

NURSERY SCHOOLS: CHARACTERIZATION OF HEAVY METAL CONTENT IN INDOOR DUST

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ABSTRACT

Interior floor dust is found to be one of the major pathways of childhood exposure to indoor air pollutants. This study aims to carry out a general survey of heavy metals (Al, Ba, Cr, Cu, Fe, Ni and Pb) contamination at selected nursery school buildings in Shah Alam, Selangor and to study their relationship with the surrounding environment. The samples were collected using a brush and a plastic dust pan, after which the samples were digested using the wet digestion method. The heavy metal concentration was determined by inductively coupled plasma – optical emission spectrometer (ICP-OES). The results show that the heavy metal concentrations at nursery school building were in the range 901.2 - 1510.0, 13.3 - 76.7, 12.0 - 22.6, 22.2 - 42.7, 1489.0 - 7919.0, 5.5 - 14.4, 13.2 - 64.6, 93.3 - 220.4 mg kg⁻¹ for Al, Ba, Cr, Cu, Fe, Ni and Pb respectively. The heavy metal concentration in the investigated areas followed the order Fe > Al > Zn > Pb > Ba > Cu > Cr > Ni. Principal Component Analysis (PCA) was carried out to ascertain the possible contributing factors towards the metal concentrations and thereby determine which metals have a common origin. PCA analysis indicated that three factors indicated source of mixed origin including mobile vehicle, street dust and natural sources.

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INTRODUCTION

Dust consist of solid matter or particulates in the form of fine powder (less 100 μm), lying on the ground or on the surface of objects or blown about by natural forces or mechanical forces (Adekola & Dosumu, 2001). Indoor dust is present in the indoor environment as a composite of particulate matter derived from interior and exterior sources. Dust can enter an indoor environment in several ways such as infiltration from outdoor sources and internally from smoking, incense burning, buildings and furniture materials, consumer products and occupant activities (Al-Rahji and Seaward, 1996; Turner & Simmonds, 2006). Indoor dust is a repository for environmental pollutants such as heavy metals that may accumulate indoors and is an important pathway of exposure to metal for humans. There is an increasing concern about heavy metals contamination in indoor environment since most people spend a great extent of their time indoors (Klepeis et al., 2001; Sharpe, 2004).

A number of studies have suggested that there is a possibility that metals in the indoor dust can accumulate in humans, either directly or indirectly by inhalation, ingestion as a result of hand-to mouth activity or via dermal contact absorption (Al-Rahji & Seaward, 1996; Molhave et al., 2000). Young children, especially toddlers, can easily ingest soils or indoor dusts unintentionally since they spend most of their time indoors and much of this time is spent in contact with floors, engaging in mouthing of hands, toys and other objects or the consumption of food contaminated by hands (Mohd Tahir, 2007; Adekola & Dosumu, 2001).

Heavy metals have an effect on biochemical mechanisms, especially because they can be bioaccumulated. An infant or child is extremely vulnerable to environmental interference because their organs are developing rapidly at early stage of development, making them more susceptible to functional damage or disorders (Yaaqub et al., 1991). These groups are also vulnerable to heavy metal poisoning since this is the period for maximal brain growth and differentiation (Tong & Lam, 2000). Besides, the rate of absorption of heavy metals from the digestion system and the hemoglobin sensitivity to these metals in children is much higher than in adults (Tong & Lam, 1998). It is now widely accepted that dust and soil are the predominant sources of heavy metals to which young children are exposed by mouthing of contaminated indoor dust (Chatterjee & Banerjee, 1999; Tong & Lam, 2000; Chattopadhyay et al., 2003).

Considerable attention has been paid to the study of metal pollution in city air, roadside dust and soils. However, there is a lack of concern on the presence of heavy metals in indoor dust in buildings such as in the nursery schools in Malaysia. Since there is limited data on dust contamination in the nursery schools, this study is important.

METHODOLOGY

Site sampling

Shah Alam is located in the center of the west coast of Peninsular Malaysia, at an altitude of 75 m, being about 25 km from Kuala Lumpur, capital city of Malaysia. It is the capital city of Selangor state, the fastest growing state which has experienced rapid urbanization and industrialization in the last decades, with a present population estimated at 584,350. The nursery school buildings selected for this study lie mainly in the Shah Alam city. The schools sites were located at three different land use types; nursery 1 located inside residential area (Section 7), nursery 2 located close to commercial area (Section 9) and nursery 3 located close to industrial areas (Section 17). Table 1 shows the site description of selected nurseries.

Table 1: Site description of the nursery schools

Site	Landuse Background	Building Type	Number of occupants	Number of windows	Ventilation condition
Nursery 1 (Section 7)	Residential area, 800 m from main road with high	Double storey, corner lot	22 traffic flow	3	Fan, natural ventilation all the time
Nursery 2 (Section 9)	Closed to commercial zone area, 10 m from main road	Double storey, corner lot	30 with high traffic	6	Fan, natural ventilation, air conditioned in main room
Nursery 3 (Section 17)	Closed to industrial zone area, 10 m from main road with	Single story, corner lot	28 high traffic	6	Fan, natural ventilation, air conditioned in main room

Sample collection

Indoor dust was collected from three nurseries representing three different background sites of different land use types within Shah Alam city area during March-April 2010. Using a clean plastic brush and pan, dust was collected inside the nursery building by sweeping the classroom floor which was most accessible to the children. The indoor dust was then transferred into a resealable plastic bag, brought to the laboratory and placed in a desiccator for 24 h, sieved through a 100- μ m screen, and finally oven dried at 105°C for 24 h.

Sample and data analysis

Immediately after drying, about 0.3 - 0.5 g of the fine portion of the dust was then digested by using 3 mL of mixture solution (HCl-HNO₃-H₂O) in a ratio of 2 : 2 : 2 to form aqua regia acid at 95°C for at least one hour until white fumes appeared. The extract was cooled and was filtered through Whatman No. 42 filter papers. The filtrate was then made up to a volume of 50 mL in the volumetric flask with distilled water and was analyzed for metal content by using Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) to determine the concentration of Al, Ba, Cr, Cu, Fe, Ni, Pb and Zn heavy metals. The blank experiment was carried out by repeating the procedure for sample preparation without the sample. The composition of the blank solution was compared with the sample solution to identify the elemental composition of heavy metals in the dusts.

Data were analyzed for analysis of variance (ANOVA), correlation functions and factors analysis using statistical functions in Microsoft Excel and Statistical Packages for the Social Sciences (SPSS), including.

RESULTS AND DISCUSSIONS

Heavy metals concentration

The mean concentrations of heavy metals in the indoor dust samples are summarized in Table 2. The concentration of heavy metals in nursery schools building were depends upon dustiness and ventilation of the building. The highest concentration heavy metal obtained was Fe with the mean concentration 4225.33 mg/kg and followed by Al with the mean concentration of 1229.58 mg/kg. Both Al and Fe are abundant elements in the Earth's crust (Al-Khashman, 2004; Hunt et al., 2008). These elements have been produced by alteration (friction) and distributed or transported via wind blow and can be associated with soil or street dust. The result indicated that soil or street dust play an important role in the concentration build up in indoor dust in the nursery school building.

Table 2: Descriptive statistics of indoor dust heavy metal concentration (mg/kg) (*N* = 9)

	Al	Ba	Cr	Cu	Fe	Ni	Pb	Zn
Mean	1229.58	30.90	16.88	30.19	4225.33	9.00	31.24	148.71
SD	214.77	18.91	3.61	6.25	2282.01	3.24	17.49	44.19
Min	901.20	13.30	12.00	22.20	1489.00	5.50	13.20	93.30
Median	1149.00	27.40	16.20	29.50	3931.00	9.10	25.50	159.00
Max	1510.00	76.70	22.60	42.70	7919.00	14.40	64.60	220.40

SD – Standard deviation

Heavy metals find their way into indoor building or in this case children's nurseries either as airborne dust or through items used or activities carried out within the nursery by occupant's activities. In addition, activities carried out at surrounding area or in the vicinity also contribute to indoor dust and may direct or indirectly characterize the type of metals found indoor. The locations of all nursery schools were close to the main road with high traffic density and therefore it is expected to contain high lead (Pb) (31.24 mg/kg) in indoor dust related to the automobile emission (Chattopadhyay et al., 2003). Pb is a universal pollutant in an urban environment due to automobile emission (Al Rahji and Seaward, 1996), and despite the gradual shift from leaded to unleaded petrol as fuel for automobile, it still remains as a major pollutant for some urban areas including Shah Alam city.

Other metals such as Zn, Cu, Cr, Ni and Ba were also related to automobile emission. As cited throughout the literature, the source of Zn in dust may have its origin from automotive sources i.e. wear and tear of vulcanized rubber tyres, lubricating oils and corrosion of galvanized vehicular parts (Li et al. 2001; Al-Khashman, 2004; Adachi and Tainosho, 2004). The source of Cu, Cr and Ni in dust is believed to be from car components, tyre abrasion, lubricants corrosion of cars, engine wear, thrust bearing, brushing, bearing metals and brake dust respectively (Al Rahji and Seaward, 1996; Al-Khashman, 2004; 2007).

Although heavy metals in dust could be derived from indoor and outdoor sources, the result of this study indicated that major influence was from outdoor sources. The possible routes of heavy metals entering the schools building were through the open windows for cooling and ventilation (Komarnicki, 2005). While recognizing the fact that, the movement of occupant's in and out from building also contributed the heavy metals concentration in the building, its contribution was less obvious from the contribution from ambient sources.

Correlation coefficient analysis

Pearson's correlation coefficient can be used to measure the degree of correlation between logarithms of the heavy metals data. The correlations of heavy metals in indoor dusts of the nursery schools building are depicted in Table 3. All the metal pairs showed negative relations except for Al-Ni, Al-Zn, Cu-Fe and Ni-Zn pairs which were significant at 95% and/or higher confidence level. Al, Ni and Zn significantly correlated with each other (0.792 and 0.749) at 95% or higher confidence level, which may indicate a common sources origin, such as automobile emission.

Factor analysis

The principal component matrix analysis is given in Table 4. Principal Component Analysis (PCA) was carried out to ascertain the possible contributing factors towards the metal concentrations and thereby determine which metals have a common origin.

Table 3: Correlation matrix for the heavy metal concentrations

	Al	Ba	Cr	Cu	Fe	Ni	Pb	Zn
Al	1.000	0.519	-0.323	-0.215	0.282	0.792*	-0.075	-0.749*
Ba		1.000	-0.242	0.160	-0.145	0.527	0.591	-0.415
Cr			1.000	-0.127	0.364	-0.205	0.323	0.292
Cu				1.000	-0.730*	0.008	0.311	0.375
Fe					1.000	0.018	-0.258	-0.238
Ni						1.000	0.386	-0.871**
Pb							1.000	-0.227
Zn								1.000

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

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

Table 4: Factor loadings and communalities of heavy metals

Item / Component	Factor-1	Factor-2	Factor-3
Eigenvalue	3.21	2.19	1.43
Explained variances (%)	40.2	27.3	17.8
Al	0.876	-0.226	-0.200
Ba	0.700	0.428	0.168
Cr	-0.332	-0.194	0.864
Cu	-0.165	0.874	-0.112
Fe	0.133	-0.870	0.313
Ni	0.928	0.102	0.062
Pb	0.326	0.585	0.706
Zn	-0.913	0.209	0.003

Three factors that have eigenvalues > 1 were extracted. The total variance explained by these three factors was 85.3%. The first factor explains the greatest amount of variance (40.2%) which is predominantly loaded by Ni, Zn, Al and Ba. This factor may indicate a source of mixed origin including air-borne emissions originated from mobile vehicle, street dust and soil dust. The second factor (27.3%) is characterized by high loading of Cu and Fe but moderately by Pb, which is characteristically identified with vehicles and street dust. Pb also has been distributed between the second and third factor with moderate load value. The third factor is indicative of automobile emission sources.

CONCLUSION

The chemical analysis of indoor dust sample in nursery schools building in this study showed the distribution and concentration of heavy metals within the area of study. The results show the concentration of heavy metals at three nursery schools building were in range of 901.2-1510.0, 13.3-76.7, 12.0-22.6, 22.2-42.7, 1489.0-7919.0, 5.5-14.4, 13.2-64.6, 93.3-220.4 mg kg⁻¹ for Al, Ba, Cr, Cu, Fe, Ni and

Pb respectively. The result of heavy metal concentration in investigated areas were in order Fe > Al > Zn > Pb > Ba > Cu > Cr > Ni. Data analyses indicate that automobile emission is the major source of these heavy metals in indoor dust. The concentrations of heavy metals in nursery schools building were influenced by the dustiness and ventilation of the building.

Since the health effects caused by contaminated dust may have long-term effects on the children, action should be taken to avoid or minimize the potential risks of this silent epidemic. Therefore a good housekeeping practice such as frequent wet mopping and vacuuming and good maintenance of the ventilation system by closing those windows that are facing major roads should be taken into consideration in order to reduce children exposure to contaminated dust by heavy metals in nursery school buildings.

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