Health risk assessment of heavy metals in indoor dust from Bushehr, Iran

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ABSTRACT
Environmental contamination with heavy metals is one of the main concerns on a global scale and the risk related to exposure to heavy metals present in indoor dust is considered as a serious threat to human health. Therefore, the purpose of the current research was to evaluate the heavy metals concentrations in indoor dust and their potential risks in urban areas in Bushehr city, Iran. Fifty-four indoor dust samples were collected from different buildings including lab rooms, offices, school rooms and households within the Bushehr City, during May – July 2016 and analyzed using ICP-AES (Arcousmodel, Germany). The sum of hazard quotient (hazard quotient (HQs) for heavy metals for adults declined in the order of Cr > Cd > Cu >Ni > Zn > Pb for the household while the order of ΣHQ for trace metals for adults in offices is Cr > Cd > Ni >Cu > Zn > Pb. Moreover, the values ΣHQ for trace metals for children declined in the order of Cr > Cd > Zn > Ni > Cu > Pb for the schools while the order of ΣHQ for trace metals for children in households is Cd > Zn >Cu > Cd > Ni > Cr > Pb. For all heavy metals, the HQs was about an order of magnitude higher for children than for adults. These findings can be attributed to the more vulnerability of children to the toxic substances.

Key words: Indoor Dust; Heavy Metals; Risk Assessment; Bushehr

INTRODUCTION
Due to this fact that people spend more time in indoor environments, it has become the main considerable interest amongst academic and government agencies [1-3]. The indoor dust has been reported in many types of research which can act as a sink for various pollutants including heavy metals [4]. Several types of research have been carried out to quantify heavy metals in indoor dust, such as dust of residential, official and school building. The average values of heavy metals in these researches were in the range of 35-250 mg kg^{-1} for Cr, 0.80-6.5 mg kg^{-1} for Cd, 0.20-3.63 mg kg^{-1} for Hg, 91-2740 mg kg^{-1} for Cu, 396-3104 mg kg^{-1} for Zn 28-406 mg kg-1 for Pb [5-7].

Heavy metals can enter the body through common pathways including Inhalation, dust ingestion, and dermal contacts [8, 9]. It has been reported that exposure of children to contaminated dust by ingestion a considerable amount of heavy metals via the hand-mouth route as well as another pathway of exposure [10, 11]. Exposure to some heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), zinc (Zn) and chromium (Cr) can lead to various diseases such as nervous system, cardiovascular, blood and bone diseases, kidney failure, gingivitis, tremors among others [12, 13]. Thus, there is a need to be studied the levels of heavy metals in indoor and assess health risks of them.

As far as we know, there is no published data on heavy metal concentrations in indoor dust in Bushehr, Iran. Therefore, this work is the first to report heavy metal concentrations in settled dust collected from indoor environments of Busehr. So, the main objectives of the current work were:

- To quantify heavy metals in the settled dust collected indoor environments of Bushehr.
- To compare the findings of heavy metal concentrations with the values found in literature worldwide.
- To use the results to assess the human health risk of metals.

MATERIALS AND METHODS
Dust samples were collected from the indoor environment of a total 54 different buildings, including lab rooms, offices, school rooms, and houses within the Bushehr City, during May – July 2016. Samplings were done by gently sweeping the floors, corners of landscape buildings, Window sills, steps and pavements with a clean brush. At least 5 g of indoor dust was collected and transferred into resealable plastic bags and clearly labeled. The sample bags were moved to the laboratory and sieved

to eliminate any debris such as visible hair, soil, and grit. In the laboratory, dust samples were oven-dried at 45°C for 48 hours and homogenized completely.

Dust samples digestion was done using a Berghof-MWS2 model microwave digestion system (Berghof Speedwave®). About 0.2g of each dust sample was withdrawn and put in a digester vessel and then 6 mL HNO3, 2 mL of HCl and 1 ml of HF were added and digested at room temperature overnight. The analysis of Zn, Cu, Cd, Cr, Ni, and Pb was carried out by using ICP-AES (Arcousmodel,Germany). All runs were carried out in duplicate and average values were selected for further analyses.

There are three common pathways for exposure to heavy metals related to indoor dust including ingestion (Ing), inhalation (Inh) and dermal contact (Der). Equations 1-3 were used to calculate dose received via each of these exposure pathways:

$$D_{Ing} = C \times \frac{IngR \times EF \times ED}{BW \times AT} \times 10^{-6} \quad (1)$$

$$D_{Inh} = C \times \frac{InhR \times EF \times ED}{BEF \times BW \times AT} \quad (2)$$

$$D_{Der} = C \times \frac{SL \times SA \times ABS \times EF \times ED}{BW \times AT} \times 10^{-6} \quad (3)$$

In these equations, D stands the daily intake (mg kg−1 day−1) via ingestion pathway (Ding), inhalation pathway (Dinh) and dermal contact (Dder). EF: exposure frequency; ED: exposure duration, BW: the average body weight, AT: averaging time for non-carcinogens, SA: the skin surface area, SL: skin adherence factor, ABS: dermal absorption factor, PEF: particle emission factor and C is exposure-point concentration.

In order to risk assessment schools and households with exposure were evaluated for children and offices and households for adults. Risk Assessment (RA) was determined using hazard quotient (HQ).

$$HQ = \frac{D_{Ing}}{RfD_0} = \frac{D_{Inh}}{RfD_0 \times GIABS} \times \frac{D_{Der}}{RfC_i \times 100 \mu g.mg^{-1}} \quad (4)$$

Here, RfDo and RfCi are reference dose and inhalation reference concentration, respectively.

Statistical analysis

The normality of all data was checked with the Shapiro–Wilk test before analyzing. Data indicated non-normal distributions ($p<0.001$) for main of the analyzed heavy metals. Therefore, non-normal distributions of data were assumed for all heavy metals in all sampling environment. Moreover, the description statistics analysis such as mean, standard deviation, median, min, and max was done for heavy metal concentration in indoor dust. These analyses were done and calculated with the SPSS statistical package version 19.0 (SPSS Inc.)

RESULTS

Heavy metal levels in households, lab rooms, Offices and school room dust

Indoor settled dust collected from 54 indoors during May–July 2016 within the Bushehr city were analyzed for the values of heavy metals. The concentrations of the Pb, Cd, Cr, Ni Cu and Zn in settled dust collected from households (n = 19), school rooms (n = 11), offices (n=15), and lab rooms (n = 9) from the metals studied are given in Table 1.

As shown in Table1, for household indoor dust, the order of the heavy metals concentration is Zn > Cu > Pb > Cr > Ni > Cd. The mean concentrations of Zn, Cu, Pb, Cr, Ni and Cd in household dust samples were 1423, 234, 93.4, 83.5, 42 and 5.4 mg kg^{-1}, respectively. Also, the mean values of Zn, Cu, Pb, Cr, Ni and Cd in school rooms dust samples were 876, 189, 53, 49, 43 and 3.1 mg kg^{-1}, respectively. Moreover, the contents of Zn, Cu, Pb, Cr, Ni and Cd in offices dust samples were 1967, 261, 73, 65, 39 and 7.6 mg kg^{-1}, respectively. Finally, the contents of Zn, Cu, Pb, Cr, Ni and Cd in lab rooms dust samples were 2711, 414, 176, 151, 39 and 23 mg kg^{-1}, respectively.

The levels of the Pb, Cd, Cr, Ni Cu and Zn obtained in this work with those found in the other locations around the world are compared and given in Table2.

Health risks from heavy metals in indoor dust of Bushehr were calculated for two groups including children and adults. The findings of these calculations are given in Table 3. As can be seen in Table3, the values ΣHQ for heavy metals for adults declined in the order of Cr > Cd > Cu >Ni > Zn > Pb for the household while the order of ΣHQ for trace metals for adults in offices is Cr > Cd > Ni >Cu > Zn > Pb. Moreover, the values ΣHQ for trace metals for children declined in the order of Cr > Cd > Zn > Ni > Cu > Pb for the schools while the order of ΣHQ for trace metals for children in households is Cd > Zn >Cu > Cd > Ni > Cr > Pb.

Table 1: Total heavy metal concentrations (mg kg^{-1}, dry weight) in indoor dust

Heavy metals	Statistical Analyzes	Households	Lab rooms	Offices	School rooms
Pb	Mean	93.4	142	73	53
	Standard Deviation	173	111	64	29
	Median	43	97	58	42
	Min	5.7	24	14	12
	Max	1132	352	241	121
Cd	Mean	5.4	23	7.6	3.1
	Standard Deviation	9.7	37	7.9	2.6
	Median	3.4	13.2	5.4	2.5
	Min	0.4	1.4	0.87	.45
	Max	65.6	192	21	6.1
Cr	Mean	83.5	151	65	49
	Standard Deviation	167	143	14	31
	Median	54.7	89	68	36
	Min	13.5	29	41	13
	Max	1323	518	76	102
Ni	Mean	42	176	39	43
	Standard Deviation	47	87	15	17
	Median	37	156	37	47
	Min	6.7	32	12	19
	Max	276	618	62	71
Cu	Mean	189	414	261	234
	Standard Deviation	179	378	114	167
	Median	138	301	198	198
	Min	33	65	78	21
	Max	1167	1412	419	615
Zn	Mean	876	3241	1967	1423
	Standard Deviation	1786	2711	1761	880
	Median	856	2219	1321	912
	Min	754	1201	761	312
	Max	13231	8162	7124	5162

Table 2; Comparison of the distribution of heavy metals in indoor dust presented in current research with those reported in other studies

Location	Building type	Sample number	Pb	Cd	Cr	Ni	Cu	Zn	References
Bushehr, Iran	Households	19	93.4	5.4	83.5	42	189	876	Current study
Bushehr, Iran	Lab room	9	142	23	151	176	414	3241	Current study
Bushehr, Iran	School room	11	53	3.1	49	43	234	1423	Current study
Bushehr, Iran	Offices	15	73	7.6	65	39	261	1967	Current study
Sydney, Australia	House	82	389	4.4	83.6	27.2	147	657	[5]
Pretoria, South Africa	Office	6	126	2.53	160	69.8	2740	1300	[14]
Ottawa, Canada	Home	50	406	6.46	86.7	62.9	206	716	[15]
Istanbul, Turkey	Home and office	39	30	0.95	89	282	200	984	[16]
Hong Kong	School	53	164	4.7	N.R	167	N.R	2241	[17]
Christchurch, New Zealandb	House	N.R	724	5.2	N.R	N.R	190	21700	[18]
Toronto, Canada	Lab	15	137	25.3	145	170	631	3198	[19]
Dharan, S. Arabia	House	9	35.5	1.51	137	26.1	91.1	396	[20]
Warsaw, Poland	Home	27	124	N.R	90	30	109	1070	[21]

Table 3: Health risks from heavy metals in indoor dust of Bushehr

Groups	Type of environment	Metals	HQ			ΣHQ
			Ingestion	Dermal	Inhalation	
Adults	Households	Pb	2.1×10^{-5}	4×10^{-5}	-	6.1×10^{-5}
		Cd	6.1×10^{-4}	5.5×10^{-4}	9.5×10^{-8}	1.15×10^{-3}
		Cr	2.5×10^{-3}	1.63×10^{-3}	1.1×10^{-7}	4.4×10^{-3}
		Ni	2.81×10^{-4}	1.25×10^{-4}	5.76×10^{-6}	5.02×10^{-4}
		Cu	1.1×10^{-3}	2.1×10^{-5}	-	1.12×10^{-3}
		Zn	7.4×10^{-5}	9.1×10^{-8}	-	7.41×10^{-5}
	Offices	Pb	1.51×10^{-5}	3.1×10^{-5}	-	4.52×10^{-5}
		Cd	9.25×10^{-4}	6.23×10^{-4}	9.8×10^{-9}	1.51×10^{-3}
		Cr	1.53×10^{-3}	9.87×10^{-4}	7.1×10^{-9}	3.1×10^{-3}
		Ni	3.77×10^{-4}	4.01×10^{-4}	5.5×10^{-6}	6.01×10^{-4}
		Cu	4.01×10^{-4}	1×10^{-5}	-	4.02×10^{-4}
		Zn	4.3×10^{-5}	1.01×10^{-6}	-	4.31×10^{-5}
Children	Households	Pb	2.3×10^{-4}	8.1×10^{-5}	-	3.12×10^{-4}
		Cd	7.87×10^{-3}	6.87×10^{-4}	7.07×10^{-8}	7.96×10^{-3}
		Cr	3.2×10^{-2}	2.82×10^{-3}	1.2×10^{-9}	3.25×10^{-2}
		Ni	3.4×10^{-3}	4.1×10^{-4}	9.98×10^{-6}	3.87×10^{-3}
		Cu	6.41×10^{-3}	1.4×10^{-5}	-	6.42×10^{-3}
		Zn	7.0×10^{-3}	3.1×10^{-5}	-	7.02×10^{-3}
	Schools	Pb	1.21×10^{-4}	2.4×10^{-5}	-	1.23×10^{-4}
		Cd	3.2×10^{-3}	4.27×10^{-3}	5×10^{-8}	7.01×10^{-3}
		Cr	1.21×10^{-1}	1.41×10^{-2}	6.2×10^{-8}	1.34×10^{-1}
		Ni	2.2×10^{-3}	1.12×10^{-4}	1.02×10^{-5}	2.37×10^{-3}
		Cu	1.21×10^{-3}	4.2×10^{-6}	-	1.22×10^{-3}
		Zn	6.2×10^{-3}	2.2×10^{-5}	-	3.2×10^{-3}

DISCUSSION

The most abundant metal in the entire selected indoor environment was Zn. The high standard deviations found for some heavy metals concentrations demonstrating the high in-homogeneity of the dust samples. The levels of trace metals observed in the current research with those reported in various locations around the world. The Pb values detected in household dust in Bushehr were lower than the values reported for Sydney, Australia, and Christchurch, New Zealand but they were higher than the values reported for Istanbul, Turkey and Warsaw, Poland. Lower Cr levels were observed in household dust in Bushehr compared with those observed in Dharan, S. Arabia and Warsaw, Poland whereas the Cr concentration in Bushehr was higher than Sydney, Australia. Elevation of Zn in household dust was detected in the current research when compared with Christchurch, New Zealand and Istanbul, Turkey and lower when compared to Sydney, Australia. The levels of elements in office dust in Bushehr were lower than those reported for Sydney, Australia but Cd and Zn are exceptional. The contents of Pb, Cr. Ni and Zn in lsb dust in Bushehr were higher than the values reported for Toronto, Canada, but the levels of Cd and Cu were higher than the values reported for Toronto, Canada.

Amongst other contaminants in indoor dust, heavy metals need a comprehensive study because of their high toxicity, non-degradable features and adverse impacts on human health [22]. The IARC has categorized the carcinogens into five group to show whether the agents can cause cancer, which include Group 1 (carcinogenic to humans), Group 2A (probably carcinogenic to humans), Group 2B (possibly carcinogenic to humans), Group 3 (not classifiable as carcinogenic to humans) and Group 4 (probably not carcinogenic to humans). From the International Agency for Research on Cancer (IARC) agents' classification, Cr, As, Cd and Pb are treated as potential non-carcinogenic and carcinogenic metals, whereas other heavy metals (Co, Cu, Al, Fe, Ni, and Zn) are classified as non-carcinogenic elements [23]. Thus, health risk assessment was used to determine the potential adverse health effects of human exposure to pollutants.

The values for inhalation HQs in selected heavy metals in this work were ten times to ten thousand times lower than the HQs of ingestion and dermal contact. Similar findings have been reported for indoor dust in previous researches. For all heavy metals, the HQs were about an order of magnitude higher for children than for adults. These findings can be attributed to the more vulnerability of children to the toxic substances. In addition, children are also more sensitive to heavy metals in indoor dust due to their behaviour such as hand-to-mouth activities, crawling and fast growth rate [24]. Moreover, Olujimi *et al*.[4]reported that the ingestion of indoor dust is the main toxic metal exposure route for children as children like to play on the house floor and ingest the indoor dust indirectly [25]. Dust can easily cling to children's skin and be ingested by children unintentionally [25]. Finally, the fine particles of dust could be inhaled into the children's lungs because of air suspension caused by wind [26].

CONCLUSION

The current research gives some good information about the concentrations of heavy metals (Pb, Cd, Ni, Cu, and Zn) in indoor dust collected from Bushehr city, Iran. The results show that the values of heavy metal in dust of the lab was higher the other indoors. The Pb values detected in household dust in Bushehr were lower than the values reported for Sydney, Australia, and Christchurch, New Zealand but they were higher than the values reported for Istanbul, Turkey and Warsaw, Poland. For all heavy metals, the HQs were about an order of magnitude higher for children than for adults. These results can be justified with more vulnerability of children to the toxic pollutants.

ETHICAL ISSUES

There is no ethical issue.

CONFLICT OF INTEREST

Authors of the manuscript did not have a conflict of interest.

AUTHORS' CONTRIBUTION

Authors contribute to this study as following items:
Seyed Enayat Hashemi:Study design
Saeed Ardashiri: Study statistical analysis and reviewing the final version of the manuscript.

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