A preliminary study of health risk assessment and heavy metals exposure among residents in Kampar, Perak

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Abstract. This preliminary study focused on assessing the carcinogenic and non-carcinogenic risk of residents due to heavy metal exposure in the indoor settled dust of 34 randomly selected households in Kampar, Perak, Malaysia. The indoor dust samples of residential houses (n=34) were collected and analysed for the concentration of heavy metals (Fe, Zn, Cu, Pb, Cr, Mn) using inductively coupled plasma mass optical emission spectrometry (ICP-OES). Health risk due to heavy metals exposure were assessed by determining the Carcinogenic Risk (CR), Hazard Quotient (HQ) and Hazard Index (HI). Results showed median concentrations of heavy metals in the indoor settled dust samples were in descending order of: Zn (6367.75 mg/kg) >Fe (2064.81 mg/kg) >Pb (59.22 mg/kg) >Cu (49.36 mg/kg) >Mn (41.97 mg/kg) >Cr (22.75 mg/kg). Carcinogenic risk (CR) of Pb and Cr of both adults and children were within the accepted limit (1×10^{-4} to 1×10^{-6}). Whereas the HQ and HI of the heavy metals for both adults and children were below 1 which indicates there is no non-carcinogenic risk posed to the Kampar community. Nevertheless, this study provides crucial baseline data for researchers and government authorities in studying and developing indoor air quality relevant guidelines and regulations in Malaysia.

1 Introduction

Nowadays, the advanced development of digital technologies has driven most people to spend a majority of their time (90%) staying indoors, such as in homes, offices, educational institutions. Exposure to indoor air pollutants could be a serious concern for the public as it is associated with harmful health effects. Indoor dust contains complex matrices of both inorganic and organic pollutants, such as heavy metals (HMs), polyaromatic hydrocarbons (PAHs) and more [1]. Among these dust pollutants, heavy metal concentrations in the dust are particularly concerning due to their toxic and non-degradable properties, which bring along myriad drawbacks to human well-being and environmental issues [2].

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The United States Environmental Protection Agency (USEPA) recognises the health impacts due to HMs exposure and has classified HMs into carcinogenic and non-carcinogenic groups [3]. Residents could be exposed to HMs in the household settled dust through three major pathways: inhalation, oral intake and dermal contact [4-5]. Health risk assessment (HRA) could be used to assess the potential carcinogenic and non-carcinogenic risks associated with heavy metal exposure [6] and expressed as Carcinogenic Risk (CR) and Hazard Index (HI), respectively. If the CR within the acceptable range (1×10^{-4} to 1×10^{-6}), it indicates no potential carcinogenic risk to residents. If the HI value is below 1, it indicates no potential non-cancerous risk to residents. Thus, the purposes of this research were to determine the concentrations of HMs (Fe, Zn, Pb, Cu, Cr, Mn) in household settled dust in Kampar and to assess the health risk of heavy metal exposure among adults and children in the home environment in Kampar.

2 Method

2.1 Study design, study location and samples collection

This study was a cross-sectional study that was carried out in Kampar (4° 18' 0" N, 101° 9' 0" E), one of the ex-tin mining towns in Perak in the late 19th century. Kampar district has a land area of 667 km^2 and a population density of 156 people/km^2 [7]. The study was conducted between January and March 2023 at four residential areas in Kampar town. The respondents were invited randomly by asking their consent to enter their house to collect the indoor house dust. House characteristics including geographical location, age of the house and types of building occupancy (e.g. single-family home or student dormitory) were recorded.

For the dust sample collection, the dust was collected using a handheld vacuum cleaner from accessible places (floor, fan, furniture, windowsills) in these 34 households respectively. Then, the collected dust was tightly sealed in a plastic zip lock bag and carefully labelled to distinguish it from the respective households. The dust samples were then stored in the laboratory refrigerator under -18°C prior to sample treatment and analysis. The dust cup filter was strictly replaced after each household dust collection. Besides that, the head of the vacuum cleaner was washed with detergent and soaked in 1% HNO_3 overnight then rinsed with distilled water to prevent cross-contamination [8].

2.2 Samples treatment and analysis

For the dust samples treatment, the dust samples were dried under 105 °C for 24 hours and sieved through a plastic mesh (<100 um) [8]. Approximately 0.5 g to 1.0 g of house dust was weighed and digested in 30 mL aqua regia solution (36% HCl and 63% HNO_3 in 3:1 ratio). The mixtures were digested using a hotplate for approximately 1 hour to facilitate the digestion under constant stirring until the solution was nearly dry and stop to emit brownish gas [9]. The digested samples were cooled to room temperature and followed with diluted to 50 mL using MilliQ water and filtered through 0.45 µm CA syringe filter. Then, the concentrations of Zn, Fe, Pb, Cu, Cr, Mn were analyzed by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) (Model: Optima 7000 DV).

2.3 Health risk assessment

The non-cancerous risk of HMs exposure in household settled dust among adults and children was assessed through three different routes (oral intake, dermal contact and inhalation). The calculations of average daily intake (ADI) for three exposure routes were performed using Equation (1) to Equation (3) [10-11]. For each of the element of concern, the Hazard Quotient (HQ) and Hazard Indexes (HI) were calculated using Equation (4) and Equation (5) [10-11].

$$ADIoral= [(C \times IR \times EF \times ED)/ (BW \times AT)] \times 10^{-6} \quad (1)$$
$$ADIder= [(C \times SA \times SAF \times ABS \times EF)/ (BW \times AT)] \times 10^{-6} \quad (2)$$
$$ADIinh= [(C \times InhR \times EF \times ED \times PEF)/ (BW \times AT)] \quad (3)$$
$$HQ= ADI \times RfD \quad (4)$$
$$HI= \sum HQoral + HQder + HQinh \quad (5)$$

where, C = concentration of pollutant (mg/kg); IR = ingestion rate (mg/kg) children: 200 mg/kg, adult: 100 mg/kg; EF = exposure frequency (360 days/year); ED = exposure duration (years) children: 6 years, adult: 20 years; BW = body weight (kg) children: 32.3 kg, adult: 60.43 kg; AT = average time (years) carcinogenic risk: 70* 365 days, non-carcinogenic risk: ED* 365 days; SA= expose dermal area (cm^2) children: 2800 cm^2, adult: 5700 cm^2; SAF= dermal adherence factor (mg cm^{-2}) children: 0.2 mg cm^{-2}, adult: 0.07 mg cm^{-2}; ABS= dermal absorption factor (0.001); InhR = inhalation rate (m^3/day); PEF= particle emission factor (1.36×10^9 m^3/kg); RfD= reference dose (mg/kg/day) for Fe oral/dermal/inh= 7.00E-01, for Zn oral/inh= 3.00E-01, dermal= 6.00E-02, for Pb oral=3.50E-03, dermal= 5.52E-04, inh=3.52E-02, for Cu oral/inh= 4.00E-02, dermal= 1.20E-02, for Cr oral= 3.00E-03, dermal=6.00E-05, inh= 2.86E-05, for Mn oral= 2.40E-02, dermal/inh= 1.40E-02 [10-13].

The potential carcinogenic health risks due to exposure to Pb and Cr among children and adults were calculated [12]. Lifetime Carcinogenic risk (LCR) was estimated from the sum of route ingestion, dermal absorption and inhalation as shown in the following formulas of Equation (6) and Equation (7):

$$CR= ADI \times CSF \quad (6)$$
$$LCR= \sum CRoral + CRder + Crinh \quad (7)$$

where, CSF= cancer slope factor (mg/kg/day) Pb & Cr: 4.20E-02 [10-13].

2.4 Data analysis

The analysed results and calculated data were keyed in and further analysed using IBM Statistical Package for the Social Science (SPSS) version 26.0. The concentration of HMs in the household settled dust was analysed using frequency test. The comparison of HMs profiles in house-settled dust from different residential areas were analysed using Kruskal Wallis H tests. The data analysed was considered as significant difference at 95% confidence interval with significant value $p<0.05$.

3 Results and discussion

3.1 Concentrations of heavy metals in household-settled dust and the factors associated with their concentrations

In this study, the highest measured median concentration of HMs was Zn [median ± interquartile range (IQR) = 6367.75 ± 5872.25 mg/kg), followed by Fe (median ± IQR = 2064.81 ± 3290.78 mg/kg), Pb (median ± IQR = 59.22 ± 52.20 mg/kg), Cu (median ± IQR = 49.36 ± 49.74 mg/kg), Mn (median ± IQR = 41.97 ± 36.92 mg/kg) and Cr (median ± IQR = 22.75 ± 24.70 mg/kg). Table 1 shows dust collected from Westlake and Aston Settlement contained significantly higher concentration of Zn, Fe and Pb ($p<0.05$). This might be due to most of the Westlake houses are used as student dormitories. Some students wearing shoes enter into the indoor house area which may bring in the outdoor soil and dust particles that adhere to their shoes or barefoot [14]. Moreover, there was a notably higher number of occupants per household (up to 12 people in one house) in the Westlake area compared to normal single household families.

Table 1. Comparison of mean rank values for heavy metals in household settled dust between different geography locations.

Geography location	Zn	Fe	Pb	Cu	Cr	Mn
Eastlake	9.00	18.00	10.33	19.33	21.33	16.67
Meadow Park	14.70	10.10	13.50	16.10	12.60	13.40
Aston Settlement	23.29	19.29	20.57	13.14	18.43	15.86
Westlake	21.00	22.82	23.09	20.55	19.27	22.73
Kruskal Wallis H	8.884	8.900	8.854	2.770	3.720	4.959
p-value	0.031*	0.031*	0.031*	0.428	0.293	0.175

note: $*p< 0.05$

Besides types of building occupancy, traffic density is another factor that associated with HMs concentrations. The findings in study were in line with other previous study which reported urban areas with heavy traffic flow have higher HMs upsurge [8]. Lead is a significant indicator of pollutants released from vehicular emissions besides Cd, Cu, Zn, Mn, and Ni [15-17]. Aston Settlement is a notable old-aged residential area constructed in 1938 and it is near the wet market and commercial areas that are crowded with residential activities. Westlake residential area is also with higher traffic density due to the dense student population. It was observed that many students own a motorcycle or car which easier their daily travelling. These HMs are mainly emitted from the vehicles that use gasoline and diesel engines, and wear and tear of automobile components for instance tyres and brake pads [14].

Table 2 shows Sperman's correlation between the trace elements in the household dust. Fe and Mn were significantly correlated with each other ($r=0.875$, $p<0.001$). This has corresponded with the findings reported in other previous studies [18]. The significant correlations could relate to the elements were originated from the earth's crust. All elements were found significantly positively correlated which indicates they could share the same origin except for Zn-Cu and Cu-Pb. The insignificant correlation between the elements might indicate they independently originate from different sources which could be influenced by several factors, such as the enrichment of the elements that can originate from different anthropogenic activities resources, natural geological properties and chemical reactions of the particular elements [15].

Table 2. Correlations between the elements in indoor household dust.

	Zn	Fe	Pb	Cu	Cr	Mn
Zn	1.000					
Fe	0.612**	1.000				
Pb	0.561**	0.292	1.000			
Cu	0.260	0.544**	0.185	1.000		
Cr	0.392*	0.510**	0.351*	0.460**	1.000	
Mn	0.662**	0.875**	0.380*	0.459**	0.503**	1.0000

note: *$p< 0.05$, **$p< 0.01$, $n = 34$

3.2 Health risk assessment

The carcinogenic and non-carcinogenic risks posed to adults and children due to HMs in indoor household-settled dust were assessed using the aforementioned Equation. (1) - (7), respectively. The calculated results review the decline sequence for HI of the trace elements was Zn> Pb> Cr> Fe> Mn> Cu for both children and adults in this study. According to Figure 1, no non-carcinogenic effect (HI<1) for children and adults were found due to their HMs exposure in household settled dust. Similar to the other studies' findings, the non-carcinogenic risk of children was found higher than the adults, which indicated that the children were at a greater health risk through the HMs exposure. This could be because their exposure was influenced by lower body weight and higher ingestion rate. Besides, children may unconditionally ingest the HMs containing dust due to hand-to-mouth behaviour [19]. The major pathway for HMs exposure was oral intake followed by dermal, then the least pathway was through inhalation [18].

Pb and Cr are the HMs that pose carcinogenic risks to humans. In this study, the calculated LCR values were within the acceptable range of 1×10^{-4} to 1×10^{-6}, in which the LCR values of Pb and Cr elements for children were 1.3×10^{-6} and 5.00×10^{-6}, while for adults were 1.17×10^{-6} and 4.51×10^{-6}, respectively. Similar to non-carcinogenic risk, children were at higher risk compared to adults for the total carcinogenic risk. Thus, the findings of this study revealed no potential carcinogenic effect on children and adults due to HMs exposure in household settled dust. Although, there was no significant health risk posed to both children and adults, the potential health risk should not be ignored. Long-term exposure to highly toxic elements can lead to their accumulation in body organs and cause irreversible chronic illness [19].

4 Conclusion

In conclusion, the highest concentration of HMs measured in this research was Zn, followed by Fe, Pb, Cu, Mn and lastly Cr. Households located near busy roads were measured with higher concentrations of HMs, especially for Fe. In this study, there was no non-carcinogenic risk posed to both children and adults (HI < 1), and the carcinogenic risks (LCR) for both children and adults were within the acceptable range (1×10^{-4} to 1×10^{-6}). However, children were at a greater risk compared to adults when exposed to HMs in household-settled dust. This study provides crucial baseline data for future researchers and government authorities in studying and developing indoor air quality relevant guidelines and regulations in Malaysia. Although there were no non-carcinogenic and carcinogenic risks associated with the HMs exposure in the household settled dust, it is recommended to have regular household cleaning to reduce indoor dust build-up which can deteriorate indoor air quality.

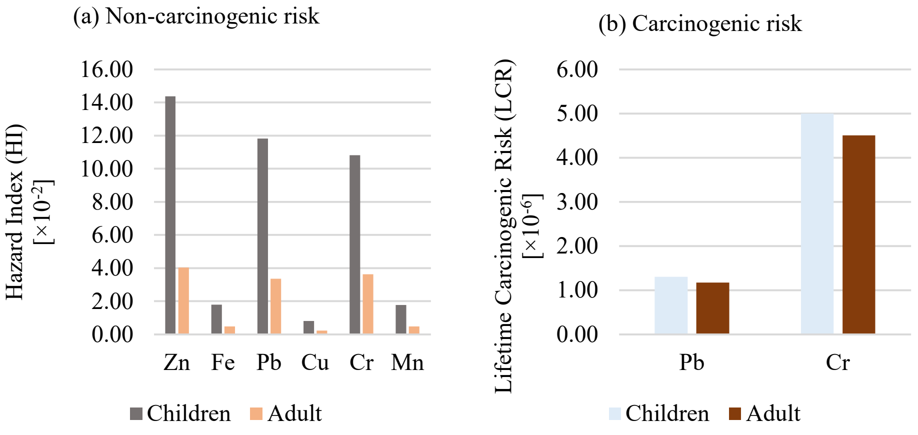

Fig. 1. Health risk assessment of trace elements in household settled dust among children and adults in Kampar. Figure 1(a) shows the HI value and Figure 1(b) shows LCR value.

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