

ORIGINAL ARTICLE

Composition of Heavy Metals in Indoor Dust and Their Possible Exposure: A Case Study in Laboratories of Faculty Applied Sciences UiTM Shah Alam

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ABSTRACT

Introduction: Given the growing concern over metal pollution in interior dust, this study aims to advance knowledge of the heavy metal composition and potential causes of indoor dust pollution. **Materials and methods:** Indoor dust samples were collected from three laboratories in the Faculty of Applied Sciences University Teknologi MARA, Shah Alam. The laboratory included the Food Chemicals Analysis Laboratory, Emission Control and Air Analysis Laboratory, and Textile Chemistry Laboratory, which were chosen based on stratified random sampling. The analysis of the dust samples' compositions for lead (Pb), chromium (Cr), zinc (Zn), and nickel (Ni) was carried out using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). **Results:** The heavy metals were present in the following order of concentrations: Zn > Ni > Cr > Pb. This study also discovers how to calculate the Index of geo-accumulation (Igeo). The vast majority of Zn and Ni Igeo values fall within the "very highly polluted" category with the highest Igeo class, 13.2584 and 7.355, respectively, exceeding background levels above 5. In addition, this study identified the possible sources of heavy metals in laboratory dust and found two primary sources of heavy metal contamination in the laboratory dust. Pb, Cr, and Ni pose as Cluster 1, which comes from anthropogenic sources such as laboratory-related activities, while Zn, as Cluster 2, originates from natural sources. **Conclusion:** To ensure the safety of laboratory occupants, future research monitoring assessments of indoor dust should be considered.

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(6). Heavy metal contamination is a severe health issue since it results in over 4.5 million pneumonia-related deaths per year worldwide (12%), stroke (34%), ischemic heart disease (26%), chronic obstructive pulmonary disease (22%) and lung cancer (6%) (7).

INTRODUCTION

Research on the topic of metal contamination in indoor dust has expanded in tandem with growing concern over the matter in recent decades (1). More scientists have concentrated on indoor dust pollution in recent years (2). People are now exposed to chemicals and harmful materials for more extended periods of time indoors, which is the leading cause of this rising importance (3). Indoor dust is the primary source of human exposure to air pollution (4).

Numerous studies have discovered that indoor dust has significant concentrations of heavy metals (5). Previous research has associated acute health problems such as headaches, respiratory infections, and chronic health effects of metals, such as cancer caused by heavy metals

Indoor dust in a university centre, like a laboratory, impacts work, study, and research productivity and efficiency, as well as the health of students and lecturers (8,9). Because of these health concerns, the interior air quality of places, including laboratories, has become crucial to the occupants. According to Balali-Mood (10), harmful compounds such as heavy metals in laboratory dust can readily enter human bodies through eating, cutaneous contact, and inhalation.

Indoor sources of heavy metals in laboratory dust include chemicals and reagents used in experiments or processes (11). Some laboratory-grade chemicals may contain heavy metal impurities; mishandling or spills can release these metals into the laboratory environment. Laboratory equipment and instruments, such as metal

surfaces, fittings, and connectors, can also be a source of heavy metals in dust due to degradation or corrosion (12). Additionally, laboratory samples, particularly those containing naturally occurring heavy metals or obtained from the environment, can introduce heavy metal contaminants into the dust through handling and manipulation (13). Laboratory waste, including improperly disposed chemicals or materials, can further contribute to heavy metal contamination in dust. Maintenance and cleaning activities, if not conducted properly, can generate dust particles containing heavy metals as they are re-suspended in the air. An earlier study revealed that indoor laboratories have a larger concentration of metal than other types of buildings. Masindi and Muedi (14) stated that indoor dust samples (Cd, Cu, Pb) in air-conditioners were found to be higher than normal levels found in soil in Pakistan. The surrounding outside sources (automotive workshops, tyre wear, and leaded gasoline) and internal sources (interior sources) contributed to the presence of heavy metals in air-conditioned indoor dust samples (lead-based paint) (15).

Therefore, this study intends to assess the concentration of metals in indoor dust, specifically in laboratory buildings at UiTM Shah Alam, Malaysia. This study also identified the possible exposure of the heavy metals in indoor dust. The findings will help identify high-risk areas and activities, inform occupational health and safety practices, and guide the development of preventive measures to reduce heavy metal exposure risks in laboratories.

MATERIALS AND METHODS

Sampling location

This research was conducted in Shah Alam, Selangor, in the laboratories of the Faculty of Applied Sciences Universiti Teknologi MARA.

This study was conducted in October 2023. The samples were collected from the laboratory building from three different buildings and were chosen as the sampling sites. The sampling site is chosen based on stratified random sampling. Indoor dust was collected from three laboratories representing different buildings in the faculty. The Site sampling included the Food Chemicals Analysis Laboratory in Building A, the Emission Control & Air Analysis Laboratory in Building B and the Textile Chemistry Laboratory in Building C.

Sampling Procedure

The apparatus was set up before the experiment began. The dust collection method used in this investigation was modified from the research of Dinh et al. research (16). Dust from the interior was gathered with a delicate paintbrush. Indoor dust was collected in the laboratory building using a clean plastic brush and pan to sweep the floor areas that are most accessible to the occupants,

such as the window, table, chair and floor. Once inside, the dust moved into a plastic bag that was sealed and delivered to the lab; it was desiccated for a whole day, then sieved through a 100-meter screen and oven-dried for a full day at 105°C. From three sampling locations, there are four heavy metals (Pb, Cr, Zn, Ni) were assessed with five duplicates. Therefore, the total of sample analysis is 60.

Heavy Metal Analysis

After the drying process, 0.5 grams of the dust was then digested by using 10 ml of mixture solution (HCl-HNO₃) in a ratio of 3:1 to form aqua regia acid at 105°C until white fumes appeared using a hotplate. After cooling, Whatman No. 42 filter sheets were used to filter the extract. Then, samples were diluted with HNO₃ 5% and put into plastic centrifuge tubes. Then, inductively coupled plasma optical emission spectrometry (ICP-OES) was used to reveal the concentration of Pb, Cr, Ni, and Zn. Standard multi-element solutions made via dilution (1,000 mg/L) of each standard were used to calibrate the ICP-OES instrument.

Statistical Analyses

Data analysis has been performed using statistical software Origin Pro and the Statistical Package for the Social Sciences (SPSS) Ver. 26.0. Descriptive statistics were used in this study in order to summarise and present a dataset's key characteristics. Furthermore, the distribution of concentrations of heavy metals will be evaluated using Shapiro-Wilk normality tests to see if the data has a normal distribution or not. The data is considered normal if the Shapiro-Wilk Test's Sig. Value is higher than 0.05. The data substantially departs from a normal distribution if it is less than 0.05. For small sample sizes (<50 samples), the Shapiro-Wilk test is a suitable approach.

Additionally, a one-way analysis of variance (ANOVA) test was run to determine whether there were any noteworthy variations in the average laboratory concentrations of heavy metals among the research locations. The standard deviation of the data was statistically analysed to ascertain its accuracy. In this work, correlation analysis was employed to assess the degree of a relationship and potential relationship between the heavy metals. When the Sig. The value is less than 0.05, and there are strong and noteworthy associations.

Principal Component Analysis (PCA) is used to find potential contributing factors to the heavy metals in the laboratory dust and, consequently, identify which metals have a common origin by taking into account source identification uncertainty. The possible sources of heavy metal in water were interpreted using multivariate PCA algorithms (17). By analysing the concentration of heavy metals in dust, Cluster Analysis (CA) with a dendrogram may be used to divide the heavy metals into

multiple groups, which will help extract comprehensive information from the dataset and provide insight into the distribution of heavy metals by identifying similarities or differences. CA was implemented into practice to classify the components that originated from various sources. Cluster analysis can be used to find groups of samples (such as soil or water samples) with similar profiles of heavy metal concentrations in the context of heavy metal concentrations. The most widely used metric for determining how similar or unlike two parameters or objects are to one another is the Euclidean distance, sometimes known as the straight-line distance.

Index of Geo-accumulation (Igeo)

The Index of Geo-accumulation (Igeo) was used to assess all sampling locations in order to determine the quantity of pollution present in the dust sample in the laboratory area. Muller (1979) classified Igeo into seven classes. One of the pollution index parameters, Igeo, compares the current concentration of heavy metals with the background level to calculate the hazardous level of soil (18). The degree of metal contamination in dust can be determined and defined by comparing present concentration with reference levels. It can be computed using equation 1 as follows:

$$I_{geo} = \log_2 [C_i / 1.5 C_{ri}] \quad (1)$$

Where C_i is the measured concentration of the examined metal i in the dust sample, and C_{ri} is the geochemical background concentration or reference value of the metal i . Factor 1.5 is used because of possible variations in background values for a given metal in the environment as well as very small anthropogenic influences (1p.18).

Ethical Clearance

This study was approved by Research Ethics Committee, Faculty of Applied Sciences Universiti Teknologi MARA Shah Alam No. FERC/FSG/24/162(PG-EX).

RESULTS

Figure 1 displays the amounts of heavy metals (Pb, Cr, Zn, and Ni) in indoor dust samples from a chosen laboratory at UiTM. With a mean concentration of almost 36.55 mg/kg, zinc had the highest concentration of all the heavy metals found in indoor dust. Ni (2.92 mg/kg), Cr (0.78 mg/kg), and Pb (0.77 mg/kg) were the next most concentrated. Pb, Cr, Zn, and Ni concentrations in

indoor dust were less than those in topsoil. This could suggest that there is less heavy metal contamination in the interior environment.

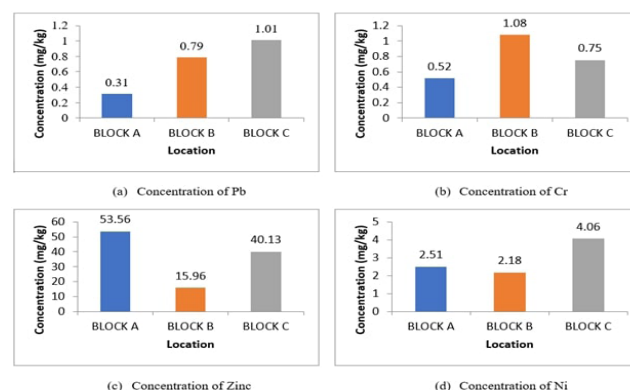


Figure 1: Average Concentration of Heavy metals in different buildings

Table II displays the outcomes of the Geo-accumulation Index (Igeo) data analysis. For the components Pb and Cr, the analysed dust can be classified as unpolluted to highly polluted based on the classes set for Igeo. Regarding Zn and Ni, they are regarded as extremely contaminated. Most sampling sites had unpolluted pollution, according to the Igeo computation. In contrast to other elements, zinc had a substantially greater Igeo than other heavy metals.

Table II: Geo-accumulation Index (Igeo)

Heavy metals	Reference (top soil)	Geo-accumulation Index (Igeo)		
		Building A	Building B	Building C
Pb	3.45	-0.4739	0.8639	1.2141
Cr	1.58	-0.8889	0.4150	-0.34
Zn	274.42	13.2584	11.5110	12.8419
Ni	60.45	6.6599	2.0214	7.355

In this study, the relationship between each element and the sources of heavy metals in the laboratory dust of the Faculty of Applied Sciences, UiTM Shah Alam, was analysed using Pearson correlation analysis with Principal Component Analysis (PCA) and Cluster Analysis (CA). The result of PCA is shown in Table III and illustrated in Figure 3. Two factors were extracted from the dust samples. However, the correlation between element pairs for all elements of heavy metals was summarized in Table IV.

Table III: Eigenvalue of Each Element of Heavy Metals in Dust Samples

	Eigenvalues			Eigenvectors		
	Eigen-value	Percentage of variance	Cumulative	Element	PC1	PC2
1	2.27	56.60%	56.70%	Pb	0.58	0.26
2	1.16	29.11%	85.81%	Cr	0.53	-0.31
3	0.38	9.61%	95.42%	Zn	-0.46	0.56
4	0.18	4.58%	100.00%	Ni	0.38	0.71

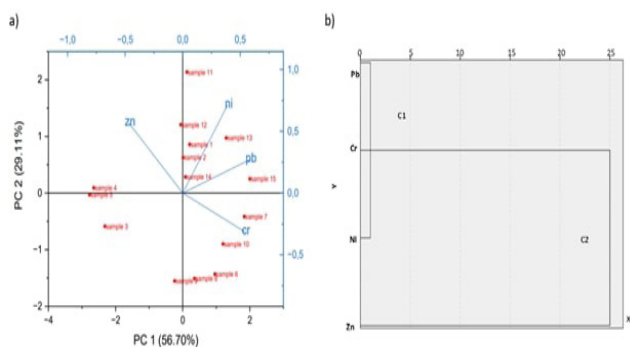


Figure 3: Principal Component Analysis of heavy metals in laboratory dust (a) and Cluster analysis dendrogram for indoor laboratories' dust (b)

Table IV: Pearson Correlation Analysis for Heavy Metals in The Laboratory Dust

Element	Pb	Cr	Zn	Ni
Pb	1			
Cr	0.761**	1		
Zn	-0.374	-0.629	1	
Ni	0.481	0.239	-0.029*	1

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (1-tailed)

DISCUSSION

Concentration of Heavy Metals in Indoor Dust

The concentration of Pb from three selected laboratories in Building A, Building B, and Building C are shown in Figure 1 (a). The highest concentration of Pb was from Lab C in the Textile chemistry Laboratory with the value 1.01 mg/kg followed by building B in Emission Control & Air Analysis Laboratory with value 0.79 mg/kg and building A with 0.31 mg/kg in Food Chemicals Analysis Laboratory. There are not any established benchmark values for heavy metals in dust at the moment. Therefore, in order to evaluate the amounts of heavy metal pollution in dust, the WHO environmental quality guidelines for soils were consulted. The WHO's suggested threshold of 2 mg/kg for tolerable lead levels in soil was not surpassed by the lead levels found in site samples (9).

The highest concentration of Pb in building C may be due to many factors. The potential sources of lead contamination in building materials include textile materials that may be present in textiles, either as a

component of the fibres themselves or as a result of processing (19). The equipment in the laboratory Lab C is also rusty and may be the cause of Pb contamination. The old and rusty materials may deteriorate over a period of time, maybe resulting in lead contamination. This is supported by the study stating that laboratory infrastructure, pipelines, or older equipment have been manufactured or maintained with substances that contain lead (20). The Pb contamination is attributed to the accumulation of Pb from earlier use of leaded paint (21). According to a study reported by Hasan et al., (22) higher Pb concentrations in household dust are likely caused by accumulating Pb-based paint sources. Additional potential causes of lead contamination in building C include inadequate waste disposal. This is suggested by the study that stated that improper procedures and unintentional leaks or spills of lead-containing solutions or chemicals within a laboratory setting, which, if not properly managed and cleaned up, result in increased lead concentrations (23).

Figure 1 (b) shows the concentration of Cr in the different buildings in the Faculty of Applied Sciences UiTM Shah Alam. The highest concentration in Building B in the Emission Control & Air Analysis Laboratory, with a value of 1.08 mg/kg, followed by Building C in the Textile Chemistry Laboratory, with a value of 0.75 mg/kg and Building A, with 0.52 mg/kg in Food Chemicals Analysis Laboratory. Chromium in all dust samples in the different laboratories was found to be lower than the permissible limit, which is 1.30 mg/kg recommended by The World Health Organization (WHO).

In a laboratory focused on emission control and air analysis, the presence of excessive levels of chromium could be attributed to the following reasons. The presence of a significant quantity of Cr in the laboratory may be directly linked to specific experiments or testing operations undertaken by the laboratory. The findings of the study suggest that the existence of a quantity of Cr in the laboratory is related to particular testing operations (24). Samples from industrial facilities, environmental monitoring stations, or research projects that inherently contain elevated concentrations of chromium as a result of adjacent industrial activities or particular emission sources are submitted to the Laboratory of Emission Control & Air Analysis (25).

The concentration of Zn from three selected laboratories in Building A, Building B, and Building C are shown in Figure 1 (c). The highest concentration of Zn was from Building A in Food Chemicals Analysis Laboratory with a value of 53.56 mg/kg, followed by Building C in Textile Chemistry Laboratory with a value of 40.13 mg/kg and Building B with 15.96 mg/kg in Emission Control & Air Analysis Laboratory. In this study, the WHO's permissible limit for Zn concentration in soil was 50

mg/kg, and the Food Chemicals Analysis Laboratory in building A was found to be greater than the permissible limit.

A study revealed zinc (Zn) as the dominant heavy metal in indoor dust across all laboratories within a building, with an average concentration of 36.55 mg/kg. This finding is noteworthy as Zn can originate from both natural sources and human activities (26). While essential in small amounts for human health (27), excessive exposure or deficiency can be detrimental, potentially increasing susceptibility to carcinogens (28). The high Zn concentration in the Food Chemicals Analysis laboratory was particularly unexpected, considering normal operating conditions (7). Potential sources include research activities involving Zn analysis in food items, improper cleaning of food residues or spills, and occupant movement carrying food particles on clothing or hands (29).

Other factors potentially influencing Zn levels include building materials and equipment. Corrosion of Zn-coated materials, including paint, plastic products, and furniture woods, can release Zn dust (7). Additionally, zinc-containing equipment, containers, and materials used in the laboratory can deteriorate over time, releasing Zn particles (24). Furthermore, high-humidity sulfur oxide and other reduction-oxidation agents might contribute to the corrosion of zinc-coated steel, potentially adding to the indoor Zn burden (30).

Figure 1 (d) shows the concentration of Nickel (Ni) in the different buildings in the faculty of Applied Sciences UiTM Shah Alam. Ranging from the highest concentration in Building C in the Textile Chemistry Laboratory, with a value of 4.06 mg/kg, followed by Building A in the Food Chemicals Analysis Laboratory, with a value of 2.51 mg/kg and Building B in the Emission Control & Air Analysis Laboratory with 2.18 mg/kg. The concentration of Ni in soil samples was between 1.83 and 14.87 mg/kg. The permissible limit for Ni by WHO is 10 mg/kg. The sample was below this recommended limit, so it is concluded that the dust in the laboratory is safe from the hazardous effects of Nickel. Nickel has been considered to be an essential trace element for human and animal health but in safe quantities.

The presence of a high concentration of nickel (Ni) in a laboratory involved in textile chemistry should not be typical or intentional, as nickel is not a common or desired element to have in such a laboratory setting. Nickel is an element that is not conventionally regarded in the field of textile chemistry (31). The presence of nickel in a textile chemistry laboratory may be attributed to a variety of factors. For instance, the laboratory may receive textile samples for analysis that inherently comprise nickel. As reported by Rujido-Santos et al. (32), the analysis of textile samples that contain nickel or nickel-based finishes can introduce nickel into the

laboratory environment.

Moreover, nickel may be present in the materials of the equipment used in textile chemistry experiments in the laboratory. The study conducted by Bielak and Marcinkowska (33) reported that nickel-containing alloys may be present in laboratory equipment, glassware, or instruments used in textile chemistry experiments. Over time, wear and corrosion of these materials can lead to the release of nickel particles into the laboratory environment (19). The laboratory may possess infrastructure or equipment that comprises nickel components, and over time, these components can deteriorate or release nickel, potentially leading to contamination into the air in the form of dust (34). Cross-contamination may occur if laboratory personnel handle substances or compounds that have been exposed to nickel in other areas of the facility or during previous experiments (35).

Statistical Analysis of Heavy Metal in Indoor Dust

A series concentration of the standard solution for the selected element was prepared for this analysis within the range of 1 ppm to 5 ppm. The high-value regression coefficient (R^2), which is near value 1.0, results in a linear calibration as it will represent the actual concentration of the element. Table I shows the regression coefficient (R^2) for the calibration curve used to analyze the selected heavy metal. The regression coefficient (R^2) value has been approved for the acceptable fit of the obtained intensity against concentration to the regression line as the value is more than 0.9.

This study showed a wide range of heavy metal concentrations. The standard analysis was carried out to describe the heavy metal contents in dust. The descriptive statistics of indoor dust heavy metal concentration are shown in Figure 2.

Table I: Statistical Analysis of Heavy Metal

Element	Regression coefficient (R^2)	Shapiro-Wilk			ANOVA		
		Statistic	df	Sig	F value	P value	Mean square
Pb	0.9999	0.94	15	0.40	3.70	0.56	0.36
Cr	1	0.93	15	0.30	5.48	0.20	0.39
Ni	0.9972	0.89	15	0.07	4.62	0.33	5.05
Zn	0.9998	0.92	15	0.22	7.81	0.007	18.16

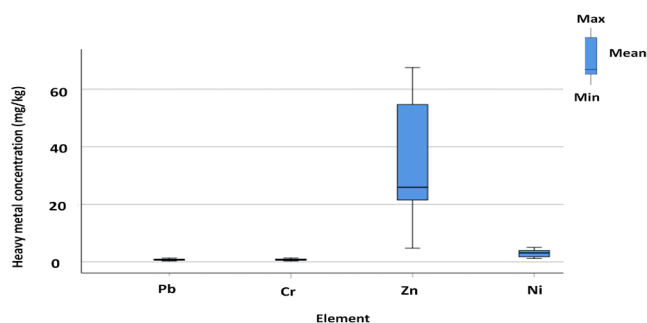


Figure 2: Descriptive statistics of heavy metal concentrations in laboratory dust

The Shapiro-Wilk test was applied to test the data normality, considering that the available sample was small. One can draw the conclusion that in the case of dust sample, all the elements have normal distribution because the Sig. value of the Shapiro-Wilk test was greater than 0.05 and the data presented in Table I.

One-way ANOVA has been used to determine whether there were any statistically significant differences between heavy metal concentrations among all sampling sites. Table I also shows the one-way ANOVA analysis result. Based on the table, it has been shown that *the p*-value of Zn is < 0.05 , meaning that there were significant differences between sampling sites, while the values of Pb, Cr and Ni were greater than 0.05, which means that the levels were not significant between sampling sites.

Index of Geo-accumulation (Igeo) for Heavy Metals in Laboratory Dust

To measure the pollution level in the dust sample, all sampling sites were evaluated using the geo-accumulation index (Igeo). The topsoil near the sampling site was used as a reference sample for calculations. The index of geo-geo-accumulation (Igeo) was applied in this study to determine and define metal contamination in the dust by comparing the current concentration with the background concentration. The reference used to calculate Igeo was obtained from the concentration of topsoil nearest the laboratory with a 100-300m distance. Igeo helps to identify which heavy metals in laboratory dust may be of concern in terms of contamination. Based on the result, Igeo values of Zn indicate an increase in concentration compared to the background levels, signalling potential pollution (13).

Sources of Heavy Metal Concentration in Laboratory Dust

Reducing pollution and dangers to human health requires identifying the sources of heavy metals. Since PCA is thought to be an efficient approach for source identification, it was used to identify the sources of heavy metals in indoor dust at various locations (20). PCA's outcome is displayed in Table III and depicted in Figure 3. The dust samples yielded two components, which were extracted. The principal component 1 (PC1) often accounts for the greatest variability in the dataset tested, according to the transformation that the PCA produced (36). The results indicate that PC1 (56.70%) and PC2 (29.11%) each contributed to and jointly explained 85.81% of the variance in the total. This is consistent with the intricate source of contamination in the lab.

Pb and Cr were strongly weighted in the first group (PC1), which accounted for 56.70% of the variance and had the highest cumulative contribution rate. Their loading in PC1 suggests that they come from similar sources, which could be natural sources like the crust of the planet. Both metals in PC1 indicate anthropogenic

sources associated with routine laboratory work, spills, or chemical decomposition over time. These metals suggest exposure through mishandling, chemical use, or equipment corrosion. Lead contamination can occur from chemicals and reagents used during analysis, such as those found in analytical chemistry or textile laboratories. Pb may also come from deteriorating equipment (old lab instruments, glassware with lead seals) or chemical handling practices that involve compounds containing lead (36). Another metallic element present in the crust of the Earth is chromium. It can be found in a number of oxidation states, the most prevalent being chromium (III) and chromium (VI). Chromium can be found naturally in various minerals and chromite ore, which is iron chromium oxide. In trace amounts, chromium can also be found in soil, water, and some foods such as fruits, whole grains, and meats (37). In laboratory contexts, chromium is commonly found in materials like chromate-based reagents, stainless steel lab equipment, or chemical catalysts. Labs involved in textile chemistry may also use chromium in dyeing processes. In emission control studies, chromium compounds might appear in air analysis samples.

The second group (PC2) explained 29.11% of the variance with loadings of Zn and Ni. PC2 highlights that Zn and Ni contamination is likely tied to the maintenance and operation of lab equipment, as well as material wear-and-tear, rather than natural soil or airborne sources. This reflects indoor lab activities such as emissions monitoring and chemical experimentation. Zinc contamination is likely related to instrumental corrosion (e.g., metallic lab components) or chemical waste handling. It is also common in materials related to plumbing, galvanization processes, or catalysts used in air emission studies (31, 38). In the textile lab, nickel can come from dyes, finishes, and lab tools that contain nickel alloys, which degrade over time. In the emission control lab, nickel might be present in catalysts used for air and water treatment experiments, contributing to nickel residues in dust (39).

Based on Pearson's correlation coefficient, there is a positive correlation between Pb and Cr ($r = 0.761$, $P < 0.01$). This was also supported by the result of the PCA that stated the loading of Pb and Cr in PC1 may imply that they originated from similar sources. The negative correlation between Zn and Ni ($r = -0.029$, $P < 0.05$) was found. The elements from PC2 from PCA analysis that were Zn and Ni suggest that when the concentration or presence of Zn increases, the concentration or presence of Ni tends to decrease. It's important to note that correlation does not imply causation, meaning that one variable causing the change in the other is not necessarily implied by the correlation alone (40).

In this work, statistical analysis also included the use of cluster analysis (CA). In environmental studies, the most used multivariate statistical technique is called CA

(41). Finding a method of grouping observations where several groups or variables share observed qualities was the aim of cluster analysis. The hierarchical clustering was summarised using a dendrogram. In the current study, the sources of similarity of heavy metals in dust samples were assessed using CA. In Figure 3, which displays the dendrogram from cluster analysis of the metals composition in the dust of indoor laboratories, Euclidean distances for similarities were calculated. Two groups were found: Cluster 1 and Cluster 2. PC1 consisted of Pb, Cr, and Ni, while Zn, which constituted PC2, was connected to PC1 via a significant linkage distance.

According to Figure 3, Cluster 1 may be attributed to human sources; this conclusion is consistent with (42), which suggests that natural sources (soil) may have contributed to Cluster 2. Naturally, zinc is one of the highest quantities found in the Earth's crust. Students' movement and activities, as well as wind blowing in from the outside, could bring soil dust containing zinc into the interior environment (43).

CONCLUSION

This study achieved its goals of analyzing heavy metal concentrations in laboratory dust, calculating the geo-accumulation index, and identifying possible sources. Zn > Ni > Cr > Pb was the heavy metal concentration order. Zinc had the greatest range and highest mean concentration, followed by Pb, Ni, and Cr. Pb, Cr, and Ni were within WHO limits, but Zn was above. The distribution of heavy metal concentrations was typical. Zn and Ni Igeo readings are mostly "very highly polluted", with the highest Igeo class 13.2584 and 7.355, respectively, and far surpass baseline levels 5. Unlike Zn and Ni, Pb and Cr Igeo levels indicate unpolluted to moderately polluted situations, posing lesser environmental and health hazards. Some Pb and Cr readings are moderately contaminated, but their total levels are far lower than Zn and Ni. This wide range of Igeo values among metals emphasizes the need to utilize this index to identify priority pollutants for monitoring and mitigation. This investigation also found two main causes of heavy metal contamination in laboratory dust. Pb, Cr, and Ni may be contaminated by laboratory activities, but Zn comes from soil dust, emphasizing the need for dust control. Pb, Cr, and Ni from laboratory chemicals, equipment, and procedures are anthropogenic sources (Cluster 1). Natural resources Cluster 2 is mostly Zn, perhaps transported indoors by soil dust from movement, activity, or wind. Further research was needed to identify metal contamination sources and identify health-risk mitigation strategies. The study covers three sites, requiring additional investigation at other labs for broader assessment. To reduce health concerns, dust control, laboratory hygiene, and heavy metal monitoring are essential. There are few references on dust-focused heavy metal concentration limits.

Due to the lack of dust heavy metal limitations, this investigation compared soil limits to dust samples.

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