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Distribution and Health Risk Assessment of Heavy Metals in Surface Dusts of Maha Sarakham Municipality

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Abstract

Using the case of Maha Sarakham municipality, the research aims to monitoring the impact of urban land use and particle size distribution on the heavy metal (HM) contamination in surface dusts and carried out research into the exposure and health risk assessment of heavy metals on the fine size dusts. Samples were collected from five function areas. The contents of HM (lead, zinc, copper, and cadmium) in surface dusts were determined. Results showed only Zn concentration tended to increase with decreasing particle sizes. Results revealed the highest zinc concentrations from all areas. The parking lot samples contained the highest amount of heavy metals. HIs for all metals were lower than their threshold values, indicating without health hazards. The study will be beneficial for the municipality in terms of non-point source pollution control/management to promote the health of urbanites.

Keywords: heavy metals; urban land use; size distribution; surface dust; health risk assessment.

1. Introduction

Dusts on urban impervious surface have become one of the most important issues in urban environmental management. On one hand, surface dusts can be easily re-suspended under certain outside

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dynamic condition, pollutants adsorbed on them enter human body by the pathways of respiratory inhalation and direct skin contact and cause negative health effects (Glikson, Rutherford, & Simpon, 1995; Tervahattu, Kupiainen, & Raisanen, 2006; Grimm, Faeth, Golubiewski, & Redman, 2008). Children and the elderly, whose immune systems are either underdeveloped or age-compromised as well as the inadvertent ingestion of significant quantities of dust through hand-to-mouth pathways, are more vulnerable to toxicity (Mielke, Gonzalez, & Smith, 1999; Rasmussen, Subramanian, & Jessiman, 2001). Study shows that lead toxicity is associated with deficits in central nervous system functioning that can persist into young adulthood. Hair lead and cadmium are correlated with both reduced intelligence scores and lowered school achievement scores (Oskarson, Hallen, & Sundberg, 1995). The toxicity of Cu, Cd, Zn is acknowledged, These elements can change the function of the human central nervous system and respiratory system, and disrupt the endocrine system. On the other hand, pollutants attached to surface dusts can be transferred to the surrounding aquatic environment with runoff and can cause a serious threat to the water environment and human health (Jartun, Ottesen, Steinnes, & Volden, 2008; Zhao, Li, & Wang, 2011). Surface dust as an important carrier of contaminants, is a typical non-point source pollution (Ball, Jenks, & Aubourg, 1998; Bris, 1999; Li, Lau, Kayhanian, & Stenstrom, 2005; Duong & Lee, 2011). Surface dusts are a complex environmental media. Their composition reflects inputs from a variety of sources, including water transported material from surrounding soils and slopes, dry and wet atmospheric deposition, biological inputs, road surface wear, road paint degradation, vehicle wear (tires, body, brake linings, etc.), vehicle fluid and particulate emissions, and inputs from the wear of sidewalks and buildings (Sutherland, Tack, Tolosa, & Verloo, 2000). Surface dust is a valuable environmental archive as this material is located on paved areas that are directly connected to a city's storm drainage system, and surface dusts have been identified as the primary source of urban nonpoint pollutants entering the receiving waters (Sutherland, Jelen, & Minton, 1999). The particle size of the dusts has an important influence on the mobility of particles and their associated pollutant concentrations (Bian & Zhu, 2009). Heavy metals including copper (Cu), lead (Pb), zinc (Zn) and cadmium (Cd) in surface dusts derived from different activities i.e. industrial activities, vehicle emissions, and wear of tyre and road surface are of particular concern due to the large impact of these heavy metals on the environment and human health (Watt, Thomton, & Cotter-Howells, 1993; Mielke, Gonzales, & Smith, 1999; Adriano, 2001). Therefore, studying on the characteristics of urban surface dust pollution is not only an important aspect of evaluation of quality of urban environment, but also of great significance for human health. Several studies of heavy metals contamination, distribution and source identification of street dusts in many cities have been carried out. However, there is no information available on potentially toxic metals in surface dusts and their distribution in particle size fractions in Maha Sarakham city, Thailand. The objectives of this initial study are to understand the particle size distribution characteristic of surface dusts from different function areas, to determine the heavy metal concentrations in each size range of surface dusts, and to evaluate the surface dusts on human health hazards using health risk assessment model. The results of this study in Maha Sarakham are valuable for the selection of the urban sweeping vehicles to remove more pollutants in surface dusts. In addition, Our Findings are beneficial for the source control of non-point source pollution management and improving environmental quality to promote the health of urbanites in Maha Sarakham Municipality.

2. Materials and methods

2.1. Study area

Maha Sarakham province is situated in the heart of Northeast Thailand. Maha Sarakham Municipality is the capital of the province. It occupies an area of 556.7 km^2 being a rolling plain without mountain or hill with the Chi River flows through. Maha Sarakham Municipality is characterized by relatively low quality sandy soil and a typical tropical climate with long dry season from February to May. The average temperature is approximately 34℃ during the rainy summer season from June to October, and 22℃ during the winter season from October to February. The annual average rainfall recorded is 1239.7 mm with a total of 104 rainy days. The population in the Municipality of Maha Sarakham has been estimated to be 142 325 inhabitants in 2005, and average density is 255.7 persons/km^2. The principal occupations of Maha Sarakham people are cultivation and animal raising. Outstanding home industry of Maha Sarakham is sericulture and silk fabric production. The main means of transport is motorcycles, and there are few private cars.

2.2. Sampling sites and technique

Surface dusts were collected from 14 different sites in five different function areas in Maha Sarakham Municipality, Function areas were classified as commercial, parking lot, residential, park and traffic. The sampling sites were marked on the map shown in Fig. 1, and the detail information of sampling was given in Table 1. Sartor and Boyd (1972) investigated the distribution of sediment across the whole road surface and found that 95% of the sediment load occurred within 1 m of the road adjacent to the edge of the road. Therefore, in this study, the sample of surface dusts was collected by sweeping many areas of 1×1m^2 surface adjacent to the edge of the road with a dustpan and brushes in each sampling site and stored in the self sealed plastic bag during December 15-17, 2011 following a dry weather period of about 7 days. Sample mass collected was between 200 and 350g for each sampling site. Soil samples were also sampled in the place of less human interference to estimate the baseline conditions.

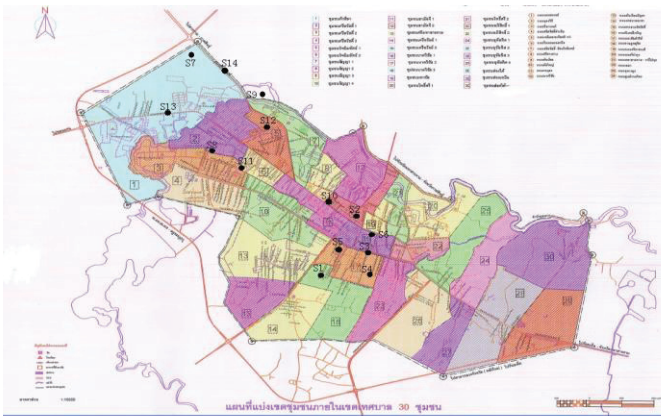

Fig. 1. Sampling sites location on the map

2.3. Particles sieving

The surface dust samples were air-dried in the laboratory just for 3 days because samples were collected under dry weather. The samples from the same function area were then mixed together to represent this function area. The mixed sample was separated two subsamples, one part was treated as a bulk sample and sieved through a 850μm stainless sieve, and the other part was sieved for 5 min using a sieve-shaker and a nest of new stainless steel sieves into six grain size fractions. The fractions sieved were: <53 μm, 53-125 μm, 125-250 μm, 250-500 μm, 500-850 μm and >850 μm. The mass of dusts in each size fraction was weighed and the mass proportion was calculated. Heavy metal analysis was conducted on bulk samples and individual grain size fractions less than 850 μm in diameter. No larger fractions were analyzed because the coarser fractions carry a considerably less amount of heavy metals. The soil samples were air-dried to constant weight in laboratory. The dried samples were ground in an agate mortar acid washed and then passed through a nylon sieve with a mesh of 150 μm for further analysis.

Table. 1. Sampling sites information.

Site No	Land-use	surface pavement	Area sampled(m^2)	Total dusts mass(g)	Mass per unit area(g/m^2)
1	Commercial	cement	13	592.6	20.43
2	Commercial	asphalt	11		
3	Commercial	cement	5		
4	parking lot	cement	4	645.81	35.88
5	parking lot	cement	8		
6	parking lot	asphalt	6		
7	Residential	cement	24	837.61	17.82
8	Residential	asphalt	13		
9	Residential	cement	10		
10	Park	cement	9	842.53	31.21
11	Park	cement	5		
12	Park	cement	13		
13	Traffic	asphalt	6	713.32	71.33
14	Traffic	asphalt	4		

2.4. Analytical methods

The surface dust samples and soil samples were analyzed for Pb, Zn, Cu and Cd. About 0.5000g of the bulk or sieved subsample was placed into precleaned erlenmeyer flask and digested on electrothermal plate at a low temperature with 10ml concentrated hydrochloric acid until about 3ml, then10ml concentrated nitric was added into the erlenmeyer flask and the erlenmeyer flask was heated at a middle temperature until the liquid is thicken, the sides of the erlenmeyer flask were rinsed with deionized water and gently heated until the residue was completely dissolved. After cooling, the solution was filtered into 50ml volumetric flask and diluted to volume with deionized water. Heavy metals concentrations were determined by FAAS (flame atomic absorption spectrometry). Reagent blanks and replicate samples were used for analytical process to assess pollution, precision and bias. The precision and bias in the analysis were less than 10%.

2.5. Estimation of heavy metal Loads in surface dusts

To determine the contribution of grains with different grain sizes to the overall contamination of the dusts, we calculated the pollutant load percentage for each grain size fraction. The grain size fraction load (GSF_{Load}) equation presented in Sutherland (Surtherland, 2003) was applied in this study:

$$GSF_{Load}(\%) = \frac{C_i \times GS_i}{\sum_{i=1}^{m} C_i \times GC_i} \times 100 \quad (1)$$

Where C_i is the heavy metal concentration associated with a dusts sample for a given grain size; GS_i is the mass percentage of an individual fraction; and m is the number of grain size fractions.

2.6. Contamination assessment method

The index of geoaccumulation (Igeo) is widely used in the assessment of contamination by comparing the levels of heavy metal obtained to a background levels originally used with bottom sediments (Muller, 1969). It can also be applied to the assessment of road dust contamination (Lu, Wang, Li, Lei, & Kang, 2010). It is computed by the following equation:

$$I_{geo} = log_2\left[\frac{C_n}{1.5B_n}\right] \quad (2)$$

Where C_n is the measured concentration of the heavy metal in road dust and B_n is the geochemical background concentration of the heavy metal (crustal average). The constant 1.5 is introduced to minimize the effect of possible variations in the background values which may be attributed to litho logic variations in the sediments (Lu, Wang, Lei, Huang, & Zhai, 2009).

The following classification is given for geoaccumulation index (Huu *et al*., 2010; Muller, 1969): <0 = practically unpolluted, 0-1 = unpolluted to moderately polluted, 1-2 = moderately polluted, 2-3 = moderately to strongly polluted, 3-4 = strongly polluted, 4-5 = strongly to extremely polluted and >5 = extremely polluted.

2.7. Health risk assessment method

The risk assessment method on soil is widely applied to the health risk assessment of heavy metals exposure to surface dust (Ferreia-Baptista & De Miguel, 2005; Chang, Liu, Li, Lin, Wang, & Gao, 2009; Zheng, Liu, Wang, & Liang, 2010). The pathways of pollutants attached to the surface dusts entering human body are hand-to-mouth ingestion, dermal absorption and mouth and nose inhalation. The dose received via each of the three paths was calculated using Eqs. (3)-(6) (USEPA, 1989, 1996).

$$D_{ing} = C \times \frac{IngR \times EF \times ED}{BW \times AT} \times 10^{-6} \quad (3)$$

$$D_{inh} = C \times \frac{InhR \times EF \times ED}{PEF \times BW \times AT} \quad (4)$$

$$D_{dermal} = C \times \frac{SL \times SA \times ABS \times EF \times ED}{BW \times AT} \times 10^{-6} \quad (5)$$

$$LADD = \frac{C \times EF}{AT \times PEF} \times \left(\frac{InhR_{child} \times ED_{child}}{BW_{child}} + \frac{InhR_{adult} \times ED_{adult}}{BW_{adult}}\right) \quad (6)$$

Where, D_{ing} is the daily dose via hand-to-mouth ingestion of substrate particles; D_{inh} is the daily dose via inhalation of re-suspended particles through mouth and nose; D_{dermal} is the daily dose via dermal absorption of trace elements in particles adhered to exposed skin; LADD is the lifetime average daily dose for cancer elements via inhalation exposure route. The other parameters` meaning and values as follow Table 2.

Table. 2. Parameter meaning and value of daily dose model of heavy metals in urban surface dusts.

Parameter	Meaning and Unit	Values		Reference
		Child	Adult	
C	exposure-point concentration, *mg/kg*	95%UCL		This study
IngR	ingestion rate, *mg/d*	200	100	USEPA, 2001
InhR	inhalation rate, m^3/d	7.6	20	Van den Berg, 1995
PEF	particle emission factor, m^3/kg	1.36×10^9		USEPA, 2001
SA	exposure skin area, cm^2	2800	5700	USEPA, 2001
SL	skin adherence factor, $mg/(cm^2h)$	0.2	0.7	USEPA, 2001
ABS	dermal absorption factor, unitless	0.001		Ferreira-Baptista & De Miguel, 2005
ED	exposure duration, *y*	6	24	USEPA, 2001
EF	exposure frequency, *d/y*	180		Ferreira-Baptista & De Miguel, 2005
BW	average body weight, *kg*	15	70	USEPA, 1989
AT	average time, *d*	ED×365(for non-carcinogens) 70×365(for carcinogens)		USEPA, 1989

For non-carcinogens the doses calculated for each element and exposure pathway are subsequently divided by the corresponding reference dose (RfD) to yield a hazard quotient (HQ), Hazard index (HI) is equal to the sum of HQ. If the value of HQ or HI is less than one, it is believed that there is no significant risk of non-carcinogenic effects. If HQ or HI exceeds one, then there is a chance that non-carcinogenic effects may occur, with a probability which tends to increase as the value of HQ or HI increases (USEPA, 2001). For carcinogens the dose is multiplied by the corresponding slope factor (SF) to produce an estimate of cancer risk. The level of cancer risk associated with exposure to this element in street dust is the range of threshold values (10^{-6} – 10^{-4}), above which environmental and regulatory agencies consider the risk unacceptable (USEPA, 1989). Hazard Index method and cancer risk method were used to assess human health risk of heavy metals exposure to surface dusts in Maha Sarakham city.

3. Results and discussions

3.1. Particle size distribution

The mass per unite sampling area in different land uses in Maha Sarakham city is displayed in table 1. Mass of surface dusts varied from 17.82 to 71.33 g/m^2 in different land uses. The mass per unit area decreased in the following order: Traffic> Parking lot> Park> Commercial> Residential. Lau and Stenstrom (2005) studied on mass loads in different land uses in the City of Canta Monica, California.

The results showed that the mass per unit area decreased in the following order: commercial> single family residential> industrial> roads> multifamily residential. The mass loads ranged from 11.83 to 30.83 g/m^2. Tian et al (2009) reported that masses of sediments smaller than 500 μm in diameter varied from 11.2 to 25.5 g/m^2 in road in the city of Beijing, China. The reasons for different results might be attributed to the different human activities, traffic volume, the sweeping frequency and type, and antecedent dry periods for sampling in different research cities. In the case of Maha Sarakham city, there was no sweeping in addition of high traffic speed leading to highest mass loads in traffic area. Although there were heavy traffic volume and concentration of human activities in the commercial area, the sweeping action was twice a day. Therefore, a large number of surface dusts were removed. The mass in the residential area was the lowest due to the less traffic volume and sweeping activity once a day.

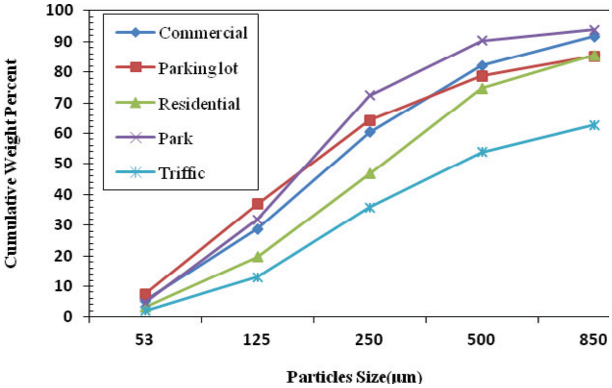

Fig.2. The surface dust weight proportion in different size ranges

Fig. 2 shows the particle size distribution for the dusts from different land uses. More than 85% of collected dusts from different land uses were less than 850 μm size except traffic area, where 62% of collected dusts was less than 850 μm. Most land uses showed similar trends, with the 53-500 μm being more abundant，notably this size fraction accounted for 77%, 71%, 72% and 86% of the total surface dust in commercial, parking lot, residential and park, respectively. This result was agreement with Lau `s (2005) findings for particle size distribution of street particles collected from different land uses in the City of Canta Monica, California. His results showed that the abundance of the 250-841 and 100-250μm fractions was more obvious, the particles were numerous in the middle size ranges. German and Svensson (2002) also reported that the largest amount of sediment was found in the sandy fractions (125-500 μm). This suggests that particulates below 850 μm are of specific concern in urban areas. Since sediment removal techniques such as street sweeping only efficiently remove relatively large particles, the problems posed by particles less than 850 μm size fractions are significant. The biggest fraction (>850 μm) showed the greatest abundance in traffic area in Maha Sarakham city. The reason for this is that the high traffic speed causes substantial crushing of the particles (Ellis & Revitt, 1982). Another possible interpretation is that there was no sweeping in the traffic area while sweeping was carried daily in other land use areas.

3.2. Heavy metal concentrations in bulk surface dusts

Heavy metal concentrations in surface dusts from different function areas are shown in Table 3. Pb, Cu, Zn and Cd were analyzed. The mean concentration of Pb, Cu, Zn and Cd was 13.12, 13.37, 58.02 and 0.55 mg/kg, separately. The concentrations of Cu and Cd in surface dusts were lower than those in soil, Cu=47.77 mg/kg, Cd=2.21 mg/kg, while Pb and Zn concentration were significantly enriched compared to those in soil, Pb=4.7 mg/kg, Zn=19.38 mg/kg. For all of the five function areas, concentration of total Zn was the highest among the four heavy metals investigated. As Zn is used as a vulcanization agent in vehicle tyres, the higher wearing rate at high temperature may contribute to the high Zn concentration in the surface dusts in Maha Sarakham city. Land uses influences on the heavy metal concentrations of surface dusts are obvious, as shown in Table 3. In the case of Maha Sarakham Municipality, in terms of the different land uses, the maximums of Pb, Zn and Cd have been found in the sample collected from parking lot. The minimums of Pb and Cu were detected in dust sample collected from residential area with less traffic density. The sources of Pb, Cu, Zn and Cd in surface dusts were indicated by previous research as vehicles, road wear, slipperiness control, buildings (heating and corrosion) and industries (Viklander, 1998). We can conclude from the results that the source of the heavy metal attached to surface dusts mainly came from the traffic in Maha Sarakham city.

Table. 3. Heavy metal concentration in different function areas (*mg/kg*)

Land-use	Pb	Cu	Zn	Cd
Residential	4.63	9.36	46.26	0.20
Park	6.39	12.04	43.76	0.05
Commercial	11.83	17.56	83.45	0.73
Parking lot	28.40	16.67	80.69	1.67
Traffic	14.35	11.23	35.96	0.11
Soil	4.70	47.77	19.38	2.21

Table .4. Heavy metal concentration in surface dusts in major cities around the world (*mg/kg*)

City	Pb	Cu	Zn	Cd	Reference
Hongkong, China	181	173	1450	3.77	Li et al.,2001
Xi`an, China	230.52	94.98	421.46	-	Han et al.,2006
Guangzhou, China	240	176	240	2.41	Duzgoren-Aydin,2006
Shanghai, China	294.9	196.8	733.8	1.23	Shi et al.,2008
Baoji, China	408.41	123.17	715.1	-	Lu et al.,2009
Hangzhou, China	202.16	116.04	321.4	1.59	Zhang et al.,2009
Urumqi, China	53.53	94.54	294.47	1.17	Wei et al.,2009
Beijing, China	69.6	78.3	248.5	0.71	Xiang et al.,2010
Delhi, India	205	230	330	15.8	Banerjee et al.,2003
Coventry, West Midlands, UK	47.1	226.4	385.7	0.9	Charlesworth et al.,2003
Gela Town, Sicily	70	100	240	-	Manno et al.,2006
Aqaba, Jordan	167	46	144	2.3	Al-Khashman et al.,2007
Istanbul	368.3	191.1	431.2	0.3	Yetimoglu et al.,2007
Kavala, Greece	300.9	123.9	271.6	0.2	Christoforidis et al.,2009
Islamabad, Pakistan	104	52	116	5	Faiz et al.,2009
Maha Sarakham, Thailand	13.12	13.37	58.02	0.55	This work

Comparison of mean concentrations of heavy metal in the surface dusts in other cities around the world, as shown in Table 4. The mean concentrations of Pb, Cu and Zn in surface dusts sampled in Maha Sarakham city were significantly lower than those sampled in other cities. The mean concentration of Cd for surface dusts in Maha Sarakham was low compared several cities around the world except for Istanbul and Kavala. The first reason might be that there are no industrial activities, but green belts on the roadside in Maha Sarakham city, and each city has its own characteristics combination of elemental compositions. The second reason may be that motorcycles play an important part in the private transport mode, and there are few private cars, and the use of lead-free petrol in Maha Salakham city. The research displays fuel economy per unit vehicle of cars is much worse than that of a motorcycle, at the same time private cars emit more gas emission with pollutants compared motorcycles (Pongthanaisawan & Sorapipatana, 2010). The third reason may be attributed to different sample sites selected, sampling methods and analysis process leading to great changes in concentrations of heavy metal for different research cities. Therefore, it is very necessary to establish a standard and universally accepted sampling and analytical procedures for geochemical studies of surface dusts.

3.3. Distribution of heavy metal concentrations in size fractions

Heavy metals (Pb, Cu, Zn and Cd) were analyzed in each particle size range of surface dusts from commercial area due to the enough mass for analysis and the high heavy metal concentrations. The results are shown in Fig. 3. It is evident that the smallest particles, less than 53 μm, had the highest metal concentrations (mg/kg) as follows: Pb 53.7, Cu 54.31, Zn 182.44 and Cd 1.95. The important implication is that metals associated with the fine fraction of surface material will be readily transported to adjacent soils Aeolian processes and will probably be dispersed via storm water canals to the adjacent estuary and may not be contained within gully pots. This further strengthens the importance of removing fine particulates from surface dusts. The concentration of Pb decreased with the particle size increasing for ranges less than 250 μm. While the concentration of Pb increased with the particle size increasing for fractions larger than 250 μm. The results are difficult to interpret for fractions larger than 250 μm. The change of Cu concentration with particle size is irregular. The concentration of Zn was the only metal showing steadily increasing with decreasing particle sizes, This result is agree with other researchers` findings (Xiang, Li, Shi, & Liu, 2010; Zhao, Li, & Wang, 2011). This phenomenon occurs because smaller particles have larger surface areas to absorb pollutants. The variation of Cd concentration exhibited a more complex pattern, with concentration in the 53-125 μm fraction less than these in other fractions. The reason for this is unknown.

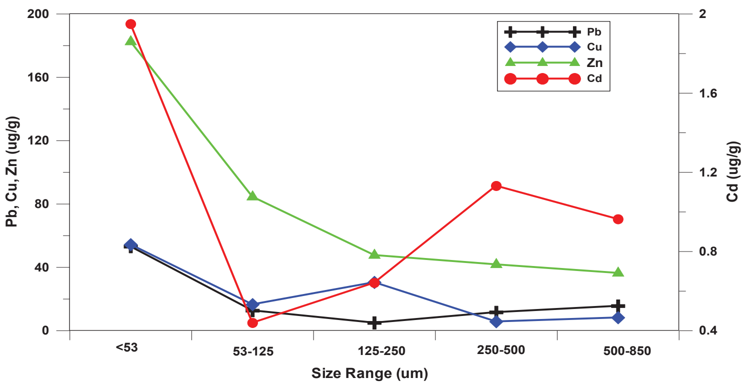

Fig. 3. Heavy metal concentrations in each size range

Loading combines element concentrations, on a grain size basis, with data on the mass percent of individual grain size classes. Few studies of environmental media have computed heavy metals loads on a grain size. Howaver, from fluid transport theory it is well know that sediment grain size is an important factor controlling entrainment and transport threshiolds (Bridge, 2003). Additionally, from the contaminant literature it is apparent that there is a grain size control on metal sorption and biotic ingestion, and thus bioavailability. In this paper, the percentage of heavy metal concentration load for each particle size fraction was also analyzed. The results are shown in Fig. 4. The heavy metal mean load percentage of surface dusts in size rang <53, 53-125, 125-250, 250-500 and 500-850 µm was 17.85%, 23.84%, 29.76%, 19.39% and 8.88%, separately. This was disaccord with the highest concentrations of heavy metal in the smallest size range, less than 53 µm. The reason was that the particle mass was more aboundant amoung 53-125, 125-250 and 250-500 µm size ranges, especially in 125-250 µm size range in commercial area. It demonstrates that athough smaller particles in surface dusts have larger surface areas to absorb pollutants, the particles were numerous in the middle size ranges, and the heavy metal concentration loads were also high in these size ranges. It suggests that more attention should be paid to the mass loading combining with element concentrations in the surface dusts. High-efficiency sweeping technology is currently the best management practice to remove more surface dusts in order to reduce pollution with runoff when rainfall.

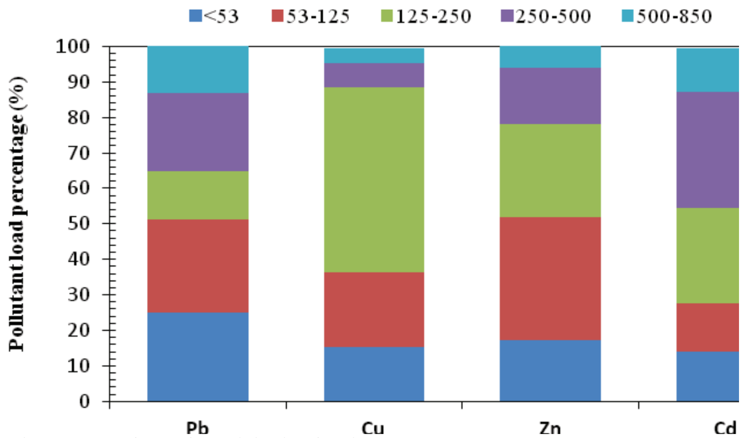

Fig. 4. The pollutant load percentage for each particle size fraction

3.4. Assessment result of heavy metals in surface dusts

The calculated results of I_{geo} of heavy metals in surface dusts are displaied in Fig.5. The I_{geo} ranges from -3.95 to -1.32 with a mean value of -2.69 for Pb, 0.41 to 1.32 with a mean value of 0.89 for Cu, 0.59 to 1.52 with a mean value of 0.93 for Zn, -6.05 to -0.99 with a mean value of -3.46 for Cd. The mean values of Igeo are in the following order: Zn> Cu> Pb> Cd. The values of Igeo of Pb and Cd falling into class 1 indicate Pb and Cd in surface dusts are practically unpolluted. The mean Igeo and 60% Igeo of Cu falling into class 2 show unpolluted to moderately pulluted. Percentage Igeo of Zn falls in class 2(60%) and class 3(40%) indicating that Zn is unpolluted to moderately polluted and moderately polluted in surface dusts. As far as the overall behavior of heavy metals under study is concered, on the basis of Igeo it can be said that the surface dusts samples in Maha Sarakham are practically unpolluted for Pb and Cd, and unpolluted to moderately polluted and moderately polluted for Cu and Zn.

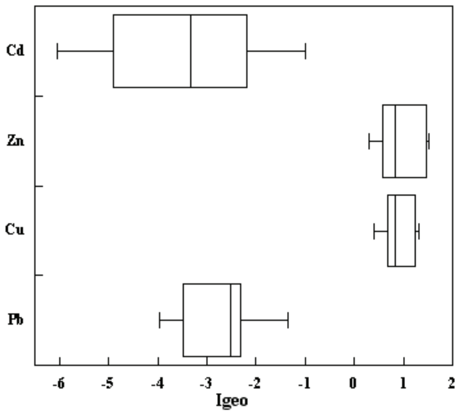

Fig. 5. Box-plot of I_{geo} for heavy metals in surface dusts

3.5. Health risk assessment of heavy metals exposure to surface dusts

The results of the risk assessment are shown in Table 5. Average daily dose of ingestion of dust particles for all metals were much higher than those of inhalation of re-suspended dust particles and dermal absorption with dust particles. The highest levels of risks were associated with the route of ingestion of dust particles to children and adults for all metals, followed by dermal contact. The inhalation of re-suspended through mouth and nose seemed to be negligible due to inhalation of dust particles is 3-6 orders of magnitude lower than the other two paths. Similar results were obtained by Zheng (2010) in a study of exposure to heavy metals in street dust in the zinc smelting district and Fang (2010) in a study of exposure to heavy metals in surface dust of Wuhu urban area.

The orders of non-cancer hazard indexes of metals were Cd>Pb>Cu>Zn to children and Pb>Cd>Cu>Zn to adults. The HQs and HIs for all heavy metals are lower than 1, which indicated that the adverse health impact on children and adults exposure to heavy metals in surface dusts was relatively light in Maha Sarakham city.

For Cd, the cancer risk was also calculated by Eq. (6). The level of cancer risk associated with exposure to this element in street dust (i.e. 1.82×10^{-10}) falls within the range of threshold values (10^{-6} - 10^{-4}) above which environmental and regulatory agencies consider the risk unacceptable, it means there was no cancer risk in Maha Sarakham city. From the results, we also can conclude that the exposure of the surface dusts to children could exhibit more potential health risk compared to adults.

Table. 5. Exposure dose, hazard quotient and risk for each element and exposure pathway (mg/kg • d)

	Pb	Cu	Zn	Cd
RfD_{ing}	3.50E-03	4.00E-02	0.30	1.00E-03
RfD_{inh}	3.50E-02	4.02E-02	0.30	1.00E-03
RfD_{dermal}	5.25E-04	1.20E-02	6.00E-02	1.00E-05
Sf_{inh}				6.30
Child				
D_{ing}	9.83E-05	1.07E-04	4.04E-04	3.70E-06
D_{inh}	2.75E-09	3.00E-09	1.13E-08	1.03E-10

D_{dermal}	2.75E-07	3.00E-07	1.13E-06	1.04E-08
LADD				2.88E-11
HQ_{ing}	2.81E-02	2.68E-03	1.35E-03	3.70E-03
HQ_{inh}	7.85E-08	7.45E-08	3.76E-08	1.03E-07
HQ_{dermal}	5.24E-04	2.50E-05	1.89E-05	1.04E-03
$HI=\sum HQ_i$	2.86E-02	2.71E-03	1.37E-03	4.73E-03
Cancer risk				1.82E-10
Adult				
D_{ing}	1.05E-05	1.15E-05	4.33E-05	3.96E-07
D_{inh}	1.55E-09	1.69E-09	6.37E-09	5.83E-11
D_{dermal}	4.20E-07	4.58E-07	1.73E-06	1.58E-08
LADD				2.88E-11
HQ_{ing}	3.01E-03	2.87E-04	1.44E-04	3.96E-04
HQ_{inh}	4.42E-08	4.20E-08	2.12E-08	5.83E-08
HQ_{dermal}	8.00E-04	3.82E-05	2.88E-05	1.58E-03
$HI=\sum HQ_i$	3.81E-03	3.25E-04	1.73E-04	1.98E-03
Cancer risk				1.82E-10

4. Conclusions

Mass loading of surface dusts varied from 17.82 to 71.33 g/m^2 in different land uses in Maha Sarakham city. The mass per unit area were in the following order: Traffic> Parking lot> Park> Commercial> Residential. The surface dusts between 53 and 500μm in diameters were more abundant in commercial, parking lot, residential and park. The concentrations of heavy metals in surface dusts in Maha Sarakham were lower than these in other cities around the world. Parking lot had higher concentrations of Pb, Zn and Cd compared with commercial, residential, park and traffic. For the concentrations of heavy metals in different particle size ranges. Results show that only Zn concentration tended to increase with decreasing particle size. The concentration of Pb decreased with the particle size increasing for ranges less than 250 μm. While the concentration of Pb increased with the particle size increasing for fractions larger than 250 μm. The changes of Cu and Cd concentration with particle size are irregular. Although particles in the smallest size range attached the highest heavy metal concentrations, the dusts were numerous between 53 and 500μm in diameter, the heavy metal concentration loads were also high in these size ranges. It demonstrates that the urban sweeping vehicles should update the dust sweeping devices to remove not only the fine particle but also the coarser particles. Igeo reveals that Pb and Cd of surface dusts were practically unpolluted, and surface dusts samples were unpolluted to moderately polluted and moderately polluted with Cu and Zn. The non-cancerous risk indexes of four metals from the three ways were lower than 1 and the cancer risk of Cd was low its threshold value, indicating without health hazards and cancer risk in Maha Sarakham city.

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