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Short Communication

Heavy metal accumulation in indoor ceiling fan dust from residential areas of Kathmandu Municipality, Nepal: A potential urban environmental problem

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Abstract

Heavy metals accumulation in indoor dust from residential areas of Kathmandu municipality is increasingly becoming an urban environmental issue of health concern. In this study, ceiling fan dust samples were collected from residential buildings of 5 core areas of Kathmandu viz., Basantapur, Nayabazar, Bhotahity, Bagbazar and Kirtipur (reference). The collected dust samples were analyzed for the concentrations of Cd, Zn, Ni and Cu using Atomic Absorption Spectrophotometer. Metal concentrations indicated that ceiling fan dust from all the sampling sites contained high levels of heavy metals compared to reference site. Results revealed that Bagbazar site was found to have the highest accumulation of all the metals and Basantapur recorded the lowest concentrations in dust samples. In all the sampling locations, the metal accumulations were obtained in abundance following the order as Zn > Cu > Ni > Cd. The average accumulations of all the sampling sites for Cd, Zn, Ni and Cu in dust samples were 0.77, 423.68, 29.04 and 244.08 µg/g respectively while the enrichment factor indicated a slight to excessive degree of metal enrichment. The correlation analysis showed the similar sources of contamination to metal levels in indoor dust. A regular monitoring is suggested for indoor environmental status in urban areas of Kathmandu.

Keywords: Dust, Heavy metals, Indoor environment, Kathmandu municipality.

Introduction

Dust may be considered to be a derivative of solid, liquid and gaseous materials produced from different sources[1] and can range from 1 to 1000µm in size[2]. They originate from different sources depending on climate, human activities, soils and rocks of the surrounding areas etc., and hence their composition varies[3]. In fact, the components and quantity of dust are often regarded as pollution indicators.

Heavy metals such as Cu, Pb, Fe, Cd, Ni, Cr and Zn can be suspended into dust particles from various sources which may include industrial discharges, vehicular emissions, automobile accessories, oil lubricants, materials corrosion and construction and demolition activities[4]. Through atmospheric deposition, they will eventually fall to the ground and/or resuspended into the atmosphere again[5,6]. There is a growing issue of the subject in the scientific community today since their presence in the urban environment has become the potential threat to humans due to their toxic effects[7].

According to the US EPA (1986) report, populations exposed to Cd, Cu, and Zn pollutants are victims of nervous system failure[8]. Therefore, the monitoring of such material has gained a top priority in risk assessment programs particularly in evaluating the risk of inhalation and ingestion of dust for humans, especially for children[9].

Although studies on this pertinent area are rather few, these are more relevant with researches on household or indoor dust[10-12]. Despite the abundant literature about dust, there are very limited research reports on heavy metal accumulation in indoor ceiling fan dust in Nepal. Hence, the objectives undertaken for the present study were to determine the concentrations of metals (Cd, Zn, Ni and Cu) in ceiling fan dust collected from residential buildings of five different core residential areas including control and to carry out contamination assessment using enrichment factor for characterizing different indoor environment in Kathmandu municipality.

Materials and methods

Study area, collection of dust sample and processing: Among Kathmandu, Lalitpur and Bhaktapur districts of Nepal, Kathmandu is the first city in the country with the municipal status (Metropolitan city). The city is densely populated with 20,288 inhabitants per square kilometer. For the present study, five core residential areas of Kathmandu municipality *viz.*, Basantapur, Nayabazar, Bhotahity, Bagbazar and Kirtipur (control) were selected for ceiling fan dust collection in order to compare the levels of metal contaminations for characterizing the different indoor environment. The sampling locations for ceiling fan dust measurements were based on different domain activities. A brief description of the sampling locations under investigation is given in Table-1.

Table-1: Description of sampling sites in Kathmandu municipality.

Site No.	Name of sampling sites	Site description
1	Basantapur	Medium traffic load, residential and religious area, traditional buildings and pagodas, tourist area, and densely populated
2	Nayabazar	Medium to heavy traffic load, residential and commercial area, densely populated and Ring-road junction
3	Bhotahity	Medium traffic load, religious area, residential and commercial area, and densely populated
4	Bagbazar	Medium to heavy traffic, residential area, shopping complexes, institutions and densely populated
5	Kirtipur (control)	Low traffic load, sparse residential and undisturbed area

Dust from ceiling fan was sampled randomly from residential buildings of each selected core sampling location. The samples were collected during dry season. From each point of sampling locations, about 5-10 g of dust was collected from the ceiling fan using a brush and a dustpan. The collected samples were directly transferred to polyethylene bags and sealed tightly before taken to the laboratory for further processing. For ease and to maintain uniformity, dust sample from first floor only was collected. For the sampling purpose, only rust free ceiling fans were selected to avoid any kind of metal contamination. The samples were placed in an oven and dried for 24 hr at 105 °C to drive out moisture and used without sieving. It is due to the fact that all sizes of the dust particles trapped by fans are potentially inhaled by humans[13].

Determination of heavy metals (Cd, Zn, Ni and Cu): For determination of heavy metal concentrations, accurately 0.5 g of each dried sample was weighed and taken in digestion tube (3 replicates) and digested in 20 ml of freshly prepared aqua-regia (v/v 1:3 HNO_3:HCl)[14]. The digestion tubes were placed on the digestion block and subjected to temperature programming heating the tubes initially at 40°C for 1 hour first and then to 140°C for the next 2-3 hours. The tubes were cooled and filtered using Whatman filter paper 42. The filtrates were transferred into separate 50-ml volumetric flasks, and the volume was made up to the mark with distilled water. Then, all the polyethylene containers pre washed with acid solution were filled up with the sample solutions and stored at 4°C until further analysis. The same process was repeated for all the samples under investigation.

The standard solutions (1000 ppm) of certified grade for Cd, Zn, Ni and Cu were obtained from Merck, Germany. Distilled water was used for diluting the standards into solutions of required concentrations and used for calibration. The content of 4 elements (Cd, Zn, Ni and Cu) was determined by Atomic Absorption Spectrophotometer (Model 2380, Perkin Elmer, Inc., Norwalk, CT, USA) using air-acetylene flame. The instrumental parameters were maintained as per the recommendation of the manufacturing company. Quality control was maintained throughout the experiment by analyzing simultaneously the reagent blanks, standard samples and duplicate samples. The analytical precision, measured as relative standard deviation, was routinely 3–5%. Data were analyzed using statistical software. Descriptive statistics such as mean and standard deviation were calculated and computed. The Spearman's correlation coefficients (r) among the parameters were calculated at 5% significance level ($p<0.05$).

Assessment of Contamination index (Enrichment factor, EF_x): EF_x was used to estimate the amount of metals introduced anthropogenically in dust in ceiling fan. The factor was calculated with respect to the natural concentration of each fraction in the area studied, by the expression given below[15]:

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

Where: X refers to the concentration of metal in each sample (µg/g) and X_{ref} is the reference concentration of metal in each sample (µg/g) from the study area. Here, Kirtipur (control) was taken as reference area and the concentration of metal from this area was taken as reference concentration. The selection of reference site was based on non-evidence of anthropogenic activities in the past and present to a significant extent.

The degree of pollution as demonstrated by enrichment factor (EF_x)[16] is classified 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).

Results and discussion

Heavy metal accumulation in dust samples: Cd, Zn, Ni and Cu were determined in dust samples collected from 5 sampling sites including reference site. Table-2 represents the average metal concentrations (µg/g dry weight) in dust samples from different sampling sites of Katmandu municipality.

The indoor metal accumulation may be expected from various reliable sources such as indoor pollutants, infiltration of outdoor dust and indoor humidity accelerating absorption of metals [20]. During the period of sampling, it was observed that most of the sampling sites were poorly ventilated as the windows were seldom opened by the occupants. Jabeen et al.[12] also found similar results in the interior house dust with little ventilation with the source of Cd contamination from paintings and carpets[12]. Furthermore, the higher level of metals in the present study might be due to collection of dust particles in the ceiling fans over long period.

Table-2: Heavy metal accumulation (µg/g dry wt.) in ceiling fan dust from different locations of Kathmandu municipality (Mean ± SD) and Enrichment factor (EF).

Sampling sites	No of samples analyzed (N)		Cd	Zn	Ni	Cu
Basantapur	10	Mean	0.15 ± 0.04	250.15 ± 9.44	12.38 ± 1.03	126.27 ± 6.30
		EF	1.9	2.5	1.8	1.9
Nayabazar	8	Mean	0.84 ± 0.03	497.20 ± 16.10	36.64 ± 2.46	277.29 ± 7.78
		EF	10.5	5.0	5.4	4.1
Bhotahity	9	Mean	0.50 ± 0.15	350.24 ± 10.20	23.61 ± 4.23	204.22 ± 61.45
		EF	6.3	3.6	3.5	3.0
Bagbazar	12	Mean	1.58 ± 0.12	597.13 ± 22.24	43.52 ± 5.75	368.55 ± 18.65
		EF	19.8	6.1	6.4	5.4
Kathmandu municipality	39	Mean of all sites	0.77	423.68	29.04	244.08
Kirtipur (Control)	6	Mean	0.08 ± 0.01	98.64 ±8.12	6.76 ± 0.58	68.34 ± 6.56

In addition, the accumulation of heavy metals in ceiling fan dust could be due to the atmospheric deposition of dust inside houses. Sources such as mechanical abrasion of vehicles, brake linings, lubricant oil, tyres and gaskets also contribute significantly an ample quantity of Cu and Zn[21]. Moreover, metal concentration, distribution, and its' retention time in street dust are likely to be influenced by weather as well[22]. Fergusson et al.[23] found a strong correlation between metal loadings and the quantity of dust accumulated in house and also with the volume of carpet used[12].

The correlation among heavy metals under study is shown in Table-3. Data reveled significance (at least $p<0.05$) and positive correlations between Cu-Ni (0.918), Zn-Cd (0.464), Ni-Cd (0.229), Ni-Zn (0.289), Cu-Cd (0.457), and Cu-Zn (0.807). Such correlations among Cd, Zn, Ni, and Cu might indicate similar sources of contamination such as traffic emissions, construction and demolition activities and other anthropogenic activities.

Table-3: Spearman's correlations among metals.

	Cd	Zn	Ni	Cu
Cd	1			
Zn	0.464	1		
Ni	0.229	0.289	1	
Cu	0.457	0.807*	0.918*	1

Enrichment of heavy metals: Table-2 also shows enrichment level for sampling sites, with the level of metals influenced by locations. Following the enrichment factors (location wise), the results revealed that Nayabazar and Bagbazar demonstrated similar metal enrichment order as Cd>Ni>Zn>Cu. While Bhotahity followed enrichment order Cd>Zn>Ni>Cu, Basantapur showed different order as Zn>Cd=Cu>Ni. Likewise, Bagbazar fan dust was excessively enriched with Cd (EF = 19.8) but Bhotahity and Nayabazar locations demonstrated severe to very severe degree of enrichment for Cd (EF = 6.3 to 10.5). Basantapur dust showed only slight enrichment of the metal (EF=1.9). As for Zn, Nayabazar and Bagbazar dust showed severe enrichment (EF=5.0 to 6.1), while Basantapur and Bhotahity dust demonstrated moderate degree of enrichment (EF = 2.5 to 3.6). For Ni, dust samples of Nayabazar and Bagbazar showed severe enrichment (EF= 5.4 to 6.4) while Bhotahity dust showed moderate enrichment (EF = 3.5). For Basantapur, slight enrichment (EF = 1.8) was noted for the same metal as that of Cd. For Cu like that of Ni, same pattern of metal enrichment was recorded in all the study areas.

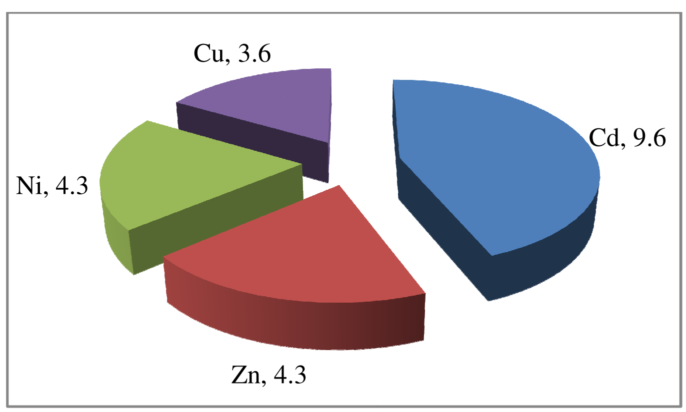

Figure-1: Total metal enrichment in indoor dust of Kathmandu municipality.

Considering the mean of all four study locations and enrichment factor calculated thereafter, it appears that indoor dust environment as demonstrated by ceiling fan dust from some core residential areas of Kathmandu municipality is enriched very severely by Cd (EF = 9.6), severely by Zn and Ni (EF = 4.3) and moderately by Cu (EF = 3.6) as shown in Figure-1.

Conclusion

The present investigation was carried out to assess the accumulation of Cd, Zn, Ni and Cu in ceiling fan dust from residential buildings of some core area of Kathmandu municipality for characterizing different indoor environment. Results suggested that dust samples contained elevated levels of metals in all the locations compared to control site. The levels of metal accumulation were obtained as Zn>Cu>Ni>Cd in all the sampling sites. This indicates the preferential distribution of metals which is distinctly influenced by the study area and metal sources. Considering the overall metal levels, the affected area by their indoor dust pollution may be ranked as Bagbazar > Nayabazar > Bhotahity > Basantapur. Correlation analysis among metals revealed similar sources of contamination.

Contamination assessment in all the sampling sites showed a varying degree of metal enrichment ranging between slight to excessive. Among the sampling site, ceiling fan dust from Bagbazar was found more susceptible and Basantapur showed least susceptible for metal enrichment. Considering the mean metal enrichment from dust of all the four sampling sites, the indoor environment in the residential areas of Kathmandu municipality is contaminated very severely by Cd, severely by Zn and Ni, and moderately by Cu. The size of dust particle is often considered as a factor for major environmental and health hazard because they are easily transported and inhaled. Hence, we conclude that a monitoring of indoor dust environment at regular interval is needed in urban areas of Kathmandu considering its relationship with human health.

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