*Journal of Institute of Science and Technology 2019, **24(1)**: 6-18*
ISSN: 2469-9062 (print), 2467-9240 (e)
Doi: http://doi.org/10.3126/jist.v24i1.24622

Research Article

DETERMINATION AND CONTAMINATION ASSESSMENT OF HEAVY METALS IN STREET DUST FROM DIFFERENT TYPES OF LAND-USE IN KATHMANDU DISTRICT, NEPAL

Sudarshana Shakya[1], Samikshya Baral[2], Priya Belbase[2], Mohd Nur E Alam Siddique[3], Abd Naser HJ Samoh[4], Banani Das[5], Prem Kumar Shrestha[6], Pawan Raj Shakya[6]*

[1]Department of Botany, Bhaktapur Multiple Campus, Tribhuvan University, Bhaktapur, Nepal
[2]Department of Environment Science, Padma Kanya Multiple Campus, Tribhuvan University, Kathmandu, Nepal
[3]Department of Analysis & Development, Global Environment Consultant Ltd., Dhaka, Bangladesh
[4]Department of Chemistry, Yala Rajbhat University, Yala, Thailand
[5]Dhaka Laboratory, Department of Environment, Ministry of Environment and Forest, Bangladesh
[6]Department of Chemistry, Padma Kanya Multiple Campus, Tribhuvan University, Kathmandu, Nepal
[*]Corresponding author: pawansh2003@yahoo.com

*(**Received:** February 16, 2019; **Revised**: April 18, 2019; **Accepted:** April 26, 2019)*

ABSTRACT

A total of forty seven street dust samples, collected from five different types of land use *viz.*, industrial, urban, heavy traffic road, residential and undisturbed areas (control) of Kathmandu district (Nepal), were subjected to characterize the physico-chemical parameters such as pH, electrical conductance (EC), total alkalinity (T. Alk), total organic carbon (TOC) and particle size distribution. Four heavy metals of Cd, Cu, Pb and Zn were determined in dust samples using flame atomic absorption spectrophotometer (FAAS). It was found that all types of dust samples possessed alkaline nature along with variation in EC, T. Alk and TOC values. Results revealed that the dust of industrial areas contained high concentrations of Zn (143.3 mg/kg) and Cu (106.42 mg/kg), whereas the heavy traffic areas were mainly affected by Cd (0.90 mg/kg) and Pb (70.08 mg/kg). The average metal concentrations of Cd, Cu, Pb and Zn in dust of all the types of land use in Kathmandu were found to be 0.73, 68.86, 51.46 and 104.30 mg/kg and their average metal enrichment factors were 2.28, 5.50, 1.92 and 3.17, respectively. The results were also compared against heavy metals status in street dust from various cities/countries around the world. Pollution indices such as contamination factor (CF), degree of contamination (CD) and geo-accumulation index (Igeo) showed different classes of metal contamination in street dust of Kathmandu indicating traffic emission, automobiles, construction and demolition activities and other anthropogenic activities as the potential sources.

Keywords: Street dust, Kathmandu district, Heavy metals, Pollution indices, Enrichment factor

INTRODUCTION

Heavy metals are continuously released into the terrestrial environment, due to the continuous urbanization and industrialization, posing a great threat to human health. Street dust, particles deposited on paved road, originates from the interaction of solid, liquid and gaseous materials produced from different sources (Banerjee 2003, Pradhanang 2015). They are relatively complex materials, the compositions of which are seldom constant. It is an important environmental indicator of metal contamination from atmospheric deposition (Wright *et al.* 2018). Street dust receives varying inputs of anthropogenic metals from various stationary and mobile sources such as vehicular traffic, industrial activities, power plants, residential fossil fuel burning, waste incineration, construction and demolition activities, and re-suspension of contaminated soil (Bilos *et al.* 2001). The potential source of Pb contamination is from leaded gasoline; Cu, Zn and Cd are from car components, tyre abrasion, lubricants, industrial and incinerator emissions (Wilcke *et al.* 1998a). The source of Ni and Cr in street dust is believed to be due to corrosion of cars (Akhter & Madany 1993) and chrome plating of some motor vehicle parts (Al-Shayep & Seaward 2001). About half of zinc and copper contribution to the environment in urban areas is from automobiles.

Nepal is a country that has experienced population explosion and accelerated urbanization in the last six decades between 1952 and 2015. Kathmandu, the bowl-shaped capital city of the country, has become densely populated and juxtaposes rapid urbanization, resulting in land use and socio-economic change (Sharma 2003, Thapa & Murayama 2009). High population growth, dramatic land use change and socioeconomic transformations have brought the inconsistency of rapid urbanization and environmental consequences in Kathmandu valley (Thapa & Murayama 2009, Thapa *et al.* 2008). The city has many vulnerable areas plagued with consistently higher concentration of heavy metal pollutants due to rapid construction and demolition activities, vehicle emissions and industrial activities etc (Das *et al.* 2018). These activities potentially contribute to toxic heavy metals in street dust which may enter human body through inhalation, ingestion and dermal contact. It is, therefore important to assess heavy metals contamination in street dust considering the environmental and public health issue. Although there are extensive works noted in the related area in many developed countries around the world, a very few assessment has been made in a developing country like Nepal. Hence, the aim of the present study was to examine heavy metal concentrations in street dust collected from different types of land use in Kathmandu district and to assess contamination levels using three pollution indices *viz.*, contamination factor (CF), degree of contamination (CD) and index of geo-accumulation (Igeo).

MATERIALS AND METHODS

Sampling area and collection

For the present study, five different types of land areas *viz.*, industrial, urban, heavy traffic, residential and undisturbed (control) were selected. The selection of forty seven sampling sites for street dust measurements were based on different domain activities such as industrial activities, traffic load, population density, commercial, non-commercial and other anthropogenic activities as briefly described in Table 1. The sampling sites of the dust collection from different types of land use across Kathmandu district were located using GIS mapping method as shown in Fig. 1.

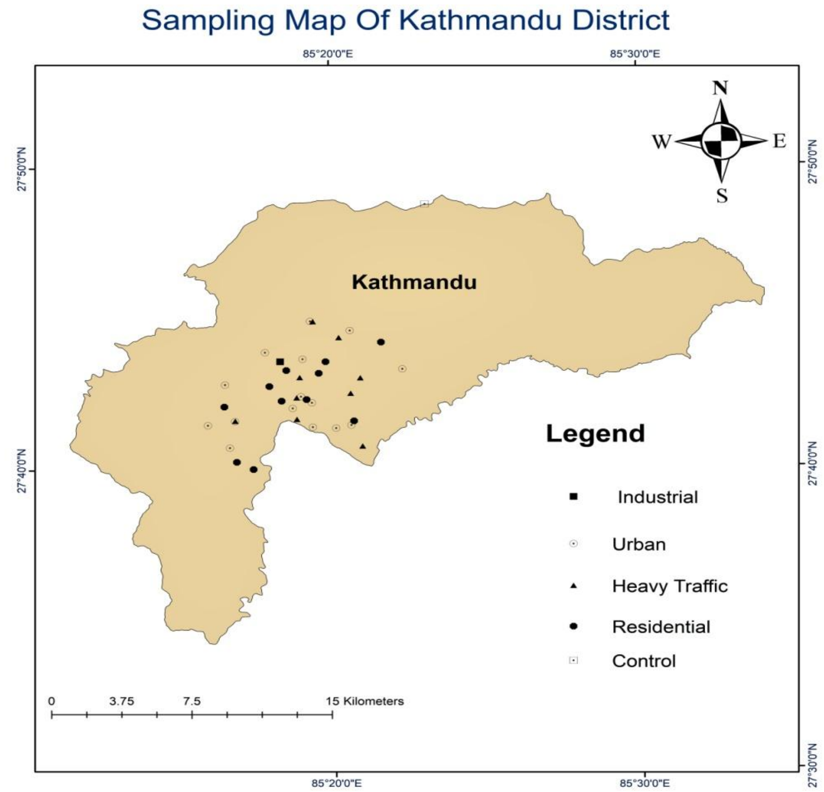

Fig. 1. Location of the sampling sites representing different types of land-use in Kathmandu district

Initially, a field survey was made in order to enlist a number of potential sampling sites and categorized them under three major land use zones *viz.*, urban, heavy traffic road and residential. The number of initially selected sampling sites under urban, heavy traffic road and residential zones reached to 50, 34 and 40 respectively. All the sampling sites were numbered consecutively. From the category of each land use zone, 30 per cent of the total sampling sites were finally selected for dust sample collection using a simple lottery method. This method of sampling was justified for the present study because each of the initially selected sampling sites had an equal chance of participation in the study. Hence, the number of sampling sites under urban, heavy traffic road and residential zones finally were 15, 10 and 12 respectively (Table 1). As for the industrial area, Balaju Industrial Estate, the first industry of national interest established in Kathmandu in 1960 AD, was selected while Shivapuri area as the background (control). So far, no other industries of similar category were found in Kathmandu which could be included in this study. Hence, five sampling points were selected from the Balaju Industrial Estate, within the industrial periphery at an equidistance of 100 meter from its' centre for the collection of street dust samples.

Table 1. Description of sampling sites across Kathmandu district

Land use area	Sample No. (n)	Locations of sampling sites	Activities at the sampling sites
Industrial	5	Balaju Industrial Estate	Automobile workshop, domestic appliances, metal work, plastic and pipe, textile, poultries, rubber, feed furniture, footwear, carpets and *thankas*, metal crafts etc.
Urban	15	Thapathali, Sundhara, Durbarmarg, Baneshwor, Putalisadak, Sitapaila, Gongabu, Baudha, Sinamangal, Bansbari, Kirtipur, Naikab, Kalanki, Balaju, Samakhusi	High traffic load, high anthropogenic activities, densely populated area, hospitals, educational institutions, super markets, big departmental stores, hotels, mechanical and automobile workshops etc.
Heavy traffic road	10	Ratnapark, Chabahil, Maharajgunj chakrapath, Gongabu, Kalanki, Balkhu, Gaushala, Tripureshowr, Koteshowr, Lazimpat	Heavy traffic density, bus parks, business complexes, hospitals, commercial buildings, cinema halls, huge anthropogenic activities etc.
Residential	12	Gairidhara (Naxal), Baluwatar, Kasthamandap, Kapan, Shantinagar, Ason, Dallu, Panga, Chobhar, Bagbazar, Nayabazar, Syuchatar	Medium traffic load, limited commercial activities, limited number of departmental stores and cluster residential area
Undisturbed (control)	5	Shivapuri	Low traffic load, low anthropogenic activities, sparse residential and unpolluted area

The same procedure was applied for Shivapuri, which was selected as the control area. The selection of Shivapuri area as control was based on the fact that the area is unpolluted as well as undisturbed particularly due to sparse residents with low population density and limited anthropogenic activities such as industrial, commercial, traffic load etc. Our field observations also revealed that there was no evidence of anthropogenic activities in the past as well and no signals of disturbances. Hence, a total of 47 street dust samples including those from control area were collected during dry season (March to May, 2018) to avoid rain washing of heavy metals. The sample collection was carried out by sweeping an area of about 1 m^2 from the paved roads using a brush and plastic dustpan. The amount of dust collected from each site was 250-500 g. In order to avoid re-suspension of the finest particles during sampling, the sweeping was made slow and collected directly into plastic bags and labeled. Samples were not collected adjacent to site-specific pollution sources.

Analysis of dust properties

Street dust collected from sampling sites were air dried and passed through a 2 mm metal free sieve to remove rocks, leaves and other debris. The sieved dust samples were preserved as stock in labeled plastic bags with zip lock and stored in a dry place for further processing and analytical purposes. Physico-chemical parameters such as pH, electrical conductivity (EC), total organic carbon (TOC) and total alkalinity were determined (in triplicate) as follows:

Determination of pH and EC: pH and EC of dust samples were determined in 1:5 dust suspensions following standard methods for examination of water and waste water (APHA 1995) with modification as necessity. Accordingly, 20 g of each sample was weighed in a beaker and 100 ml of distilled water added to it. The mixture was stirred in magnetic stirrer for an hour. The pH and EC of the unfiltered dust suspension were recorded using a glass electrode digital pH meter (Model 101, ESICO International) and a digital conductivity meter (Model alpha-06, ESICO International) respectively. Before recording pH and EC, both the instruments were calibrated as per instruction manuals.

Determination of total organic carbon (TOC): Total organic carbon in dust samples was determined by titrametric method as described by Walkey and Black (1934). Accordingly, 1.0 g of each stock sample was weighed and transferred to into a dry 500 mL conical flask. To this, 10 ml of 1 N $K_2Cr_2O_7$ solution and 20 mL of concentrated H_2SO_4 were added and mixed by gentle swirling. The flask was kept in hot air-oven for about 30 minutes at 150° C. After the reaction was over, the contents were diluted with 200 ml of distilled water followed by addition of 0.2 g of sodium fluoride and 1 mL of diphenylamine indicator. The sample was titrated with 0.4 N ferrous ammonium sulphate until the colour of the solution changed from black to brilliant green at the end point. A blank was also run with same quantity of the chemicals without sample.

Determination of total alkalinity: Total alkalinity (as $CaCO_3$ equivalent) in dust samples was determined following modified standard methods for examination of water and waste water (APHA 1995). For this, 20 g of each dust sample was weighed in a beaker and 100 mL of distilled water added to prepare a 1:5 dust suspension. The mixture was stirred mechanically for an hour. The clear suspension was filtered through Whatman No. 40 filter paper using Buchner funnel. Then, 50 mL of the filtrate was taken in a conical flask and 1-2 drops of phenolphthalein indicator was added. The solution remained colourless (Phenolphthalein alkalinity, PA = 0) for all samples showing absence of carbonate and hence total alkalinity (TA) due to bicarbonate was determined by adding 1-2 drops of methyl orange to the same sample and titrated with 0.1 N HCl until the yellow colour changed to pink at the end point.

Fractionation of dust samples

For fractionation of particle size, 100 g of each air-dried sample (2 mm sieved size) 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 (Christoforidis & Stamatis 2009). 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. Percent distribution of dust in each particle size fraction was then calculated. All the experiment was carried out in triplicate.

Determination of heavy metals in dust

Concentration of heavy metals in dust samples was determined by following a standard protocol (Chrisroforidis & Stamatis 2009). For this, 1.0 g of each stock sample was weighed in an acid washed beaker and 10 ml conc. nitric acid was added to it. The sample was then digested over the hot plate at low temperature partially covering the beaker with watch glass. Digestion process was continued until acid volume was reduced to 1-2 ml. Whenever needed more acid was added to carry out complete leaching of metals from the sample. After complete digestion, the interior of the beaker was washed with about 10 mL double distilled water. The sample solution was then warmed for few minutes and cooled to room temperature. Sample was filtered through medium textured Whatman filter paper collecting the filtrate in 25 mL volumetric flask. The beaker was washed with small portions of distilled water adding the washings into the same funnel and collecting filtrate into the same volumetric flask. The final volume was then made with distilled water and mixed well to homogenize the sample. Cd, Cu, Pb and Zn were determined in the digested samples by flame atomic absorption spectrophotometer (SOLAAR M5 Dual Automizer, 180-900nm, Thermo Elemental, UK) using air-acetylene flame. All the standard solutions (1000 ppm) for Cd, Cu, Pb and Zn 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 with dilute (1:1) nitric acid for 24 h and then rinsed with double distilled water before use. The nitric acid (E. Merck, Germany) was of analytical grade and was used without further purification. The instrumental parameters were those recommended by the manufacturer. The precision and analytical accuracy were checked by analysis of standard reference materials NIST SRM 1648. The recovery percentage of metal concentrations from the reference materials was 98 % (Cd), 96.3 % (Cu), 98 % (Pb) and 98.1 % (Zn). In order to determine the precision of the analytical process, few samples from the sampling sites were analyzed three times. The standard deviation for the pretested samples was calculated to be 2.5, 2.1, 2.9 and 3.1 % for Cd, Cu, Pb and Zn respectively and can be considered satisfactory for analysis of dust samples. The detection limits were 9, 3, 9 and 3 μgL^{-1} for Cd, Cu, Pb and Zn, respectively.

Assessment of contamination using pollution indices

Heavy metal contamination of street dust was assessed using single (contamination factor, CF and index of geo-accumulation, Igeo) and integrated (degree of contamination, CD) pollution indices. The contamination factor (CF) and degree of contamination (CD) were suggested by Håkanson (1980) and defined as follows:

$$CF = Cs / Cb \quad (1)$$

$$CD = \Sigma\, CF \quad (2)$$

Where, Cs is the measured concentration of the examined metal in street dust and Cb is the geochemical background concentration or reference value of the metal or the background value (control) of heavy metals in the uncontaminated dust. The contamination is classified into four groups as follows: low ($CF < 1$), moderate ($1 \leq CF < 3$), considerable ($3 \leq CF < 6$) and very high ($6 \leq CF$).

In this study, four categories of CD was used to evaluate metal contamination levels as follows: low ($CD < 5$), moderate ($5 \leq CD < 10$), considerable ($10 \leq CD < 20$), and very high ($20 \leq CD$) degree of contamination. If the CD values exceed 20, then it is necessary to take immediate counter measures to reduce heavy metal contamination in the road dust. An index of geo-accumulation (Igeo) was originally defined by Müller (1969), and can be calculated by the following equation (3):

$$Igeo = \log2\, [Cs / (1.5Cb)] \quad (3)$$

The factor 1.5 is used because of possible variations in background values for a given metal in the environment and to detect very small anthropogenic influence. Müller (1969) classified Igeo for each metal to the following categories: Igeo ≤ 0 = practically unpolluted; 0 < Igeo ≤ 1 = unpolluted to moderately polluted; 1 < Igeo ≤ 2 = moderately polluted, 2 < Igeo ≤ 3 = moderately to strongly polluted; 3 < Igeo ≤ 4 = strongly polluted; 4 < Igeo ≤ 5 = strongly to extremely polluted and Igeo ≥ 5 = extremely polluted.

Statistical analysis

Descriptive statistics such as frequency, percentage, mean and standard deviation were used wherever applicable. Correlation analyses among the dust properties and metals were performed with SPSS v.19.0 (SPSS Inc., Chicago, USA).

RESULTS AND DISCUSSION

Dust properties

Dust properties such as pH, electrical conductivity (EC), total organic carbon (TOC) and total alkalinity as $CaCO_3$ equivalent in dust samples from different types of land use were analyzed. Table 2 shows variable ranges and mean values of pH, EC, total alkalinity and TOC among the land uses. The dust samples from all the land uses exhibited alkaline nature. The alkaline nature of the dust samples reflects the richness of carbonate and/or bicarbonate salts (Yaalon 1997) and also from the aging road and building materials (Sutherland & Tolosa 2000). Alkaline nature of dust was also reported by Christoforidis & Stamatis (2009) and Karmacharya & Shakya (2012) in their studies.

Variable EC values were found among the land use types in this study. The amount of salt content in dust may account for variation in range of EC among the study areas. The salinity of dust samples may be attributed to the presence of ions such as Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, NO^{3-} , PO_4^{3-}, CO_3^{2-} and HCO_3^- (Fuente *et al.* 2006). Total alkalinity shows that dust samples from Kathmandu are mainly due to bicarbonates (carbonate not detected). Dust naturally contains carbonates and/or bicarbonates or lime and even then the calcium carbonate-rich parent material will continue to weather, producing more soluble carbonate and buffering the soil solution pH (Christoforidis & Stamatis, 2009).

The elevated level of TOC in the present study indicates that dust is an important sink of organic material in Kathmandu, which is subsequently transported by wind or runoff water and accumulated along the street dust. Besides, organic materials from anthropogenic waste and vehicle oil or gasoline that contain hydrocarbons may equally contribute to the organic carbon content in dust (Stone & Marsalek 1996). This is consistent with the findings of Herath *et al.* (2013) who also reported high organic matter content in Colombo metropolitan region due waste disposal, leakage of lubricants and vehicle oil. Further, the present study is also in agreement with the work of Karmacharya and Shakya (2012) and Acosta *et al.* (2011) who reported similar results in properties of street dust.

Distribution of dust in particle size fractions

Dust particle size is considered as one of the important dust properties. Table 3 shows mean percent distribution of dust in seven different particle size fractions from different land uses. Results revealed that dust particle size of 425-150 µm was the main dominant fraction in all the studied areas and varied from 49.17 % (urban) to 56.53 % (residential) of the total fraction. This finding is also supported by the work of Karmacharya and Shakya (2012) who reported dust particle of 425-150 µm mesh size as the major fraction by percentage in street dust. However, the composition of dust may vary depending on climate, human activities, soils and rocks of the surrounding areas etc (Amato *et al.* 2010). The dust particle with a smaller size is often considered risky for environment and human health (EPA 1999).

Heavy metal concentrations in street dust

Table 4 shows the mean concentrations of Cd, Cu, Pb and Zn in street dust from all five types of land use. Results revealed that the mean concentration of all metals in dust samples from the industrial, urban and residential land uses was found to be in order of their abundance as Zn>Cu>Pb>Cd. On the contrary, heavy traffic and undisturbed area exhibited the elemental order by their abundance as Zn>Pb>Cu>Cd. In all cases, Zn appeared to be highly mobile than Cu, Pb and Cd, because of its small ionic size and exhibited greater binding affinity for dust particles. The extent of their mobility and binding affinities, however depend on redox potential and pH of the surrounding environment (Hermann & Neumann-Mahlkau 1985). The metal levels in the street dust (mean of all locations) from Kathmandu district were 104.3 mg/kg for Zn, 68.9 mg/kg for Cu, 51.5 mg/kg for Pb, 0.73 mg/kg for Cd and these values are comparatively higher than those of the control area (Table 4). Highest levels of Cu, Cd, Pb and Zn were also found in dust samples from industrial, urban, heavy traffic area and the lowest levels of metal concentrations from the rural area as reported in earlier studies (Herath *et al.* 2013; Abbasi *et al.* 2013; Tanushree *et al.* 2011; Ewen *et al.* 2009). They attributed different types and levels of anthropogenic activities in such land uses as the main reason for the contamination of heavy metals in street dust.

The industrial dust was found to be affected mostly by Zn and Cu, and the heavy traffic road dust 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 (143.3 mg/kg) and Cu (106.42 mg/kg) were found in industrial dust whereas heavy traffic road dust showed the highest concentration of Cd (0.90 mg/kg) and Pb (70.08 mg/kg). Moreover, the industrial dust varied from 98.5-179.8 mg/kg for Zn and 80.7-140.4 mg/kg for Cu and the range of metal in heavy traffic road dust was from 0.66-1.22 mg/kg for Cd and 61.6-77.0 mg/kg for Pb. The observed levels of difference in the present study were most likely due to variation in the sources of metals.

Table 2. Dust properties from different types of land use (Mean ± SD, n=3) in Kathmandu

Land uses		pH	EC (µS/cm)	T. Alk as $CaCO_3$ mg/100 gm	TOC (%)
Industrial	Mean	8.2 ± 0.1	807 ± 98	148 ± 62	0.98 ± 0.06
	Range	8.1 - 8.4	709 - 950	67 - 220	0.87 - 1.06
Urban	Mean	8.6 ± 0.6	638 ± 297	123 ± 40	1.35 ± 0.38
	Range	7.8 - 9.3	168 - 1050	85 - 189	1.05 - 2.09
Heavy traffic	Mean	8.4 ± 0.7	754 ± 477	165 ± 86	1.35 ± 0.16
	Range	7.2 - 9.2	241 - 1400	67 – 305	0.96 - 1.60
Residential	Mean	8.4 ± 0.3	544 ± 261	115 ± 39	1.00 ± 0.15
	Range	7.8 - 8.7	276 - 932	43 - 153	0.80 - 1.21
Control	Mean	7.8 ± 0.2	479 ± 365	107 ± 35	0.92 ± 0.12
	Range	7.4 - 8.0	177 - 1177	61 - 153	0.82 - 1.15

EC= electrical conductivity, T. Alk= total alkalinity & TOC= total organic carbon

Table 3. Distribution of particle size fraction (%) (Mean ± SD)

Particle size (µm)	Industrial	Urban	Heavy traffic	Residential	Control
2000-710	14.35 ± 4.38	11.01 ± 5.41	11.59 ± 9.70	11.40 ± 9.31	21.43 ± 5.14
710-425	8.97 ± 3.03	9.48 ± 1.18	8.6 ± 4.84	13.22 ± 1.67	20.12 ± 3.88
425-150	52.18 ± 18.4	49.17 ± 12.20	54.13 ± 17.48	56.53 ± 12.37	51.37 ± 10.04
150-75	8.49 ± 7.24	17.03 ± 17.58	10.15 ± 17.34	12.46 ± 6.56	4.65 ± 4.27
75-53	16.43 ± 7.44	11.40 ± 8.20	12.5 ± 15.89	3.14 ± 1.30	1.56 ± 0.91
53-38	2.90 ± 2.27	1.44 ± 0.94	2.86 ± 3.11	2.15 ± 2.81	0.82 ± 0.67
<38	0.49 ± 0.18	0.79 ± 0.59	0.12 ± 0.16	1.4 ± 2.21	0.09 ± 0.15

Table 4. Heavy metal concentration (mg/kg) in street dust (Mean ± SD) from different types of land use in Kathmandu

Land uses		Cd	Cu	Pb	Zn
Industrial	Mean	0.86 ± 0.17	106.4 ± 22.4	54.3 ± 8.2	143.3 ± 28.5
(n = 5)	Range	0.63 - 1.14	80.7 - 140.4	42.5 - 67.2	98.5 - 179.8
Urban	Mean	0.70 ± 0.15	64.9 ± 10.8	46.9 ± 8.8	111.4 ± 18.7
(n =15)	Range	0.51 - 0.90	50.2 - 82.5	38.9 - 61.4	86.3 - 139.6
Heavy traffic	Mean	0.90 ± 0.22	53.7 ± 9.6	70.1 ± 6.0	89.4 ± 12.3
(n =10)	Range	0.66 - 1.22	40.4 - 65.6	61.6 - 77.0	76.0 - 110.5
Residential	Mean	0.46 ± 0.07	50.4 ± 6.0	34.6 ± 6.3	73.1 ± 7.4
(n =12)	Range	0.37 - 0.58	42.5 - 58.8	24.8 - 42.6	64.8 - 86.4
Kathmandu district	Mean of all land uses	0.73	68.9	51.5	104.3
Control	Mean	0.32 ± 0.04	12.5 ± 1.8	26.8 ± 4.2	32.9 ± 3.5
(n =5)	Range	0.25 - 0.39	10.0 - 14.6	21.3 - 34.0	28.5 - 38.6

The present results are comparable with the work of Acosta *et al*. (2011) who reported higher concentration of Zn (205 mg/kg) in dust of industrial area and Pb (85 mg/kg) in highways. Besides, the results are supported by Ambade (2012) as well found higher concentration of Zn in dust of industrial environment of Bhilai city, India. In the present study, cadmium exhibited significantly low levels in all the samples compared to Cu, Pb, and Zn in consistent with the findings of Faiz *et al.* (2009) who concluded that the street dust generally contained lower levels of Cd than other metals. The attrition of automobile tires, car abrasion, lubrication oils and galvanized parts of vehicles are possible sources of Cd contamination (Wilcke *et al.* 1998a). Cadmium concentrations range from 0.07 to 0.10 ppm in diesel oils, 0.20 to 0.026 ppm in lubricating oils and 20 to 90 ppm in automobile tire (Akhter & Madany 1993).

Cu is associated with inorganic fertilizer in industrial area whereas zinc from recreational, domestic and commercial sources (Markus & McBratney 1996). Besides, 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 (Markus & McBratney 1996). As thousands of vehicles ply on narrow streets of Kathmandu, release of Cd, Cu, Pb and Zn from automobile sources as mentioned above are likely to cause metal contamination in street dust of Kathmandu.

This is further supported by Basel Convention report (BCR 1999) which discloses vehicle tires contain total of approximately 1.5 % by weight of hazardous waste compounds. These compounds, outlined as Cu, Zn, Pb, Cd, organohalogens and many others are encased in the rubber compound or present as an alloying element. The copper compounds are used as alloying constituent of metallic reinforcing material. The zinc compound as zinc oxide is retained in the rubber matrix. Cadmium as cadmium compound present in trace levels is used as an attendant substance of the zinc oxide. Similarly, lead and lead compounds present in trace levels are used as attendant substance of the zinc oxide. Hence, it may be suggested that tens of thousands of vehicles in Kathmandu may potentially release heavy metals in street dust through attrition of automobile tires, car abrasion, lubrication oils etc.

The correlation between different parameters is frequently expressed by Pearson's correlation coefficient that indicates their potential sources (Puth *et al.* 2014). The correlation coefficients among the dust properties and heavy metals in this study are listed in Table 5. The positive correlation was observed between Cd and Pb ($r = 0.796$, $p<0.05$), Cu and Pb ($r = 0.789$, $p<0.05$) and Cu and Zn ($r = 0.899$, $p <0.05$) implying common sources of their origins. Atmospheric deposition of these metals is associated with traffic emissions. Besides, EC and Cd also showed positive correlation ($r = 0.779$, $p<0.05$) between them indicating that Cd has greater affinity for anions such as Cl^-, NO_3^-, SO_4^{2-}, PO_4^{3-}, CO_3^{2-} and HCO_3^- in dust (Fuente *et al.* 2006). Moreover, the results revealed positive correlations, though not significant, among the parameters suggesting common contaminant sources.

Metal enrichment in street dust

The average metal enrichment in Kathmandu which is the ratio of average metal concentration from all land uses to the metal concentration from control area is presented in Fig. 2. Based on the average metal concentration from all land uses and enrichment factor calculated thereafter, it can be concluded that metal enrichment in street dust from Kathmandu is at considerable level for Cu (EF = 5.50) and Zn (EF = 3.17); and moderate level for Cd (EF = 2.28) and Pb (EF = 1.92) (Fig. 2). Accordingly, the metal enrichment in street dust from Kathmandu follows in order as Cu>Zn>Cd>Pb. This result has consistency with the study of Shakya et al. (2014) who also obtained metal enrichment in dust of Kathmandu Valley in similar order as Cu>Zn>Cd>Pb.

Table 5. Pearson's correlation coefficients among dust properties and heavy metals

	pH	**EC**	**T. Alk.**	**TOC**	**Cd**	**Cu**	**Pb**	**Zn**
pH	1.00	0.458	0.528	0.244	0.442	0.338	0.452	0.323
EC	0.458	1.00	0.376	0.339	**0.779***	0.462	0.522	0.410
T. Alk.	0.528	0.376	1.00	0.422	0.338	0.442	0.482	0.568
TOC	0.244	0.339	0.422	1.00	0.522	0.342	0.462	0.420
Cd	0.442	**0.779***	0.338	0.522	1.00	0.256	**0.796***	0.512
Cu	0.338	0.462	0.442	0.342	0.256	1.00	**0.789***	**0.899***
Pb	0.452	0.522	0.482	0.462	**0.796***	**0.789***	1.00	0.472
Zn	0.323	0.410	0.568	0.420	0.512	**0.899***	0.472	1.00

**The correlation is significant at the 0.05 level*

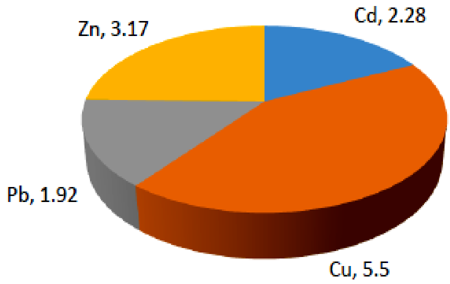

Fig. 2. Average metal enrichment in street dust of Kathmandu district

Environmental status of Kathmandu

The mean concentrations of heavy metals in the present study were compared with those in street dust from different cities/countries with a view to evaluate environmental status of Kathmandu (Table 6). Among the metals, the level of Cd (0.73 mg/kg) in the present study was higher than Beijing, China (0.64 mg/kg) but was comparatively lower than those from North China, Guiyang, Edinburgh and Delhi (Table 6). Similarly, the mean Cu concentration in the present study was comparatively higher than those present in Edinburgh (57 mg/kg) but lower than other listed cities/ countries. The level of Pb was found to be significantly low compared to other listed cities. For Zn, with the exception of Dammam, Saudi Arabia (79.1 mg/kg), majority of the listed cities have significant levels of the metal. It has been reported that the potential sources of Cu, Zn and Cd contaminations in street dust were car components, tyre abrasion, lubricants, industrial and incinerator emissions, and Pb from leaded gasoline (Markus & McBratney 1996, Wilcke *et al.* 1998b). Besides, Cu was also associated with inorganic fertilizers in agricultural areas, and Zn from recreational, domestic, and commercial sources (Markus & McBratney 1996). Moreover, the interplay of sources of metals, land use type, traffic volume, fuel quality, distance from the road, human habits, populations, etc. of each city determines the metal concentration in street dust (Charlesworth *et al.* 2003, Nnaji 2015). Hence, it may be suggested that degree of heavy metals contamination in street dust in a particular location or area depends mainly on the level and types of anthropogenic activities.

Assessment of contamination levels using pollution indices

Three types of pollution indices such as contamination factor (CF), degree of contamination (CD) and geo-accumulation index (Igeo) were used to assess metal contamination levels in Kathmandu. The contamination factor and index of geo-accumulation are single pollution indices (Håkanson 1980) whereas the degree of contamination is integrated pollution index (Müller 1969). The assessment of metal contamination using these pollution indices is most important for the human survival (Barbieri 2016). Tables 7 and 8 show the contamination factor, degree of contamination and geo-accumulation index and their classifications based on the metal contamination levels. The contamination factor (CF) indicates the amount of anthropogenically introduced metal in street dust with respect to the natural concentration. Results showed that the contamination factor for Cu was found to be the highest among the analyzed metals in street dust and in all land use types in the order as industrial > urban > heavy traffic > residential (Table 7).

The contamination factor (CF) indicates the amount of anthropogenically introduced metal in street dust with respect to the natural concentration. Results showed that the contamination factor for Cu was found to be the highest among the analyzed metals in street dust and in all land use types in the order as industrial > urban > heavy traffic > residential (Table 7).

Table 6. Comparison of heavy metals (mg/kg) in street dust from mean value of all land uses in Kathmandu district with those of other cities/countries around the world

Countries	Cd	Cu	Pb	Zn	References
Kathmandu/Nepal	0.73	68.9	51.5	104.3	Present Study
Dammam/ Saudi Arabia	-	71.6	65.2	79.1	Al-Rashdi *et al.* (2017)
North China	2.84	107.3	177.0	514.5	Wan *et al.* (2016)
Guiyang/China	1.54	138.0	129.0	479.0	Xiaoyan *et al.* (2014)
Edinburgh/UK	1.0	57.0	118.0	213.0	Pal *et al.* (2011)
Delhi/India	2.65	191.7	120.7	284.5	Suryawanshi *et al.* (2016)
Beijing/China	0.64	72.1	201.8	219.2	Du *et al.* (2013)

Table 7. Contamination factor (CF), degree of contamination (CD) and geo-accumulation index (Igeo) of all land uses in Kathmandu district

Contamination factor (CF)				
Heavy metals	**Industrial**	**Urban**	**Heavy traffic**	**Residential**
Cd	2.69	2.19	2.81	1.44
Cu	8.51	5.20	4.30	4.00
Pb	2.03	1.75	2.65	1.30
Zn	4.36	2.88	2.30	1.90
Degree of contamination, CD = ΣCF	17.59	12.02	12.06	8.64
Geo-accumulation index (Igeo)				
Heavy metals	**Industrial**	**Urban**	**Heavy traffic**	**Residential**
Cd	0.55	0.46	0.57	0.28
Cu	1.70	0.84	0.76	0.73
Pb	0.43	0.37	0.54	0.24
Zn	0.87	0.58	0.49	0.40

Table 8. Classification of pollution indices based on contamination factor and degree of contamination values

Pollution index (Contamination factor)				
Land use	**Low (CF<1)**	**Moderate (1≤CF<3)**	**Considerable (3≤CF<6)**	**Very high (6≤CF)**
Industrial	-	Cd, Pb	Zn	Cu
Urban	-	Cd,Pb,Zn	Cu	-
Heavy traffic	-	Cd,Pb,Zn	Cu	-
Residential	-	Cd,Pb,Zn	Cu	-
Pollution index (Degree of contamination)				
Land use	**Low (CD<5)**	**Moderate (5≤CD<10)**	**Considerable (10≤CD<20)**	**Very High (20≤CD)**
Industrial			(+)	
Urban			(+)	
Heavy traffic			(+)	
Residential		(+)		

Accordingly, industrial, urban, heavy traffic and residential types of land use showed 8.51, 5.20, 4.30 and 4.00 as CF values for Cu, respectively. Except for heavy traffic road, the contamination factor for Pb was found to be least in favour of all types of land use. Evidently, the contamination factor showed moderate contamination level ($1 \leq CF < 3$) for Cd in all the land uses in the present study (Table 8). On the contrary, the contamination factor for Cu indicated very high contamination level ($6 \leq CF$) in industrial area and considerable contamination levels ($3 \leq CF < 6$) in urban, heavy traffic and residential areas, respectively.

The highest contamination factor for Cu in the industrial land use may be attributed to mechanical workshops as well as automobiles that may release significant amount of Cu and Zn from tire and brake abrasions (Thorpe & Harrison, 2008). The Pb for all the land uses was found under moderate contamination level ($1 \leq CF < 3$). Moreover, the contamination factor indicated considerable contamination level ($3 \leq CF < 6$) for Zn in industrial area and moderate contamination level ($1 \leq CF < 3$) in urban, heavy traffic and residential areas. These results indicated that the street dust of Kathmandu district was found to be highly contaminated with Cu followed by Zn, Cd and Pb.

Similarly, degree of contamination (CD) is also one of the important contamination indices that indicate the measure of the sum of all metals anthropogenically accumulated in street dust. The degree of contamination computed for each land use is shown in Table 7. It was found that industrial land use showed the highest degree of metal contamination (17.59) followed by heavy traffic (12.06), urban (12.02) and residential (8.64). These results revealed considerable degree of contamination ($10 \leq CD < 20$) for industrial, urban and heavy traffic area (Table 8). Residential land use, however indicated moderate level ($5\leq CD < 10$) in terms of degree of contamination. Higher degree of contamination is often a matter of worry because of tremendous anthropogenic activities that occur at these sites during rush hours of the day. Long term exposure within the neighborhood can lead to adverse health effects particularly on children, pregnant women and the aged who all are known to be vulnerable (Du *et al.* 2013).

Geo-accumulation index (Igeo) is the indicator used to assess the presence and intensity of anthropogenic contaminant deposition on surface soil (Barbieri 2016). This index of potential contamination is calculated by the normalization of one metal concentration in the topsoil with respect to the concentration of a reference element. The geo-accumulation index (Igeo) was found to be variable among the analyzed metals as well as types of land use (Table 7). Apparently, the Igeo value was found to be the highest for Cu in all the types of land use while Pb appeared to have the least values of all. Accordingly, the Igeo value for Cu was found to be the highest in industrial (1.70) followed by urban (0.84), heavy traffic (0.76) and residential (0.73) types of land use. The highest Igeo value for Cu in the industrial land use is most likely due to vehicular and industrial emissions, application of inorganic fertilizer in the surrounding agricultural areas and waste disposal (Lu *et al.* 2009). Likewise, the Igeo values obtained for Pb were 0.43, 0.37, 0.54 and 0.24 respectively for industrial, urban, heavy traffic and residential types of land use. Based on the Igeo values, the pollution levels was classified as follows (Table 9): all land use types were found to have Igeo values for $0 < Igeo \leq 1$ class indicating the environment unpolluted to moderately polluted level for Cd, Pb and Zn. While the industrial land use showed Cu at moderately polluted level ($1< Igeo \leq 2$); urban, heavy traffic and residential land uses showed Igeo values for $0 < Igeo \leq 1$ class for the same metals. Hence, these land use types were found to have unpolluted to moderately polluted level of metal contamination.

As in the present study, Sampson *et al.* (2011) also used the mathematical models such as index of geo-accumulation (Igeo), enrichment factors (EF), contamination factor and degree of contamination to identify possible levels of pollution from anthropogenic sources on surface dust collected from major and busy roads in the city of Accra, Ghana. Similar to the findings of the present study, all the models agreed well in their results giving moderate to significant levels of pollution for the most part of the selected sites. Similarly, Shakya and Pradhananga (2013) used the same pollution indices for assessing Pb, Cd and Hg contamination in roadside dust collected from Kathmandu-Bhaktapur road section of Arniko Highway, Kathmandu valley which indicated various levels of contamination identical to the present study. They also reported traffic emission, automobiles and other anthropogenic activities as the potential sources of the metal contamination.

Table 9. Classification of pollution based on Geo-accumulation index of all land uses in Kathmandu district

Pollution index	Industrial	Urban	Heavy traffic	Residential
(1):(Igeo≤0)	-	-	-	-
(2):(0<Igeo≤1)	Cd, Pb, Zn	Cd, Cu, Pb, Zn	Cd, Cu, Pb, Zn	Cd, Cu, Pb, Zn
(3):(1<Igeo≤2)	Cu	-	-	-
(4):(2<Igeo≤3)	-	-	-	-
(5):(3<Igeo≤4)	-	-	-	-
(6):(4<Igeo≤5)	-	-	-	-
(7):(Igeo≥5)	-	-	-	-

(1): practically unpolluted; (2): unpolluted to moderately polluted; (3): moderately polluted; (4): moderately to strongly polluted; (5): strongly polluted; (6): strongly to extremely polluted & (7): extremely polluted

CONCLUSIONS

The present study was carried out with a view to assess environmental status of Kathmandu by physico-chemical characterizations and determining heavy metals concentration in street dust from five different types of land use. The pH, EC, total alkalinity and TOC parameters varied in their levels among the land uses due to different physico-chemical properties of street dust. Among the seven particle size fractions, street dust of 425-150 µm sieve size remained the dominant portion in all the land uses. Elevated levels of heavy metals were found to contaminate street dust from all the land use types. The mean concentrations of the analyzed metals in all types of land uses were found to be in the order of elemental abundance as Zn>Cu>Pb>Cd. Although the concentrations of heavy metals in dust samples were found to be variable among the land uses, the industrial dust was predominated by Zn and Cu, whereas the heavy traffic road dust by Cd and Pb. The average metal concentrations of Cd, Cu, Pb and Zn in dust from all the types of land use in Kathmandu were found to be 0.73, 68.86, 51.46 and 104.30 mg/kg and their average metal enrichment factors were 2.28, 5.50, 1.92 and 3.17, respectively. These findings suggest the prevalence of different types and levels of anthropogenic activities such as traffic emission, automobiles, construction and demolition activities etc., in such types of land use in Kathmandu. The mean concentrations of Cd, Cu, Pb, and Zn in street dust from Kathmandu district may be considered to be moderate when compared against those cities/countries listed for the present study.

Due to the increasing anthropogenic activities such as injudicious use of fertilizers and pesticides, industrial and vehicle emissions, waste disposal, air pollution etc., the life capacity of soils has been continuously decreasing. As a matter of fact it is very important to distinguish between the natural background values of elements and anthropogenic inputs, and to understand that the background values change from area to area and with the scale of the area investigated. To evaluate the heavy metals contamination rate, three different indices like contamination factor (CF), degree of contamination (CD) and geo-accumulation index (Igeo) were used in the present study. The CF and Igeo values for Cu were found to be highest among the analyzed metals and in all land use types in the order as industrial > urban > heavy traffic > residential. Similarly, the industrial land use showed the highest CD value. Accordingly, the CF ranged from moderate to very high contamination levels whereas CD from moderate to considerable levels with respect to the analyzed metals in street dust for different types of land use. Likewise, the Igeo values ranged from unpolluted to moderately polluted level with respect to the analyzed metals for different types of land use.

Heavy metals can be generated in the street dust both from natural sources and anthropogenic activities. Depending on their concentration in dust particles and soils, they may determine a potential toxicity to living organisms. Their entry in the food chain represents a geochemical risk because of their toxicity to human health, especially to the occurrence of bioaccumulation phenomena. Hence, the present study may be expected to provide baseline information for addressing environmental pollution due to heavy metal pollutants in street dust. The dust particles having smaller size are often considered a major environmental and health hazard because they are easily transported and inhaled. Hence, we conclude from the present study that a monitoring plan is necessary to evaluate the evolution of metal concentration in dust in order to develop proper measures for reducing the risk to human health due to inhalation, ingestion and dermal contact.

ACKNOWLEDGEMENTS

The authors are grateful to Department of Applied Chemistry, BHU, Varanasi, India for FAAS analysis and Padma Kanya Multiple Campus, Tribhuvan University, Kathmandu for providing laboratory facilities and logistic support.

REFERENCES

Abbasi, Md. N., Tufail, Md. and Chaudhary, Md. M. 2013. Assessment of heavy elements in suspended dust along the Murree highway near capital city of Pakistan. *World Applied Sciences Journal* **21**(9): 1266-1275.

Acosta, J.A., Faz, A., Kalbitz, K., Jansen, B. and Martınez-Martınez, S. 2011. Heavy metal concentrations in particle size fractions from street dust of Murcia (Spain) as the basis for risk assessment. *Journal of Environmental Monitoring* **13**(11): 3087-3096.

Akhter, M.S. and Madany, I.M. 1993. Heavy metals in street and house dust in Bahrain. *Water, Air and Soil Pollution* **66**(1-2):111-119.

Al-Rashdi, A.A., Ebqa'ai, M., Harb, M.K. and Faidi, F. 2017. A solid phase extraction procedure for the determination of heavy metals in street dust from Dammam, kingdom of Saudi Arabia and estimation of the health risk. *Journal of Materials and Environment Sciences* **8**(6): 2050-2061.

Al-Shayep, S.M. and Seaward, M. 2001. Heavy metal content of roadside soils along ring road in Riyadh (Saudi Arabia). *Asian Journal of Chemistry* **13**(2): 407-423.

Amato, F., Querol, X,. Johansson, C., Nagl, C. and Alastuey, A. 2010. A review on the effectiveness of street sweeping, washing and dust suppressants as urban PM control methods. *Science of the Total Environment* **408**(16): 3070-3084.

Ambade, B. 2012. Evaluation of heavy metal contamination in road dust fallout of Bhilai city. *International Journal of Advanced Engineering Research and Studies* **1**(4): 81-83.

APHA. 1995. *Standard methods for examination of water and wastewater*. 9th Edition, American Public Health Association, Washington DC.

Banerjee, A.D.K. 2003. Heavy metal levels and solid phase specification in street dusts of Delhi, India. *Environmental Pollution* **123**(1): 95-105.

Barbieri, M. 2016. The importance of enrichment factor (EF) and geo-accumulation index (Igeo) to evaluate the soil contamination. *Journal of Geology and Geophysics* **5**: 1-4.

BCR. 1999. *Identification and management of used tyres*. Basel Convention Report Series, SBC No. 99/008.

Bilos, C., Colombo, J.C., Skorupka, C.N., Rodriguez Presa, M.J. 2001. Sources, distribution and variability of airborne trace metals in La Plata City area, Argentina. *Environmental Pollution* **111**(1): 149-158.

Charlesworth, S., Everett, M., McCarthy, R., Ordonez, A. and de Miguel, E. 2003. A comparative study of heavy metal concentration and distribution in deposited street dusts in a large and a small urban area: Birmingham and Coventry, West Midlands, UK. *Environment International* **29**(5): 563-573.

Christoforidis, A., and Stamatis, N. 2009. Heavy metal contamination in street dust and roadside soil along the major national road in Kavala's region, Greece. *Geoderma* **151**(3-4)**:** 257-263.

Das, B., Bhave, P., Puppala, S. and Byanju, R. 2018. A global prospective of vehicular emission control policy and practices; an interface with Kathmandu Valley case, Nepal. *Journal of Institute of Science and Technology* 23: 76-80.

Du, Y., Gao, B., Zhou, H., Ju, X., Hao, H. and Shuhua, Y. 2013. Health risk assessment of heavy metals in road dusts in urban parks of Beijing, China. *Procedia Environmental Sciences* **18**: 299-309.

EPA. 1999. Particulate matter ($PM_{2.5}$) Speciation Guidance, Final Draft. 1st edition, Environmental Protection Agency, October 7, USA.

Ewen, C, Anagnostopoulou, M.A. and Ward, N.I. 2009. Monitoring of heavy metal levels in roadside dusts of Thessaloniki, Greece in relation to motor vehicle traffic density and flow. *Environment Monitoring and Assessment* **157**(1-4): 483-498.

Faiz, Y., Tufail, M., Javed, M.T., Chaudhry, M.M. and Siddique, N. 2009. Road dust pollution of Cd, Cu, Ni, Pb and Zn along Islamabad Expressway, Pakistan. *Microchemical Journal* **92**: 186-192.

Fuente, D. de la, Chico, B. and Morcillo, M. 2006. The effects of soluble salts at the metal/paint interface: advances in knowledge. *Portugaliae Electrochimica Acta* **24**(2): 191-206.

Håkanson, L. 1980. An ecological risk index for aquatic pollution control: A sedimentological approach. *Water Research* **14**: 975-1001.

Herath, H.M.D.V., Pitawala, H.M.T.G.A., Gunathilake, J. and Dalugoda, T.Y.S. 2013. Heavy metal contamination in road deposited sediments in Colombo urban area. In: *Proceedings to 29th Technical Sessions of Geological Society of Sri Lanka*, 127-130.

Hermann, R. and Neumann-Mahlkau, P. 1985. The mobility of zinc, cadmium, copper, lead, iron and arsenic in groundwater as a function of redox potential and pH. *Science of the Total Environment* **43**(1-2): 1-12.

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

Lu, X., Wang, L., Lei, K., Huang, J. and Zhai, Y. 2009. Contamination assessment of copper, lead, zinc, manganese and nickel in street dust of Baoji, NW China. *Journal of Hazardous Materials* **161**(2-3): 1058-1062.

Markus, J.A. and Mcbratney, A.B. 1996. An urban soil study: heavy metals in Glebe, Australia. *Austrian Journal of Soil Research* **34**(3): 453-465.

Müller, G. 1969. Index of geo-accumulation in sediments of the Rhine River. *Geojournal* **2**(3): 108-118.

Nnaji, J. 2015. Assessment of heavy metal contamination of agricultural soils and cassava leaves along Umuahia-Ikot-Ekpene highway, Abia state. *Research Journal of Pharmaceutical, Biological and Chemical Sciences* **6**(2): 301-304.

Pal, S.K., Wallis, S.G. and Arthur, S. 2011. Assessment of heavy metals emission from traffic on road surfaces. *Central European Journal of Chemistry* **9**(2)**:** 314-319.

Pradhanang, S. 2015. Distribution and fractionation of heavy metals in sediment of Karra River, Hedauda, Nepal. *Journal of Institute of Science and Technology* 19(2): 123-128.

Puth, M.T., Neuhauser, M. and Ruxton, G.D. 2014. Effective use of Pearson's product–moment correlation coefficient. *Animal Behavior* **93:** 183-189.

Shakya, P.R. and Pradhananga, A.R. 2013. Determination and contamination assessment of Pb, Cd, and Hg in roadside dust along Kathmandu-Bhaktapur road section of Arniko Highway, Nepal. *Research Journal of Chemical Sciences* **3**(9): 18-25.

Shakya, P.R., Karmacharya, N., Kansakar, S.B.S., Shakya, R.K., Wagle, K.K. and Shrestha, M. 2014. Determination of heavy metals in street dust from different types of land use of Kathmandu Valley, Nepal. *Research Journal of Chemical Sciences* **4**(7): 82-92.

Sharma, P. 2003. Urbanization and development. In: *Population Monograph of Nepal*, Central Bureau of Statistics: Kathmandu, Nepal. pp. 375.

Stone, M. and Marsalek, J. 1996. Trace metal composition and speciation in street sediment Sault Ste. Marie, Canada. *Water, Air and Soil Pollution* **87**(1-4)**:** 149-169.

Suryawanshi, P.V., Rajaram, B.S., Bhanarkar, A.D. and Rao, C.V. 2016. Determining heavy metal contamination of road dust in Delhi, India. *Atmósfera* **29**(3): 221-234.

Sutherland, R.A. and Tolosa, C.A. 2000. Multi-element analysis of road deposited sediment in an urban drainage basin, Honolulu, Hawaii. *Environmental Pollution* **110**(3): 483-495.

Thapa, R.B. and Murayama, Y. 2009. Examining Spatiotemporal Urbanization Patterns in Kathmandu Valley, Nepal: Remote Sensing and Spatial Metrics Approaches. *Remote Sensing* **1**: 534-556.

Thapa, R.B., Murayama, Y. and Ale, S. 2008. City profile Kathmandu. *Cities* **25**(1): 45-57.

Thorpe, A. and Harrison, R.M. 2008. Sources and properties of non-exhaust particulate matter from road traffic: A review. *Science of the Total Environment* **400**(1-3): 270-282.

Wan, D., Han, Z., Yang, J., Yang, G. and Liu, X. 2016. Heavy metal pollution in settled dust associated with different urban functional areas in a heavily air-polluted city in North China. *International Journal of Environment Research and Public Health* **13**(11): 1119.

Wilcke, W., Kretzschmar, S., Bundt, M., Saborío, G. and Zech, W. 1998b. Aluminium and heavy metal partioning in a horizon of soils in costarican coffee plantations. *Soil Science* **163**(6): 463-471.

Wilcke, W., Muller, S., Kanchanakool, N. and Zech, W. 1998a. Urban soil contamination in Bangkok: heavy metal and aluminum partioning in topsoils. *Geoderma* **86**(3-4): 211-228.

Wright, L.P., Zhang, L., Cheng , I., Aherne, J. and Wentworth, G.R. 2018. Impacts and effects indicators of atmospheric deposition of major pollutants to various ecosystems- a review. *Aerosol and Air Quality Research* **18**: 1953-1992.

Xiaoyan, L., Shuting, Z. and Mei, Y. 2014. Accumulation and risk assessment of heavy metals in dust in main living areas of Guiyang City, Southwest China. *Chinese Journal of Geochem*istry **33**(3): 272-276.

Yaalon, D.H. 1997. Soils in the Mediterranean region: what makes them different? *Catena* **28**(3-4): 157-169.