Sains Malaysiana 40(6)(2011): 569–575

Heavy Metal Concentrations in Ceiling Fan Dusts Sampled at Schools Around Serdang Area, Selangor

(Kepektan Logam Berat di dalam Habuk Kipas Siling yang Disampel di Sekolah-sekolah di Serdang, Selangor)

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ABSTRACT

In this study, ceiling fan dust samples were collected from three schools in the district of Serdang Selangor, Malaysia. The sampled dust were analysed for the concentrations of Cd, Cu, Fe, Ni, Pb and Zn. The heavy metal ranges found in all the schools were 2.96-7.74 µg/g dry weight for Cd, 75-442 µg/g dry weight for Cu, 3445-3852 µg/g dry weight for Fe, 24-66 µg/g dry weight for Ni, 140-734 µg/g dry weight for Pb and 439-880 µg/g dry weight for Zn. SMK Seri Serdang School was found to have elevated concentrations of Cd, Cu, Ni, Pb, and Zn which indicated the anthropogenic sources of the study sites. In comparison to other reported studies in the literature, the maximum levels of Cd, Cu, Ni, and Pb were comparable or higher to those cities reported. Therefore, more monitoring studies should be conducted in future since dusts could be related to human health hazards and the dusts can be used as a potential monitoring tool for heavy metal pollution in the atmosphere.

Keywords: Ceiling fan dust; heavy metals; schools

ABSTRAK

Di dalam kajian ini, habuk kipas siling telah dikumpul di tiga sekolah di kawasan Serdang Selangor, Malaysia. Habuk yang disampel telah dianalisis untuk kepekatan bagi Cd, Cu, Fe, Ni, Pb dan Zn. Julat kepekatan logam berat di semua sekolah adalah 2.96-7.74 µg/g berat kering bagi Cd, 75-442 µg/g berat kering bagi Cu, 3445-3852 µg/g berat kering bagi Fe, 24-66 µg/g berat kering bagi Ni, 140-734 µg/g berat kering bagi Pb and 439-880 µg/g berat kering bagi Zn. SMK Sri Serdang didapati mempunyai kepekatan tinggi bagi Cd, Cu, Ni, Pb and Zn and ini menunjukkan sumber antropogenik di kawasan kajian. Berbanding dengan kajian yang dilaporkan di dalam kepustakaan, tahap maksimum bagi Cd, Cu, Ni, dan Pb adalah setanding atau lebih tinggi daripada bandar-bandar yang dilaporkan. Oleh itu, lebih kajian pemonitoran perlu dijalankan pada masa hadapan kerana habuk boleh dikaitkan dengan risiko kesihatan manusia dan habuk boleh digunakan sebagai alat pemonitoran yang berpotensi bagi pencemaran logam berat di atmosfera.

Kata kunci: Habuk kipas siling; logam berat; sekolah

INTRODUCTION

Respirable dust is defined as particles having a mean aerodynamic diameter lower than 5 µm (Pearson & Sharples 1995). This dust is easily respired into the lung and suspended in the alveoli. Thus, in the long run, it can be hazardous to human health. According to Yongming et al. (2006), components and quantity of street dusts are environmental pollution indicators. The present study focussed on ceiling fan dusts is thus a potential indicator of atmospheric pollution.

Rapid growth of the industry, population, and transportation system can contribute increasing pollution levels in nearby surrounding area including heavy metals in dust (Lin et al. 2002). Therefore, heavy metals in dust are a significant sign of pollution in urban environments (Manno et al. 2006; Lu et al. 2009).

Atmospheric dust not only potentially affects human health (Meng & Lu 2007), it is also a source of environmental pollution (Wilkening et al. 2000; Wolterbeek 2002). Dust has a crucial role in affecting the fertility of soils and functioning of ecosystems (McTainsh & Strong 2007; Wolterbeek 2002). Atmospheric dust suspended in the air will eventually deposit on the surface of the water and topsoil, thus introducing toxic substances into the biosphere (Wolterbeek 2002).

Particle size and chemical composition of dust could decide the significant impact of dust on air quality, public health, and climate (Maring et al. 2003). Furthermore, dust ingestion, dermal contact or breathing is a common pathway by which toxic metals can easily invade into the human body system (Abrahams 2002). The metals such as Cd, Ni and Pb are known examples of elements that exert negative health effects from inhalation and have been observed from both occupational and ambient air exposure (Vincent 2005). For instance, children are more susceptible to the respirable toxic dust from their ambient surroundings, especially in schools that are near to the heavy traffic routes (Lin et al. 2002). Since most of the schools in Serdang areas are near the vicinity of the heavy traffic routes and the conditions will get worse when the concerned parents arrived at the end of the school hours to fetch their children. In Malaysia, there are only limited studies on the heavy metals in dusts (Latif et al. 2009; Tahir et al. 2007; Yap et al. 2007) and on the organic pollutants were reported by Omar et al. (2007).

Therefore, it is deemed important to study and monitor their ambient surrounding through ceiling fan dusts since ceiling fans are common and cheap cooling systems in many schools of Malaysia. The objective of this study was to determine the total concentrations of heavy metals in the ceiling fan dust collected from three schools in Serdang area namely SMK Sri Serdang, SJK Tamil Sri Serdang and SK Sri Serdang, around Serdang area.

MATERIALS AND METHODS

Three samplings were conducted between 16 and 20 January 2009 at the three schools found in Serdang area (Figure 1). For SMK Sri Serdang, ceiling fan dusts were collected from Physic Laboratory, Chemistry Laboratory and Guardroom (all located in the ground floor of the school). For both SJK Tamil Sri Serdang and SK Sri Serdang, the ceiling fan dusts were collected from first and second floors of classrooms of the schools. The reason why these dust samples were collected from different floors was due to their availability for collection. We were unable to collect in all the floors of the schools because some classrooms had done the cleaning before our samplings were conducted.

A total of 2-3 samples of dusts was taken from each sampling site. The dusts were collected by using clean tissue papers. All dusts were collected from ceiling fans not previously rusted. Later, they were put into clean plastic bags and were labelled. Descriptions of all sampling sites are given in Table 1.

The methodology of the analysis of heavy metals in the dust followed those described for sediments (Yap et al. 2002). The dust was dried at 105°C in an oven until constant dry weights. However, the ceiling dusts were not sieved since all these suspended particles were potentially inhaled by humans (Yap et al. 2007). The direct aqua-regia method was used to digest the samples. About 0.5 g of dust sample was weighed and placed in a digestion tube. They were digested with HNO_3 (Analar grade, BDH 69%) and $HClO_3$ (AnalaR grade; BDH 60%) in the ratio of 4:1. The digestion tube was placed on the digestion block and heated at 40°C for an hour and 140°C for the next 3 h (Yap et al. 2002). Then, the digested solutions were added to 40ml by using double-distilled water. The solution was filtered with Whatman No.1 filter paper and stored in an acid-washed polyethylene bottle (Yap et al. 2002, 2007). The filtered samples were determined for Cd, Cu, Fe, Ni, Pb, and Zn concentrations by using an air-acetylene flame Atomic Absorption Spectrophotometer (AAS) Perkin-Elmer Model AAnalyst 800. All data were presented in µg/g dry weight (dw). All equipment and glassware were first acid-washed to avoid external contamination. Procedural blanks and quality control samples made from standard solution for each metal were analyzed together with the digested samples. The quality of the method used was checked against a Certified Reference Material (CRM) for Soil (International Atomic Energy Agency, Soil-5, Vienna, Austria). The agreement between the analytical results for the certified reference material and the measured values for each metal was satisfactory with the recoveries being between 80 and 110% (Table 2).

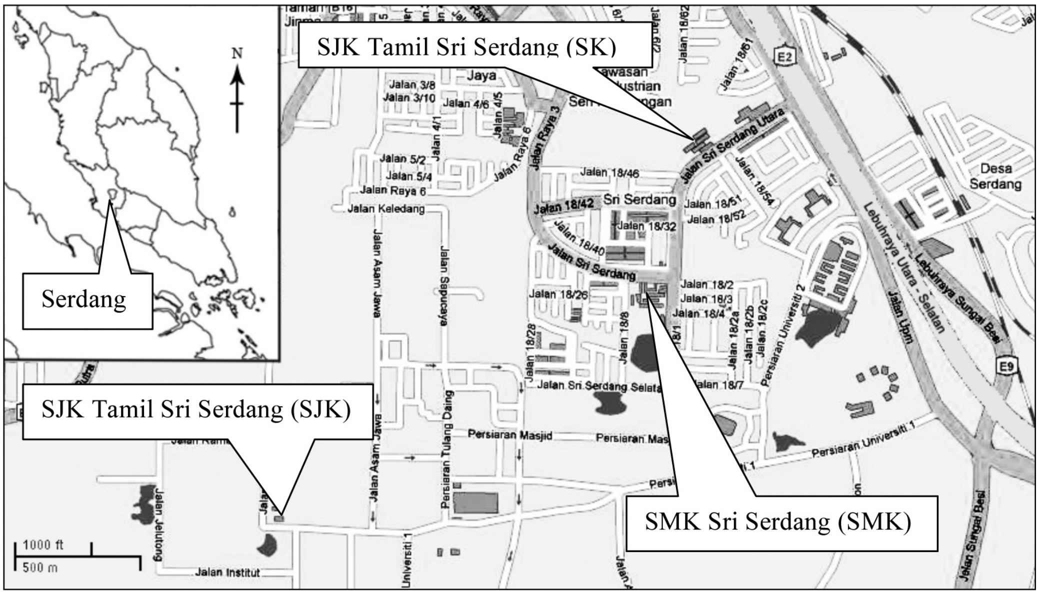

FIGURE 1. Sampling map for the dust samples collected from three schools in Serdang area. (Insert: Map of Peninsular Malaysia)

TABLE 1. Descriptions of sampling sites for ceiling fan dusts in the schools of Serdang area (N= number of samples analyzed)

No.	Sampling sites	N	Date of sampling	Description of vicinity in the surrounding of sampling sites
1.	SMK Sri Serdang (SMK1) (Physic Laboratory at the ground floor)	3	16 Jan 2009	Heavy traffic, construction, located close to street.
2.	SMK Sri Serdang (SMK2) (Physic Laboratory at the ground floor)	2	16 Jan 2009	Heavy traffic, construction, located close to street.
3.	SMK Sri Serdang (SMK3) (Guardroom)	3	16 Jan 2009	Heavy traffic, construction, located at the school entry and close to the streets.
4.	SJK Tamil Sri Serdang (SJK1) (1st Floor)	3	19 Jan 2009	Heavy construction in progress.
5.	SJK Tamil Sri Serdang (SJK2) (2nd Floor)	2	19 Jan 2009	Heavy construction in progress.
6.	SK Sri Serdang (SK1) (1st Floor)	3	20 Jan 2009	Heavy traffic, industrial activities.
7.	SK Sri Serdang (SK2) (2nd Floor)	3	20 Jan 2009	Heavy traffic and industrial activities.

TABLE 2. Comparison of metal concentrations (mean, all in μg/g dry weight except for Fe in %) between certified values of certified material material (CRM) (Soil-5, IAEA) and analytical

Metals	CRM values (C)	Measured values (M)	Percentage of recovery (M/C)
Cd	1.50	2.16	144
Cu	77.0	72.8	94.4
Fe	4.45	3.12	70.1
Ni	13.0	17.9	138
Pb	129	133.1	103.2
Zn	368	326	88.6

The data which had been converted were analysed by using Statistical Package for Social Science (SPSS) for Window version 15.0, and STATISTICA software for cluster analysis. Each site is clustered together using the average between groups linkages based on the Euclidean distance. Pearson's correlation analysis was used to see the relationships between the total concentrations of all metals in the ceiling fan dusts collected from all schools. All the data were $\log_{10}$(mean + 1) transformed in order to reduce the variance (Zar 1996). One-way ANOVA Student-Newman-Keuls test (Day & Quinn 1989) was used to elucidate where differences occurred among the metal levels in the different tissues of oysters and sediment samples collected from all sampling sites. All the comparisons were made at the 95% ($P< 0.05$) level of significance.

RESULTS

Table 3 shows the total concentrations of heavy metals in the ceiling fan dust collected from three schools in Serdang area. The ranges for the concentrations of Cd, Cu, Fe, Ni, Pb and Zn found in all the schools were 2.96-7.74 μg/g dry weight, 75-442 μg/g dry weight, 3445-3852 μg/g dry weight, 24-66 μg/g dry weight, 140-734 μg/g dry weight and 439-880 μg/g dry weight, respectively.

In general, SMK2 (Chemistry Lab) was found to have the highest concentrations of Cu, Ni, Fe, and Pb while SMK3 (Guardroom) had the highest level of Zn. Interestingly, elevated levels of Cd were found in SMK1 (Physic Lab) and SJK1 (2nd Floor).

From Table 4, all the pairwises between all the metals comes from the dusts are significantly and positively correlated (at least $p<0.05$), except for Fe. This indicates that Cd, Cu, Ni, Pb and Zn had a common source of anthropogenic impacts while Fe is possibly not of anthropogenic origin.

Figure 2 shows the dendrogram which was obtained through cluster analysis for 7 different sampling sites whereby each site is grouped together based on their similarity of concentrations of Cd, Cu, Ni, Pb, and Zn (Fe is not included since Fe is not a common anthropogenic

TABLE 3. Concentrations (mean ± SE, µg/g dry weight) of heavy metals in the ceiling fan dusts collected from three schools in Serdang area

No.	Sites	Cd	Cu	Fe	Ni	Pb	Zn
1.	SMK1	7.72 ± 0.40 C	215 ± 5.54 D	3643 ± 12.5 B	65.1 ± 1.11 D	514 ± 16.1 E	768 ± 3.19 D
2.	SMK2	6.40 ± 0.44 BC	442 ± 7.26 F	3852 ± 40.9 D	65.7 ± 1.77 D	734 ± 13.1 F	818 ± 8.01 E
3.	SMK3	5.92 ± 0.14 B	378 ± 7.44 E	3612 ± 5.57 B	60.2 ± 1.83 D	454 ± 8.71 D	880 ± 5.58 E
4.	SJK1	3.97 ± 0.40 A	87.5 ± 0.88 B	3668 ± 13.1 B	33.4 ± 2.27 B	218 ± 22.2 B	617 ± 0.47 B
5.	SJK2	2.96 ± 0.06 A	74.9 ± 0.77 A	3701 ± 19.4 C	24.3 ± 2.28 A	140 ± 4.58 A	439 ± 5.70 A
6.	SK1	7.74 ± 0.24 C	145 ± 2.03 C	3448 ± 20.8 A	39.7 ± 1.95 B	332 ± 3.12 C	721 ± 2.38 C
7.	SK2	6.90 ± 0.09 BC	148 ± 3.07 C	3445 ± 13.5 A	47.1 ± 1.13 C	339 ± 5.82 C	725 ± 2.14 C

Note: All abbreviated names followed those described in Tables 1. Student-Newman-Keuls (SNK) comparisons of metal concentrations in all sampling sites. Metal concentrations of different sites sharing a common letter (in bold) are not significantly different ($P > 0.05$) while those not sharing a common letter (in bold) are significantly different ($P < 0.05$)

TABLE 4. Pearson's correlation analysis between total concentrations of Cd, Cu, Fe, Ni, Pb and Zn found in ceiling fan dusts collected from three schools in Serdang area

	Cd	Cu	Fe	Ni	Pb	Zn
Cd	1	0.468*	-0.394	0.747**	0.684**	0.781**
Cu		1	0.354	0.852**	0.904**	0.800**
Fe			1	0.129	0.299	-0.127
Ni				1	0.935**	0.900**
Pb					1	0.824**
Zn						1

Note: *= Correlation is significant at the 0.05 level (2-tailed).
**= Correlation is significant at the 0.01 level (2-tailed).

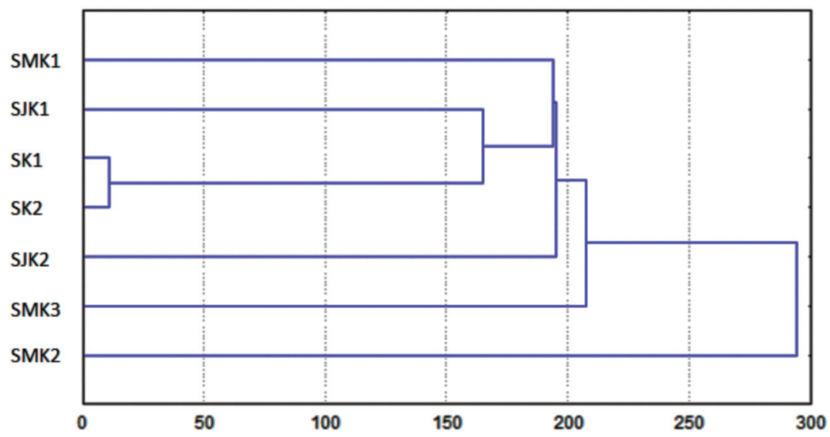

FIGURE 2. Hierarchical cluster of Cd, Cu, Ni, Pb & Zn found in the ceiling fan dusts collected from three schools in Serdang area. Note: All abbreviated names followed those as described in Table 1

metal). From the dendrogram (Figure 2), it is clearly shown that SMK2 is clustered differently from the rest of sampling sites, thus supporting the higher metal concentrations in the dust samples at SMK2 when compared to other sampling sites.

DISCUSSION

Our results clearly showed that SMK Seri Serdang had an elevated concentrations of Cd, Cu, Ni, Pb and Zn in the ceiling fan dusts whereas SK Seri Serdang recorded a high Cd concentrations. This is also supported by Pearson's correlation analysis between heavy metals in ceiling fan dusts. Elevation of heavy metal concentrations in the ceiling fan dusts collected from SMK Seri Serdang could be a result of various anthropogenic sources which are mobile and stationary (Bilos et al. 2001; Manno et al. 2006). The anthropogenic sources of SMK Seri Serdang could be related to heavy road traffic which circulates around the school. It was assumed that the sources of the ceiling fan dusts were mostly originated from outside since the white boards with erasable ink pens were used for teaching instead of chalks.

Sources of Pb in ceiling fan dust can also originate from industrial activities and automotive emissions near the school. Lu et al. (2009) reported the contamination of heavy metals in the streetdust of Baoji (China) was attributable to vehicular automatobile emissions. The ceiling fan dusts could be related to street dusts in which their metal concentrations can be attributed by tyre abrasion, the corrosion of metallic parts of cars and industrial emissions (Arslan et al. 2001; Jiries et al. 2001; Al-Khashman 2004).

It is a common practice to compare mean concentrations of heavy metals in dusts in different urban environments (Charlesworth et al. 2003; De Miguel et al. 1997; Duzgoren-Aydin et al. 2006), although there are no universally accepted sampling and analytical procedures for geochemical studies of urban deposits. Table 5 shows comparison of present metal data with those in the household dusts of different urban environments. For Cu and Pb, their maximum values from the present study were higher when compared to all households reported for Sydney of Australia (Chattopadhyay et al. 2003), Hong Kong (Tong & Lam 2000), Ottawa of Canada (Rasmussen et al. 2001)and Warshaw of Poland (Lisiewicz et al. 2000). As for Cd, the maximum value is found to be higher than all the households reported for Sydney, Hong Kong and Ottawa.

Elevation of Fe is found from the present study when compared with Sydney and lower when compared to Ottawa. Total mean concentration of Ni is found to be higher when compared with 3 urban cities reported for

TABLE 5. Comparison of heavy metal concentrations (mean, μg/g dry weight) between dusts samples found in the present study with those reported in the literature

No.	Locations	N	Cd	Cu	Fe	Ni	Pb	Zn	References
1.	Indoor dust from Bahrain		1.90	NA		10	517	202	Madany et al. (1994)
2.	Indoor and outdoor dust in Riyadh, Saudi Arabia.		0-8.1	20.8-1240		11.9-188.4	41-3151	150-1740	Al-Rajhi & Seaward (1996)
3.	Household dust from UK		0.6-4.9	71-799		27.2-97.1	56.8-358	213-1300	Turner & Simmonds (2006)
4.	Hong Kong households	151	4.3	311	-	-	157	1410	Tong & Lam (2000)
5.	Ottawa households, Canada	50	4.4	171	13200	54	233	628	Rasmussen et al. (2001)
6.	Sydney households, Australia	82	1.9	103	2740	16	85	437	Chattopadhyay et al. (2003)
7.	Indoor dusts of Warsaw household, Poland	27	-	129	-	42	158	1150	Lisiewicz et al. (2000)
8.	Dungun (Terengganu) nursery indoor dusts-Industrial area	6	NA	71	5500	NA	116	738	Tahir et al. (2007)
9.	Dungun (Terengganu) nursery indoor dusts-Town area	7	NA	20	2600	NA	57	558	Tahir et al. (2007)
10.	Dungun (Terengganu) nursery indoor dusts-Village area	5	NA	42	3200	NA	61	337	Tahir et al. (2007)
11.	Ipoh (Perak) residential area	3	5.37-16.70	159-229	3470-4455	43-58	NA	563-816	Yap et al. (2007)
12.	Serdang (Selangor) flat houses	3	11.40-13.71	163-270	3446-4440	28-36	NA	688-868	Yap et al. (2007)
13.	Serdang (Selangor) schools, Malaysia	19	2.96-7.74	75-442	3445-3852	24-66	140-734	439-880	This study

Note: N = Numbers of replicates analysed. NA= data not available.

Ottawa, Sydney and Warshaw. As for Zn, the maximum level found from this study is lower than Hong Kong and Warshaw but higher than Ottawa and Sydney. In comparison to heavy metals in dusts collected from Serdang and Ipoh by Yap et al. (2007), Cd levels from the present study was lower while Cu was higher. For Fe and Zn, they were comparable and within the ranges reported by Yap et al. (2007). For Ni, the level was slightly higher than those reported for Serdang and Ipoh. The levels of Cu and Pb were higher while levels of Fe and Zn were comparable and within those from Dungun nursery indoor dusts covering industrial, town and village areas (Tahir et al. 2007). However, the levels of Cd, Fe, Ni, Pb and Zn as reported by Latif et al. (2009) for semi-urban area in Malaysia were not comparable due to the concentrations and units (all were < 1.0 μg/g dry weight which were unlikely especially for Fe) reported were inaccurate and therefore unacceptable for comparison.

According to the Intergovernmental Panel on Climate Change (IPCC 2007), the methods used to estimate anthropogenic contribution to dust emissions involve large uncertainties. Mineral dust is the major contributor to aerosol loading (IPCC 2007). There is an immediate need to establish a standard procedure to represent and analyze urban samples must be carried out effectively (Duzgoren-Aydin et al. 2006). Perhaps, ceiling fan dusts is one of the alternatives towards this end since most of the houses in Malaysia have ceiling fans.

Particulate matter, the dust in the air is one of the fastest-growing types of environmental pollution. The fallout of atmospheric particles is an important factor when considering the fate and effects of air pollution on human health. The toxicological risks of heavy metals found in the dusts which are potentially inhaled by humans have much uncertainty, mainly due to poor knowledge of the aerosol's chemical, physical and optical properties. Thus, it is important to provide baseline information on the heavy metal levels in the ceiling fan dusts for future environmental monitoring studies in Malaysia.

Conclusion

The present data showed some elevated levels of Cd, Cu, Ni and Pb were found in the ceiling fan dusts collected from some schools in Serdang area. The elevated metal levels found in the dusts, were mostly related to anthropogenic sources and should be given proper attention in future monitoring studies since dusts can serve as an atmospheric indicator of heavy metal pollution. Perhaps, other organic pollutants such as the carcinogenic chemicals polycyclic aromatic hydrocarbon should be included for the future monitoring studies besides the heavy metals.

Acknowledgements

The authors wish to acknowledge the financial support provided through the Research University Grant Scheme (RUGS), [Vote no.: 91986], by Universiti Putra Malaysia.

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Received: 23 March 2010
Accepted: 2 September 2010