Research Journal of Chemical Sciences ISSN 2231-606X
Vol. **4(7),** 82-92, July **(2014)** *Res. J. Chem. Sci.*

Determination of Heavy metals in Street Dust from Different Types of Land Use of Kathmandu Valley, Nepal

Shakya Pawan Raj*[1], Karmacharya Neena[1], Kansakar Swahit Bir Singh[1], Shakya Ramesh Kaji[1], Wagle Krishna Kumari[2] and Shrestha Mahesh[1]
[1]Faculty of Science, Padma Kanya Multiple Campus, Tribhuvan University, Bagbazar, Kathmandu, NEPAL
[2]Central Department of Environmental Science, Tribhuvan University, Kirtipur, Kathmandu, NEPAL

Available online at: www.isca.in, www.isca.me
Received 27th June 2014, revised 4th July 2014, accepted 16th July 2014

Abstract

A total of 45 street dust were sampled from five different types of land use viz., industrial, urban, heavy traffic road, residential and undisturbed areas of Kathmandu valley, Nepal. The samples were fractionated into seven different particle sizes (2000-710, 710-425, 425-150, 150-75, 75-53, 53-38 and <38 µm) and analyzed for Cd, Cu, Pb and Zn using Atomic Absorption Spectrophotometer (AAS). The effect of particle sizes on metal distribution were also assessed using three contamination indices such as enrichment factor (EF), distribution factor (DF) and mass loading (%) for metals. Results revealed that the dust of industrial use was found to have the highest concentrations of Zn (135.1 mg kg^{-1}) and Cu (98.9 mg kg^{-1}) while the heavy traffic road use exhibited the highest concentrations of Cd (0.85 mg kg^{-1}) and Pb (63.6 mg kg^{-1}) in dust samples. The mean concentrations of all the land uses for Cd, Cu, Pb and Zn in bulk samples were 1.3, 62.3, 44.5 and 99.0 mg kg^{-1} respectively while the enrichment ratio for the metals in dust of Kathmandu valley were found to be 4.8, 7.3, 2.4 and 3.4 respectively. The concentration of all metals in different particle size fractions was found to be increased with decrease in their sizes indicating the preferential partitioning of metals in fine particle sizes. The enrichment factor revealed a slight to severe degree of enrichment for all the land uses and for all metals with few exceptions. The distribution factor indicated the preferential accumulation of metals in the finest particle fractions (<38 µm). Similarly, the mass loading (%) for metals showed that the coarse particle size fractions (>75 µm) contributed more than 50% of all metals to the total concentration of bulk samples.

Keywords: Heavy metals, street dust, Kathmandu valley, contamination indices.

Introduction

In recent years, there has been an increased concern regarding the contamination of the heavy metals in street dust because of their potential toxic effects. Since the metals remain stable and as persistent environmental contaminants, they tend to accumulate in living organisms, increasing its harmful effects. Also, street dust is an important pathway in the exposure of people to toxic elements[1]. For instance, 5–10% of the allergenicity in California was reported to be due to atmospheric total suspended particulate matter attributed by paved road dust emissions[2]. Therefore, a high priority has been set on such materials for health risk and environment assessment programs[3].

Street dust investigation is particularly important for several reasons. One of the major reasons is that street dust is freely being inhaled by those traversing the streets. Particularly, significant quantities of dust are likely to be ingested by young children because of their behavior of mouthing non-food objects and repetitive hand/finger sucking[4]. Besides, children have a much higher absorption rate of heavy metals from digestion system and higher hemoglobin sensitivity to heavy metals than adults[5].

Kathmandu valley has some vulnerable areas plagued with consistently higher concentration of heavy metal pollutants due to rapid and haphazard urbanization, construction and demolition activities, vehicle emissions and industrial activities etc. These activities contribute potentially toxic heavy metals in street dust. Considering these issues, it is important to undertake studies on heavy metal contamination in street dust from different types of land use of the valley considering the environmental and public health concern. However, very few assessments in the related areas have been made in developing countries like Nepal in general and the valley in particular. Therefore, the objectives of the present study were to: i. determine Cd, Cu, Pb and Zn in street dust (bulk and seven particle size fractions) from five different types of land use of the valley such as industrial, urban, heavy traffic road, residential and undisturbed areas and ii. investigate the effect of particle size fractions (seven particle sizes) on metal distribution in street dust using enrichment factor, accumulation factor and mass loading of metals.

Material and Methods

Description of the study area and sampling: Kathmandu valley that comprises Kathmandu, Lalitpur and Bhaktapur

districts of Nepal has a population of more than 2.5 million. Three major industrial estates and many other factories are located in rapidly and haphazardly urbanized areas of the valley along with a number of private buildings, hospitals, educational institutions, commercial plazas and residential apartments. The number of motor vehicles in the valley has increased rapidly in recent years.

The area of the valley is roughly 650 km^2 and is elongated east-west with an average altitude of about 1350 m above the sea level. The surrounding hills are about 2800 m above the sea level. The valley is characterized by a semi tropic, warm and temperate climate having an average precipitation of 2,000 mm/year. About 80% of rain falls in the monsoon period during June and July.

Initially, a GIS based sampling map of the Kathmandu valley was designed (figure 1) and located the study sites (n = 5) at different land uses of the valley**:** industrial, urban, heavy traffic road, residential and undisturbed (control) areas. A total of 45 street dust samples representing an equal number from all the three districts and the land uses of the valley were collected by sweeping an area of about $1m^2$ from the paved roadsides using a brush and plastic dustpan during morning hours. The sampling was carried out during stable weather condition i.e., in dry season (November – January) to avoid rain washing of the heavy metals. The amount of dust collected in each land use was 0.5–1.0 kg. Samples were not collected adjacent to site-specific pollution sources.

Analysis of Dust Properties: Dust samples collected from all the five land uses were dried in hot-air oven at 105°C for 24 hours and then passed through a 2 mm metal free sieve to obtain bulk samples for further processing and analytical purposes. Dust properties such as pH, electrical conductivity (EC), organic carbon (OC) and total alkalinity as $CaCO_3$ equivalent were then analyzed as follows: soil pH and electrical conductivity in 1:5 soil/water suspensions using glass electrodes[6]; organic carbon by titrametric method[7] and total alkalinity by volumetric method[6] respectively.

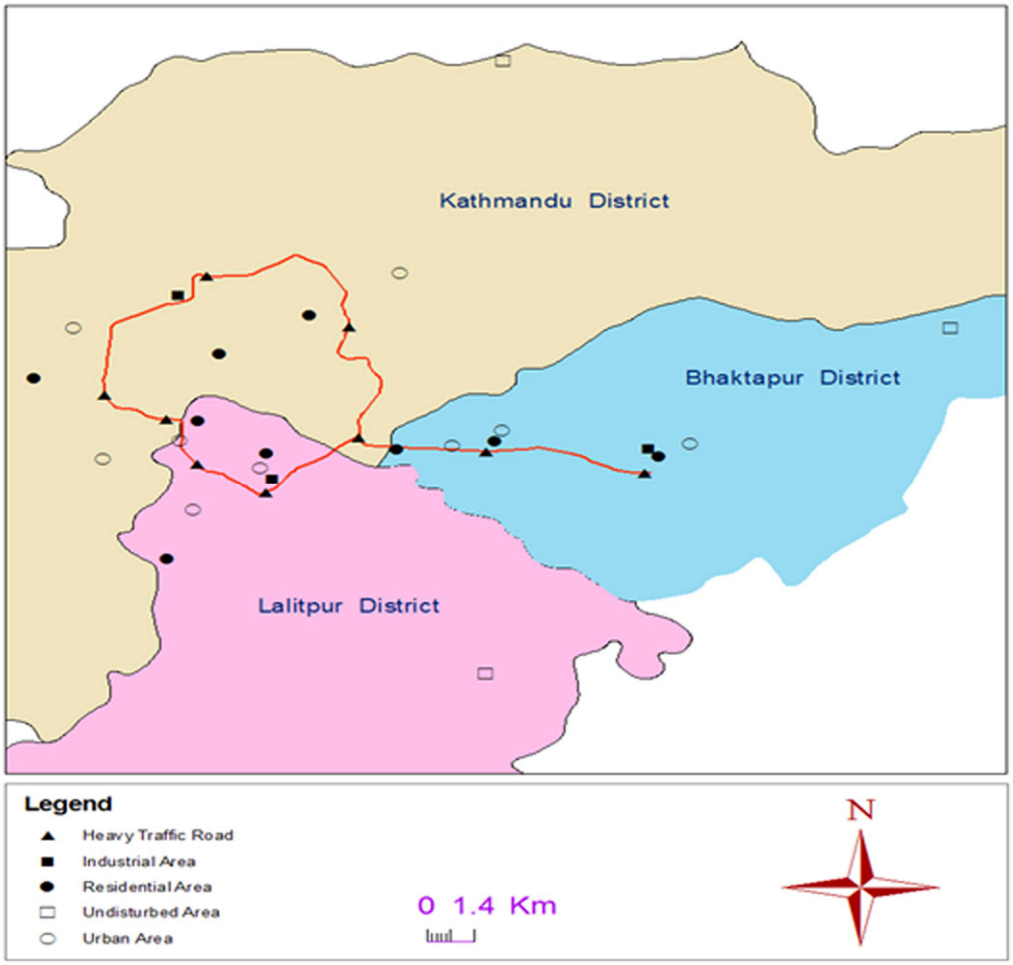

Figure-1
A GIS based sampling map of different land uses of Kathmandu valley

Fractionation of dust samples: In each experiment, 100 g of the oven-dried bulk sample was passed through a stack of six sieves of different sizes in the order (top to bottom) as 710, 425, 150, 75, 53 and 38 µm subjecting to three 10 minutes shaking episodes. Following the experiment, each sample yielded fractions of seven particle sizes as 2000-710, 710-425, 425-150, 150-75, 75-53, 53-38 and <38 µm respectively. Percent distribution of dust in each particle size fraction was then calculated.

Determination of Cd, Cu, Pb and Zn in bulk and particle size fractions: Heavy metals determination was carried out by following the procedure as described in literature[8] with slight modification. For each sample, bulk and particle size fraction, 1.0 g of sample was digested with 10 ml concentrated nitric acid over the hot plate at low temperature. The digestion was continued until the volume was reduced to 1-2 ml. After complete digestion, the sample was filtered through medium textured Whatman filter paper collecting the filtrate in 25 ml volumetric flask. The final volume was then made with doubly-distilled water and mixed well to homogenize the sample. The metal concentrations were determined by atomic absorption spectrometer (novaAA305, Analytikjena, Germany) using air acetylene flame. All the standard solutions (1000 ppm) for Cd, Cu, Pb and Zn were certified and obtained from Merck, Germany. These solutions were diluted carefully to the required concentrations with doubly-distilled water. All the glassware and plastic vessels were treated by dilute (1:1) nitric acid for 24 h and then rinsed with distilled water before use. The acid, HNO_3 (E. Merck, Germany) was of analytical grade and used without further purification. The instrumental parameters were those recommended by the manufacturer. Quality assurance of analytical results was controlled using the reference materials traceable to NIST manufactured by Merck, Germany. The recovery percentage of metal concentrations from the reference materials was between 96.3 and 110%. In order to determine the precision of the analytical process, few samples were analyzed by three times. The standard deviation for both samples was calculated to 1.5 and 3.0% respectively and can be considered satisfactory for environmental analysis.

Assessment of contamination indices: The contamination levels of heavy metals in street dust of all the five land uses were analyzed using enrichment factor (EF_x), distribution factor (DF_x) and mass loading (%) of metals.

Enrichment factor: The amount of anthropogenically introduced metal in the different particle size fractions of street dust was estimated using an enrichment factor (EF_x). EF_x was calculated with respect to the natural concentration of each fraction in the area studied, by using the following expression[9]:

$$EF_x = X/X_{ref} \quad (1)$$

where X is the concentration of the metal in each fraction (mg kg^{-1}) and X_{ref} is the background concentration of metal in each fraction (mg kg^{-1}) from the study area. In the present study, the concentration of metal from undisturbed (control) area was taken as the background concentration of metal in each fraction. The selected undisturbed areas are lands without evidence of past and current anthropogenic activities and no signals of disturbances were observed during the sampling.

The enrichment factor (EF_x) was classified into five groups as follows: slight (1.1-2.0), moderate (2.1-4.0), severe (4.1-8.0), very severe (8.1-16.0) and excessive (>16.0)[10].

Distribution factor: Distribution factor (DF_x) is one of the important contamination indices which was used in the present study to evaluate in which fraction the metals are preferentially accumulated. DF_x was calculated with respect to the bulk dust sample using the following expression[11]:

$$DF_x = X_{fraction}/X_{bulk} \quad (2)$$

where $X_{fraction}$ and X_{bulk} are concentrations of metal (mg kg^{-1}) in a given particle size fraction and bulk sample, respectively. If DF_x is greater than unity for a specific fraction, the metal is enriched in this fraction.

Mass loading (%) of metals: This index reveals the percentage of metal present in each fraction. To evaluate the metal mass loading (%) in given particle size fraction (PSF) the following index was calculated using a modified equation (3)[12];

$$PSF_{loading} = 100 \times \left(\frac{X_i \times PS_i}{\sum_{i=1}^{7} X_i \times PS_i}\right) \quad (3)$$

where *Xi* is the metal concentration in a determined particle size fraction in mg kg^{-1}, considering seven classes per sample, and *PSi* is the mass percentage of that fraction in the sample. The summation of the index values for the individual sample will always be 100%.

Statistical analysis: All statistical analyses and data processing in this study were performed on an IBM-PC computer. Descriptive statistics such as mean, range, percentage and standard deviation were performed after multi-element analysis. The Pearson's correlation coefficients (r) among dust properties and metals were calculated by $p<0.05$.

Results and Discussion

Dust properties: Table 1 shows properties such as pH, electrical conductivity (EC), total alkalinity as $CaCO_3$ equivalent, and organic carbon (OC) analyzed in dust of all the five land uses under the present investigation.

The pH is usually considered as an indicator or measurement of the chemical nature of dust. This parameter in dust of all the land uses was found to be variable and mostly alkaline. Considering all the land uses, the pH values were found in the range of 7.4 in dust of the undisturbed area to 9.2 in the heavy traffic one. The highest mean value (pH = 8.8) and maximum

range (8.2-9.2) were recorded in dust of the heavy traffic area. The results are also in agreement with the work of Karmacharya and Shakya[13], who also reported alkaline nature of street dust in Kathmandu valley. The alkaline nature of the dust samples reflects the richness of carbonate[14].

The electrical conductivity (EC) is the ability of a material to carry electrical current. Results showed that the EC values in dust were very variable among the land uses. The mean value was recorded higher in dust of the industrial use while the undisturbed one showed the minimum value. The amount of salt content in dust may account for such variation in the parameter among the study areas. The ions such as Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, NO^{3-} , PO_4^{3-}, CO_3^{2-} and HCO_3^- constitute the ionic salinity[15]; the higher EC value in dust of the industrial use are likely due to a spill of material rich in salts. Table 2 shows the positive correlation between EC and Cd ($r = 0.799$, $p<0.05$) indicating that both have the common source of the metal and salts in dust samples.

Total alkalinity is the measure of the capacity of water to neutralize a strong acid. Results revealed that the total alkalinity in dust of all the land uses was higher than the undisturbed one. Among the studied uses, dust of the heavy traffic road showed the maximum value of total alkalinity (157.8 mg/100g) and the range between 95.0 - 260.0 mg/100g. Industrial (137.2 mg/100 g) and urban (138.9 mg/100 g) dust showed almost equal mean values of the total alkalinity. Phenolphthalein alkalinity was not detected in any of the samples analyzed. So, the alkalinity for the dust samples in Kathmandu valley is mainly for carbonates and bicarbonates[6].

Organic carbon (OC) in dust of all the land uses was found to be higher than the undisturbed use. Both the heavy traffic and industrial uses showed nearly the same percentage of OC content. The percentage of OC however varied from 1.8 in dust of the undisturbed area (control) to 2.7 in the heavy traffic road area while considering all uses. The elevated level of OC indicates that dust is an important sink of organic material in Kathmandu valley, which is subsequently transported by wind or runoff water and accumulated along the roadside dust. Besides, organic material from anthropogenic waste and vehicle oil or gasoline that contains hydrocarbons may equally contribute to the organic carbon content in dust[16].

Distribution of particle size fractions: Particle size fractions are also considered as one of the dust properties. Table 3 shows different fractions of dust particle sizes in different land uses.

Fractionation of bulk samples into various particle sizes revealed that the amount of dust association increased gradually from 2000-710 µm to 450-150 µm size and then decreased eventually to <38 µm. Such distribution of dust particle sizes followed a similar pattern in almost all the land uses under the present investigation. Results revealed that 450-150 µm particle size was the main dominant fraction in all the studied areas and varied from ~ 35 (industrial) to 40% (residential) of the total fraction. The composition of dust may vary depending on climate, human activities, soils and rocks of the surrounding areas etc.[17]. The dust particle with a smaller size is often considered risky for environment and human health[18]. If this risk were assessed in the present study, the percentage of three fine particle sizes (75-53, 53-38 and <38 µm) upon grouping would reveal the high risk for humans and the environment in the order as: industrial (30%) > urban (29%) > residential (28%) > heavy traffic (25%) > undisturbed (13%).

Table-1
Properties of dust from different land uses (mean ± SD; n=9) in Kathmandu valley[1]

Land uses		pH	EC (µS/cm)	T. Alk. as $CaCO_3$ (mg/100g)	OC (%)
Industrial	Mean	8.02 ±0.19	1254 ± 265	137.2 ± 50.8	2.6 ± 0.29
	Range	7.7-8.2	976-1663	75.0-210.0	2.4-3.0
Urban	Mean	8.3 ± 0.29	1202 ± 372	138.9 ± 70.6	2.3 ± 0.4
	Range	8.0-8.9	802-1830	70.0-255.0	1.9-2.7
Heavy traffic	Mean	8.8 ± 0.31	1092 ± 158	157.8 ± 52.0	2.7 ± 0.6
	Range	8.2-9.2	852-1342	95.0-260.0	2.0-3.5
Residential	Mean	8.3 ± 0.59	1075 ± 204	81.7 ± 15.8	2.1 ± 0.6
	Range	7.5-8.9	905-1368	65.0-110.0	1.8-3.0
Undisturbed	Mean	7.9 ± 0.27	394 ± 165	75.6 ± 16.9	1.8 ± 0.3
	Range	7.4-8.0	225-650	55.0-110.0	1.4-2.3

[1]EC: electrical conductivity; T. Alk.: Total alkalinity; OC: organic carbon

Heavy metals in street dust (bulk size): Heavy metal concentrations investigated in street dust samples (bulk size) of all the five land uses of Kathmandu valley are presented in table 4.

Results showed that the mean metal content of all the uses can be ranked by their abundance in the street dust as follows: Zn > Cu > Pb > Cd. However, the distribution of metals with respect to each land use was found to be variable to some extent. While the metals from the industrial, urban and residential areas showed the same elemental abundance order as Zn > Cu > Pb > Cd, the heavy traffic and undisturbed areas exhibited the elemental order by their abundance as Zn > Pb > Cu > Cd. In all the cases, Zn is comparatively more mobile element and the least being Cd. However, the positive correlation between Cd and Pb ($r = 0.786$, $p<0.05$), Cu and Pb ($r = 0.792$, $p<0.05$) and Cu and Zn ($r = 0.898$, $p <0.05$) show their common sources of contamination. Taking into account the concentration of metals in undisturbed areas and all the land uses, the lowest levels were found from the undisturbed area.

Table-2
Pearson's correlation coefficients among dust properties and metals of the present study

	pH	EC	T.Alk.	OC	Cd	Cu	Pb	Zn
pH	1.00	0.465	0.572	0.252	0.412	0.310	0.432	0.363
EC	0.465	1.00	0.367	0.314	0.799*	0.562	0.512	0.399
T. Alk	0.572	0.367	1.00	0.402	0.312	0.412	0.456	0.596
OC	0.252	0.314	0.402	1.00	0.511	0.332	0.561	0.410
Cd	0.412	0.799*	0.312	0.511	1.00	0.245	0.786*	0.544
Cu	0.310	0.562	0.412	0.332	0.245	1.00	0.792*	0.898*
Pb	0.432	0.512	0.456	0.561	0.786*	0.792*	1.00	0.452
Zn	0.363	0.399	0.596	0.410	0.544	0.898*	0.452	1.00

[1]EC: Electrical conductivity; T. Alk.: Total alkalinity; OC: Organic carbon, Significance level : $*p <0.05$

Table-3
Distribution of particle size fractions (%)

Particle size fraction (µm)	Industrial	Urban	Heavy traffic	Residential	Undisturbed
2000-710	1.04 ± 0.28	1.03 ± 0.31	0.93 ± 0.81	1.90 ± 1.95	20.25 ± 9.33
710-425	12.82 ± 4.58	10.43 ± 0.68	10.34 ± 6.07	9.10 ± 2.67	16.04 ± 2.75
425-150	34.69 ± 4.21	38.51 ± 5.06	38.93 ± 4.39	39.51 ± 7.96	38.89 ± 3.45
150-75	20.52 ± 4.99	19.92 ± 2.18	23.73 ± 6.21	21.55 ± 1.37	11.71 ± 3.56
75-53	22.98 ± 6.09	21.50 ± 4.22	17.50 ± 5.59	19.51 ± 7.88	5.24 ± 3.84
53-38	4.32 ± 2.01	5.96 ± 3.89	5.02 ± 1.64	5.69 ± 0.74	3.29 ± 3.49
<38	2.78 ± 0.79	1.86 ± 1.81	2.72 ± 0.21	2.37 ± 0.74	3.96 ± 4.09

Table-4
Heavy metals concentration (mg/kg) in street dust; mean ± SD; n=9 and Enrichment factor

Land uses		Cd	Cu	Pb	Zn
Industrial	Mean	0.78 ±0.18	98.9 ± 21.0	45.8 ± 6.3	135.1 ± 27.4
	Range	0.57–1.08	73.8 -133.5	33.5 - 58.4	89.0 - 165.3
	Enrichment factor	2.8	11.6	2.5	4.6
Urban	Mean	0.63± 0.14	59.8 ± 7.2	39.4 ± 5.7	105.6 ± 15.5
	Range	0.42-0.81	41.6 -73.7	31.7 - 55.3	81.4 - 149.3
	Enrichment factor	2.3	7.0	2.1	3.6
Heavy traffic	Mean	0.85 ±0.25	46.8 ± 8.5	63.6 ± 6.1	75.5 ± 11.3
	Range	0.61– 1.17	36.4 - 77.7	52.8 - 89.7	59.0 - 103.8
	Enrichment factor	3.0	5.5	3.4	2.6
Residential	Mean	0.42 ±0.09	43.7 ± 7.3	29.2 ± 5.9	79.8 ± 9.5
	Range	0.31-0.64	31.5 - 63.4	20.7 - 45.6	63.0 - 96.3
	Enrichment factor	1.5	5.1	1.6	2.7
Kathmandu valley	Mean of all land uses	1.34	62.3	44.5	99.0
Undisturbed	Mean	0.28 ±0.05	8.5 ± 0.9	18.6 ± 1.4	29.2 ± 1.9
	Range	0.18 –0.35	7.0 – 11.3	13.3 - 25.0	25.5 - 35.8

Considering the mean of all land uses and calculating enrichment factor thereafter, it is concluded that dust of the Kathmandu valley is enriched severely by Cu (EF = 7.3) and Cd (EF = 4.8); and moderately by Zn (EF = 3.4) and Pb (EF = 2.4) as shown in figure 2. As might be evident from table 4, all the land uses showed concentrations of metals higher than those found in undisturbed areas. However, each land use showed some variation in the concentrations of Cd, Cu, Pb and Zn where the industrial dust was affected the most by Zn and Cu, and the heavy traffic road dust was mainly affected by Cd and Pb. Similarly, dust from urban and residential sites was affected mainly by Zn and Cu as in the former cases. Results showed that among all the uses under investigation, the highest concentrations of Zn (135.1 mg kg^{-1}) and Cu (98.9 mg kg^{-1}) were found in industrial dust whereas heavy traffic road dust showed the highest concentration of Cd (0.85 mg kg^{-1}) and Pb (63.6 mg kg^{-1}). Moreover, the industrial dust varied from 89.0 - 165.3 mg kg^{-1} for Zn and 73.8 - 133.5 mg kg^{-1} for Cu, and the range of metal in heavy traffic road dust was from 0.61– 1.17 mg kg^{-1} for Cd and 52.8 - 89.7 mg kg^{-1} for Pb. The observed levels of difference in the present study are most likely due to variation in the sources of metals. The potential sources of metal contamination may be industrial activities, traffic emission, automobiles and other anthropogenic activities. Pb from leaded gasoline, Cu, Zn and Cd from car components, tyre abrasion, lubricants, leakage of oil products, industrial and incinerator emissions are the main sources of contamination[19]. Besides, Cu is also associated with inorganic fertilizers in agricultural areas, and Zn from recreational, domestic, and commercial sources.

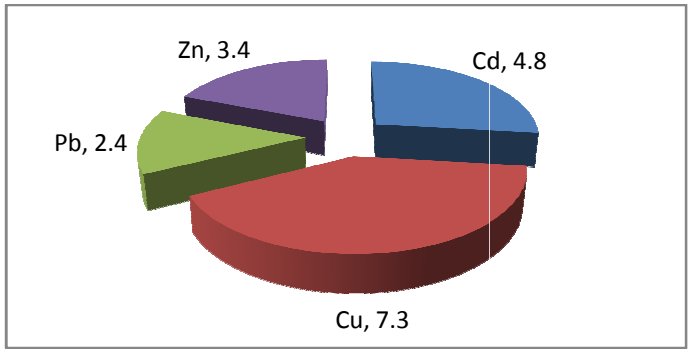

Figure-2
Total metal enrichment in dust of Kathmandu valley

A varying degree of enrichment of all metals was observed for all land-uses, with the concentration of all metals affected by the type of land-use. The results obtained from calculation of enrichment factors (land use wise) showed that industrial and urban exhibited the same order of metal enrichment as Cu > Zn > Cd > Pb (table 4). While the heavy traffic showed the order of metal enrichment as Cu > Pb > Cd > Zn, residential showed the order as Cu > Zn > Pb > Cd. The industrial dust was found to be very severely enriched by Cu (EF = 11.6), dust samples of urban, heavy traffic and residence showed severe enrichment for the same element (EF = 5.1 to 7.0). For Zn, only the industrial dust showed severe enrichment (EF = 4.6), while the rest exhibited moderate enrichment (EF = 2.6 to 3.6). For Pb, all the land uses except the residential one showed moderate enrichment (EF = 2.1 to 3.4). For Cd, all the land uses showed moderate enrichment (EF = 1.5 to 3.0).

Heavy metals in particle size fractions: Table 5 shows metal concentration in different particle size fractions in all the land uses and for all metals. Like in bulk samples, it was found that all particle size fractions from dust samples of the land uses showed concentration of metals higher than those in undisturbed use of similar fractions. In all the land uses and for all the metals, the metal concentrations were found to increase with decrease in particle sizes. Evidently, the fine particle size fraction (<38 µm) from all uses showed concentrations of metals higher than any other fractions under the present study. The concentration of metals in different particle size fractions however varied among the land uses. The results are in agreement with many studies[20,21,22] which also showed significant levels of the metals in the smaller size fraction. Preferential partitioning of metals to the fine particle size fractions in all land uses and for all metals under the present study is usually attributed to the increase in the specific surface area with the decrease of particle size[23] and concomitant increase in the proportion of reactive substrates[12] with negative charges associated with these fine particles[20].

Assessment of contamination indices: Enrichment factor (EFx) revealed that almost all the particle size fractions were found to be enriched in metals for every land use (figure 3). However, the distribution of EFs varied among the land uses and metals concerned. For Cd, all the four land uses exhibited slight to moderate degree of enrichment between fine particle size fractions, <75 µm (EF = 1.8 to 2.6). Similar degree of enrichment (EF = 1.1 to 3.4) was also observed between coarse particle sizes i.e., >75 µm in all the land uses with few exceptions. The sample from heavy traffic however showed severe degree of enrichment of Cd (EF = 6.4) in 2000-710 µm fraction. Similar results were also obtained for Pb and Zn in the same particle size fractions exhibited by some land use. This means that metals are not only bound to fine particles with high surface areas but to large fractions as well. This is probably due to various factors, including addition of metals of anthropogenic origin, aggregation of fine particles by iron oxides and carbonates[11] to which the metals could be associated. In addition, metals could be part of the mineral composition of large particles. For Cu, the enrichment pattern was found somewhat different from other metals. In almost all the land uses, Cu enrichment gradually increased between coarse particle sizes and then decreased between fine particle sizes. Besides, the industrial and residential samples between coarse particle size and the industrial sample between fine particle size (75-53 and 53-38 µm) were severely enriched with Cu. Among the land uses, the industrial dust was found more susceptible for enrichment (EF = 15.9) for the particle size 150-75 µm.

Distribution factor (DFx) revealed a similar pattern of preferential accumulation of metals in the finest fractions (<38

µm) for all the land uses and all metals (figure 4). Among the land uses, the highest values of DFs were recorded in heavy traffic use for all metals and in all fine particle sizes except Cd. Our results are in aggrement with the report of Abdel-Latif and Saleh[21] who also observed higher accumulation of metals in heavy traffic road. In the present study, the highest DFs recorded were for Cu (3.8) followed by Zn (2.8), Cd (2.6) and Pb (2.5) respectively. Similarly, all other land uses also recorded higher values for Cu among the metals. For Cd, particularly the residential use demonstrated a higher DFs in fine particle sizes. This is probably due to various factors including the use of cadmium enamel, abrasion of automobile tyres or plastic materials in which Cd is used as an additive or stabilizer[24]. It was also noted that the behaviour of all the land uses were almost similar for coarse particle fractions (>75 µm) for Cd, Cu, Pb and Zn showing that the metals were least enriched in those particular fractions. However, the fine particle size fractions (<75 µm) were found to be enriched for all land uses and all metals, and with the highest DFs in the finest fractions (<38 µm). The accumulation in the finer fraction indicates the origin of metals from anthropogenic sources.

Results revealed that the mass loading (%) for metals was found to vary among particle size fractions in all the land uses and for all metals (table 6). The total mass loading (%) for metals associated with coarse particle size (>75 µm) was comparatively higher than fine particle size (<75 µm). Coarse particle size fraction contributed approx. 50-60% of metals to the total concentration of bulk dust while the fine particle size made about 30-40% contribution to almost in all the land uses. For Cd, the heavy traffic use showed maximum mass loading (~36%) to the total concentration in 425-150 µm fraction. The industrial use showed maximum mass loading both for Cu (~35%) and Zn (33%) in 75-53 µm size fractions. Mass loading for all the metals in <38 µm fractions are comparatively minimum in all the four land uses. Acosta et al.[20] in their studies reported 50% contributions from urban and highways to the total concentration of bulk dust by particle sizes <10 µm. The highest risk of metal dispersion often lies in the fine particles since they can be easily transported by wind. Excessive accumulation of metals in such particle fractions may often be problematic since they are inhaled by human population.

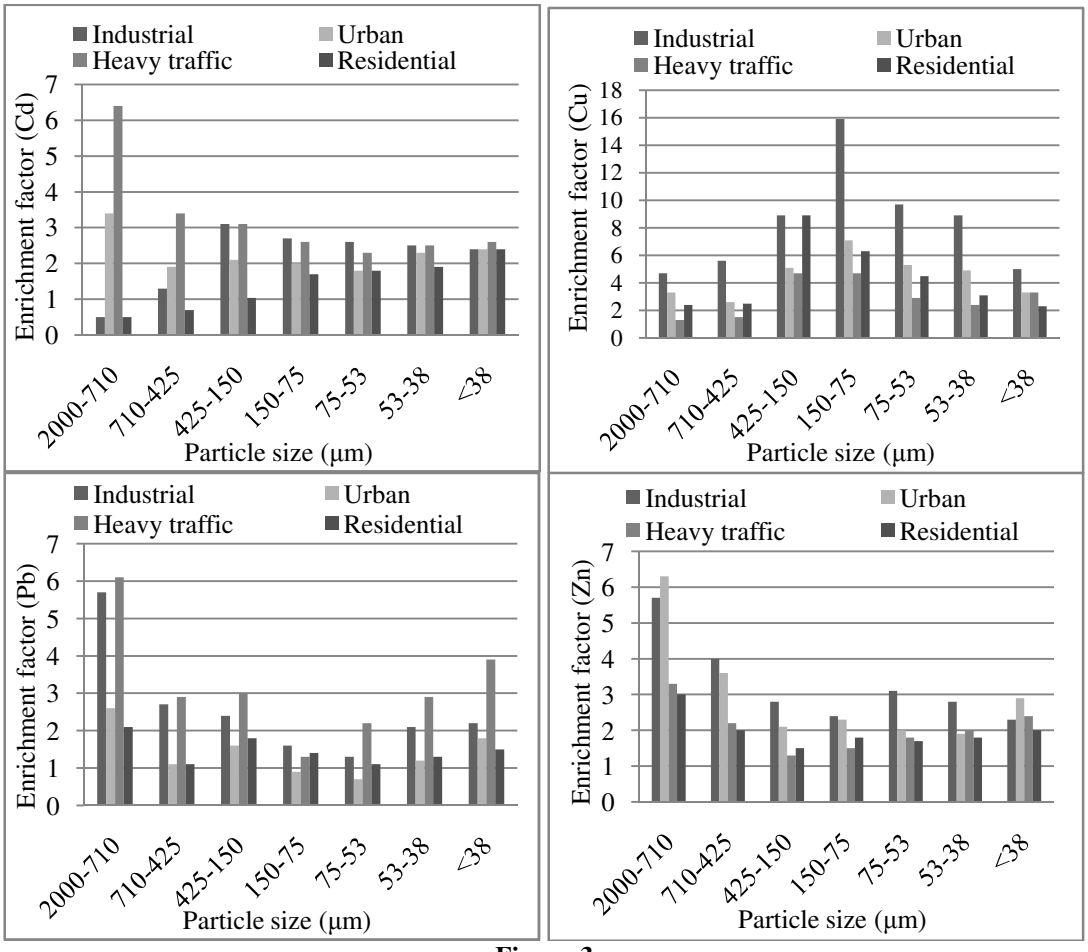

Figure-3
Distribution of enrichment factors (EFs) of metals in different particle size fractions

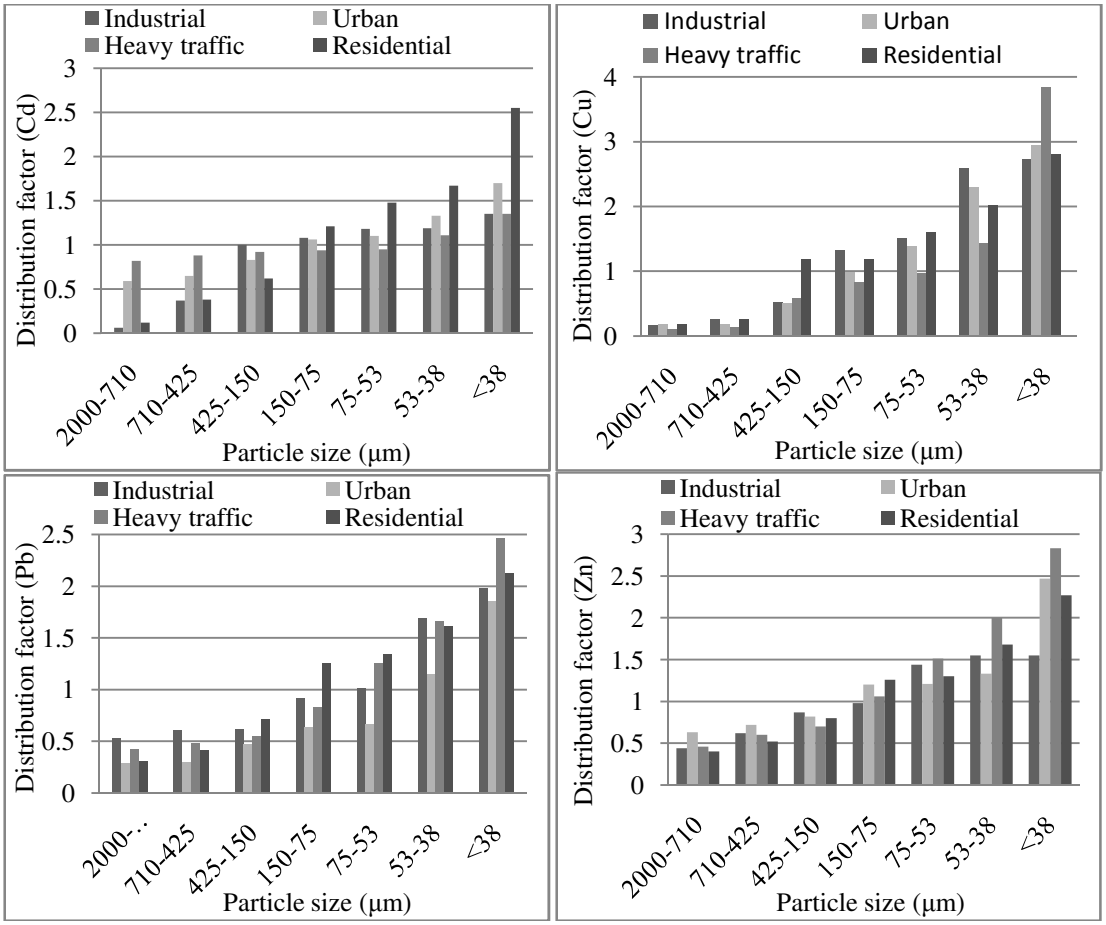

Figure-4
Distribution factors in different particle size fractions

Conclusion

From this work, it can be concluded that dust samples from all the five land uses possessed alkaline nature probably due to the presence of carbonate. The values of EC, total alkalinity and OC were found to be variable among the land uses. The positive correlation between EC and Cd reflects the formation of some metal complexes with anionic species. Among the particle sizes fractionated from the bulk samples, 425-150 μm was the dominant portion in all the land uses.

Significant levels of heavy metals were observed in bulk as well as particle size fractions of all the five land uses. Enrichment factors revealed that the Kathmandu valley dust is contaminated with Cu and the metal is enriched in all the land uses as well. Although each land use showed some variation in the concentrations of Cd, Cu, Pb and Zn due to different sources of contamination, the industrial dust was affected the most by Zn and Cu, and the heavy traffic road dust was mainly affected by Cd and Pb. Besides, the contamination level in all the land uses was higher as compared to the undisturbed (control) area for all metals investigated in this work. The levels of metals for different particle size fractions (both coarse and fine particle sizes) were found to increase with decrease in their sizes. This indicates the preferential partitioning of metals for the fine particle sizes. In addition, the concentration of all metals in the dust is markedly affected by the land use, associated with the metal sources.

Contamination assessment showed a varying degree of enrichment for all the land uses and for all the metals ranging between slight to severe. Among the land uses, the industrial dust was found more susceptible for enrichment (EF = 15.9) particularly for the particle size 150-75 μm. The values of DFs showed the preferential accumulation of metals in the finest fractions (<38 μm) for all the land uses and all metals. Like those of the enrichment factors, the mass loading (%) for metals was also found to vary among particle size fractions for all the land uses and for all metals. However, the contribution for the total mass loading for metals was considerably higher from coarse particle size (>75 μm) to the total concentration of bulk dust than fine particle size (<75 μm). Although our results showed lower values of mass loading for all the metals in <38 μm fractions, the risk assessment would be more realistic if the finest particles were used for monitoring the risk of inhalation and ingestion of dust for humans and environment.

Table-5
Heavy metals concentration (mg/kg) in particle size fractions; mean ± SD; n=9

Land uses	Particle size fraction (µm)	Cd	Cu	Pb	Zn
Industrial	2000-710	0.05 ± 0.01	16.5 ± 3.5	24.4 ± 5.4	59.4 ± 11.8
	710-425	0.29 ± 0.09	25.4 ± 6.3	28.1 ± 4.7	83.9 ± 16.3
	425-150	0.78 ± 0.14	51.5 ± 9.8	28.3 ± 6.2	118.1 ± 29.1
	150-75	0.84 ± 0.17	131.6 ±34.2	42.3 ± 12.5	132.1 ± 31.1
	75-53	0.92 ± 0.21	148.9 ± 39.8	46.3 ± 17.1	194.6 ± 67.0
	53-38	0.93 ± 0.27	251.6 ± 84.5	77.2 ± 21.6	209.4 ± 72.4
	<38	1.05 ± 0.32	269.9 ± 95.0	90.9 ± 30.2	210.0 ± 77.5
Urban	2000-710	0.37 ± 0.10	11.5 ± 1.9	11.5 ± 2.4	66.1 ± 19.4
	710-425	0.41 ± 0.09	11.5 ± 2.9	11.7 ± 1.7	75.5 ± 19.0
	425-150	0.52 ± 0.17	29.6 ± 8.7	18.4 ± 7.1	86.2 ± 25.6
	150-75	0.67 ± 0.18	58.9 ± 18.1	24.7 ± 6.7	126.3 ± 34.2
	75-53	0.69 ± 0.15	82.9 ± 23.1	26.1 ± 8.1	128.1 ± 41.7
	53-38	0.84 ± 0.24	137.3 ± 33.2	45.5 ± 9.0	141.2 ± 27.8
	<38	1.07 ± 0.43	176.0 ± 54.9	72.9 ± 14.2	260.6 ± 81.5
Heavy traffic	2000-710	0.70 ± 0.21	4.6 ± 1.1	26.4 ± 7.3	34.6 ± 8.3
	710-425	0.75 ± 0.19	6.7 ± 2.0	30.4 ± 7.7	45.4 ± 9.2
	425-150	0.78 ± 0.18	27.3 ± 5.4	34.8 ± 4.2	52.5 ± 17.2
	150-75	0.80 ± 0.21	38.8 ± 5.1	52.7 ± 9.1	80.4 ± 24.9
	75-53	0.81 ± 0.20	45.4 ± 6.7	79.7 ± 21.1	113.8 ± 35.8
	53-38	0.94 ± 0.32	67.2 ± 19.2	105.6 ± 27.2	148.4 ± 48.0
	<38	1.15 ± 0.47	179.7 ± 51.6	156.6 ± 30.3	213.9 ± 55.4
Residential	2000-710	0.05 ± 0.01	8.3 ± 1.8	9.2 ± 2.0	31.8 ± 4.3
	710-425	0.16 ± 0.06	11.2 ± 1.4	12.1 ± 2.5	41.6 ± 5.3
	425-150	0.26 ± 0.08	51.7 ± 7.0	20.8 ± 3.7	63.5 ± 7.9
	150-75	0.51 ± 0.09	51.9 ± 11.2	36.5 ± 5.3	100.8 ± 15.5
	75-53	0.62 ± 0.09	69.8 ± 9.5	39.2 ± 4.8	104.1 ± 16.0
	53-38	0.70 ± 0.25	88.2 ± 19.2	47.0 ± 7.9	134.3 ± 24.8
	<38	1.07 ± 0.58	122.4 ± 22.6	61.9 ± 9.7	181.5 ± 26.1
Undisturbed	2000-710	0.11 ± 0.01	3.5 ± 0.2	4.3 ± 0.3	18.5 ± 1.5
	710-425	0.22 ± 0.04	4.5 ± 0.8	10.6 ± 0.8	20.9 ± 1.9
	425-150	0.25 ± 0.02	5.8 ± 0.7	11.7 ± 1.2	42.1 ± 2.5
	150-75	0.31 ± 0.04	8.3 ± 1.1	25.9 ± 3.0	54.9 ± 4.3
	75-53	0.35 ± 0.04	15.4 ± 2.0	35.6 ± 3.7	63.2 ± 5.9
	53-38	0.37 ± 0.07	28.2 ± 2.7	36.8 ± 4.0	75.3 ± 7.1
	<38	0.44 ± 0.10	53.8 ± 6.3	40.5 ± 4.9	90.3 ± 9.1

Table-6
Mass loading (%) of heavy metals in different particle size fraction (µm); mean ± SD, n=9

Land Use	2000-710	710-425	425-150	150-75	75-53	53--38	<38
Mass loading for Cd (%)							
Industrial	0.1 ± 0.1	4.7 ± 1.0	34.7 ±7.4	22.1 ±9.1	27.1 ±7.0	5.1 ± 1.4	3.7 ± 0.8
Urban	0.6 ± 0.2	6.7 ± 2.1	31.8 ±8.0	21.1 ±8.0	23.5 ±5.9	7.9 ± 2.5	3.2 ± 1.0
Heavy traffic	0.8 ± 0.4	9.2 ± 2.7	35.8 ±6.2	22.4±11.0	16.7 ±4.5	5.5 ± 3.9	3.7 ± 0.4
Residential	0.2 ± 0.1	3 .6 ± 1.0	24.5 ±5.0	26.2 ±7.2	28.8 ±11	9.5 ± 3.5	6.0 ± 2.1
Undisturbed	8.0 ± 1.3	12.6 ±1.4	34.7 ±4.3	13.0 ±2.0	6.6 ± 1.1	4.4 ± 0.9	6.2 ± 1.2
Mass loading for Cu (%)							
Industrial	0.2 ± 0.1	3.3 ± 1.1	18.1 ±9.0	27.3 ± 4.2	34.6 ±5.4	11.0 ±3.7	7.6 ±2.4
Urban	0.2 ± 0.1	2.0 ± 0.5	19.1 ±6.7	19.6 ±8.2	29.8 ±8.2	13.7 ±4.1	5.5 ±1.1
Heavy traffic	0.1 ± 0.0	1.5 ± 0.6	22.7 ±5.3	19.7 ±5.0	17.0±3.9	7.2 ±2.1	10.5±2.8
Residential	0.4 ±0.2	2.3 ± 1.0	20.3 ±8.5	25.6 ±7.4	28.2 ±11	11.5 ±1.9	6.6 ± 2.0
Undisturbed	8.7 ± 1.1	8.6 ± 2.2	26.4 ±5.2	11.5 ±2.8	9.5 ±2.9	10.9±3.1	25.1 ±4.1
Mass loading for Pb (%)							
Industrial	0.6 ± 0.3	7.9 ± 2.7	21.4 ±8.2	18.9 ± 4.9	23.2 ±6.8	7.3 ± 1.5	5.5 ± 2.6
Urban	0.3 ± 0.2	0.3 ± 0.1	25.9 ±7.2	20.9 ± 8.0	25.2 ±11	18.7 ±8.1	8.1 ±2.2
Heavy traffic	3.9 ± 1.0	5.9 ± 0.8	21.0±10.4	19.7 ±4.9	21.6±9.0	8.3 ± 1.6	7.0 ±3.1
Residential	0.6 ± 0.2	3.8 ± 0.9	28.2±13.1	27.0 ± 7.0	26.2±13	9.1 ± 1.9	5.0 ± 2.0
Undisturbed	5.7 ± 1.9	11.9±1.8	26.7 ±3.5	17.3 ± 2.2	11.1 ±2.8	7.5 ± 1.4	9.6 ± 1.8
Mass loading for Zn (%)							
Industrial	0.5 ± 0.2	8.0 ± 3.0	30.3±8.2	20.1 ±6.5	33.1 ±6.2	6.7 ± 2.2	4.3 ± 0.9
Urban	0.6 ± 0.1	7.2 ± 1.9	31.4±13.1	23.8 ±7.1	26.1 ±7.2	8.0 ± 3.1	4.6 ± 1.8
Heavy traffic	4.3 ± 0.8	6.2 ± 2.1	27.1 ±8.2	25.3 ±4.5	26.4 ±8.1	9.9 ± 3.4	7.7 ± 2.4
Residential	0.8 ± 0.3	4.8 ± 1.8	31.4±11.2	27.2±10.7	25.5 ±8.6	9.6 ± 2.7	5.4 ± 1.1
Undisturbed	12.0 ±2	11.5 ±2.2	29.0 ± 4.0	22.0 ±8.0	11.3 ±3.1	8.5 ± 1.9	12.3 ±2.2

Acknowledgements

The authors are grateful to University Grants Commission, Kathmandu, Nepal for the award of faculty research grant without which this research work would not have been possible. The authors are also thankful to Aastha Scientific Research Service Pvt. Ltd., Kathmandu for providing service for AAS analysis of dust samples.

References

1. Sammut M.L., Noack Y., Rose J., Hazemann J.L., Proux O., Depoux M., Ziebel A. and Fiani E., Speciation *of* Cd and Pb in dust emitted from sinter plant, *Chemosphere*, **78**, 445–450 **(2010)**

2. Miguel A.G., Cass G.R., Glovsky M.M. and Weiss J., Allergens in paved road dust and airborne particles, *Environ Sci Technol*, **33,** 4159–4168 **(1999)**

3. Government of Canada, In Order Adding Toxic Substances to Schedule 1 to the Canadian Environmental Protection Act, Canada Gazette, **135**, 1–8 **(2001)**

4. Bargagli R, *Trace Elements in Terrestrial Plants*: an Ecophysiological Approach to Biomonitoring and Biorecovery Springer-Verlag, Berlin, Germany **(1998)**

5. Hammond P.C., 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)**

6. Trivedy R.K. and Goel P.K. Chemical and Biological Methods for Water Pollution Studies, Envirnmental Publications, Oriental Printing Press, Aligarh **(1986)**

7. Walkley A. and Black C.A., An examination of Degtja reff methods for determining soil organic matter and a proposed modification of the chromic and titration method. *Soil Sci*, **37**, 29–38 **(1934)**

8. Christoforidis A. and Stamatis N., Heavy metal contamination in street dust and roadside soil along the major national road in Kavala's region, Greece, *Geoderma*, **151**, 257–263 **(2009)**

9. Madrid L*.,* Diaz-Barrientos E. *and* Madrid F., Distribution of heavy metal contents of urban soils in parks of Seville. *Chemosphere,* **49***,* 1301-1308 *(***2002***)*

10. Lacatuso R., In Appraising levels of soil contamination and pollution with Heavy Metals, Europea Soil Bureau Research Report No. 4. **(1998)**

11. Acosta J.A., Faz A., Arocena J.M., Debela F. and Martınez-Martınez S., Distribution of metals in soil particle size fractions and its implication to risk assessment of

playgrounds in Murcia City (Spain), *Geoderma*, **149**, 101–109 **(2009)**

12. Sutherland R.A., Lead in grain size fractions of road-deposited sediment, *Environ Pollut*, **121**, 229–237 **(2003)**

13. Karmacharya N. and Shakya P.R., Heavy metals in bulk and particle size fractions from street dust of Kathmandu city as the possible basis for risk assessment, *Scientific World*, **10**, 84-89 **(2012)**

14. *Yaalon* D.H., Soils in the Mediterranean region: what makes them different?, *Catena, **28**, 157-169* ***(1997)***

15. Fuente D., Chico B. and Morcillo E., The effects of soluble salts at the metal/paint interface: advances in knowledge. *Port Electrochim Acta*, **24**, 191–206 **(2006)**

16. Stone E.A., Schauer J.J., Quraishi T. and Mahmood A., Chemical characterization and source apportionment of fine and course particulate matter in Lahore, Pakistan, *Atmos Environ*, ***44***, *1062*-1070 **(2010)**

17. Amato F., Querol X., Johansson C., Nagl C. and Alastuey A., A review on the effectiveness of street sweeping, washing and dust suppressants as urban PM control, Sci Total Environ, **16**, 3070–3084. **(2010)**

18. Homolya J., In Particulate matter (PM2.5) Speciation Guidance Document, January 21, DRAFT 131, U.S. EPA. **(1999)**

19. Markus J.A. and McBratney A.B., An urban soil study: heavy metals in Glebe, Australia, *Austrian J Soil Res,* **34**, 453–465 **(1996)**

20. Acosta J.A., Faz A., Kalbitz K., Jansen B. and Martınez-Martınez S., Heavy metal concentrations in particle size fractions from street dust of Murcia (Spain) as the basis for risk assessment, *J Environ Moni,* **13**, 3087–3096 **(2011)**

21. Abdel-Latif N.M. and Saleh I.A., Heavy Metals Contamination in Roadside Dust along Major Roads and Correlation with Urbanization Activities in Cairo, Egypt, *Journal of American Science*, **8**, 379-389 **(2012)**

22. Ewen C, Anagnostopoulou M.A. and Ward N.I., Monitoring of heavy metal levels in roadside dusts of Thessaloniki, Greece in relation to motor vehicle traffic density and flow, *Environ Monit Assess*, **157**, 483-498 **(2009)**

23. Ljung K., Selinus O., Otabbong E. and Berglund M., Metal and arsenic distribution in soil particle sizes relevant to soil ingestion by children, *Appl Geochem*, **21**, 1613–1624 **(2006)**

24. Basel Convention Series, Identification and Management of Used Tyres. SBC No. 99/008 **(1999)**