ISSN-1996-918X

Pak. J. Anal. Environ. Chem. Vol. 12, No. 1 & 2 (2011) 32-41

Assessment of Heavy Metals in Street Dust in Kathmandu Metropolitan City and their Possible Impacts on the Environment

Chirika Shova Tamrakar* and Pawan Raj Shakya

Department of Chemistry, Faculty of Science, Padmakanya Multiple Campus, Tribhuvan University, Bagbazar, Kathmandu, Nepal

Received 22 July 2011, Revised 14 September 2011, Accepted 19 September 2011

Abstract

Street dust often contains elevated concentrations of heavy metals and can influence on environment and human health. Therefore, a study on the characteristics of heavy metals in street dusts at different localities was carried out in the metropolitan city of Kathmandu of Nepal. A total of 20 street dusts have been sampled from four sampling sites with various activities or characteristics such as mechanical workshops (MWK), motor parks (MPK), market areas (MKA) and residential areas (RDA) and analyzed for Zn, Pb, Ni, Cr and Cd using the atomic absorption spectrophotometric method. Results showed that street dust samples contained significant levels of the metals studied compared to the values from the control site. The variation in concentration of most of the heavy metals determined decreased in an order represented as MWK>MPK>MKA>RDA>Control. While the RDA and MKA give the same element abundance order as Zn > Pb > Ni > Cr > Cd, the MPK and MWK show different abundance order in some elemental contents. In all the street dusts, zinc is the most available and labile element followed by lead. From the place of low activity (RDA) to the place of high activity (MWK), the metal concentrations in street dusts varied from 55.4-419.3 μg g^{-1} for Zn, 12.3-116.8 μg g^{-1} for Pb, 4.9-86.3 μg g^{-1} for Ni, 1.4-14.3 μg g^{-1} for Cr and 0.3-39.6 μg g^{-1} for Cd respectively. Results indicate that the metal pollutants in street dusts could significantly contribute to deteriorate the environmental status of the city of Kathmandu metropolis.

Keywords*:* Heavy metals; Environment; Street dust; Kathmandu Metropolitan City

---

Introduction

Heavy metal contamination in urban street dust has become a growing concern in recent years. Urban surfaces receive deposits from various sources such as vehicle emissions, industrial discharges, domestic heating, waste incineration and other anthropogenic activities through atmospheric transport as well as from local human activities [1-3]. Street dusts and top roadside soils in urban area are indicators of heavy metal contamination from atmospheric deposition. Key heavy metals are thereby Pb from leaded gasoline, Cu, Zn and Cd from car components, tyre abrasion, lubricants, industrial and incinerator emissions [4, 5]. The source of Ni and Cr in street dust is believed to be corrosion of cars [6,7] and chrome plating of some motor vehicle parts [8] respectively.

Street dust investigation is of particular importance here for two main reasons. First, street dust is freely being inhaled by those traversing the streets and those residing within the vicinity of the streets. The more the dusts on such streets become contaminated with heavy metals, the more such people are exposed to the health hazards associated with such metals. Second, the street dust is one of the major mediums through which heavy metals

*Corresponding Author Email: chirikat@yahoo.com

may find their ways into soils and surface and underground water through rains and subsequently living tissues of plants, animals and human beings. In recent years, there is a growing concern for the potential contribution of ingested dust to metal toxicity in humans [9,10]. Young children are more likely to ingest significant quantities of dust than adults because of the behavior of mouthing non-food objects and repetitive hand/finger sucking [11]. Besides, children have a much higher absorption rate of heavy metals from digestion system and higher hemoglobin sensitivity to heavy metals than adults [12].

Kathmandu, the capital of a developing country, Nepal in South Asia has a population of 2.5 million. It is located between 27^0 45'. 27^0 47' N latitude and 85^0 20'. 85^0 25' E longitude. The city of Kathmandu metropolis has gone through rapid and haphazard urbanization in the past decade. This fastest growing city with high commercial activities harbors around 3 hundred thousand vehicles and the number is likely to be doubled in next few years (Office of Traffic Police, Kathmandu – personal communication). Hence, the pollution concentrations of urban centers of Kathmandu are reaching the point of potential serious consequences. Particulates of smaller size and mass are persistent in the environment and exert health impact to exposed resident population in urban setting [13]. Dust, smoke and various toxic gases have threatened our existence and well-being. So, it is important to monitor the environmental status of the city before implementing preventing and controlling measures of various kinds of pollution.

Although there have been considerable number of studies on the concentration of heavy metals in street dust, the vast majority have been carried out in developed countries with long histories of industrialization [14]. Very few studies have been carried out in developing countries like Nepal. Little interest has been focused on the contamination of street dust by other heavy metals in regions like the city of Kathmandu metropolis. Such data on pollutant metal concentration of street dust in such areas are extremely scarce. This paper therefore reports the concentration of heavy metals in street dusts at different sites in the city of Kathmandu metropolis particularly from the places of high activities to the places of low activities *viz.*, mechanical workshops, motor parks, market areas and residential areas. Similar studies have not been previously conducted in this region, in terms of the distribution of metals in street dusts. Specifically in the present study, (1) the total content of Zn, Pb, Ni, Cr and Cd in dusts at different sampling sites of activities in the city was determined, and (2) the dust results from this area were compared with those available in various areas throughout the world.

Experimental

Sample collection

For the present study, four sampling sites with various characteristics such as mechanical workshops (MWK), motor parks (MPK), market areas (MKA) and residential areas (RDA) were selected along the major streets in the city of Kathmandu metropolis (Fig. 1).

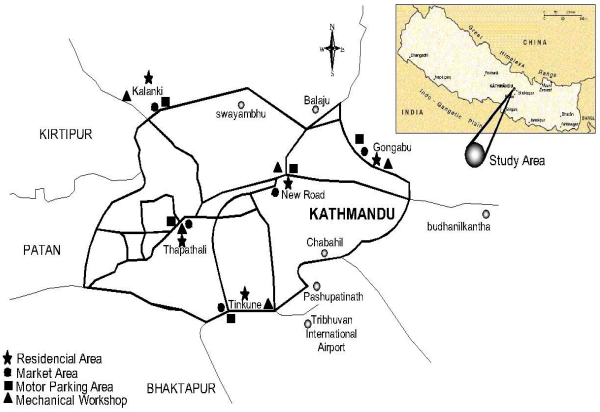

Figure 1. **Location Map of Study area (Kathmandu Metropolitan City).**

A total of 20 street dust samples (five replicates of each characteristic or the place of activity) were obtained from the sampling sites throughout the city during dry season to avoid rain-washing out the heavy metals. (Table 1) shows the description of the traffic and population loads and land use characteristics of the sampling locations. The dust sampling was carried out by gently sweeping an area of about 1 m^2 from pavement edges using brush and plastic dustpan. Dusts were not collected adjacent to site-specific pollution sources. At each sampling location about 10 g of the top 1 cm layer of soil (control) was collected at a distance of approximately 3m from the edge of

Table 1. **Traffic and population loads and land use characteristics of the sampling locations.**

Site No.	Sample code (or abbreviations)	Sampling sites	Traffic load	Population load	Land uses
1	RDA	KLK, GGB, TKN, THP, NR	Low	Dense	Residential area
2	MKA	KLK, GGB, TKN, THP, NR	Medium	Dense	Market area
3	MPK	KLK, GGB, TKN, THP, NR	Heavy	Dense	Motor- parking area
4	MWK	KLK, GGB, TKN, THP, NR	Heavy	Dense	Mechanical workshop
5	Control	KLK, GGB, TKN, THP, NR	-	-	-

KLK = Kalanki, GGB = Gongabu, TKN = Tinkune, THP = Thapathali, NR = New Road;
Classification of traffic load: Low = 50-100 vehicles hr^{-1}, Medium = 100-500 vehicles hr^{-1}, Heavy = >500 vehicles hr^{-1};
Population load: Dense = >5000 inhabitants sq. km^{-1}

the street with a stainless steel shovel. These samples were transferred to clean polyethylene bags. All the samples were dried at 105 ^{0}C for 24 hr to drive out moisture. On cooling each sample was sieved through a sieve of 250 μm diameter. Precautions were taken to avoid contamination during sampling, drying and storage.

Pretreatment of samples

Aliquots (1.0 g) of <250 μm dust and soil fractions were subjected to chemical extraction using 10 ml of aqua-regia (modified) [15] and microwave-heated in polytetrafluorethylene vessels and with the following program: 700 W, 10 min hold time and 1000W, 10 min hold time (duration of the program: 35 min., max. T=260 °C, max. P=30 bar) using an Anton Paar microwave extraction system. This digestion method was proved to extract the total quantities of native metals from the dust samples. The content was filtered through a Whatman no. 40 filter paper into a 100mL calibrated flask. The clear digested solutions were made upto the mark with double-distilled water.

Reagents and instrument

All the standard solutions (1000 ppm) for Zn, Pb, Ni, Cr and Cd were certified and obtained from FLUKA AG, Switzerland. These solutions were diluted carefully to the required concentrations with double-distilled water. All the glassware and plastic vessels were treated by dilute (1:1) nitric acid for 24 h and then rinsed with double-distilled water before use. The acids such as HNO_3 and HCl (E. Merck, Germany) were of analytical grade and used without further purification. Doubly distilled water was used throughout the experiment.

A SOLAAR M5 Dual Automizer Atomic Absorption Spectrophotometer with a standard photomultiplier, 180-900nm, Thermo Elemental, UK was used to analyze all the samples. The instrumental parameters were those recommended by the manufacturer.

Applications

Initially, the Atomic Absorption Spectrophotometer (AAS) was sufficiently warmed up for about 30 minutes. Hollow cathode lamps manufactured by Photron Pvt. Ltd., Australia were used along with a deuterium background corrector at respective wavelengths using an air-acetylene flame. Background correction measurements were made by means of non-absorbing lines, and blanks were determined by completion of the full analytical procedure without samples. After each analytical run, the calibration curve was displayed on the screen and a visual check was made for linearity and replication. Prior to each analysis, the instruments were calibrated with a series of the standard solutions of each specific metal already prepared according to manufacturer's recommendations. The sample solutions were passed through the column by a flow rate of 2mL min^{-1} [16]. Quality assurance of analytical results was controlled using the reference materials "NIST SRM 1648" for dust. The recovery percentage of metal concentrations from the reference materials was between 95.3 and 97.1%. In order to determine the precision of the analytical process, samples from the sites 1 and 4 (Table 1) were analyzed by three times. The standard deviation for

both samples was calculated to 2.5 and 3.1% respectively and can be considered satisfactory for environmental analysis.

Metal concentration was calculated using the working formula given below:

$$\text{Concentration of metal, } \mu g/g = \frac{\text{Observed Conc (ppm)} * \text{Vol of Sample Prepared (mL)}}{\text{Wt. of Dust Sample (g)}}$$

The statistics

All statistical analyses and data processing in this study were performed on an IBM-PC computer using Statistical Package for Social Sciences (SPSS) program. Descriptive statistics (mean, range, standard deviation) were performed after multi-element analysis. The inter-element correlation coefficients (r) for street dust samples were calculated by $p<0.05$. The contamination ratio for each site separately for street dust was calculated; Contamination ratio is the average metal concentration of a site over (:) the metal concentration of the reference site (control).

Results and Discussion

Heavy metals in street dust

The concentration of metals (mean, ranges and standard deviation) and the contamination ratios in street dust samples of various characteristics in the city of Kathmandu metropolis and the control site are presented in (Table 2). Mean metal content can be ranked by abundance in the street dusts of all the sampling categories as follows: MWK > MPK > MKA > RDA > Control. The decrease in order of metal abundance from the places of higher activities to the place of lower activities may probably be due to the decrease in vehicle emissions, traffic density and other related issues. The order is similar in all the street dusts of the sampling sites. The distribution of metal contents was however found to have varied to some extent. While the metals of RDA and MKA and the control site give the same element abundance order as follows:

Control site, RDA and MKA: Zn > Pb > Ni > Cr > Cd

the samples of MPK and MWK show different abundance order in some elemental contents as follows:

MPK: Zn > Ni > Pb > Cr > Cd

MWK : Zn > Pb > Ni > Cd > Cr

Obviously, MWK (the place of highest activities) has significantly high street dust contamination as these areas have significant volume of repair and maintenance of motor vehicles. Here, the vehicular activities such as automobile emissions, leakage of fuels and lubricating oils, car abrasion, chrome plating of vehicle parts and traffic flows are sufficiently high and hence these are the major sources of the elevated metal contents of MWK dust samples. Besides, the reason for decrease in metal abundance from MWK to RDA may be due to the decrease in such activities. (Table 3) shows inter-element correlations for street dust samples.

In all the street dusts, the Zn content (mean and range) was found in significantly high concentration and is the most available and labile element followed by Pb. The mean values of Zn in RDA, MKA, MPK and MWK were 77.9, 85.2, 126.0 and 304.7 $\mu g\ g^{-1}$ and ranged from 55.4 - 103.6, 65.4 - 90.6, 120.2 - 129.5 and 109.7 - 419.3 $\mu g\ g^{-1}$ respectively. The Zn contamination ratios of these sampling sites were 1.3, 1.4, 2.1 and 5.0 respectively. These results reveal that the metal concentration increased as per the activities of the sampling sites. The findings in the present study could indicate that motor vehicles and materials used around the sampling sites and leakage of oil products, car abrasion and car lubricants are the main sources of Zn [7]. A good correlation between Zn and Pb (r=0.879) exists (Table 3). (Table 4) compares metal contents in street dust samples in various locations throughout the world as cited in a report by Christoforidis and Stamatis (2009) [17]. In the absence of knowledge regarding activities or characteristics of the sampling sites in the various cities or countries, comparison of data recorded and comments on the causes of the differences between metal levels may be unjustified. However, the mean Zn content of MWK is found to be higher than various sites in Bahrain (152 $\mu g\ g^{-1}$), Luanda (98 $\mu g\ g^{-1}$, Angola) and Kavala (272 $\mu g\ g^{-1}$, Greece) but is significantly lower than many other reported values (Table 4) of various sites of countries and cities. Besides, the mean Zn contents of RDA, MKA and MPK are also significantly lower as compared to the reported values of various sites.

Table 2. **Concentration levels of heavy metals (μg g^{-1}) in street dust samples from various areas of Kathmandu Metropolitan City.**

Area (Sample code)		Zn	Pb	Ni	Cr	Cd
Residential area (RDA)	Mean	77.9	14.7	6.2	3.0	0.4
	Range	55.4 - 103.6	13.5 - 16.2	4.9 – 7.7	1.4 - 4.5	0.3 - 0.5
	SD	14.3	1.4	2.7	1.1	0.1
	Contamination ratio	1.3	1.2	1.6	1.1	1.0
Market area (MKA)	Mean	85.2	16.3	8.7	3.2	1.1
	Range	65.4 - 90.6	12.3 - 20.3	7.2 – 9.9	1.9 - 4.0	0.9 - 1.3
	SD	9.6	2.0	1.0	1.0	0.1
	Contamination ratio	1.4	1.3	2.2	1.1	2.8
Motor parking area (MPK)	Mean	126.0	27.0	35.8	7.1	5.4
	Range	120.2 - 129.5	17.1 - 32.5	5.1 - 51.6	6.1 - 8.3	1.0 - 7.1
	SD	3.1	5.5	16.6	0.9	1.2
	Contamination ratio	2.1	2.2	9.0	2.5	13.5
Mechanical workshop (MWK)	Mean	304.7	80.3	52.9	9.1	15.9
	Range	109.7 - 419.3	24.2 - 116.8	5.4 - 86.3	2.9 - 14.3	5.1 - 39.6
	SD	115.8	29.4	26.3	4.5	18.3
	Contamination ratio	5.0	6.5	13.2	3.3	40.0
Control	Mean	60.5	12.3	4.0	2.8	0.4
	Range	50.0 – 158.9	8.6 – 15.9	3.6 – 4.1	2.0 – 8.9	nd – 0.5
	SD	38.8	7.3	0.9	10.2	1.1

nd = not detectable; SD = standard deviation

Table 3. **Interelement correlations for street dust samples from the whole study area.**

Element	Zn	Pb	Ni	Cr	Cd
Zn	1.000				
Pb	**0.879**	1.000			
Ni	0.617	0.665	1.000		
Cr	0.457	0.657	**0.833**	1.000	
Cd	0.358	0.408	0.521	0.789	1.000

High significance by $p<0.05$ are in bold

Table 4. **Ranges or the mean level of the heavy metal concentrations (μg g^{-1}) in street dust samples in various sites of countries and cities.**

Area	Zn	Pb	Ni	Cr	Cd	Reference
Kathmandu (Nepal)	55.4-419.3**	12.3-116.8**	4.9-86.3**	1.4-14.3**	0.3-39.6**	Present work
Kavala (Greece)	272*	301*	58*	196*	0.2*	[17]
Baoji (china)	715*	408*	49*	-	-	[18]
Amman (Jordan)	358*	236*	88*	-	1.7*	[19]
Kayseri (Turkey)	33-733	28-312	16-217	17-81	0.1-14.6	[20]
Xian (China)	421*	231*	-	167*	-	[21]
Luanda (Angola)	98*	266*	10*	26*	1.1*	[22]
Yazgat (Turkey)	-	69*	77*	33*	3.0*	[23]
Instanbul (Turkey)	226-1852	61-383	10-66	-	1.0-6.7	[24]
Birmingham (U.K.)	534*	48*	-	-	1.6*	[25]
Coventry (U.K.)	385*	47*	-	-	0.9*	[25]
Aviles (Spain)	4829*	514*	-	42*	22.3*	[26]
Manchester (U.K.)	653*	265*	-	-	-	[27]
Various sites (Bahrain)	152*	697*	126*	144*	72.0*	[7]
Cuenca (Equador)	44-1018	19-970	-	-	0.6-1.4	[28]
Kuala Lumpar (Malaysia)	344*	2466*	-	-	3.0*	[29]
London (U.K.)	680*	1030*	-	-	3.5*	[30]
Athens (Greece)	75-241	65-259	-	-	1.8-4.3	[31]
Various sites (Nigeria)	12-48	4-243	1-3	0.7-2.6	0.2-1.7	[32]
Various sites (Hong- Kong)	-	438-1612	-	-	0.2-2.3	[33]
Lancaster (U.K.)	160-3725	150-15000	15-126	10-91	1.0-14.6	[34]

*Mean values, **Range between

RDA to MWK

On the contrary, the cadmium content in all the sampling sites (Table 2) was found to be comparatively low among the heavy metals studied except the MWK which recorded higher Cd content (15.9 μg g^{-1}) than Cr (9.1 μg g^{-1}). However, the Cd contamination ratios were found to be significantly high in almost all the street dusts. The Cd contamination ratio of MPK and MWK has its highest values (13.5 and 40.0 respectively). Results indicate that automobiles, leakage of oil products, car abrasion and car lubricants are the main sources of Cd contamination [7] in the present study. Besides, the metal plating and tire enforced with metals are considered the likely common anthropogenic sources of cadmium in street dust through burning of tyres and bad roads. It was reported that the cadmium level in car tyres is in the range of 20 to 90 (μg g^{-1}) as associated Cd contaminations in the process of vulcanization [35]. The uses of cadmium-plated and galvanized equipment in food processing, cadmium-containing enamel and pottery glazes, and cadmium base pigments or stabilizer in plastics may also be significance sources of contaminations. The mean and ranges of the Cd content in the present study are however more or less comparable with the reported values of the various sites of the countries and cities (Table 4).

Lead is the element of most concern in environmental heavy metal pollution. The Pb content was found in its highest mean level (80.3 μg g^{-1}) as well as contamination ratio (6.5) in MWK. The metal content ranged from 13.5 - 16.2, 12.3 - 20.3, 17.1 - 32.5 and 24.2 - 116.8 μg g^{-1} respectively in RDA, MKA, MPK and MWK. There is an increase in elemental concentration from place of low activities for example, residential area to places of higher activities like motor parks, mechanical workshops etc. The lead main source may be directly associated with

emissions from vehicle exhausts, which seems still use of leaded gasoline although having reportedly banned in Nepal. However, it is generally agreed that automobile exhaust accounted for the elevated lead levels as all the samples were collected at major streets. Despite the sharp increase of unleaded fuel utilization, followed by a rapid decline of Pb levels in the atmosphere, the content of Pb in urban street still remains high with a consequent associated risk for children via the soil–hand–mouth pathway [11]. By considering the general range of the total lead content, it appears that the total lead content in RDA, MKA, MPK and MWK are below the critical concentration of 500 μg g^{-1} [36]. Lead data from this work fall within the range as reported in various sites in Nigeria and also nearly match with some lower range limits in Cuenca (Equador) and Kayseri (Turkey) only. The lead level is however far below the levels in comparison with majority of the sites of countries and cities (Table 4).

Distribution of Ni in RDA, MKA, MPK and MWK ranged from 4.9 - 7.7, 7.2 - 9.9, 5.1 - 51.6 and 5.4 - 86.3 μg g^{-1} respectively and the control site showed a normal range of 3.6 – 4.1 μg g^{-1}. The highest concentration of the metal was found in MWK (52.9 μg g^{-1}, contamination ratio: 13.2) and was attributed to the pollution originating from corrosion of cars, traffic and anthropogenic activities [6]. A good correlation between Ni and Cr (r=0.833) was calculated (Table 3). This level of Ni in the investigated area was generally lower than those determined in other cities like Kavala (Greece), Amman (Jordan), Yazgat (Turkey) and various sites in Bahrain except Baoji (China) and Luanda (Angola) and various sites in Nigeria.

Distribution of Cr level in the sampling sites (RDA, MKA, MPK and MWK) on the other side ranged from 1.4 - 4.5, 1.9 - 4.0, 6.1 - 8.3 and 2.9 - 14.3 μg g^{-1} respectively with average values of 3.0, 3.2, 7.1 and 9.1 μg g^{-1}. The highest chromium level was detected in MWK (9.1 μg g^{-1}, contamination ratio: 3.3). In general, this chromium mean value is significantly lower than those measured in other cities (Table 4) of the world like Kavala (Greece), Xian (China), Luanda (Angola), Yazgat (Turkey), Aviles (Spain) etc. The chromium in street dust is associated with the chrome plating of some motor vehicle parts [8].

Possible environmental impacts due to the heavy metals

Release of heavy metals is one of the most significant environmental problems caused by the anthropogenic activities. Recently, there has been an increased concern regarding the occurrence of the heavy metals because of their toxicity. Due to high concentration in the environment, these metals may not only pollute the environment but also enter the food chain from soils [37]. Exposure to the metal ions in sufficient quantities can have serious impacts on human health [38].

Nickel and zinc are some of the metals, which are essential at very low concentrations for life because they have important roles in metabolic processes taking place in living cells. Cadmium and lead on the other side are nonessential metals, which are known to cause severe damage in living organisms even at low concentrations [39]. The presence of these metals ions at elevated levels in the environment is often toxic to living organisms [40]. This involves blocking essential functional groups, displacing essential metal ions, or modifying the active confirmation of biological molecules resulting in the inhibition of a variety of metabolic as well as enzyme activities in living organisms. The metal toxicity has a direct effect on various physiological and biochemical processes such as photosynthesis, chlorophyll content and reduction in plant growth [41].

Large quantities of cadmium and zinc can be found in soils. The metal ions bind strongly to soil particles and some of these dissolve in water causing metal pollution. Hence, they accumulate in the bodies of water and soil organisms. They can interrupt the activity in soils, as they negatively influence the activity of soil microorganisms and earthworms. The breakdown of organic matter in the soil may seriously slow down because of this. On zinc-rich soils only a limited number of plants have a chance of survival. Water soluble zinc that is located in soils can contaminate groundwater. Zinc ions may also increase the acidity of water [42].

Body functions of phytoplankton can be disturbed when metal like lead interferes. Phytoplankton is an important source of oxygen production in seas and many larger sea-animals eat it [41]. Fishes can also accumulate lead in their bodies, when they live in the metal-contaminated waterways. The metal that enters the bodies is able to bio-magnify up the food chain. Chromium (III) is an essential element at trace level whereas Chromium (VI) is mainly toxic to living organisms. High concentrations of chromium can cause respiratory problems in animals, a lower ability to fight disease, birth defects, infertility and tumor formation [43].

It is evident from the present study that significant levels of heavy metals particularly Zn and Pb are present in the street dust in the city of the Kathmandu metropolis. Among the sampling sites, MWK and MPK in all the sampling locations demonstrate significant levels of metal contamination and the vicinity of the studied areas are, therefore quite vulnerable posing threats to the environment and human health. Besides, MKA and RDA also demonstrate appreciable amount of metal contamination. The findings of the present study are in agreement with several studies. Devkota *et al.* (1997) studied air pollution of the Kathmandu city due to Cd and Pb using lichens as biomonitors [44]. They found higher accumulation of Cd and Pb in the lichens collected from the vicinity of the city than those from remote areas. However, Pb was obtained in higher level compared to that of Cd suggesting that the polluted air of the city was mainly due to increasing vehicle emissions and traffic loads. Similarly, it was studied that the transport sector emitted about 5 tons of Pb in the Kathmandu Valley in 2005 and 6 tons of Pb in 2010 [45]. Tripathi *et al.* (1993) measured the atmospheric deposition of trace metals like Pb, Cd, Cu and Zn at Deonar, Bombay [46]. The bulk deposition flux for these metals was found to vary from 0.3 to 102.1 kg km^{-2} yr^{-1} with the deposition velocities which varied from 0.05 to 2.5 cm s^{-1}. They suggested that the atmospheric deposition of the trace metals in Bombay was mainly due to increasing vehicular emissions. Homady *et al.* (2002) had noticed the significant increases in the total contents of Fe, Cu, Pb, Zn, Ni, Mn and Cr in ambient dusts at some vehicular service stations in Jordan [47].

Although the present study has not covered the research aspect regarding the impacts of the heavy metals on the environmental status in the city of Kathmandu metropolis, the metal pollution however brings about the consequences as described above. A future work, however, will be needed to study in the related area.

Conclusions

From this study, it can be concluded that significant contamination of street dust was observed in the city of Kathmandu metropolis. The heavy metal contaminations in street dust show a considerable decrease from place of high activities to a place of low activities (mechanical workshops to residential areas). This decrease might indicate aerial deposition of metal particulates in the street dust environment from extraneous sources and not only a function of soil type. The distribution of the metal concentration of the dust in the study area indicated that automobile and metal construction works could be responsible for the build up of the heavy metals in the street dust along the major streets and mechanical workshops through the emission of particulates as the highest metal concentrations were found here. The street dust environment had a significantly high content of Zn followed by Pb and generally their levels increased with increasing traffic volume and welding of metals in urban areas. However, a future work may require a detailed study on correlation between the number of vehicles and street dust contamination for more fact findings.

The present study may probably be the first of its kind in the related area in a developing country like Nepal. The study would, therefore provide significant information for redressing the environmental pollution due to heavy metal pollutants in street dusts. Moreover, the present study may open a wide prospect as well as provide a guideline for further investigation into the related areas elsewhere in developing countries.

Acknowledgements

We are most grateful to the Research Division, Office of the Rector, Tribhuvan University, Nepal for the research grant without which this research project would have been

difficult for us to accomplish. We wish to thank Aastha Laboratory Service (Pvt.) Ltd., Kathmandu, Nepal for providing us the laboratory facilities. We would also like to thank all the staffs of Faculty of Science, Padma Kanya Campus, Tribhuvan University, Nepal for the encouragement and logistic support.

References

1. M. G. Gibson and J.G. Farmer, *Environ. Pollut. B* 11 (1986) 117.
2. R. M. Harrison, D.P. H. Laxen and S. J. Wilson, *Environ. Sci. Technol.,* 15 (1981) 1378.
3. I. Thornton, *Metal contamination of soils in urban areas*. In: Bullock, P., Gregory, P.J. (Eds.), Soils in the Urban Environment, Blackwell (1991).
4. J. A. Markus and A. B. McBratney, *Aus. J. Soil Res.,* 34 (1996) 453.
5. W. Wilcke, S. Muller, N. Kanchanakool and W. Zech, *Geoderma*, 86 (1998) 211
6. J. E. Ferguson and N. Kim, *Sci. Total Environ.,* 100 (1991) 125.
7. M. S. Akhter and I. M. Madany, *Water, Air and Soil Pollut.* 66 (1993) 111.
8. S. M. Al-Shayep and M. R. D. Seaward, *Asian J. Chem.,* 13 (2001) 407.
9. T. Chirenje, L. Q. Ma and L. Lu, *Water, Air and Soil Pollut.,*171 (2006) 301.
10. H. I. Inyang and S. Bae, *J. Hazardous Mater.,* 132 (2006) 5.
11. R. Bargagli, *Trace Elements in Terrestrial Plants*: an Ecophysiological Approach to Biomonitoring and Biorecovery. Springer-Verlag, Berlin, Germany (1998).
12. P. C. Hammond, *Metabolism of lead*. In: Chisolm, J. J., O'Hara, D. M. (Eds.), Lead Absoption in Children: Management, Clinical, and Environmental Aspects. Urban and Schwarzenberg, Baltimore—Munich (1982).
13. P. L. Kinney and M. Lippmann, *Arch. Environ. Health*, 55 (2000) 210.
14. Q. M. Jaradat and A. K. Momani, *Turk J. Chem.,* 23 (1999) 209.
15. M. Sheibani, F. Marahel, M. Ghaedi, M. Montazerozohori and M. Soylak, *Toxicol. Environ. Chem.,* 93 (2011) 860.
16. M. Jamshidi, M. Ghaedi, K. Mortazavi, M. Nejati Biareh and M. Soylak, *Food Chem. Toxicol.,* 49 (2011) 1229.
17. A. Christoforidis and N. Stamatis, *Geoderma,* 151 (2009) 257.
18. X. Lu, L. Wang, K. Lei, J. Huang and Y. Zhai, *J. Hazardous Mater.,* 161 (2009) 1058.
19. O. Al-Khashman, *Environ. Geochem. Health* 29 (2007) 1.
20. S. Tokalioglu and S. Kartal, *Atmos. Environ.,* 40 (2006) 2797.
21. H. Yongming, D. Peixuan, C. Junji and E. Posmentier, *Sci. Total Environ.,* 355 (2006) 176.
22. L. F. Baptista, and E. De Miguel, *Atmos. Environ.,* 39 (2005) 4501.
23. V. Divrikli, M. Soylak, L. Elic and M. Dogan, *J. Trace and Microprobe Techni.,* 21 (2005) 351.
24. N. Sezgin, H. C. Ozcan, G. Demir, S. Nemlioglu and C. Bayat, *Environ. Internat.,* 29 (2003) 979.
25. S. Charlesworth, M. Everett, R. McCarthy, A. Ordonez and E. De Miguel, *Environ. Internat.,* 29 (2003) 563.
26. A. Ordonez, J. Loredo, E. De Miguel and S. Charlesworth, *Arch. Environ. Contamin. Toxicol.,* 44 (2003) 160.
27. D. J. Robertson, K. G. Taylor and S. R. Hoon, *Appl. Geochem.,* 18 (2003) 269.
28. C. N. Hewitt and G. B. B. Candy, *Environ. Pollut.,* 63 (1990) 129.
29. M. N. Ramlan and M. A. Badri, *Environ. Technol. Lett.,* 10 (1989) 435.
30. M. J. R. Schwar, J. S. Moorcroft, D. P. H. Laxen, M. Thomson and C. Armorgie, *Sci. Total Environ.,* 68 (1988) 25.
31. N. Yassoglou, C. Kosmas, J. Asimacopoulos and C. Kallianou, *Environ. Pollut.,* 47 (1987) 293.
32. C. L. Ndiokwere, *Environ. Pollut., B*-7 (1984) 35.
33. W. M. Lau and H. M. Wong, *Environ. Res.,* 28 (1982) 39.
34. R. M. Harrison, *Sci. Total Environ.,* 11 (1979) 89.
35. K. N. Yu, Z. L. Yeung and R. C. W. Kwok, *Appl. Radiat. Isot.,* 58 (2003) 339.
36. ICRCL (Interdepartmental Committee on the Redevelopment of Contaminated Land), *Guidance on the assessment and*

redevelopment of contaminated land, Department of Environment, London, Guidance Note (1987) 59/83.
37. S. A. Mashi, S. A. Yaro and P. N. Eyong, *Manag. Environ. Qual.,* 16 (2005) 71.
38. D. Roy, P. N. Greenlaw and B. S. Shane, *J. Environ. Sci., Health* 28 (1993) 37.
39. G. M. Gadd, *New Phytol.,* 124 (1993) 25.
40. T. C. Hustchison, *Wat. Pollut. Res. Can.,* 8 (1973) 68.
41. G. N. Reddy and M. N. V. Prasad. *Environ. Expt. Bot.,* 30 (1990) 251.
42. G. M. Gadd and A. J. Griffiths, *Microb. Ecol.,* 4 (1978) 303.
43. B. D. Honeyman and P. H. Santschi, *Environ. Sci. Technol.,* 22 (1988) 862.
44. B. Devkota, C. B. Baniya and G. S. P. Ghimire, *Ecoprint,* 4 (1997) 61.
45. http://www. Research studies into airpollution.htm Accessed 15 August (2011).
46. R. M. Tripathi, S. C. Ashawa and R. N. Khandekar, *Atmos. Environ.,* 27 (2003) 269.
47. M. Homady, H. Hussein, A. Jiries. A. Mahasneh, F. Al-Nasir and F. Khleifat, *Environ. Res.,* 89 (2002) 43.