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Determination and Contamination Assessment of Pb, Cd, and Hg in Roadside Dust along Kathmandu-Bhaktapur Road Section of Arniko Highway, Nepal

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Abstract

Lead (Pb), cadmium (Cd) and mercury (Hg) were analyzed by atomic absorption spectrophotometer (AAS) in roadside dust samples collected from 10 major sampling sites along Kathmandu-Bhaktapur road section of Arniko Highway, Kathmandu valley, Nepal. Elevated levels of the heavy metals were found in the dust samples which were compared with background values (control). The metal concentrations varied from 69.09-471.40 mg/kg for Pb, 1.56-6.15 mg/kg for Cd and 0.59-1.89 mg/kg for Hg respectively along with the average concentrations 245.36 mg/kg, 2.89 mg/kg and 1.04 mg/kg, respectively for the same elements. These values were compared with results from various cities/countries world wide. Pollution indices such as contamination factor (CF), degree of contamination (CD) and geo-accumulation index (Igeo) of the heavy metals indicated various levels of contamination in the roadside dust across the study sites. The results suggest that traffic emission, automobiles and other anthropogenic activities are the potential sources of the metal contamination.

Keywords: Heavy metals, roadside dust, contamination assessment, Arniko Highway.

Introduction

Road surfaces receive varying amount of heavy metals by the process of atmospheric deposition, sedimentation, impaction and interception[1]. Particularly in urban areas, the top soils and roadside dusts are indicators of heavy metal contamination from atmospheric deposition. Industries, traffic, mining activities, smelters and construction are some of the main anthropogenic sources of heavy metal pollution. The traffic source includes vehicles (tire wear, brake linings, fuel combustion, etc.) and road infrastructure (pavement wear, corrosion of galvanized steel crash barriers, etc.)[2]. It has been reported that the pollutants such as As, Cd, Cr, Cu, Ni, Pb and Zn due to heavy traffic are at high concentration levels at the sites close to the roadside soils and dusts that affect the air environmental quality[3]. More than 90% of the large particles of lead from vehicle emissions deposit close to the road within 1.5 m when the size is greater than 5 µm[4]. It is believed that automobiles are not only responsible for metal pollution but also many other elements, emitted from similar sources. Liang *et al*[5] reported that several kinds of gasoline contain 0.2–3.3 ng g^{-1} of Hg. The enormous production of gasoline is, therefore likely to bring about Hg pollution[6]. Besides, Hg is also used in the interior lights of a van and high intensity discharge-type headlights.

Presence of heavy metals at elevated levels in the environment may be hazardous to human health. Lead exposure even at low concentration has been found to interfere with specific enzyme systems and blood production for humans. Other serious potential results of lead exposure are behavioral. Brain damage has been well documented in case of lead poisoning in children[4]. It has been noted that children could ingest dust contaminated with heavy metals via their hands to mouths sucking behaviour[7]. For children in urban surroundings, the dust of streets and playgrounds is a potentially significant source of lead, and that the lead in such dust can be over 1000 ppm (0.1%)[4]. In addition to Pb, heavy metals such as Zn, Cd and Hg are good indicators of contamination in street dust because they appear in gasoline, car components, oil lubricants, and industrial and incinerator emissions[8].

A considerable number of studies are available in literature regarding the contamination of heavy metals in roadside dust in developed countries. Few studies have been carried out in developing countries. Little interest has been focused on the related field along major roadways in regions like Kathmandu valley. Hence, there is a need to identify the level of toxic contaminations in the urban environment because of their association with human health. The objective of this study was, therefore to determine and assess contamination levels of some toxic heavy metals such as Pb, Cd and Hg in roadside dust along the major road section of the country i.e. Kathmandu-Bhaktapur road section of Aniko Highway.

Material and Methods

The site of investigation – Kathmandu-Bhaktapur Road Section of Arniko Highway: Kathmandu is the capital of Nepal which is located between 27^0 45' - 27^0 47' N latitude and 85^0 20' - 85^0 25' E longitude. The Kathmandu valley has gone through rapid and haphazard urbanization with recent development of transport infrastructure. Traffic records show around twelve hundred thousand vehicles in the valley alone (Office of Traffic Police, Kathmandu - personal communication). One of the heaviest traffic existing roads in the valley is Kathmandu-Bhaktapur road section of the Arniko Highway. Approximately a 10 km segment of this road section was upgraded in 2011 with the grant assistance from the government of Japan by expanding the previous two-lane road to six-lanes. The road was designed to serve not only to ensure smooth transportation of goods and people between Kathmandu and Bhaktapur, but also to play an important role linking the Kathmandu valley with the Eastern Terai via the Arniko Highway and the Sindhuli Road (which connects Dhulikhel-Sindhuli-Bardibas on the East-West Highway). Besides, the road project was expected to bring a positive impact to the Nepalese economy and also improve access to health and education institutions for the residents along the road. At present, this road section sees a daily traffic volume of more than 50,000 vehicles, making it one of the busiest trunk roads in the country (Office of Traffic Police, Kathmandu - personal communication). There exist intense residential places (especially near sampling sites which are just 10 to 100 m away from the road) and numerous small and medium facilities (e.g. automotive repair workshops, hospitals, shopping complexes, educational institutions etc.) in the surrounding of this selected route. This route constitutes a very busy portion of the highway and therefore selected in the present study to investigate heavy metal contamination. A brief description of the study sites along the road section of the highway is presented in table 1.

Sampling and pre-treatment: For the present study, 10 major sampling sites were located along the Kathmandu–Bhaktapur road section starting from Tinkune (Kathmandu) to Surya Binayak (Bhaktapur). Roadside dust samples were collected from i. Tinkune, ii. Jadibuti Chowk, iii. Lokanthali, iv. Gathaghar, v. Sundar Nagar, vi. Thimi Bazar, vii. Hanumante Bridge, viii. Sallaghari, viv. Chuni Devi and x. Surya Binayak. A map of the location of sampling sites is shown in figure 1. Each of the sampling sites is located at an approximately 1 km apart and hence dust samples were collected from almost an equal distance representing these sites. From each site, about 0.5 kg of dust samples were collected from alternate left and right sides of the highway using plastic dust pan and brush to avoid possible contamination from the sampling tools. From each site, 3 sub-samples were gathered from 1 m apart and collected separately in plastic bags. All the collected samples were dried at 60°C for 3 days and passed through a 2 mm sieve, then submitted for analysis.

For background level (control), dust samples were collected from Dadhikot (11) shown in figure 1, an undisturbed area about 5 km south-east of the road section. The selected control site is the area without evidence of past and current anthropogenic activities and no signals of disturbances were observed during the sampling. The samples were colleted during dry season to avoid rain washing out the heavy metals.

Table-1
Description of sampling sites along Kathmandu-Bhaktapur road section of Arniko Highway

Site No.	Sampling sites	Site code	Description of the sampling sites
1	Tinkune	TKN	Linked to the TIA airport and Bhaktapur, sub station, heavy traffic and commercial plazas
2	Jadibuti Chowk	JBC	Crossing, government institution, traffic load, residential and commercial areas
3	Lokanthali	LKT	Residential area, commercial activities and private institutions
4	Gathaghar	GTG	Residential and commercial areas, educational institutions and traffic burden
5	Sudar Nagar	SDN	Residential area, commercial markets and private institutions
6	Thimi Bazar	TMB	Densely populated and commercial areas, heavy traffic load, crossing, sub station, hospitals, private and government institutions
7	Hanumante Bridge	HMB	Bagmati river, open field on either side and low traffic load
8	Sallaghari	SLG	Turning point to Nagarkot and Banepa, heavy traffic and sparse residential area
9	Chuni Devi	CND	Residential area, commercial activities, medium traffic load and private institutions
10	Suryabinayak	SBN	Crossing, densely populated area with commercial activities, sub station, traffic load and private institutions
11	Dadhikot (Undisturbed area; Control)	CTL	Very low traffic, sparse residential and undisturbed area

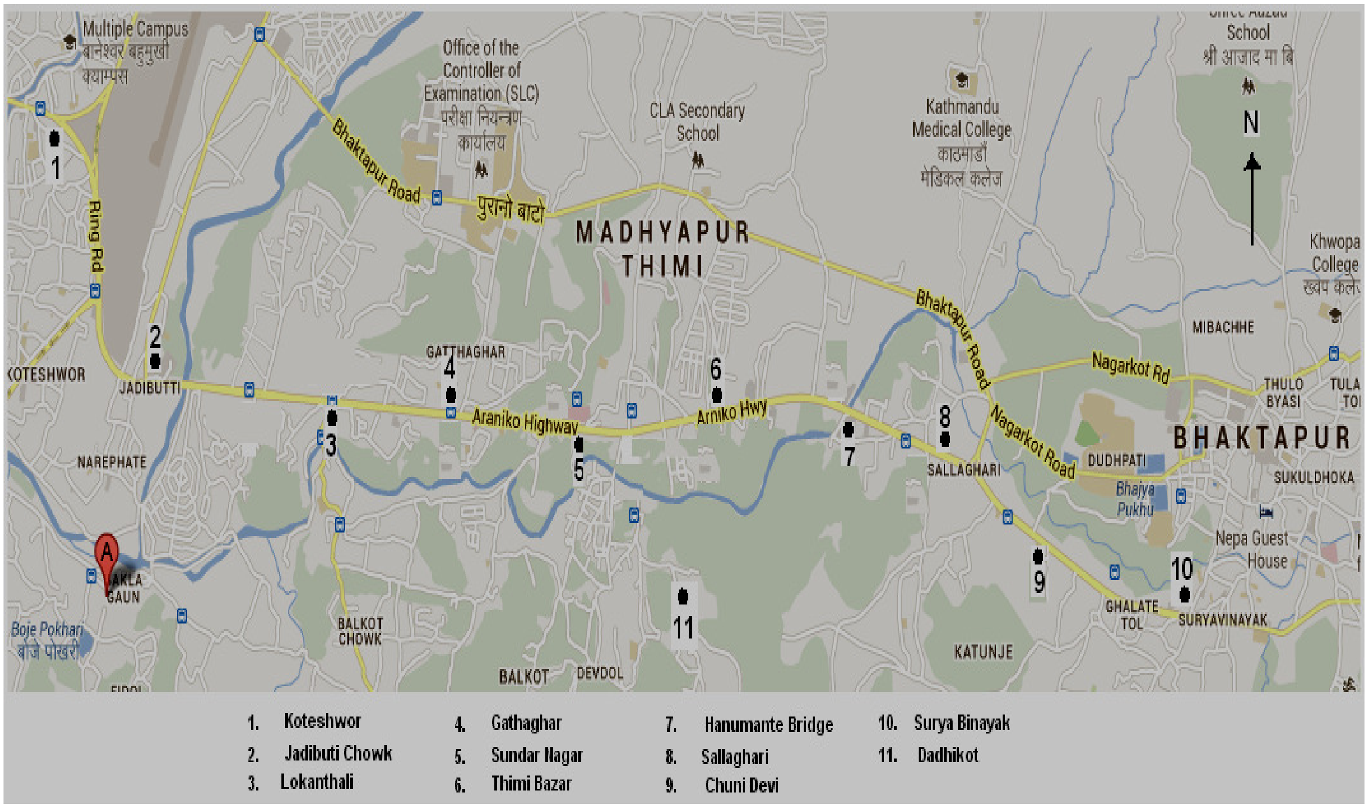

Figure-1
A map of sampling sites along Kathmandu-Bhaktapur road section of Arniko Highwway

Analysis of dust properties: The following properties were analyzed in the samples: soil organic carbon (OC) by titrimetric method; soil *p*H in H_2O using a glass electrode in a 1:5 soil/water suspension and electrical conductivity (EC) in a 1:5 soil/water suspension as described by Trivedy and Goel[9] and cation exchange capacity (CEC)[10].

Determination of Pb, Cd and Hg in dust : One gram of each dried and sieved dust sample was placed in a 50 ml volumetric flask used exclusively for digestion and boiled gently with 20 ml of 6M HCl for 1 hour on a sand bath[11]. After thermal release, the extract was filtered with Whatman No. 40 filter paper and made the final volume of 50 ml (henceforth, extract solution) in the flask. Hg concentration in the extract solution was detected by a cold vapor atomic absorption spectrophotometer with a sulfuric acid (H_2SO_4) and tin chloride ($SnCl_2$) solution.

For Pb and Cd, 1.0 g of the sieved sample was placed in 300 ml beaker and boiled at 230°C with 15 ml of nitric acid (HNO_3) and 25 ml of perchloric acid ($HClO_4$)[11]. After completely turned to ash, the digested solution was filtered and made the volume up to 50 ml in a volumetric flask. The metal concentrations were determined by atomic absorption spectrophotometer (Hitachi model 180-270). The accuracy of this study was checked by an analysis of standard reference materials (SRM) from the National Institute of Standards and Technology.

Assessment of contamination level: In this study, heavy metal contamination of roadside dust was analyzed using single (contamination factor, *CF* and index of geoaccumulation, *Igeo*) and integrated (degree of contamination, *CD*) indices. The contamination factor (*CF*) and degree of contamination (*CD*) were suggested by Håkanson[12] 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 the road 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 soil. The contamination was classified into four groups as follows: low ($CF < 1$), moderate ($1 \leq CF < 3$), considerable ($3 \leq CF < 6$) and very high ($6 \leq CF$)[13].

In this study, four categories of *CD* were 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[14]. If the *CD* values exceeded 20, then it was 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[15], and can be calculated by the following equation:

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

Factor 1.5 is used because of possible variations in background values for a given metal in the environment as well as very small anthropogenic influences. Müller[21] classified *Igeo* for each metal to 5 grade-categories as follows: $Igeo \leq 0$ = practically unpolluted; $0 < Igeo \leq 1$ = unpolluted to moderately polluted; $1 < Igeo \leq 2$ = moderately polluted, $2 < Igeo \leq 3$ = moderately to strongly polluted; $3 < Igeo \leq 4$ = strongly polluted; $4 < Igeo \leq 5$ = strongly to extremely polluted and $Igeo \geq 5$ = extremely polluted.

The Statistics: All statistical analyses and data processing in this study were performed on an IBM-PC computer using Statistical Package for Social Sciences (SPSS) program. Descriptive statistics such as mean and standard deviation values were performed after multi-element analysis. The inter-element correlation coefficients (r) for roadside dust samples were calculated by $p<0.01$.

Results and Discussion

Roadside dust properties: Table 2 shows the results of pH, electrical conductivity (EC), organic carbon (OC) and cation exchange capacity (CEC) obtained from all roadside dust collected.

The pH and EC are usually considered as indicators or measurement of the chemical nature of road dusts. The pH values obtained at all sampling sites were within the alkaline range, 7.59 (LKT) to 8.21 (TMB). The alkaline nature of the dust samples reflects the richness of carbonate salts[16] and high stability of the pH due to small difference among the sites.

The EC is the ability of a material to carry electrical current. In water, it is generally used as a measure of the mineral or other ionic concentration. The EC values measured ranged from 197.00 (SDN) to 407.00 µS/cm (TMB). The same was recorded as 178.67 µS/cm in dust sample of the control site (CTR). The relatively higher EC values compared to the control site could be due to the presence of high levels of ionizeable materials in the sampling sites, including metal cations as well as anions[17]. The highest salt concentration in the roadside dust of Thimi bazaar (TMB) is likely due to a spill of material rich in salts in the surrounding sampling site.

The percentage of OC ranged from 0.95 (SDN) to 2.97 % (TKN) with 0.80 % of the same detected at the control site. This indicates that the amount of OC content in dust for all the sampling sites is generally high. It may therefore be concluded 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 road section of the highway. Besides, the other sources of OC content may be hydrocarbons from the vehicle oil or gasoline and organic material from anthropogenic waste[18].

The CEC of a soil is a measure of the quantity of sites on soil surfaces that can retain positively charged ions by electrostatic forces[19]. Cation exchange sites are found primarily on clay and organic matter surfaces and higher CEC is associated with high metal retention. Results showed that the measured CEC values for dust samples were in the range of 3.36 cmol/kg (HMB) to 10.81 cmol/kg (CTR). The lower levels of CEC in the dust samples for all the experimental sites compared to the control site were probably influenced by high organic matter obtained in dust which increased metal-ligand complexes formed[18].

Heavy metals in the roadside dust: The average concentrations of Pb, Cd and Hg measured in the roadside dust samples from the specified sites along the Kathmandu-Bhaktapur road section of Arniko Highway are presented in table 2. The average concentrations of these metals thus obtained have been compared with data from some collected literature given in table 3. The results obtained for each element are discussed.

Lead: Lead concentrations were found in the range of 69.09 (HMB) to 471.40 mg/kg (TMB) according to the results from the 10 sampling sites. The average concentration of Pb was found to be 245.36 mg/kg in the dust samples across the road section of the highway. Results revealed that the average concentration of lead in the roadside dust is about 8 times higher than that of the lead concentration in the control site (32.93 mg/kg). These values indicate that leaded fuel could be the potential source of lead contamination in the dust samples. Since leaded gasoline in Nepal was phased out and distribution of lead free petroleum started in 1999, Pb emissions could, therefore be produced from some other sources rather than fuel combustion. Smichowski *et al*[20] considered brake wear and loss of Pb wheel weights as the main sources of this element in the urban environment in addition to leaded gasoline. Lead is not only present in fuels as a natural component but also in brake pads and tire rubber. This could possibly be the reasons for high contamination of the metal across the road section citing it as one of the busiest trunk roads in the country. Besides, the high content of Pb at Thimi Bazar (TMB) could be attributed to some other anthropogenic effects since the area is harbored with high density road traffic including automobile repairing workshops in surroundings and high buildings resulting possibly in low wind speed at the point. The low wind speed might also be the cause of highest metal accumulation at this study site[20].

Table 3 compares metal contents in roadside dust samples in various locations throughout the world. The comparison with the other countries shows that 3 countries have higher values while 7 have lower concentration values for Pb. Accordingly, lead data from this work are higher than the findings in Hong Kong (China)[1], Islamabad (Pakistan)[21], Amman (Jordan)[22], Birmingham (UK)[23], Dhaka (Bangladesh)[24], Istanbul (Turkey)[25] and Mubi (Nigeria)[26] and lower than those found in Paris (France)[2], Luanda (Angola)[27], and Bahrain (Bahrain)[28].

Table-2
Heavy metal concentrations (mg/kg) and dust properties in different sampling sites along Kathmandu-Bhaktapur road section of the Arniko highway (n=3, mean, standard deviation)

Sampling sites	pH	EC (µS/cm)	OC (%)	C.E.C. (cmol/kg)	Pb	Cd	Hg
TKN	8.16 (0.19)	406.67 (25.15)	2.97 (0.71)	7.36 (0.38)	361.01 (23.90)	4.26 (0.66)	1.54 (0.12)
JBC	7.96 (0.10)	396.33 (15.18)	2.43 (0.60)	9.10 (0.66)	346.90 (16.06)	3.18 (0.19)	1.14 (0.07)
LKT	7.59 (0.16)	319.67 (30.66)	1.57 (0.21)	3.77 (0.78)	198.26 (41.07)	1.67 (0.32)	0.73 (0.27)
GTG	7.86 (0.71)	283.33 (27.51)	1.10 (0.20)	4.59 (0.61)	151.05 (29.22)	2.63 (0.46)	0.81 (0.24)
SDN	7.76 (0.20)	197.00 (25.06)	0.95 (0.45)	4.40 (0.39)	145.25 (19.83)	2.14 (0.28)	0.63 (0.17)
TMB	8.21 (0.51)	407.00 (19.70)	2.40 (0.36)	7.0 (0.62)	471.40 (45.22)	6.15 (0.57)	1.89 (0.32)
HMB	7.50 (0.30)	230.33 (28.38)	1.30 (0.40)	3.36 (0.66)	69.09 (22.05)	1.61 (0.31)	0.74 (0.16)
SLG	8.09 (0.17)	380.33 (41.59)	2.43 (0.32)	6.25 (0.52)	372.58 (78.79)	3.08 (0.63)	1.25 (0.31)
CND	7.62 (0.04)	218.33 (23.01)	1.60 (0.30)	3.77 (0.94)	135.59 (14.67)	1.56 (0.14)	0.59 (0.09)
SBN	7.94 (0.22)	310.67 (18.01)	1.40 (0.44)	5.59 (0.58)	202.45 (14.95)	2.08 (0.25)	1.10 (0.49)
Mean all uses,n=10	-	-	-	-	245.36	2.84	1.04
CTR	7.70 (0.22)	178.67 (13.05)	0.80 (0.27)	10.81 (0.65)	32.93 (5.53)	0.82 (0.36)	0.09 (0.02)

Table-3
The comparison of heavy metals (mg/kg) along the Kathmandu-Bhaktapur road section of Arniko Highway with those of some cities/countries of the world

City/Country	Pb	Cd	Hg
Kathmandu/Nepal (Present study)	245.36	2.84	1.04
Hong Kong/ China[1]	93.4	2.18	-
Paris/ France[2]	1450	1.7	-
Islamabad/ Pakistan[21]	104	5	-
Amman/ Jordan[22]	199	0.78	-
Birmingham/ UK[23]	48	1.68	-
Dhaka/ Bangladesh[24]	74	-	-
Istanbul/ Turkey[25]	185.8	2.32	-
Mubi/ Nigeria[26]	207	0.67	-
Luanda/Angola[27]	351	1.1	-
Bahrain/Bahrain[28]	697.2	7.2	-
Bhilai city/India[29]	813.2	-	2.1
Kalava/Greece[30]	300.9	0.2	0.1

Cadmium: Cadmium exhibited significantly low levels in all the samples compared to Pb in consistent with the findings of Faiz[21] who concluded that the street dust generally contained lower levels of Cd than other metals. The Cd levels were found to be in range of 1.56 (CND) to 6.15 mg/kg (TMB) across the road section of the highway. The average concentration of Cd was found to be 2.84 mg/kg in the dust samples while the sample from the control site measured 0.82 mg/kg. This indicates that the average concentration of Cd is nearly 4 times higher to that of the control site. The attrition of automobile tires, car abrasion, lubrication oils and galvanized parts of vehicles are possible sources of high Cd contamination. Cadmium concentrations range from 0.07 to 0.10 ppm in diesel oils and 0.20 to 0.026 ppm in lubricating oils. Cadmium in automobile tire ranges from 20 to 90 ppm[28]. In general, the cadmium mean value from this work (2.84 mg/kg) is higher than those detected in other cities of the world except Bahrain[28], 7.2 mg/kg.

Mercury: Distribution of Hg along the sampling sites ranged from 0.59 (CND) to 1.89 mg/kg (TMB) with an average of 1.04 mg/kg for the same. The level of Hg in the control site was found to be 0.09 mg/kg. This indicates that the average Hg value in this study is nearly 12 times higher than that of the Hg value in the control site. The relatively higher concentrations of Hg in the study sites may be attributed to the pollution originating from traffic and anthropogenic activities. It is reported that several kinds of gasoline contain Hg and the combustion of gasoline brings Hg pollution[5]. In addition, Hg is used in the interior lights of a van and high intensity discharge-type headlights. Although few data on Hg contamination have been reported (table 3), in general, mercury mean value from this work (1.04 mg/kg) was higher than Kalava (Greece)[29], 0.1 mg/kg and lower than Bhilai city (India)[30], 2.1 mg/kg.

Correlation Analysis: The inter-element correlation coefficient (r) for roadside dust is presented in table 4. The correlation measures the strength of a linear relationship between any two variables. The results indicate that all the elemental pairs, Cd/Hg (r=0.912), Pb/Cd (r=0.702) and Pb/Hg (r=0.794) have very good correlation with each other. This means that roadside dust contamination by the metals originated from a common anthropogenic source.

Table-4
Inter-element correlations for roadside dust samples from the whole study sites

Element	Pb	Cd	Hg
Pb	1.000		
Cd	*0.702	1.000	
Hg	*0.794	*0.912	1.000

Significance level; *p<0.01

Pollution indices: The heavy metal contamination of the roadside dust was evaluated on the basis of the contamination factor and the degree of contamination as suggested by Hakanson[12]. Table 5 shows the values of the contamination factor and degree of contamination due to heavy metals. The contamination factor (*CF*) indicated very high contamination level ($6 \leq CF$) of Hg in all the sampling sites while Pb in six sites (TNK, JBC, LKT, TMB, SLG and SBN) and Cd in only one site (TMB) were observed. In the roadside dust for Pb (GTG, SDN and CND) and Cd (TKN, JBC, GTG and SLG), the contamination factors indicated considerable contamination levels ($3 \leq CF < 6$). Similarly, for Pb only HMB was found under moderate contamination level ($1 \leq CF < 3$) and for Cd, five sites *viz.*, LKT, SDN, HMB, CND and SBN fall under this class. These results indicate that the roadside dust across the road section under investigation was very highly contaminated with Hg followed by Pb and Cd.

The degree of contamination (*CD*) computed for each experimental site is shown in table 5. LKT, GTG, SDN, HMB and CND gave *CD* values of 16.17, 16.80, 14.02, 12.28 and 12.58 respectively. This shows considerable degree of contamination ($10 \leq CD < 20$) at five sampling sites. The highest degree of contamination ($20 \leq CD$) was found at TKN, JBC, TMB, SLG and SBN which is worrying because a lot of hawking activities occurred 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 are all known to be vulnerable.

The geo-accumulation index (I_{geo}) was calculated for the heavy metals and the results are given in table 5. The pollution level obtained from this analysis is as follows: four sampling sites (GTG, SDN, HMB and CND) were found to have $0 < I_{geo} \leq 1$ for Pb which shows that the environment is unpolluted to moderately polluted while two sampling sites (LKT and SBN) had $1 < I_{geo} \leq 2$ which indicates moderately polluted level by this element. The rest of the sampling sites (TKN, JBC, TMB and SLG) were found to have $2 < I_{geo} \leq 3$ which indicates moderately to strongly polluted environment. For the eight sampling sites (JBC, LKT, GTG, SDN, HMB, SLG, CND and SBN), Cd was found $0 < I_{geo} \leq 1$ indicating that the environment is in unpolluted to moderately polluted level while two sampling sites (TKN and TMB) lied in the range $1 < I_{geo} \leq 2$ indicating that the environment is in the moderately polluted level. The contribution of Hg is such that five sampling sites (LKT, GTG, SDN, HMB and CND) were found to have $1 < I_{geo} \leq 2$ moderately polluted level and three sites (JBC, SLG and SBN) showing moderately to strongly polluted environment. Similarly, TKN was found under strongly polluted ($3 < I_{geo} \leq 4$) class for Hg while TMB under strongly to extremely polluted ($4 < I_{geo} \leq 5$) class for the same element. The overall behaviour of these elements is that the environment along the road section is relatively less affected by Cd compared to Pb and Hg.

Conclusion

The present study was focused on the concentrations of Pb, Cd and Hg and their pollution levels in the roadside dust along the Kathmandu-Bhaktapur road section of Arniko Highway. From this work, it can be concluded that the dust samples exhibited an alkaline nature with variable electrical conductivity values. In addition, the elevated OC content and low level of CEC in dust samples compared to the control site were probably due to the influence of high organic matter and increased metal-ligand complexes formed. The mean concentrations of the metals in all the sampling sites were found to be higher than the background value (control) with the order of elemental abundance as Pb > Cd > Hg. Although leaded gasoline was phased out in Kathmandu in 1999, it seems that Pb is still a significant urban pollutant probably due to fuel combustion, automobiles and other urban activities. Among the sampling sites, the dust from Thimi Bazar (TMB) recorded the highest concentration of all the metals under investigation.

The contamination factor (*CF*) showed that Pb, Cd and Hg gave moderate to very high contamination level. Further, Hg was found to be a very significant contaminant in all the experimental sites compared to Pb and Cd. The results of the degree of contamination (*CD*) showed considerable to the highest degree of contamination level. Similarly, the index of geoaccumulation (*Igeo*) gave values in the range between unpolluted to moderately polluted level and strongly to extremely polluted level indicating the possibilities of the accumulation of heavy metals from anthropogenic sources. The results of all the indices employed agreed well in explaining the levels of the elements present in the roadside dust samples. Within the scope of this study, further studies will be required to ensure about the real sources of pollutants along with atmospheric transportation modeling. This would help in adopting the most efficient measures for reducing the risk of inhalation and ingestion of dust for humans and risk for the environment.

Table-5
Contamination factor (*CF*), degree of contamination (*CD*) and geo-accumulation index (*Igeo*) of potential toxic metals in roadside dusts along the road section

CF										
	TKN	**JBC**	**LKT**	**GTG**	**SDN**	**TMB**	**HMB**	**SLG**	**CND**	**SBN**
Pb	10.96	10.54	6.02	4.59	4.41	14.32	2.10	11.31	4.12	6.15
Cd	5.20	3.88	2.04	3.21	2.61	7.50	1.96	3.76	1.90	2.54
Hg	17.11	12.67	8.11	9.00	7.00	21.00	8.22	13.89	6.56	12.22
CD	33.27	27.09	16.17	16.80	14.02	42.82	12.28	28.96	12.58	20.91
Igeo										
	TKN	**JBC**	**LKT**	**GTG**	**SDN**	**TMB**	**HMB**	**SLG**	**CND**	**SBN**
Pb	2.21	2.13	1.21	0.93	0.89	2.89	0.42	2.28	0.83	1.24
Cd	1.05	0.78	0.41	0.65	0.53	1.51	0.40	0.76	0.38	0.51
Hg	3.45	2.56	1.64	1.82	1.41	4.24	1.66	2.80	1.32	2.46

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