Block 5	Dokan	35° 93' 06.43"	44° 96' 29.35"
18	Tile 1	Industrial Area / Sulaymaniyah	35° 34' 39.52"	45° 24' 22.23"
19	Tile 2	Industrial Area / Sulaymaniyah	35° 34' 53.58"	45° 24' 30.15"
20	Tile 3	Industrial Area / Sulaymaniyah	35° 34' 84.38"	45° 24' 42.43"
21	Marble 1	Industrial Area / Sulaymaniyah	35° 35' 19.38"	45° 26' 22.37"
22	Marble 2	Industrial Area / Sulaymaniyah	35° 35' 27.54"	45° 26' 29.43"
23	Marble 3	Industrial Area / Sulaymaniyah	35° 35' 59.58"	45° 26' 34.14"
24	Behaton (Paving Slabs) 1	Industrial Area / Sulaymaniyah	35° 32' 79.59"	45° 21' 44.23"
25	Behaton (Paving Slabs) 2	Industrial Area / Sulaymaniyah	35° 32' 64.48"	45° 21' 32.23"
26	Behaton (Paving Slabs) 3	Industrial Area / Sulaymaniyah	35° 32' 51.33"	45° 21' 29.35"
27	Stone Crusher 1	Bazian	35° 51' 65.30"	45° 02' 27.46"
28	Stone Crusher 2	Tanjaro	35° 32' 16.46"	45° 30' 34.45"

Sample collecting and preparation

Dust samples were collected from the indoor environment of a total 28 different building material factories, including production place, for Sulaymaniyah governorate, during June-November 2024. Samplings were done by using Go-Des GD-B627 wireless vacuum cleaner as a dust collector. At least 50g of indoor dust was collected and transferred into plastic containers and clearly labeled as shown in Fig. (2). The sample containers were moved to the laboratory and we used 20g of each dust samples and we turned them into pellets by using a press machine as shown in Fig. (3). A manual press machine (TP HERZOG) with a maximum load (pressure) of 200 KN has been employed; 200KN=20 tons=20,000kg. In order to create pressed powder sample tablets for XRF or X-Ray diffraction (XRD) analysis, the TP is a manually operated benchtop pelletizing press (thman and Hussein, 2025).

X-ray fluorescence (XRF)

XRF is an analytical technique used for checking the chemical makeup of various materials. The substances may be in the form of a liquid, solid, powder, thin film, or another material. Additionally,

Fig. 2: Dust sample.

Fig. 3: Pellet sample.

RF can occasionally be used to ascertain the composition and thickness of coatings and layers. There are two main methodological techniques that are wavelength dispersive analysis (WDXRF) and energy dispersive analysis (EDXRF) (Marguí *et al.,* 2022).

In this study, Rigaku-EDXRF Fig. (4) was used. EDXRF have a detector that is able to measure the different energies of the characteristic radiation coming directly from the sample. The detector can separate the radiation from the sample into the radiation from the elements in the sample. This separation is called dispersion. Energy dispersive X-ray fluorescence (EDXRF) technology is an appropriate option for these tests because to its high detection limits, sensitivity at ppm levels, and non-destructive nature (i.e., materials remain intact for additional analysis or treatments). This method is designed for the fast qualitative and quantitative measurement of major, minor, and trace elements across various sample types, and it does not require extensive training or expertise from the operator (Brouwer, 2010).

Fig. 4: X-ray fluorescence spectrometry (XRF) Instrument with their computer program.

X-ray fluorescence spectrometry (XRF) is widely preferred by petrologists and geochemists for powder analysis (Najam *et al.*, 2024).

The disc pellet samples were placed in the chamber and analyzed with a 20 mm diaphragm under vacuum Fig. (5). The main components of the spectrometer include the sample chamber and the block unit (Hussein, 2023).

Fig. 5: XRF illustrates the sample chamber.

RESULTS AND DISCUSSION

In this study, the concentrations of heavy metals in various building material factories are presented in (Table 2) as mean (average) values with standard deviation errors (S.D) in parts per million (ppm). Cement, gypsum, gypsum board, red brick, concrete block, tile, marble, behaton (paving slabs), and stone crusher factories showed varying levels of heavy metal concentrations, indicating distinct environmental contamination profiles as shown in Fig. (6).

Table 2: Mean values of heavy metals concentration (ppm) of indoor dust in the factories.

No.	Factories	Mean value ± S.D of heavy metals concentration (ppm)					
		Cu	Pb	Cr	Cd	Hg	As
1	Cement	156.50 ±	89.90 ± 1.41	52.30 ± 4.95	59.40 ± 3.54	6.85 ± 0.24	40.40 ± 3.54
2	Gypsum	65.62 ± 0.94	27.74 ± 0.67	11.66 ± 0.60	16.82 ± 0.56	0.25 ± 0.01	10.22 ± 0.33
3	Gypsum Board	23.60 ± 0.30	1.75 ± 0.93	0.64 ± 0.13	1.39 ± 0.25	0.20 ± 0.01	1.80 ± 0.22
4	Red Brick	87.20 ± 0.85	32.60 ± 5.66	34.15 ± 0.92	14.70 ± 1.41	0.24 ± 0.03	19.90 ± 1.41
5	Concrete Block	76.08 ± 1.22	67.98 ± 1.39	36.90 ± 1.39	45.92 ± 1.48	5.76 ± 0.12	24.04 ± 1.15
6	Tile	51.93 ± 0.45	16.77 ± 0.65	2.50 ± 0.33	3.85 ± 0.13	1.56 ± 0.04	4.99 ± 0.12
7	Marble	92.43 ± 0.57	28.97 ± 0.40	3.81 ± 0.67	7.85 ± 0.45	0.11 ± 0.01	9.82 ± 0.59
8	Behaton (Paving Slabs)	55.83 ± 0.35	27.77 ± 0.70	4.52 ± 0.40	5.70 ± 0.26	0.78 ± 0.05	6.60 ± 0.36
9	Stone Crusher	54.25 ± 0.35	26.00 ± 0.28	10.20 ± 0.28	15.30 ± 0.28	0.24 ± 0.01	8.42 ± 0.23
Mean Value (ppm)		73.72 ± 2.38	35.50 ± 1.35	17.40 ± 1.08	19.00 ± 1.25	1.78 ± 0.06	14.02 ± 1.77

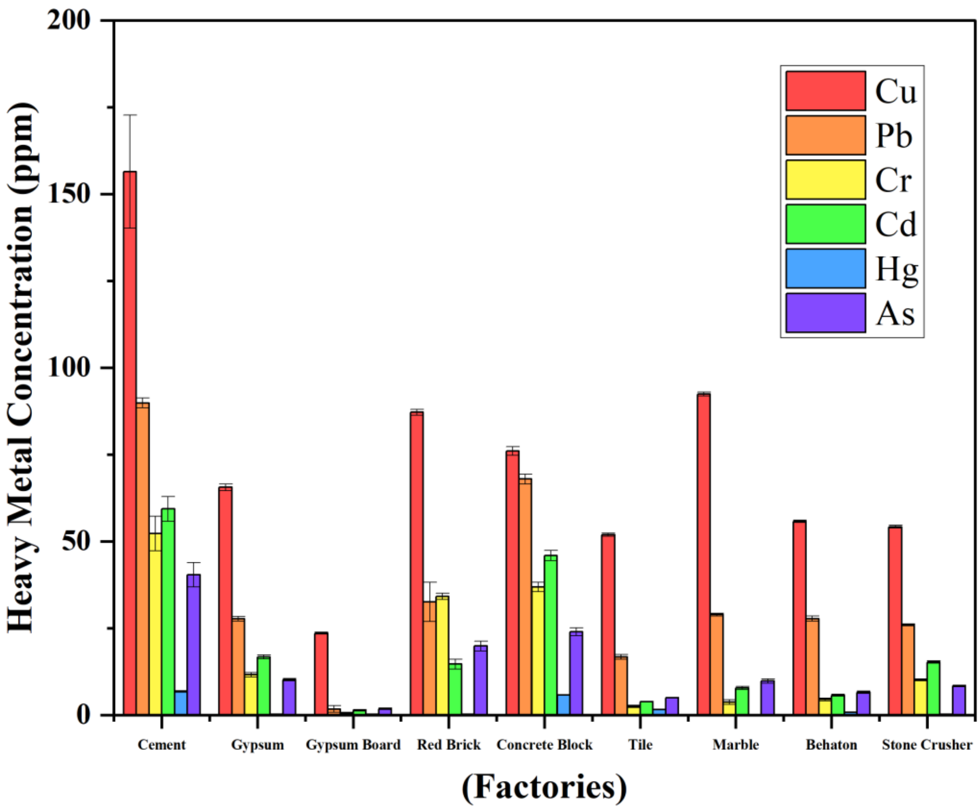

Fig. 6: Comparison between the mean values of heavy metal concentrations (ppm) of indoor dust in the factories.

Copper (Cu) is a vital trace element necessary for human health, supporting enzyme activity, immune function, and antioxidant defense. However, excessive exposure commonly from contaminated water, dust, or industrial emissions can have harmful effects. In this study, the highest mean concentration value of Cu was found in cement factories 156.50±16.26 ppm, which is above the normal range, and the lowest in gypsum board factories 23.60±0.30 ppm. The Cu concentrations in dust collected from the factories are listed in decreasing order as follows: Cement > marble > red brick > concrete block > gypsum > behaton > stone crusher > tile > gypsum board. Acute toxicity may cause symptoms such as nausea, vomiting, diarrhea, and abdominal pain, while prolonged exposure can lead to liver and kidney damage, neurological disorders, or respiratory irritation from inhalation. Certain groups, including children and individuals with Wilson's disease, are particularly vulnerable. In severe cases, excessive copper intake can be fatal, with symptoms like hypertension, coma, and jaundice (Taylor *et al.*, 2020).

Lead (Pb) levels were highest in the cement factory at 89.90±1.41 ppm and lowest in gypsum board factories at 1.75±0.93 ppm. The Pb concentrations in dust collected from the factories are listed in decreasing order as follows: Cement > concrete block > red brick > marble > gypsum > behaton (paving slabs) > stone crusher > tile > gypsum board. Lead (Pb) exposure has been linked to neurotoxicity, developmental delays in children, and cardiovascular problems in adults.

Lead (Pb) is a highly toxic heavy metal, even at low concentrations, and has severe effects on the body. Pb disrupts various biological processes, including protein folding, inter- and intracellular signaling, apoptosis, enzyme regulation, and cell adhesion (Assi *et al.*, 2016).

Chromium (Cr) is an essential trace element, particularly in its trivalent form (Cr (III)), which supports glucose metabolism and insulin function. However, excessive exposure, especially to the highly toxic hexavalent chromium (Cr (VI)), can lead to severe health problems. In this study, the highest mean concentration value of Cr was found in cement factories 52.30±4.95 ppm, which is above the normal range, and the lowest in gypsum board factories 0.64±0.13 ppm. The Cr concentrations in dust collected from the factories are listed in decreasing order as follows: Cement > concrete block > red brick > gypsum > marble > behaton > tile > stone crusher > gypsum board. Acute exposure to Cr (VI) may result in respiratory symptoms like coughing, wheezing, and nasal irritation, while prolonged exposure has been linked to lung cancer, liver and kidney damage, and skin ulcers. Cr (VI) is a recognized carcinogen, particularly through inhalation in industrial environments. Toxicity from chromium exposure via ingestion or skin contact can cause gastrointestinal issues, kidney damage, and allergic reactions, with Cr (VI) posing greater risks due to its higher ability to penetrate biological membranes compared to Cr (III). Although Cr (III) is less toxic, chronic exposure at high levels can still harm the liver and kidneys. Workers in industries using chromium compounds and communities near chromium-contaminated areas are particularly vulnerable to its effects (Zhitkovich, 2011).

Cadmium (Cd) is an extremely toxic heavy metal and has been classified as a human carcinogen by both the international agency for research on cancer (IARC) and the US national toxicology program. Cd disrupts the biosynthesis of DNA, RNA, and proteins, transforming normal epithelial cells into malignant ones and thereby exhibiting carcinogenic properties. Cadmium (Cd) levels were highest in the cement factory at 59.40±3.54 ppm, which is above the normal range, and the gypsum board factory recording the lowest at 1.39±0.25 ppm. The Cd concentrations in dust collected from the factories are listed in decreasing order as follows: Cement > concrete block > gypsum > red brick > behaton > stone crusher > marble > tile > gypsum board. Prolonged exposure to cadmium in humans is linked to lung cancer and kidney damage. Cd also interacts with essential elements such as iron (Fe), calcium (Ca), magnesium (Mg), and selenium (Se), causing functional and structural changes in various organs and disrupting secondary metabolic processes. Health effects of Cd exposure include pneumonia, general fatigue, fever, chest pain, and, in severe cases, death. Women are more affected than men due to higher dietary absorption of cadmium in the intestines, leading to elevated Cd concentrations in the urine, blood, and kidney cortex (Pan *et al.*, 2010).

Mercury (Hg) is most toxic non-essential metal to human beings. Hg is present in 3 forms-elemental Hg, inorganic Hg and organic Hg in the environment. Elemental Hg is mainly released as a vapor in the air in the environment (Park and Zheng, 2012).

Mercury (Hg) concentrations in this study, reached their maximum in the cement factory at 6.85±0.24 ppm, which is above the normal range, while marble factories had the lowest at 0.11±0.01 ppm. The Hg concentrations in dust collected from the factories are listed in decreasing order as follows: Cement > concrete block > tile > behaton > gypsum > red brick > stone crusher > gypsum board > marble. Elemental mercury (Hg) vapor primarily affects the central nervous system, leading to cognitive, motor, and sensory disturbances. Prolonged exposure can result in poor concentration, blurred vision, and unsteady gait. Severe exposure to mercury can cause significant neurological damage and even death. Mercury's harmful effects can also be transmitted from a mother to her fetus, potentially causing brain damage, blindness, mental retardation, and speech impairments. High levels of mercury exposure may result in pneumonia, pulmonary edema, and other symptoms of lung damage. At lower exposure levels, mercury can cause depression, tremors, skin rashes, and memory loss in adults, while in children, it may lead to redness, peeling skin on the hands and feet, and other symptoms (Rice *et al.*, 2014).

Arsenic (As) is a toxic heavy metal harmful to humans, with inorganic arsenic recognized as a carcinogen. In this study, arsenic (As) levels were highest in cement factories at 40.40±3.54 ppm, which is above the normal range, with the lowest in gypsum board factories at 1.80±0.22 ppm. The arsenic (As) concentrations in dust collected from the factories are listed in decreasing order as follows: Cement > concrete block > red brick > behaton > tile > gypsum > marble > stone crusher > gypsum board. Low to moderate exposure to arsenic is associated with diabetes, liver and kidney dysfunction, and neurological issues. The skin is particularly vulnerable to arsenic toxicity, often resulting in dermatitis. Women are more susceptible to arsenic-induced skin disorders than men. Common skin lesions linked to arsenic exposure include keratosis, melanosis, and pigmentation changes. Additionally, the brain is a major target of arsenic toxicity, contributing to various neurological complications (Vahidnia *et al.*, 2007; Mundey *et al.*, 2013).

Comparison of the heavy metal’s mean concentrations (ppm) in indoor dust samples obtained from past dust exposure studies around the world with this present study illustrated in (Table 3). The comparison's findings demonstrated that all heavy metals' mean concentrations in indoor dust were higher than recommended levels.

Table 3: Comparison of the heavy metal concentrations (ppm) in indoor dust samples collected from this study with reported researches around the world.

No.	Location (Country)	Heavy Metal Concentration in Indoor Dust (ppm)						Reference
		As	Cd	Cr	Cu	Hg	Pb	
1	Saudi Arabia	-	2.00	69.20	271.10	-	639.10	(Al-Rajhi *et al.*, 1996)
2	Turkey	-	1.80	254.40	513.00	-	192.50	(Kurt-Karakus, 2012)
3	China	10.81	0.49	50.90	21.65	0.098	69.12	(Chen *et al.*, 2022)
4	Malaysia	-	-	16.88	30.19	-	31.24	(Darus *et al.*, 2012)
5	Nigeria	-	0.09	10.53	-	-	23.89	(Nigeria, 2012)
6	Iran	-	11.34	11.81	-	-	32.08	(Sabzevari and Sobhanardakani, 2018)
7	UK	17.50	-	-	67.50	0.43	210.0	(Turner and Simmonds, 2006)
8	Iraq	14.02	19.00	17.40	73.72	1.78	35.50	Present study

This study has several limitations, including sampling constraints, as it focuses on a specific number of building material factories in Sulaymaniyah, which may not fully represent all similar workplaces in the region. Seasonal variations and external pollution sources were not considered, potentially influencing dust composition. The use of XRF for heavy metal analysis, while effective, has limitations in detecting trace levels with absolute precision compared to advanced techniques, and matrix effects may introduce slight measurement inaccuracies. Variations in ventilation, cleaning practices, and factory layouts could impact dust accumulation and metal concentrations. Additionally, the absence of national standards for indoor dust heavy metal concentrations in Iraq limits regulatory comparisons, and the scarcity of regional studies restricts direct contextual analysis.

CONCLUSIONS

These are based on analysis of heavy metal concentrations in indoor dusts from building material factories through X-ray fluorescence (XRF) spectroscopy. XRF allows for the non-destructive analysis of metals providing a fast and accurate detection and quantification method for dust samples. The data shows that heavy metal concentrations are highly variable between factory types. Gypsum board factories displayed significantly lower concentrations, with cement factories demonstrating consistently higher levels of Cu, Pb, Cd, Cr, Hg, and as in the atmosphere. On the other hand, the gypsum board factories exhibited the least concentrations of all the metals under investigation, indicating that their environmental threat might be significantly less when compared to cement and concrete block factories. Studies of different types of factories find high levels of these metals in the environment, along with high levels of the targeted metals, ascribed to contamination of raw materials with various metals as well as industrial processes and degradation of equipment. In comparison with studies reported elsewhere, the concentration levels of mercury (Hg) and cadmium (Cd) in our study were greater. Therefore, these results can raise a consideration for environmental monitoring and regulation scientists, especially in cement and concrete block industries, to reduce the possible hazard heavy metal contamination.

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تحديد وتحليل تركيز المعادن الثقيلة في عينات الغبار الداخلي في مصانع مواد البناء في محافظة السليمانية، العراق

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الملخص

الغرض من هذه الدراسة هو تحديد وتحليل تركيزات المعادن الثقيلة مثل النحاس (Cu) والرصاص (Pb) والكروم (Cr) والكادميوم (Cd) والزئبق (Hg) والزرنيخ (As) في عينات الغبار الداخلي في 9 أنواع من مصانع مواد البناء: الأسمنت والجص وألواح الجبس والطوب الأحمر والكتل الخرسانية والبلاط والرخام والبهاتون (ألواح الرصف) وكسارة الحجر في 28 موقعًا مختلفًا للمصنع في محافظة السليمانية – كردستان العراق باستخدام تقنية التحليل الطيفي بالأشعة السينية. تختلف المستويات القياسية للمعادن الثقيلة في عينات الغبار حسب البلد والمنظمة والمبادئ التوجيهية المحددة التي تتم الإشارة إليها. لا يوجد معيار عالمي، لكن الهيئات التنظيمية مثل منظمة الصحة العالمية (WHO) ووكالة حماية البيئة الأمريكية (EPA) والاتحاد الأوروبي (EU) وضعت حدودًا موصى بها لتركيزات المعادن الثقيلة في الغبار والتربة والجسيمات المحمولة جوًا، مثل 50-500 (Pb) جزء في المليون، 1-10 (Cd) جزء في المليون، 5-50 (As) جزء في المليون، و 10-100 (Cr) جزء في المليون (ppm). في هذه الدراسة، أظهر مصنع الأسمنت أعلى مستويات Cu(156.50±16.26 ppm)، وPb(89.90±1.41 ppm)، و Cr(52.30±4.95 ppm)، و Cd(59.40±3.54 ppm)، و Hg(6.85±0.24 ppm)، و As(40.40±3.54 ppm). وعلى النقيض من ذلك، أظهرت مصانع ألواح الجبس باستمرار أدنى تركيزات لمعظم المعادن الثقيلة، مع قيم Cu وPb وCr وCd وHg وAs عند 23.60±0.30 جزء في المليون و1.75±0.93 جزء في المليون و0.64±0.13 جزء في المليون و1.39±0.25 جزء في المليون و0.20±0.01 جزء في المليون و1.80±0.22 جزء في المليون على التوالي. أظهرت أنواع المصانع الأخرى درجات متفاوتة من التلوث. وبالمقارنة مع الدراسات التي تم الإبلاغ عنها في أماكن أخرى، كانت مستويات تركيز الكادميوم والزئبق في دراستنا أكبر. تسلط هذه النتائج الضوء على التباينات الكبيرة في تركيزات المعادن الثقيلة عبر الأنشطة الصناعية، مما يؤكد على الحاجة إلى استراتيجيات مراقبة وتخفيف بيئية مستهدفة لإدارة التلوث الصناعي بشكل فعال.

الكلمات الدالة: مصانع مواد البناء، مطيافية الأشعة السينية الفلورية، الغبار الداخلي، المعادن الثقيلة، محافظة السليمانية.