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Indoor dust composition of university laboratories and potential health risks in Pahang, Malaysia

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RESUMEN

La contaminación por polvo plantea un riesgo importante para la salud humana y los sistemas naturales, y tiene un impacto sustancial en la calidad general del aire interior y exterior. El polvo también juega un papel crucial en el transporte de elementos metálicos en un ambiente interior. Este estudio examina los niveles de metales específicos (Al, Fe, Cu, Pb, Zn) presentes en muestras de polvo recolectadas en dos laboratorios en la universidad UiTM Cawangan Pahang, Malasia. El análisis se centra en evaluar los niveles de contaminación y los posibles impactos en la salud humana. Las concentraciones de metal fueron significativamente mayores en el Laboratorio 2. Se encontró un enriquecimiento moderado de Zn en las muestras de polvo interior. Se demostró que en ambos laboratorios la principal vía de exposición a metales que planteaban riesgos para la salud era la ingestión, seguida del contacto con la piel y la inhalación, en personas de todos los grupos de edad, incluidos adultos y niños. El Zn y el Pb exhibieron un mayor riesgo potencial no cancerígeno que el Fe y el Cu. El índice de peligro (HI) y el riesgo de cáncer de por vida (LCR) estuvieron dentro de umbrales aceptables (HI < 1 y 10^{-6} <LCR < 10^{-4}) en ambos laboratorios.

ABSTRACT

Dust pollution poses a significant risk to human health and natural systems, and has a substantial impact on the overall quality of both outdoor and indoor air. Dust also plays a crucial role in transporting metal elements in an indoor environment. This study examines the levels of specific metals (Al, Fe, Cu, Pb, Zn) present in dust samples collected from two laboratories in UiTM Cawangan Pahang, Malaysia. The analysis focuses on assessing pollution levels and potential impacts on human health. The concentrations of metal were significantly higher in Lab 2. Moderate enrichment of Zn was found in the indoor dust samples. Both laboratories showed that the major route of exposure to metals posing health risks was ingestion, followed by skin contact and inhalation, for individuals of all age groups, including adults and children. Zn and Pb exhibited higher potential non-cancer risk than Fe and Cu. The hazard index (HI) and lifetime cancer risk (LCR) were within acceptable thresholds (HI < 1 and 10^{-6} < LCR < 10^{-4}) in both laboratories.

Keywords: dust, metal, university lab, health risk.

1. Introduction

Indoor dust is diverse and has an intricate combination of particulate matter originating from various sources, both inside and outside (Clarke et al., 2022). Such dust is widely recognized as a significant reservoir and transporter of diverse environmental contaminants, encompassing organic and inorganic pollutants (Wang et al., 2021). Metals such as copper (Cu), zinc (Zn), and lead (Pb) present in indoor dust are common due to their persistence, resistance to degradation, significant toxicity, and detrimental impact on human health (Zhao et al., 2021). The concentration of metals indoors tends to be higher than outside (Latif et al., 2014). It is worth noting that students spend more of their time indoors compared to people in workplace locations (Raysoni et al., 2013).

Exposure to poor-quality indoor air can potentially impact students' productivity and overall health (Zhong et al., 2014). Various researchers have indicated a potential relationship between exposure to indoor air pollution and adverse health effects, including skin irritation, cardiovascular and respiratory diseases, allergies, and cancer (Massey et al., 2012; Sloan et al., 2012; Cao et al., 2020). It has been observed that the presence of iron (Fe), arsenic (As), and lead (Pb) in indoor dust is related to an increased risk of cancer and cardiovascular damage (Massey et al., 2013). Engaging in indoor activities can pose possible health hazards due to the presence of airborne particles and exposure via oral, dermal contact, and inhalation of particulate matter (Hu et al., 2012).

Indoor air pollutants can originate from a variety of sources, depending upon occupant activities, the geographical placement of a building (Yang et al., 2015), indoor sources such as emissions from building materials (Latif et al., 2009; Srithawirat et al., 2016), and external sources like fuel combustion (Mohamad et al., 2016). The infiltration of soil or air has been identified as the main source of indoor pollutants originated from outdoor pollutants (López-Aparicio et al., 2011). According to Latif et al. (2014), particulate matter in interior air serves as a medium for the adsorption of air contaminants, which subsequently accumulate as indoor dust. The presence of a ventilation system and human activity significantly impact the suspension of tiny particles in the interior air within a building setting (Braniš et al., 2005). Smaller size particles show reduced deposition velocities and hence have longer residence times in the environment, potentially posing a risk to human respiratory health (Matson, 2005).

There are limited studies on the metal content of indoor dust in university laboratories, particularly in tropical regions. Some previous studies reported the metal concentration from the university campuses and laboratories in tropical areas (Zhong et al., 2014; Sulaiman et al., 2017; Sulaiman and Suratmin, 2020). Therefore, this study elucidates the concentration of metal concentrations (aluminum (Al), iron (Fe), copper (Cu), lead (Pb), and zinc (Zn)) found in indoor dust samples collected from several laboratories located at UiTM Cawangan Pahang, Jengka, Malaysia. Several statistical methods, including correlation and cluster analysis, were used to determine the possible origins of metals in indoor dust. The health risk assessment methodology has been employed to determine the non-cancer and cancer risks associated with metal constituents in indoor dust.

2. Materials and methods

2.1 Sampling and analysis

About 32 dust samples were collected from two engineering laboratories, Lab 1 and Lab 2, located within the academic building complex in UiTM Cawangan Pahang (Fig. 1). Lab 1 is a structural lab facing the main campus road. Lab 2, the soil mechanics lab, is on the opposite side. Both laboratories have a comparable occupancy capacity, allowing for the presence of 30 people simultaneously, with an estimated area of 200 m^2 each. The ventilation systems utilised in the building are of the mechanical supply type, with fans installed in Lab 1, and of the exhaust type, with air conditioning, in Lab 2. These sampling areas were chosen considering students' use patterns and the presence of ventilation systems that effectively confine pollutants within the building (Zhong et al., 2014; Sulaiman and Suratmin, 2020).

For all sampling locations, samples were taken for four weeks during academic activities between 09.00 and 17.00 LT. Each sampling location is equipped with a combination of exhaust ventilation systems, such as air-conditioning, and mechanical supply, such as fans. A soft brush was used to collect the indoor dust from various sources, such as fume hoods, air

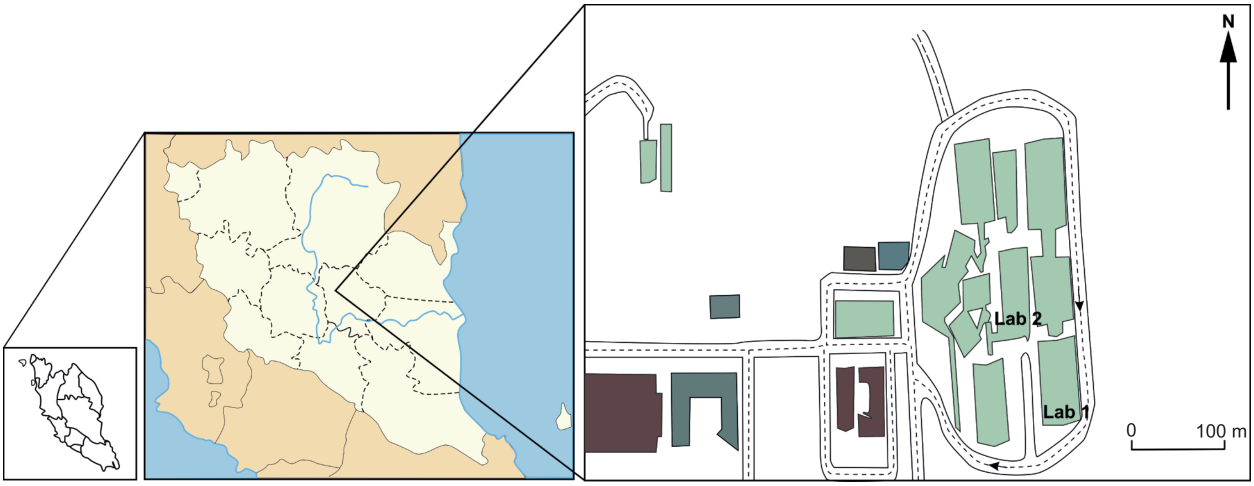

Fig. 1. Sampling locations in the university laboratories.

conditioners, benches, fans, and windows (Sulaiman et al., 2017).

The dust samples were subjected to a drying process in a laboratory oven set at a temperature of 65 ºC overnight. The dust, weighing approximately 1 g, was subsequently measured and underwent digestion using a mixture of nitric acid (HNO_3 75% GR, Merck, Germany) and hydrochloric acid (HCl 70% GR, Merck, Germany) at a 4:1 ratio. This process was carried out on a hot plate set at a temperature of 50 ºC for a duration of 1 h under a fume hood. After cooling, the solution was further filtered using filter paper and transferred into a 100 ml volumetric flask. Deionized water was then added to the filtrate until it reached the 100 ml calibration level. Concentrations of Al, Cu, Fe, Pb, and Zn in the samples were assessed using inductively coupled plasma optical emission spectrometry (ICP-OES) (Agilent 5100).

For reference, a sample of topsoil was obtained near the sampling location, about 2 m away from the building designated as the sampling point. The collection was made at a depth of 0.01 m. This study used the neighboring topsoil metal concentrations as background ratio (Sulaiman et al., 2017). The soil samples were dried in a furnace set at a temperature of 450 ºC for 3 h. The reference sample underwent digestion using the same steps as the dust samples.

The accuracy of the analytical process was verified using an analysis of a spiked sample containing a known quantity of metal standard for recovery testing, with the metal recovery rates ranging between 85 and 115%. All analysis devices underwent precleaning treatment in which they were submerged in nitric acid overnight, followed by rinsing with deionized water. An individually new soft paintbrush was used for each sampling event to prevent cross-contamination. Powder-free gloves were worn, especially when dealing with interior dust.

2.2 Enrichment factor (EF)

The enrichment factor (EF) calculation has been applied to ascertain the source of metals in samples, relying on the prevailing metal element found in the Earth's crust. Nazir et al. (2011) stated that an EF larger than 10 (EF > 10) signifies that the element is of anthropogenic origin. In contrast, an EF value less than 10 (EF < 10) indicates that the element is of natural origin. The EF was computed using Eq. (1):

$$EF = (Cx\ /Cref)_{dust} \ /\ (Cx/Cref)_{surface\ soil} \qquad (1)$$

in which $(Cx/Cref)_{dust}$ is the concentration ratio calculated from the concentrations of element x and Fe measured in indoor dust, and $(Cx/Cref)_{surface\ soil}$ is the concentration ratio in the surface soil (Latif et al., 2014). Due to its dominance in the composition of the Earth's crust, Fe is widely used as a reference element.

2.3 Statistical analysis

Prior to the statistical analysis, the datasets underwent a verification procedure. Skewness, kurtosis, and

Shapiro-Wilk test were employed to assess normality. A t-test was performed to assess potential changes in mean metal levels in the indoor dust throughout the sampling sites. Correlations between mean heavy metal concentrations were analyzed using a Pearson correlation, considering the data had a normal distribution. Cluster analysis (CA) was employed to categorize the metals derived from various sources, while a dendrogram was utilized to evaluate similarities among the heavy metal concentrations in indoor dust. Statistical evaluations were carried out using IBM SPSS v. 20.

2.4 Health risk estimation

The average daily dosage (ADD) of pollutants and possible risks from indoor lab dust were assessed. According to the United States Environmental Protection Agency (USEPA), Cu, Fe, Pb, and Zn may represent non-carcinogenic concerns. Eqs. (2)-(4) were used to compute the ADD values of pollutants. The hazard quotient (HQ) was calculated to estimate the non-carcinogenic risk (Eq. [5]). Eq. (6) was used to estimate the total non-cancer risk or hazard index (HI), encompassing the summation of HQ values (USEPA, 2011). High hazards are likely when the HQ and HI values surpass a value of 1 and vice versa.

$$\text{ADDingest} = (\text{Cdust} \times \text{IngR} \times \text{ED} \times \text{EF} \times \text{CF}) / (\text{BW} \times \text{AT}) \quad (2)$$

$$\text{ADDdermal} = (\text{Cdust} \times \text{AF} \times \text{SA} \times \text{EF} \times \text{ED} \times \text{ABS} \times \text{CF}) / (\text{BW} \times \text{AT}) \quad (3)$$

$$\text{ADDinhale} = (\text{Cdust} \times \text{EF} \times \text{ED} \times \text{ET}) / (\text{BW} \times \text{AT} \times \text{PEF}) \quad (4)$$

$$\text{HQ} = \text{ADD}/\text{RfD@RfC} \quad (5)$$

$$\text{HI} = \sum \text{HQ} \quad (6)$$

The possibility of cancer risk (CR) from indoor dust was assessed using Eqs. (7)-(9). Lifetime cancer risk (LCR) was calculated by adding the CR from three exposure routes (Eq. [10]). Only Pb was considered to be carcinogenic. The parameter values adopted to calculate health risk are shown in Table I.

$$\text{CRingest} = \text{ADDingest} \times \text{SF} \quad (7)$$

$$\text{CRdermal} = (\text{ADDdermal} \times \text{SF}) / \text{ABSGI} \quad (8)$$

$$\text{CRinhale} = \text{ADDinhale} \times \text{IUR} \quad (9)$$

$$\text{LCR} = \sum \text{CR} \quad (10)$$

3. Results and discussion

3.1 Indoor dust metal composition

Table II presents the metal concentrations of Al, Fe, Cu, Pb, and Zn measured in samples of indoor dust and surface soil collected from the sampling locations. Fe had the highest concentration relative to other metals in indoor dust samples. For Lab 1, the average Fe concentration was 79.85 ± 33.35 mg kg^{-1}, followed by Al (65.60 ± 21.90 mg kg^{-1}), Zn (5.05 ± 2.23 mg kg^{-1}), Cu (1.53 ± 0.62), and Pb (0.68 ± 0.18 mg kg^{-1}). Lab 2 showed the same trend, with average values for Fe of 127.63 ± 50.70 mg kg^{-1}, followed by Al (70.40 ± 21.20 mg kg^{-1}), Zn (4.35 ± 1.45 mg kg^{-1}), Cu (0.93 ± 0.24 mg kg^{-1}), and Pb (0.81 ± 0.24 mg kg^{-1}). Compared to nearby surface soils, indoor dust contained more metals (Table II). The results show that the interior environment exhibits greater metal pollution. The higher coefficient of variation (CV) levels specify that the metal likely is of an anthropogenic source. Metals primarily influenced by natural sources exhibit a low coefficient of variation (CV), while metals affected by man-made sources display a relatively high CV (Guo et al., 2012).

There were statistically significant variations ($p < 0.05$) in metal concentrations found in indoor dust across different sampling locations. Fe and Al concentrations in indoor dust from Lab 2 were higher than those in Lab 1. Lab 2 also showed a slightly higher Pb concentration than Lab 1. The variations in Fe and Al concentration in indoor dust collected from these two laboratories may be attributed to the introduction of soil dust into the interior environment through student activities and the nature of the laboratory. Lab 2, as the soil mechanics lab, focuses on soil as the primary material for the practical laboratory exercises.

Table I. Parameters used for the estimation of non-cancer and cancer risks.

Parameter	Unit	Value	Reference
C (concentration of metal in indoor dust)	mg kg^{-1}	—	—
SA (surface area of the skin that contacts the dust)	cm^2 event^{-1}	5700	USEPA (2002)
AF (skin adherence factor)	mg cm^{-2}	7×10^{-2}	USEPA (2002)
ABS (dermal absorption factor)	mg cm^{-2}	1×10^{-3}	Chabukdhara and Nema (2013)
EF (exposure frequency)	days year^{-1}	350	USEPA (2002)
ED (exposure duration)	years	24 (adults)	USEPA (2002)
	years	6 (children)	
ET (exposure time)	h day^{-1}	24	
CF (conversion factor)	kg mg^{-1}	1×10^{-6}	USEPA (2002)
BW (average body weight)	kg	70 (adults)	USEPA (2002)
	kg	15 (children)	
AT (averaging time)	days	8760 (adults)	USEPA (2002)
	days	2190 (children)	USEPA (2002)
RfDingest (reference dose – ingested)	mg kg^{-1} day^{-1}	Fe: 7×10^{-1} Cu: 4×10^{-2} Pb: 3.50×10^{-3} Zn: 3×10^{-1}	USEPA (2011) USEPA (2011) USEPA (2011) USEPA (2011)
RfDdermal (reference dose – dermal contact)	mg kg^{-1} day^{-1}	Pb: 5.25×10^{-3} Zn: 6×10^{-2}	ATSDR (2005) ATSDR (2005)
RfCinhale (reference concentration – inhaled)	mg m^{-3}	Pb: 3.52×10^{-3}	ATSDR (2005)
		Zn: 3.6×10^{-2}	USDOE (2011)
InR (inhalation rate)	m^3 day^{-1}	20	USEPA (2002)
PEF (particle emission factor)	m^3 kg^{-1}	1.36×10^9	USEPA (2002)
SF (slope factor)	mg kg^{-1} day^{-1}	Pb: 8.5×10^{-2}	USDOE (2011)
ABSGI (gastrointestinal absorption factor)	—	Pb: 1	USDOE (2011)
IUR (inhalation unit risk)	µg m^{-3}	Pb: 1.2×10^{-5}	USDOE (2011)

Table III compares selected metal concentrations in this study's indoor dust samples to those in previous studies' indoor dust samples. The metal concentrations in laboratories' indoor dust were comparatively lower than those reported by Latif et al. (2011), Sulaiman et al. (2017), and Fan et al. (2021). This could be related to the nature of the laboratories since previous studies have been documented from biological or chemical-based labs. However, the laboratories' indoor dust metal concentrations in this study were higher than those in Nigeria (Ajayi et al., 2023). This study found lower concentrations of indoor metals compared to indoor dust in urban homes (Kelepertzis et al., 2021; Asvad et al., 2023), except for a study by Harb et al. (2015).

3.2 Enrichment and correlation between metals

Both laboratories had a similar trend of EFs, wherein Zn had the highest EF value, followed by Al, Cu,

Table II. Metal concentrations in indoor dust of university laboratories and surface soil (mg kg^{-1}).

	Fe	Al	Cu	Pb	Zn
Lab 1					
Minimum	49.57	33.67	0.86	0.49	1.99
Maximum	132.25	99.52	2.71	0.96	8.36
Mean	79.85	65.60	1.53	0.68	5.05
Standard deviation	33.35	21.90	0.62	0.18	2.23
CV (%)	41	33	40	26	44
Lab 2					
Minimum	63.82	40.63	0.53	0.44	1.99
Maximum	219.65	100.55	1.20	1.27	6.60
Mean	127.63	70.40	0.93	0.81	4.35
Standard deviation	50.70	21.20	0.24	0.24	1.45
CV (%)	39	30	26	30	33
Surface soil	37.21	9.77	0.51	0.32	0.20

CV: coefficient of variation.

Table III. Comparison between metal concentrations (mg kg^{-1}) in indoor dust in this study and selected previous studies.

Study site	Reference	Cu	Pb	Zn
Lab 1	This study	1.53	0.68	5.05
Lab 2	This study	0.93	0.81	4.35
University's laboratory, Pahang, Malaysia	Sulaiman et al. (2017)	193	27	30776
University's laboratory, Selangor, Malaysia	Latif et al. (2011)	444.86	179.40	705.70
Universities, China	Fan et al. (2021)	93.50	158.60	665.90
Universities, Nigeria	Ajayi et al. (2023)	0.31	0.11	0.25
Urban homes, Germany	Kelepertzis et al. (2021)	101	68	722
Urban homes, Saudi Arabia	Harb et al. (2015)	0.05	0.14	0.02
Urban homes, Iran	Asvad et al. (2023)	8.50	11.67	73.17

and Pb, respectively (Fig. 2). Indoor dust indicated a higher enrichment of Zn compared to other metal elements. Based on the EF value, this study suggests anthropogenic sources of Zn (EF > 10). Lab 1 had a higher EF value of Zn compared to Lab 2. Han et al. (2011) reported that the presence of Zn in road dust has been identified as a significant component, primarily due to its release from tires, vehicle brakes, and motor oil. Since Lab 1 is located near a road and has a mechanical supply type (i.e., a fan), wind from the outside may have contributed to the Zn enrichment (Latif et al., 2014).

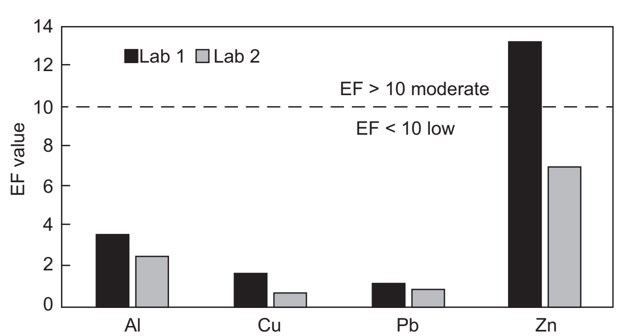

Fig. 2. Estimated enrichment factor (EF) value of metal concentrations in indoor laboratory dust.

The Pearson's correlation between indoor dust metals is shown in Table IV. Fe showed strong

Table IV. Correlation matrix between metals in laboratories' indoor dust.

	Fe	Al	Cu	Pb	Zn
Fe	1	0.148	–0.360	0.870*	0.154
Al		1	0.319	0.222	0.060
Cu			1	–0.030	0.432
Pb				1	0.332
Zn					1

*Correlation is significant at the 0.01 level (two-tailed).

positive correlations with Pb (r = 0.870). The Cu concentration had a moderate relationship (r = 0.432) with Zn. To further confirm the correlation between metals, the data went through a cluster analysis, wherein Euclidean distances were computed to determine similarities. Figure 3 depicts the cluster analysis outcomes performed on the metals found in indoor dust. The study identified three distinct clusters: C1, consisting of Cu and Zn; C2, consisting of Pb and Fel, and C3 consisting solely of Al. Metals in C1 and C2 may be influenced by anthropogenic sources, while those in C3 could be considered to have natural origins. Vehicle emissions are a significant source of Cu, Zn, and Pb (Han et al., 2011; Hassan, 2012). Another possible anthropogenic source of Zn and Pb could be linked to the use of paint containing Zn and Pb compounds (McAlister et al., 2008). Furthermore, the presence of Zn in the composition of indoor dust can

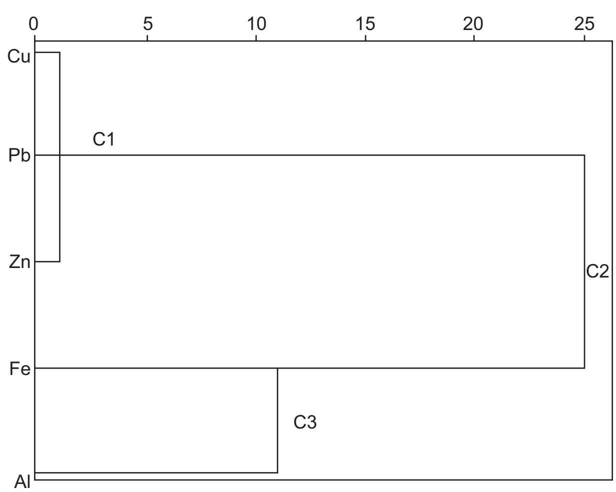

Fig. 3. Dendrogram of the indoor lab dust cluster analysis.

be attributed to the process of corrosion experienced by objects coated with Zn inside laboratory settings (Zhong et al., 2014).

3.3 Potential health risk

HQ and HI values were calculated to evaluate non-carcinogenic health hazards associated with the exposure to individual metals via oral, dermal contact, and inhalation, as well as the combined exposure to metals (Cu, Fe, Pb, and Zn). In contrast, the possible health risk of Al was not considered due to the absence of input from the World Health Organization (WHO) or the USEPA. For Fe and Cu, only the oral pathway was considered, as no information on dermal or inhalation routes has been published by USEPA or WHO. Due to the greater vulnerability of children compared to adults towards the impacts of metals, differences in the duration of exposure and body weight compared to adults (Guney et al., 2010), an independent assessment of risk was conducted for this population subgroup.

Table V lists the potential non-carcinogenic risks associated with metal composition in indoor dust. Generally, the HQ values of indoor dust exposure were below the unity value (HQ < 1), indicating low non-cancer risks to students and staff. The HQ for oral pathways suggests higher values than HQs for dermal contact and inhalation. Children have higher non-carcinogenic risks than adults, except for Fe. In terms of the hazard index (HI), children are more susceptible to non-cancer risks than adults (Fig. 4). The HI shows increment values of Pb < Zn < Fe < Cu for children; however, for adults, it shows increment values of Pb < Fe < Cu < Zn.

The findings of this study confirmed that the oral route is the most hazardous exposure pathway for metals and all population subgroups, consistent with prior research (Chabukdhara and Nema, 2013; Mohamad et al., 2016; Wang et al., 2021; Asvad et al., 2023). Indoor dust samples recorded considerably lower HQ values for dermal contact and inhalation, indicating that these pollutants are less harmful when inhaled. The relative contributions of HQingest, HQdermal, and HQinhalation to children's overall health index (HI) were 99.2, 0.73, and 0.02%, respectively. For adults, the related contributions were 97.9, 2.04, and 0.05, respectively.

The order of cancer risk (CR) values was CRingest > CRdermal > CRinhale for both children and adults

Table V. Potential non-cancer risk of metal exposure from indoor dust.

Metal	Location	HQ_{ingest}	HQ_{dermal}	HQ_{inhale}
		Adults		
Fe	Lab 1	1.56×10^{-3}		
	Lab 2	2.49×10^{-3}		
Cu	Lab 1	5.25×10^{-5}		
	Lab 2	3.18×10^{-5}		
Zn	Lab 1	2.88×10^{-5}	5.97×10^{-6}	3.52×10^{-8}
	Lab 2	1.98×10^{-5}	6.41×10^{-6}	2.43×10^{-8}
Pb	Lab 1	2.68×10^{-4}	6.56×10^{-6}	3.63×10^{-7}
	Lab 2	3.19×10^{-4}	4.53×10^{-6}	2.50×10^{-7}
		Children		
Fe	Lab 1	4.37×10^{-4}		
	Lab 2	6.99×10^{-4}		
Cu	Lab 1	1.47×10^{-4}		
	Lab 2	8.91×10^{-5}		
Zn	Lab 1	8.38×10^{-4}	2.78×10^{-5}	1.64×10^{-7}
	Lab 2	9.00×10^{-4}	2.99×10^{-5}	1.13×10^{-7}
Pb	Lab 1	6.91×10^{-3}	3.06×10^{-5}	1.69×10^{-6}
	Lab 2	4.76×10^{-3}	2.11×10^{-5}	1.16×10^{-6}

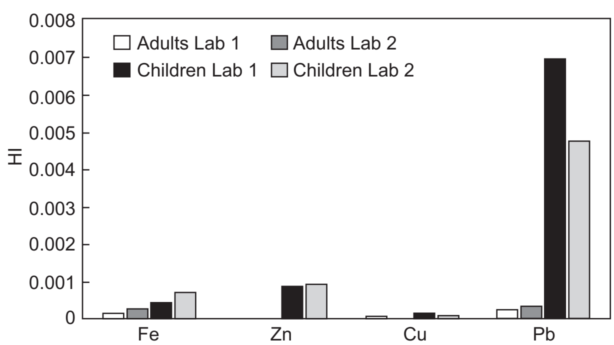

Fig. 4. Hazard index (HI) of metal exposure from indoor dust.

(Table VI). The risk associated with all exposure routes was shown to be greater in children than in adults (Fig. 5), similar to the results reported in Iran by Asvad et al. (2023). Despite the lifetime cancer risk (LCR) values in children being found to be two times greater than in adults, the values fell within the tolerated range ($10^{-6} < LCR < 10^{-4}$).

This study found that the health risk parameters (HI and LCR) remained within acceptable ranges. However, it is crucial to maintain regular monitoring of the concentrations of hazardous elements, as prior research has indicated considerable health hazards from indoor dust exposure in universities (Latif et al., 2011; Zhong et al., 2014; Sulaiman et al., 2017; Fan et al., 2021). Considering the combination of human-induced and naturally occurring emissions, it is imperative for universities and risk managers to focus not only on mitigating levels of particulate matter (PM) but also on reducing the concentration of hazardous elements and human exposure to indoor dust.

4. Conclusion

This study on the metal content of indoor dust samples from university laboratories concluded that Fe and Al had the highest concentrations among the elements investigated in the laboratories' indoor dust. Zn exhibited slightly high concentrations, but Cu and Pb showed comparatively lower levels. The average Fe, Al, Cu, Pb, and Zn concentrations in all indoor dust samples were generally higher than their

Table VI Potential cancer risk of metal exposure from indoor dust.

Metal	Location	CR_{ingest}	CR_{dermal}	CR_{inhale}
Adults				
Pb	Lab 1	7.97×10^{-9}	2.93×10^{-10}	1.52×10^{-17}
	Lab 2	9.50×10^{-9}	2.02×10^{-10}	1.05×10^{-17}
Children				
Pb	Lab 1	2.05×10^{-7}	1.36×10^{-9}	7.11×10^{-17}
	Lab 2	1.42×10^{-7}	9.43×10^{-10}	4.91×10^{-17}

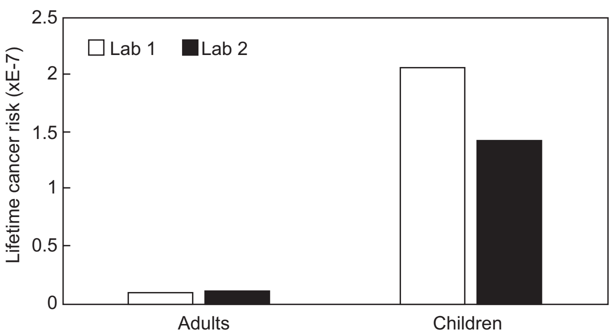

Fig. 5. Lifetime cancer risk (LCR) of metal exposure from indoor dust.

relative values in surface soil. The enrichment factor analysis indicated that the pollution levels fell within the acceptable ranges, except Zn, which exhibited a moderate degree of enrichment. Pb had a strong positive correlation with Fe. The cluster analysis confirmed that the metals were grouped into three clusters, in which two clusters may be influenced by anthropogenic sources. This study revealed that health risks linked to metals are more prominent in children as opposed to adults. The primary mode of exposure to metals for children and adults was oral, followed by skin contact and inhalation. The non-cancer risk was found within the tolerable level (HI<1), and lifetime cancer risk was at a manageable level (10^{-6} < LCR < 10^{-4}). This research proposes a thorough examination of additional potentially harmful elements, such as arsenic (As), cadmium (Cd), chromium (Cr), and mercury (Hg), in indoor dust. Additionally, it is suggested to perform a comprehensive evaluation of health hazards, considering other gastrointestinal variables. It is necessary to consider additional variables such as wind direction, and the temporal pattern of the inhabitants' activities. While the non-cancer and cancer risk levels were acceptable, this study recommends the university administration to implement precautionary measures to prevent an increase in indoor pollutants.

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