Heavy Metal Concentrations in Ceiling Fan and Roadside Car park Dust Collected from Residential Colleges in Universiti Putra Malaysia, Serdang, Selangor

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ABSTRACT

In this study, dust samples were collected from 4 residential colleges (K2, K5, KOSAS and K10) in Universiti Putra Malaysia (UPM) Serdang, Selangor. The samples were collected from ceiling fans and car parks roadside dust. Sand dust on top of the car park cover were collected using polyethylene brush, tray and kept in a polyethylene bag. Dust from ceiling fan on the first floor was collected and put into a polyethylene bag. The dust samples collected were analysed for the concentrations of Cd, Cu, Fe, Ni and Zn. It was found that K5 [Cu (62.94 ± 0.77 µg/g dw), Fe (1802.40 ± 9.81 µg/g dw), and Zn (253.34 ± 22.76 µg/g dw) of car park dust; Zn (997.20 ± 16.10 µg/g dw) (of ceiling fan dust] and K10 [Ni (26.88 ± 1.84 µg/g dw) and Zn (199.77 ± 6.64 µg/g dw) of car park dust; Cu (468.55 ± 3.67 µg/g dw), Ni (83.96 ± 0.75 µg/g dw), and Fe (3131.58 ± 27.01 µg/g dw) of ceiling fan dust] exhibited elevated concentrations of heavy metals that might be related to vehicular activities as compared to K2 and KOSAS. In general, ceiling fan dust had significantly ($P< 0.05$) higher concentrations of heavy metals than the car park dust. In comparison to other reported studies in the literature, the maximum levels of Ni and Cu were comparable or higher than those reported for major cities in the world. Hence, more monitoring studies should be conducted in the future to check for metal contamination in the dust, as this can serve as an atmospheric indicator of heavy metal pollution.

Keywords: Dust, heavy metals, UPM residential colleges

INTRODUCTION

Dust is also known as a particulate matter that can range from 1 to 1000µm in size and it receives inputs from various urban sources (Meza-Figueroa *et al.,* 2007). Heavy metals in dust particulate form will eventually be deposited on the ground and can easily be suspended by wind into the atmosphere (Sharma *et al.,* 2008; Amato *et al.,* 2009). They are potentially being hazardous to human health, especially to children (Lin *et al.,* 2002; Ng *et al.*, 2003; Meza-Figueroa *et al.,* 2007). Ferreira-Baptista and Miguel (2005) define street dust as solid particles that comprise of impervious materials and accumulate outdoors in urban environments. Street or urban roadside dust consist of vehicular exhaust particles, household dust, soil dust, construction dust and aerosols that are carried freely by air and water (Takada *et al.*, 1991; Al–Khashman, 2004; Meza-Figueroa *et al.,* 2007). Atmospheric pollution is one of the major sources of heavy metal contamination

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in soils and street dust in urban areas (Lin *et al.,* 2001). Although studies carried out on ceiling fan dust are rather few, there are more closely related research done on household or indoor dust that have mainly focused on floor or carpet dust (e.g. Kim & Fergusson, 1993; Tong & Lam, 1998; Jabeen *et al.,* 2001). Loading of heavy metals in the indoor environment are actually related to the outdoor environment (Kim & Fergusson, 1993; Tong & Lam, 1998; Jabeen *et al.,* 2001). Despite the abundant literature about dust, only Yap *et al.* (2007) have reported heavy metal levels in indoor ceiling fan dust in Ipoh and Serdang, Malaysia.

Since dust always presents in the urban environment and has the potential to contribute to metal toxicity in humans, there is a growing concern over this threat in the scientific community (Ng *et al*., 2003). The US EPA (1986) reported that populations exposed to Cd, Cu, and Zn pollutants are in risk of developing nervous system alterations which can lead to health hazards. The emissions from roadways can cause respiratory illnesses (Lin *et al.,* 2002). There have been studies done on street dust near places where children play (e.g. Ng *et al*., 2003; Meza-Figueroa *et al.,* 2007) since children are more sensitive to contaminant-bearing dust (Meza-Figueroa *et al.,* 2007).

The environmental impacts of atmospheric deposition have been studied for more than a century, and the first effect that was described on a scientific basis was probably the decline of epiphytic lichens in areas with high levels of atmospheric pollution (Wolterbeek, 2002). Heavy metals such as Cu, Pb, and Zn can be accumulated in soils from atmospheric deposition from sources such as vehicular exhausts, industrial discharges, oil lubricants, automobile parts, and corrosion of building materials (Li *et al.,* 2001). The determination of metal levels in environmental samples in top soils and urban roadside dust is therefore necessary for monitoring environmental pollution since such levels can affect the surrounding ecosystems and heavy metals can accumulate in organisms (Aksoy & Demirezen, 2006). Due to the significant contribution of street dust to pollution in the urban environment, numerous studies on heavy metals of street dust have been carried out in developed countries (Charlesworth *et al.,* 2003; Manno *et al.,* 2006), but such studies are very much lacking in developing countries.

The objectives of this study were to determine the concentrations of metals on ceiling fan and car park dust collected from four different residential colleges in the Serdang campus of Universiti Putra Malaysia (UPM) and to relate their anthropogenic sources to the human activities observed in the surroundings.

MATERIALS AND METHODS

Samples of dust were collected from four residential colleges in UPM, namely K2, K5, KOSAS, K10, in February 2009 (*Fig. 1*). The dust was collected from ceiling fans at each college, and sandy dust at car parks. For the ceiling fan dust, only the one in the rooms located on the first floor was collected. All the samples were collected from non-rusty ceiling fans. For the roadside car park dust, sand dust on top of the car park was collected using a polyethylene brush, and tray. The dust was stored in clean and labelled polyethylene plastic bags. For the preliminary study, three (3) sites at KOSAS, K2, and K5 were considered as the reference sites to K10 which is closest to main north-south highway. However, it was not certain if the metals levels would be the highest at K10, and it was for this reason that the present study was conducted.

After drying at 80°C in an oven until constant dry weights, the car park sand dust was sieved through a 53µm sieving tool. However, the fan dust samples were not sieved as they were processed immediately after drying. This is because all the airborne particles that can be trapped by fans are potentially inhaled by humans (Yap *et al.,* 2007).

The methodology of the analysis of heavy metals in the dust is similar to those described by Yap *et al.* (2002). In brief, the direct aqua-regia method was used to process the digested sample. About 0.5g of the dust sample was weighed and placed in digestion tube (3 replicates) for ceiling

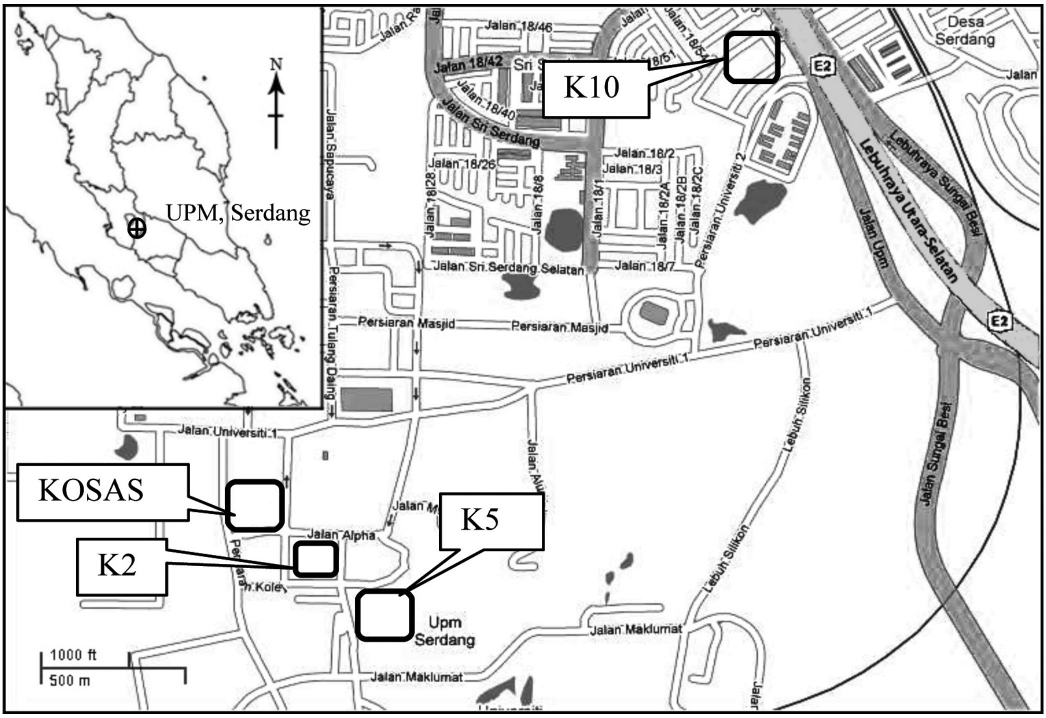

Fig. 1: Map showing the sampling site of the dust samples collected from the four residential colleges in UPM, Serdang (Insert: Map of Peninsular Malaysia).

fan dust and 1.0g of car park sand dust was used. The dust was digested with HNO_3 and $HClO_3$ in the ratio of 4:1. The digestion tube was placed on the digestion block and heated at 40°C for the 1 hour and 140°C for the next 2-3 hours (Yap *et al.,* 2002). Then, the digested solution was topped-up to 40ml by adding 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 their Cd, Cu, Fe, Ni, and Zn concentrations using an air-acetylene flame Atomic Absorption Spectrophotometer (AAS) Perkin-Elmer Model AAnalyst 800. All the data were presented in µg/g dry weight (dw).

All the equipment and glassware were first acid-washed to avoid external contamination. Procedural blanks and quality control samples, made from the standard solution for each metal, were analyzed together with the digested samples. The quality of the method used was checked against the 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 recovery percentages between 80 and 110%. All the software statistical calculations, such as (Mann-Whitney for comparison between ceiling fan dust and car park dust, One-way ANOVA for multiple testing, Pearson's Correlation and Spearman's Correlation), were carried out using the SPSS version 16 for statistical calculation.

RESULTS AND DISCUSSION

Table 1 presents the overall heavy metal concentrations (µg/g dry weight) in the ceiling fan car park dust from the four sampling. Based on the car park sand dust, K5 was found to have the highest metal concentrations of Zn (253.34 ± 22.76), Fe (1802.40 ± 9.81), and Cu (277.29 ± 7.69) as compared to other residential

TABLE 1
Comparison of the mean concentrations (μg/g dry weight) of Cd, Cu, Fe, and Zn between ceiling fan dust and car park sand dust using the Mann-Whitney test

Metal	College	N	Ceiling Fan Dust	N	Car Park Dust	Mann-Whitney (p-value)
Cd	K2	9	4.15 ± 0.84 [A]	3	3.01 ± 0.29 [c]	P=0.518 (P>0.05)
	K5	6	3.84 ± 0.03 [A]	3	2.06 ± 0.04 [ab]	P=0.020 (P<0.05)
	KOSAS	9	3.50 ± 0.25 [A]	3	2.19 ± 0.05 [b]	P=0.013 (P<0.05)
	K10	15	3.58 ± 0.22 [A]	3	1.24 ± 0.08 [a]	P=0.008 (P<0.05)
	Average	39	3.73 ± 0.17	12	2.11 ± 0.12	P< 0.05
	(Min–Max)		(3.15-5.83)		(0.72-3.76)	
Zn	K2	9	800.15 ± 8.44 [A]	3	103.68 ± 16.34 [a]	P=0.013 (P<0.05)
	K5	6	997.20 ± 16.10 [C]	3	253.34 ± 22.76 [c]	P=0.020 (P<0.05)
	KOSAS	9	850.24 ± 12.20 [B]	3	164.13 ± 5.65 [b]	P=0.013 (P<0.05)
	K10	15	897.13 ± 20.74 [B]	3	199.77 ± 6.64 [b]	P=0.008 (P<0.05)
	Average	39	892.11 ± 18.72	12	177.61 ± 9.68	(P< 0.05)
	(Min–Max)		(785.60-1029.08)		(52.27-304.64)	
Fe	K2	9	2631.62 ± 14.83 [A]	3	1687.22 ± 37.88 [a]	P=0.013 (P<0.05)
	K5	6	3008.97 ± 68.11 [BC]	3	1802.40 ± 9.81 [c]	P=0.020 (P<0.05)
	KOSAS	9	2894.41 ± 36.34 [B]	3	1691.61 ± 28.66 [ab]	P=0.013 (P<0.05)
	K10	15	3131.58 ± 27.01 [C]	3	1783.25 ± 5.40 [bc]	P=0.008 (P<0.05)
	Average	39	2976.41 ± 56.36	12	1742.89 ±13.47	(P< 0.05)
	(Min–Max)		(2603.72-3243.56)		(1552.55-1846.71)	
Ni	K2	9	46.64 ± 2.03 [A]	3	15.68 ± 1.21 [a]	P=0.013 (P<0.05)
	K5	6	46.74 ± 0.46 [A]	3	19.66 ± 0.57 [a]	P=0.020 (P<0.05)
	KOSAS	9	58.12 ± 2.23 [B]	3	13.80 ± 0.95 [a]	P=0.013 (P<0.05)
	K10	15	83.96 ± 0.75 [C]	3	26.88 ± 1.84 [b]	P=0.008 (P<0.05)
	Average	39	66.13 ± 5.35	12	20.17 ± 1.19	(P< 0.05)
	(Min–Max)		(42.59-96.35)		(9.85-38.41)	
Cu	K2	9	226.27 ± 1.23 [A]	3	18.95 ± 0.70 [a]	P=0.013 (P<0.05)
	K5	6	277.29 ± 7.69 [B]	3	62.94 ± 0.77 [c]	P=0.013 (P<0.05)
	KOSAS	9	304.22 ± 11.64 [C]	3	30.93 ± 4.08 [ab]	P=0.013 (P<0.05)
	K10	15	468.55 ± 3.67 [D]	3	43.59 ± 3.99 [b]	P=0.008 (P<0.05)
	Average	39	360.51 ± 31.11	12	37.96 ± 2.91	(P< 0.05)
	(Min–Max)		(223.84-536.00)		(16.11-76.46)	

Note: N= numbers of samples analysed
Metal concentrations at the different sites sharing common letters ([a], [b], and [c]) are not significantly different for Gabriel, One-way ANOVA testing. (P<0.05)
Metal concentrations at the different sites sharing common capital letters ([A], [B], and [C]) are not significantly different for Student-Newman-Keuls, One-way ANOVA testing (P<0.05)

colleges, whereas K10 had the highest metal concentration of Ni (26.88 ± 1.84), and K2 had the highest concentration of Cd (3.01 ± 0.29). On the other hand, K2 was found to have the lowest concentrations of Zn (103.68 ± 16.34), Fe (1687.22 ± 37.88), while Cu (18.95 ± 0.70). KOSAS was found to have the lowest concentration of Ni (13.80 ± 0.95) and K10 had the lowest concentration of Cd (1.24 ± 0.08).

As for the ceiling fan dust, K2 was found to have the highest concentration of Cd (4.15 ± 0.84) as compared to other residential colleges. Meanwhile, K5 had the highest concentration of Zn (997.20 ± 16.10). The highest concentrations of Fe (83.96 ± 0.75), Ni (83.96 ± 0.75), and Cu (468.55 ± 3.67) were found in K10. Among all the residential colleges, the lowest concentrations of Cu (226.27 ± 1.23), Ni (46.64 ± 2.03), Fe (2631.62 ± 14.83), and Zn (800.15 ± 8.44) were found in K2, while KOSAS had the lowest concentration of Cd (3.50 ± 0.25).

Looking at the location of K5, the residential college's car park is situated next to a hill slope. Thus, higher amounts of fuel were used for motor vehicles (buses, cars, motor, etc.) in low gear to go up the hill in addition to frequent braking while going downhill. Furthermore, buses also stop frequently at the Putra Food Court which is located near to K5. Hence, higher heavy metal concentrations could be expected at this site, and this corresponded well with the highest concentrations of Cu, Fe and Zn found in the car park sand dust at K5 and the high Zn concentration in the ceiling fan dust of K5. Cu and Zn could be derived from the mechanical abrasion of vehicles as they are used in the production of brass alloy and they could also come from brake linings, oil leak sumps and cylinder head gaskets (Jiries *et al.,* 2001). Tyre to road friction would be higher for up slope and down slope driving and increased braking manouvers which contribute to the higher mechanical abrasion of vehicles and greater stop-start manouvers (Ellis & Revitt, 1982). However, K5 had significantly lower Ni concentration than K10 ($p<0.05$, One-way ANOVA test), the residential college which is located nearest to the highways (Lebuhraya Utara-Selatan and Lebuhraya Sungai Besi). There is no doubt that car fuel combustion is higher (with higher volume of cars on the highway) along the vicinity of the highways. Thus, this could explain the high concentration of Ni in the car park dust and the high concentrations of Cu, Ni, and Zn in the ceiling fan dust. In particular, Cu is a common element that is used in automobile thrust bearing, brake lining, and other parts of the engine (Ng *et al*., 2003). Zn may also originate from lubricant oil and tyres of motor vehicles (Meza-Figueroa *et al.,* 2007). Ni could be involved in the vehicular fuel combustion process (Meza-Figueroa *et al.,* 2007). However, the ceiling fan dust collected in K10 had a significantly ($p<0.05$) higher concentration of Fe as well. Fe is often the major component of brake pads (Amato *et al.,* 2009). This could be due to the outdoor sources of Fe contributing to the room dust, as the residential college is situated next to the highway. The concentrations of heavy metal were reported to be higher on streets where traffic was more likely to undergo stop-start manouvers (Ellis & Revitt, 1982).

In general, the accumulation of metal found in the ceiling fan dust was observed to be resulted from different factors such as indoor pollutant sources, infiltration of outdoor dust, and the absorption of metals due to indoor humidity (Davies *et al.,* 1987). Most of the rooms where the samples were taken lack proper ventilation as the windows were either seldom or never opened by the occupants. This is in line with study by Jabeen *et al.* (2001) who showed that the interior house dust had higher concentrations of Cd and Pb, even for houses with little ventilation. Furthermore, the ceiling fan dust collected in this study had been there for a long time as the fans were not cleaned for several months to years. Therefore, heavy metal concentrations may have increased with time as compared to the outdoor street dust, as the conditions of the interior are much more stable than the outdoors.

In addition, weather is likely to influence the heavy metal distribution, concentration and retention time of the deposited street dust (Charlesworth *et al.,* 2003). A study by

Fergusson *et al.* (1984) showed that metal loadings for Cd, Cu, Pb, and Zn in house dust correlated strongly with the amount of dust in the house and this in turn correlated strongly to the amount of carpet used (Jabeen *et al.,* 2001).

K2 was found to have significantly ($p<0.05$) lower levels of Cu, Fe, Ni, and Zn for its car park dust, while Cu, Ni, Fe, and Zn ceiling fan dust when compared to the other residential colleges. KOSAS had significantly ($p<0.05$) lower concentrations of Cu, Ni, and Zn for the car park dust, and Cu and Zn for ceiling fan dust relative to the other residential colleges. The lower metal concentrations found in these two colleges could be due to the lesser road traffic activities around there as compared to K10 and K5. However, K2 had a significantly ($p<0.05$) higher concentration of Cd for its car park dust, and this was also higher but insignificant for the ceiling fan dust as compared to K10.

The correlations between heavy metal concentrations among all the car park sand dust are presented in Table 2. Based on the data given, significant (at least $p<0.05$) and positive correlations were found between Zn-Fe (0.320), Zn-Ni (0.502), Zn-Cu (0.625), Ni-Fe (0.323), and Cu-Fe (0.580). However, the positive relationships were found to be not convincing, and thus, further investigations are needed. As for the ceiling fan dust (Table 3), significant (at least $p<0.05$) and positive correlations were found between Fe-Ni (0.732), Fe-Cu (0.846), and Cu-Ni (0.918). The strong and positive correlations among Cu, Fe, Ni, and Zn in the car park dust, as well as Cu, Fe, and Ni in the ceiling fan dust might indicate that they could have come from the same sources, such as road traffic, as these metals are contained in motor vehicles. The study by Al-Khashman (2004) revealed a high correlation of the metal concentrations of Cu, Fe, Pb, and Zn which convinced him that anthropogenic activities are the main sources of heavy metal in soils. Table 3 shows that a larger proportion of Cd might have come from different sources, even though it could also be due to road traffic activities, as reported by Meza-Figueroa *et al.* (2007). This could explain why K2 had a significant ($p<0.05$) higher concentration of Cd than K10. Cd might have come from colour pigments, like the ones from carpets (Jabeen *et al.,* 2001). Cd could also come from air-borne emissions from various sources (Barnejee, 2003), as it is used to protect the surface of brass from corrosion (Charlesworth *et al.,* 2003).

TABLE 2
Pearson's Correlations for the car park dust (N=39)

	Cd	Zn	Fe	Ni	Cu
Cd	1	-0.404*	-0.747**	-0.439**	-0.371*
Zn		1	0.320*	0.502**	0.625**
Fe			1	0.323*	0.580**
Ni				1	0.279
Cu					1

TABLE 3
Spearman's correlations for the ceiling fan dust (N=15)

	Cd	Zn	Fe	Ni	Cu
Cd	1	0.064	-0.018	-0.129	0.007
Zn		1	0.664**	0.089	0.407
Fe			1	0.732**	0.846**
Ni				1	0.918**
Cu					1

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

When compared to other related studies in the literature, the mean Zn concentration for the car park dust in the present study (Table 4) was found to be higher than that of the street dust in Bahrain (Akhter & Madany, 1993). However, the concentrations of Cd, Cu, and Ni found in the car park dust in this study were lower as compared to the street dust from other studies (e.g. as reported by Fergusson & Ryan, 1984; Lehame *et al.,* 1992; Akhter & Madany, 1993; Chon *et al.,* 1995; Wang *et al*., 1998).

Table 5 shows that the overall maximum concentration ranges of Cu, Ni, and Zn in the ceiling fan dust were higher than those reported by Yap *et al.* (2007), and these increase the concern over their influence on human health. On the contrary, the overall concentrations of Cd and Fe in the ceiling fan dust were lower than those reported by Yap *et al*. (2007). Fe

TABLE 4
Comparison of the results from the global studies on heavy metal concentrations in street dust (µg/g), as compiled by Charlesworth *et al.* (2003) and in this study

City	Reference	Metal			
		Cd	Cu	Ni	Zn
New York	Fergusson & Ryan (1984)	8	355	-	1811
Seoul	Chon *et al.* (1995)	3	101	-	296
London	Lehame *et al.* (1992)	6250	61-323	32-74	-
Hong Kong	Wang *et al.* (1998)	-	92-392	-	574-2397
Bahrain	Akhter & Madany (1993)	72	-	126	152
Serdang	This study	0.72-3.76	16.11-76.46	9.85-38.41	52.27-304.64

- indicates data are available

TABLE 5
Comparisons for the values (minimum-maximum) of heavy metal concentrations (µg/g dry weight) in the fan dust collected in this study and those reported by Yap *et al.* (2007)

Location	Cd, µg/g	Zn, µg/g	Fe, µg/g	Ni, µg/g	Cu, µg/g	Reference
Serdang, Malaysia	3.15-5.83	785.60-1029.08	2603.72-3243.56	42.59-96.35	223.84-536.00	This study
Ipoh, Malaysia	5.37-16.70	563.20-815.90	3470.70-4455.46	43.97-58.55	159.99-229.32	Yap *et al.* (2007)
Serdang, Malaysia	11.40-13.71	688.39-868.10	3446.50-4440.39	28.51-36.22	163.54-270.05	Yap *et al.* (2007)

is a common element of the earth's crust, so its levels in the car park dust could be related to the mobilization of soil particles (Fung & Wong, 1995).

CONCLUSION

In conclusion, K5 (Zn, Fe, and Cu, car park dust; Zn, ceiling fan dust) and K10 (Zn and Ni, car park dust; Cu, Ni, and Fe, ceiling fan dust) were found to have high concentrations of heavy metals, since they are comparable to other reported data for major cities, and this could be related to the vehicular traffic at these residential colleges. In general, ceiling fan dust had significantly ($P< 0.05$) higher concentrations of heavy metals compared to that in the car park dust. Meanwhile, most of the heavy metals concentrations (Cd, Cu, Ni, and Fe) found in the car park dust were still low than the data reported in the literature. However, the concentrations of Zn in the car park dust and the concentrations of Cu, Ni and Zn in the ceiling fan dust undertaken in this study were found to be comparable to or higher than those reported for other cities in the literature. Thus, further monitoring studies are needed since dust is considered as a potential atmospheric indicator of heavy metal pollution and its relationship to human health should be considered seriously.

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