

HEAVY METAL CONCENTRATION OF SETTLED SURFACE DUST IN RESIDENTIAL BUILDING

(Kepekatan Logam Berat Dalam Debu Terenap Permukaan Di Bangunan Kediaman)

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Abstract

The concentrations of heavy metals (Cu, Ni, Pb and Zn) in settled surface dust were collected from nine residential buildings in different areas in Seberang Prai Tengah District, Pulau Pinang. The samples of settled surface dust were collected in 1 m² area by using a polyethylene brush and placed in the dust pan by sweeping the living room floor most accessible to the occupants. Heavy metals concentrations were determined by using inductively coupled plasma optical emission spectrometer (ICP-OES) after digestion with nitric acid and sulphuric acid. The results show that the range of heavy metals observed in residential buildings at Seberang Prai Tengah were in the range of 2.20-14.00 mg/kg, 1.50-32.70 mg/kg, 1.50-76.80 mg/kg and 14.60-54.40 mg/kg for Cu, Ni, Pb and Zn respectively. The heavy metal concentration in the investigated areas followed the order: Pb > Zn > Ni > Cu. Statistical analysis indicates significant correlation between all the possible pairs of heavy metal. The results suggest a likely common source for the heavy metal contamination, which could be traced most probably to vehicular emissions, street dust and other related activities.

Keywords: Settled surface dust, heavy metal, residential building

Abstrak

Kepekatan logam berat (Cu, Ni, Pb dan Zn) di dalam debu terenap permukaan yang diambil dari sembilan buah kediaman di lokasi berbeza di daerah Seberang Prai Tengah, Pulau Pinang. Sampel debu terenap permukaan diambil pada kawasan 1 m² menggunakan berus polietilena dan dimasukkan ke dalam penyodok debu dengan penyapu lantai pada ruang tamu yang kerap diakses oleh penghuni. Kepekatan logam berat telah dikenalpasti menggunakan spektrometer pemancaran optik gandingan plasma teraruh (ICP-OES) selepas proses pencernaan sampel dengan menggunakan asid nitrik dan asid sulfurik. Keputusan menunjukkan julat kepekatan logam berat yang diperhatikan di dalam bangunan kediaman di Seberang Prai Tengah dalam julat 2.20-14.00 mg/kg, 1.50-32.70 mg/kg, 1.50-76.80 mg/kg dan 14.60-54.40 mg/kg masing-masing untuk Cu, Ni, Pb dan Zn. Kepekatan logam berat di kawasan kajian menuruti susunan urutan: Pb > Zn > Ni > Cu. Analisis statistik menunjukkan korelasi signifikan terhadap semua pasangan logam berat. Hasil kajian mencadangkan sumber umum pencemaran logam berat yang lazim, di mana kemungkinan boleh dikesan pada pelepasan kenderaan, debu jalan dan lain-lain aktiviti yang berkaitan.

Kata kunci: Debu terenap permukaan, logam berat, rumah kediaman

Introduction

Heavy metals are among the most important pollutants in urban environment, and becoming a severe public health problem due to their acute toxicity and carcinogenicity [1]. The heavy metals are stable and persistent environmental contaminants since they cannot be degraded and destroyed. Thus any high level of heavy metals will threaten biological life. Some metals are cumulative poisons capable of being assimilated and stored in the tissues of

organism, causing noticeable adverse physiological effects and they may also act as cofactors in other diseases [2,3].

Humans are exposed to heavy metals via many pathways because these metals are ubiquitous in the environment, and originate from both natural and anthropogenic activities[4]. One of the important pathways of exposure to metal for humans is through dust. Dust is described as a solid matter composed of soil, antropogenic metallic constituents and natural biogenic materials [5]. Indoor and outdoor dust makes a significant contribution to heavy metal pollution in the environment. Recently, there is an increasing concern about heavy metal contamination in indoor environment since most of the people spend as much as 80 to 90% of their time indoor [6,7]. These percentages are easily exceeded mostly for children, infant and elderly.

Settled dust is present in the indoor environment as a composite of particulate matter derived from interior and exterior sources [8]. Settled surface dust often functions as a reservoir of hazardous particulate contaminants including trace metals. The metals in the dust can be accumulated in human body via direct inhalation, ingestion and dermal contact absorption, and pose potentially deleterious effects on the health of human beings. Children in particular are at higher risk compared to adults, because they engage in greater hand to mouth activity, while their neurological system is still developing and they having much higher absorption rate of heavy metal than adults [9].

The rapid growth of Seberang Perai Tengah area has created numerous environmental problems. Considerable attention has been paid to the study of metal pollution in city air, roadside dust and city soil [4-6]. However there is a lack of concern of the presence of trace metal in house dust. Therefore the present work is important in providing information on the level of heavy metal in settled surface dust in residential building in Seberang Jaya.

Experimental

Study Area

Seberang Perai Tengah is a district in Penang state of Malaysia. It covers an area of 2391 square kilometres with the population size estimated at 383,900. Seberang Perai Tengah experiences hot humid tropical climate and throughout the year, the temperatures ranges from 20 to 30 °C. The residential buildings selected for this study were located in Seberang Jaya city. Nine terrace houses were randomly selected for sample collection.

Sample collection and data analysis

The sample dust was collected in 1 m² area using a polyethylene brush and pan by sweeping the living room floor which was most accessible to the occupants. 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 µm screen, and finally oven dried at 105°C for 24 h.

0.5 g of the fine portion of the dried samples were weighed and mixed with 6 mL of a mixture solution consisting of (HNO₃-H₂SO₄) in a ratio of 3 : 1 and digested using microwave digester Milestone ETHOS PLUS labstation with HPR-1000/105 high pressure segmented rotor. The samples was then made up to a volume of 50 ml in the volumetric flask with distilled water and was analyzed for Pb, Ni, Cu and Zn content by using Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES). 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.

Quality control and quality assurance

In order to assess the accuracy of the results that were obtained by the methods used in this study, the blank solution were prepared and underwent the same processes and ran together with the samples in the ICP-OES. All the glassware that were use in the digestion and filtration procedures initially cleaned with soap, washed thoroughly with tap water, rinsed with distilled water and soaked in 1% HNO₃ overnight to remove any contamination by heavy metals. The glassware were then washed thoroughly with the distilled and deionized water. The samples were also left in the desiccator in order to remove the moisture. The dust samples were collected using different brush and dust pan at each sampling and kept in the sealed plastic bag to prevent contamination and to assure sample quality.

Results and Discussion

Heavy Metal Concentration

Four heavy metals (Cu, Ni, Pb and Zn) were analysed in settled surface dust from nine selected houses in Seberang Jaya. The result of heavy metal mean concentrations and their standard deviation are given in Table 1. The highest metal concentration was observed for Pb with the mean concentration of 39.48 mg/kg while the lowest metal concentration was recorded for Cu with the mean concentration of 6.84 mg/kg. The heavy metal concentration in the investigated area followed the order of Pb>Zn>Ni>Cu.

Table 1: Mean concentration of heavy metal of house dust in Seberang Prai Tengah.

Element (mg/kg)	Mean	S.D	Range
Cu	6.84	5.02	2.20-14.00
Ni	18.15	15.07	1.50-32.70
Pb	39.48	33.27	1.50-76.80
Zn	33.78	17.60	14.60-54.40

S.D = Standard Deviation

The concentration of Pb recorded was in the range of 1.50 - 76.80 mg/kg with the standard deviation of 33.27. High concentration of Pb was observed in the investigated area may be due to the house age. This may be because older homes usually have more deteriorated interior surfaces, warped windows and doors, and crevices in floors, which can trap the heavy metal particulate[10]. The enrichment of lead dust in this home maybe linked to a longer history of contamination from the former use of leaded paint, lead solder and lead pipe [10]. Pb loading rate increases significantly with house age [11]. The indoor sources such as by the presence of deteriorated or damaged paint of the old houses, carpet and furnishing may also contributed to the lead concentration in settled dust [12].

The concentration of Zn in settled dust were in the range of 14.60 – 54.40 mg/kg. The location of the houses which are closed to main road with high traffic density may have contributed to the presence of Zn in the dust. The elevated Zn content may have originated to wear and tear of vulcanised vehicle tires, and corrosion of galvanised automobile parts [13-15]. The concentration of Zn in the house dust is strongly associated with the inverse of the dustiness of the house [12]. There are a number of sources of zinc in the houses such as rubber, paints and fillers used in linoleum[16].

The concentration of Ni varies between 1.50 to 32.70 mg/kg while for Cu varies between 2.20 to 14 mg/kg. The sources of Ni and Cu in dust are believed to be from anthropogenic sources such as traffic emission and street dust. This include sources from car components, tyre abrasion, brushing, bearing metals and brake dust respectively [14,17]. One of the significant sources of indoor Cu are possibly from electric motors in vacuum cleaners and fans [18].

The results of this study suggest that the heavy metals in dust could be derived from indoor and outdoor dust. However the major influence was from outdoor sources as the selected houses in this study were ventilated with natural and mechanical (fan) ventilation system. These houses have to rely on opened windows for ventilation. The metal bearing dust particles are originated from outside, much of them from cars and some from industrial emissions, and they are atmospherically transported into the house units through the opened windows. The movement of occupants in and out from the house also contribute to the elevated level of heavy metals inside the house.

Correlation Coefficient Analysis

Pearson's correlation coefficient can be used to measure the degree of correlation between logarithms of the heavy metals data. The correlation matrix for heavy metal concentration in studied sample are summarised in Table 2. Statistical analysis indicates positive relation between all the possible pairs of heavy metal at 99% or higher confidence level. High positive correlation was found between Pb-Ni ($r=0.985$) and Zn-Cu ($r=0.819$). The result suggest that the metals originate from similar sources which may have derived from automobile emission, street dust and other related activities.

Table 2: Correlation matrix for the concentration of heavy metal

Element	Cu	Ni	Pb	Zn
Cu	1.00			
Ni	-0.909**	1.00		
Pb	-0.915**	0.985**	1.00	
Zn	0.819**	-0.852**	-0.821**	1.00

** Correlation is significant at the 0.01 level

Comparison With other reported studies

Table 3 gives the comparison between metal contents values obtained in Seberang Jaya residences indoor dust with those reported in literature. The concentrations of heavy metal in settled dust in residential building in Seberang Jaya were generally lower than those in other cities. This may be due to several factors such as industrial activities, traffic density, population density, different transportation system available and also depends on the natural concentration of those particular heavy metals in the soil. The concentration of heavy metals in Sydney metropolitan were in order of Zn, Pb, Cu and Ni as reported by Chattopadhyay et al [19]. Same trend was observed for heavy metal concentration in Sonora Mexico with the highest concentration recorded for Zn followed by Pb, Cu and Ni [20].

Table 3 : Heavy metal concentrations in comparison with mean from previous reported studies.

Authors	Metal detected (mg/kg)				Study Area
	Cu	Ni	Pb	Zn	
Current study	6.84	18.15	39.27	17.60	Seberang Prai Tengah
Tahir <i>et al.</i> , (2007) ²¹	44.00	NR	78.00	559.00	Dungun, Terengganu
Tong and Lam, (2000) ¹⁰	240.20	NR	71.50	11080.00	Hong Kong
Jabeen <i>et al.</i> , (2000) ²²	64.00	NR	477.00	241.00	Jalil Town, Gujranwala, Pakistan
Chattopadhyay <i>et al.</i> , (2003) ¹⁹	147.00	27.20	389.00	657.00	Sydney
AlRajhi <i>et al.</i> , (1996) ²³	271.10	52.90	639.10	547.00	Riyadh, Saudi Arabia
Figueroa, (2006) ²⁰	24.69	4.65	44.13	478.93	Sonora, Mexico

Conclusion

The chemical analyses of settled dust in this study provide important information on the concentration level of heavy metals in residential building in Seberang Jaya. The results show the range of heavy metals observed in residential building at Seberang Prai Tengah were in the range of 2.20-14.00 mg/kg, 1.50-32.70 mg/kg, 1.50-76.80 mg/kg and 14.60-54.40 mg/kg for Cu, Ni, Pb and Zn respectively. The heavy metal concentration in the investigated area followed the order of Pb>Zn>Ni>Cu. Statistical analysis indicated positive relation between all the possible pairs of heavy metal. The results suggest a likely common source for the heavy metal contamination. The concentration of heavy metal in settled dust in Seberang Jaya were generally lower than those of other cities around the world. The amount of heavy metal in home environment may still be able to reduce by restricting the use of windows and by practising better housekeeping such as frequent wet mopping and vacuuming.

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