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Demonstrating urban pollution using heavy metals in road dusts from Lucknow City, Uttar Pradesh, India

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Abstract

Increasing urbanization and growth in vehicular density has become a growing concern in recent years. Road dusts in urban areas are indicators of heavy metal contamination. In present study road dust samples have been taken from 30 representative locations categorized as residential, commercial and industrial areas in Lucknow city for assessing the concentration of eight heavy metals. Results showed that road dust samples contained significantly high levels of the metals as compared to the values from the background site. In all the road dusts, iron is the most available and labile element followed by zinc. Road dusts concentration varied from 2365.21-10652.01 for Fe, 94.11-374.23 for Zn, 58.80-185.56 for Mn,5.45-55.26 for lead, 6.63-60.12 for Cu, 3.07-26.45 for Cr, 2.50-18.69 for Ni and 0.14-0.85 for Cd. All concentration values are in mg/kg. Contamination was assessed on the basis of contamination factor and pollution load index. The overall degree of contamination is of the order industrial> commercial > residential. A very significant correlation was found between zinc, copper, lead and chromium. The results of multivariate analysis showed that Zn, Cr, Cu, Pb & Ni were associated mainly with anthropogenic activities while Fe and Mn was controlled by lithogenic materials.

Keywords: Anthropogenic, Background, Commercial, Heavy metal, Road dust, Traffic emission

Introduction

Roads are important infrastructure of an urban area that plays a major role in stimulating social and economic activities. Although roads are associated with several benefits, they even give rise to various harms because of it. Dust is primarily originate from the earth's crust represents complex chemical composition and formed from the interaction of solid, liquid and gaseous materials (Hjortenkrans, et al., 2006). Road dust particles comes from diversity of mobile and stationary sources such as fuel burning, waste incineration, construction and demolition activities, weathering of building material and sidewalk surface degradation, aerosols that are carried freely by air currents, water transported material from surrounding soils and slopes, vehicular & industrial generated dust (Khan, et al., 2008; Bai, et al., 2008; Wong, et al., 2006; Oliva and Espinosa , 2007; Manasreh, 2010; Wei and Yang, 2010). Dust particles are contaminated from various organic and inorganic compounds. Heavy metals in road dust may come from many different sources but one of the most important being vehicular emissions. The origin of heavy metals in the roadside dusts is generally linked to the burning of fuel in internal combustion engines, wear and tear of tires, leakage of oil from the vehicles, welding and body work and corrosion of batteries and metallic parts such as radiators, but road surface degradation, emissions from nearby industries, incineration activities, solid waste dumping, constructional activities are also play an important role (Ahmed and Ishiga, 2006; Banerjee, 2003; Ferreira-Baptista and De Miguel, 2005). The most common heavy metals introduced to the environment by overland transportation are lead, nickel, zinc, cadmium, copper, chromium, mercury, cobalt and iron (Akbar, et al., 2006; Faiz, et al., 2009). Use of leaded gasoline in previous decades is responsible for lead deposition in road side dust and soil. Cu, Zn and Cd come from tyre abrasion, engine oil and industrial emissions (Thorpe and Harrison, 2008). The source of Ni, Cd and Cr in street dust is believed to be due to corrosion of painted layer and chrome plating of motor vehicle parts (Lu, et al., 2008). Brake dust and crushed

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brake pads analyses indicate high concentrations of Iron and Copper (Adachia and Tainoshob, 2004). The concentration of metals also related with population density, traffic volume, road surface condition, construction design e.g. material of road surface and wear. The relationship between the metal content of urban soils and distance from the roads has been widely investigated and many studies have shown that metal concentrations decrease exponentially with the distance from roads (Zehetner, et al., 2009; Wu, et al., 2011). Heavy metals deposited in road dust by dry or wet atmospheric deposition, sedimentation, impaction and interception. These metal pollutants are deposited on adjacent soil and dust where they may be transformed and transported to other parts of the environment such as vegetation, underground water by leaching (Okunola, et al., 2008). Plants grown in the neighbourhood of major motorways have also been reported to contain metals such as Pb and Cd from motor vehicle emissions (Sharma and Prasade, 2010). Atmospheric deposition, leaching and resuspension in air in turn depend on various factors and other metrological conditions, such as particle size of the pollutant, wind direction, wind velocity, frequency and intensity of rain events, previous dry periods, highway or road design and vegetation cover (Pagotto, et al., 2001). Heavy metals are of particular concern due to their non-biodegradable quality, long residence time and their toxicity to human. Toxic effects of heavy metals have been well studied. Many people who use to live near roadways and industrial premises and children who used to play near roadside parks, playgrounds and schools respectively may be exposed to toxic heavy metals in road dust (Habil, et al., 2013). Human beings are exposed to road dust through three main pathways: (1) Ingestion of dust particles (2) Direct Inhalation of dust particles (3) Dermal contact or absorption of dust particles (De Miguel et al., 2007; Shi et al., 2011). In particular , more concern needs to be shown for children than adults because of their frequent hand – to- mouth activities (finger sucking) and their higher absorption rate from the digestion system, and haemoglobin sensitivity to toxic metals (Li, et al., 2007; Meza-Figueroa, et al., 2007; Shi, et al., 2008). The adverse effects of heavy metals in road dust include respiratory system disorders, nervous system interruptions, endocrine system malfunction, immune system suppression and the risk of cancer in later life (Han, et al., 2006). Lead poisoning causes permanent neurological, developmental, and behavioural disorders, particularly in children (Laidlaw, et al., 2005). Hypoglycaemia and anaemia are linked to copper excess. Cadmium listed as a suspected carcinogen and accumulates in the kidneys. Zinc is an essential element that is used for enzymatic purposes. However, excess levels will interfere with the metabolism of iron and copper within the body. Large doses will lower manganese levels and increase susceptibility to autoimmune reactions. Environmental and health effects of heavy metal contaminants in dust are dependent initially on the mobility and availability is a function of their chemical speciation and partitioning within or on dust matrices.

Materials and Method

Study Area

The study area selected for this work is Lucknow city, the capital city of Uttar Pradesh. The city lies at l80º 56’ E longitude and 26º 52’ N latitude being 128 m above sea level. It has total area of approximately 310 km^2. Good infrastructure, presence of various other amenities, well connected routes of transportation make the city densely populated with a population of 28.15 lakhs (2011 census). Being the capital, Lucknow has a well connected system of roads within itself and between other cities. Due to large population of the city and presence of number of roads, numerous vehicles run on the roads of the city ranging from public transport vehicles, heavy diesel vehicles, personal owned vehicles etc. The total vehicular population in Lucknow city as on 31^{st} march, 2013 was 1424478, which showed 8.38% growth in its number in comparison to previous year (source: RTO, Lucknow). Thirty locations were chosen for sampling collection and from each location four to six subsamples were taken and then mixed thoroughly to obtain a bulk sample. The locations were grouped into three different types of land use, viz., residential, commercial and industrial. Street dusts were collected under stable weather conditions in the cold and dry season during the year 2014. Map of study area and sampling sites are shown in figure 1.

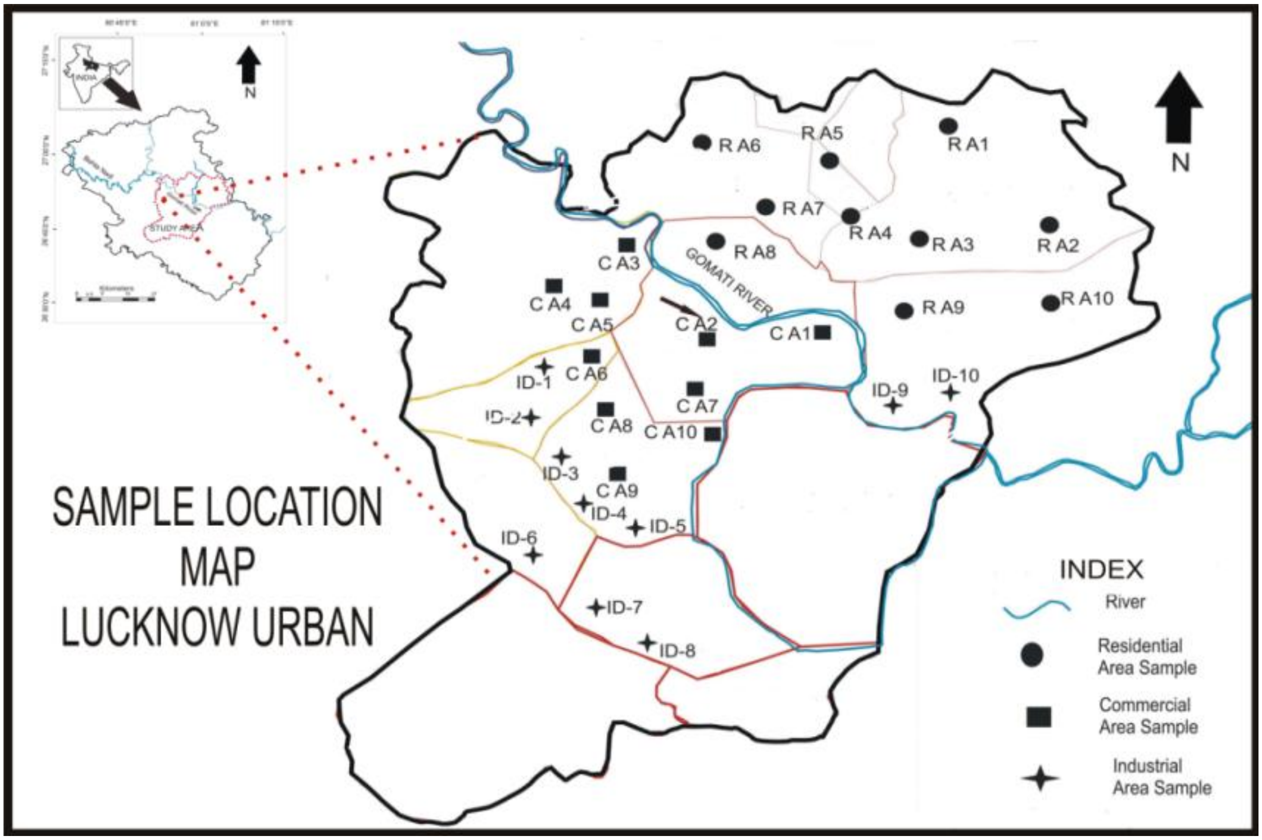

Figure 1. Map of sampling area showing sampling locations

Sampling sites and Sample collection

Thirty locations were chosen for sampling collection and from each location four to six subsamples were taken and then mixed thoroughly to obtain a bulk sample. The locations were grouped into three different types of land use, viz., residential, commercial and industrial. In a sampling point dusts was collected at roadsides with a clean plastic pan and a brush and were transferred to self sealing polybags. Description of sampling location is given in table 1.

Sampling procedure and analysis

Dust samples were air-dried and sieve through a 2 mm sieve to remove large debris, stones. One gram of sample was digested in 20ml of tri-acid mixture using an acid digestion: HNO_3, H_2SO_4, and $HClO_4$ (5:1:1). Addition digestion processes with the last three acids were needed according to the digested degree. Digested extracts were was filtered and final volume made-up to 15 ml by double distilled water. The filtrate was examined for the concentration of Pb, Ni, Fe, Cr, Cd, Cu, Zn and Mn by AAS (GBC AVANTA SIGMA). The instrument was calibrated for each metal using known CRM (Accucheck) before analysis.

Contamination assessment

To assess the extent of contamination of heavy metals in roadside dusts and also provide a measure of the degree of overall contamination along a particular location, contamination factor (CF) and pollution load index (PLI) has been applied.

Contamination Factor (CF):

The contamination Factor (CF) parameter is expressed as:

$$CF = C_{metal} / C_{background}$$

Where CF is the contamination factor, C_{metal} is the concentration of pollutant in sediment $C_{background}$ is the background value for the heavy metal. The CF reflects the heavy metal enrichment in the sediment. The CF was classified into four groups (Nasr, et al., 2006; Mmolawa, et al., 2011). Where the contamination factor CF < 1 refers to low contamination; 1 ≤ CF < 3 means moderate

Land Use Type	Sample code	Sampling area	Population load	Traffic load
Residential Area	RA-1 To RA-10	Aligang,Indiranagar,Vikasnagar, Gomtinagar, Triveni nagar	Dense	Medium
Commercial Area	CA-1 To CA-10	Hazaratganj, chowk, aminabad, Almbagh, Charbagh	Dense	Heavy
Industrial Area	ID-1 To ID-10	Chinhat ,Amausi, Mohanalganj, Aishbagh,Talkatora	Dense	Heavy

Table 1. Description of sampling location

contamination; 3 ≤ CF ≤ 6 indicates considerable contamination and CF > 6 indicates very high contamination.

Pollution load index:

Each land type is evaluated for the extent of heavy metal pollution by employing the method based on the pollution load index (PLI) developed by Thomilson et al., 1980, as follows:

$PLI = \sqrt[n]{(CF_1 \times CF_2 \times CF_3 \times \dots\dots CF_n)}$

Where n is the number of heavy metals studied (Eight in this study) .The PLI provides simple but comparative means for assessing a site quality, where a value of PLI < 1 denote perfection; PLI = 1 present that only baseline levels of pollutants are present and PLI >1 would indicate deterioration of site quality.

Background (control) data

Geochemical baseline maps are not yet available in India though work is initiated under global geochemical baseline programme. Three soil samples were collected and analyzed as a background (control) sample where there were no anthropogenic activities like traffic emission, agricultural practice and dumping influence. The mean metal concentrations of these samples were taken as local natural background data. For the dusts, the CF and PLI were calculated with respect to local natural background concentrations.

Results and Discussion

Average concentration of heavy metals in roadside dusts

The basic statistical descriptions of heavy metal concentrations (µg/g) in roadside dusts and background site are listed in table 2. On average, the concentrations of Lead is 10.74, 23.96, 42.98, Iron is 3411.34, 6666.79, 8407.46, Manganese is 82.36, 116.88, 128.83, Zinc is 117.96, 164.85, 250.23, Copper is 17.37, 16.70, 40.85, Chromium is 6.17,11.70, 14.83, nickel is 3.87, 10.31, 9.88 and cadmium is 0.34, 0.44, 0.49 for residential commercial and industrial locations respectively.

Table 2. The range and average values of heavy metals for three types of land uses

Metal	Concentration in µg/g							
	Residential		Commercial		Industrial		Background values	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
Fe	2365.21 -3942.00	3411.34 ±524.67	4524.13 -8589.23	6666.79 ±1314.44	6654.23 -10652.01	8407.46 ±1240.67	1925.56 -3869.25	3310.25 ±205.26
Mn	58.80 -112.36	82.36 ±15.81	93.00 -158.36	116.88 ±22.86	65.23 -185.56	128.83 ±40.23	40.85 -.45.12	45.23 ±10.65
Zn	94.11 -145.60	117.96 ±14.77	113.67 -222.34	164.85 ±40.37	135.75 -374.23	250.23 ±84.43	55.62 -62.40	30.50 ±4.12
Pb	5.45 -15.48	10.74 ±3.63	12.63 -42.56	23.96 ±10.79	32.32 -55.26	42.98 ±7.25	3.25 -5.69	5.12 ±2.15
Cu	6.63 -50.77	17.37 ±13.55	7.00 -32.45	16.70 ±8.79	13.35 -60.12	40.85 ±12.53	3.55 -6.66	5.6 ±3.24
Ni	2.50 -5.92	3.87 ±1.24	6.04 -18.69	10.31 ±5.02	3.53 -15.36	9.88 ±4.00	1.10 -1.55	1.36 ±0.24
Cd	0.14 -0.56	0.34 ±0.16	0.33 -0.65	0.44 ±0.11	0.23 -0.85	0.49 ±0.22	0.06 -0.10	0.08 ±0.04
Cr	3.07 -8.23	6.17 ±1.65	5.53 -18.69	11.30 ±4.37	6.90 -26.45	14.83 ±5.87	2.55 -3.25	2.80 ±0.50

The decreasing order of averages heavy metal concentration was as follows Iron >> >Zinc > Manganese > Copper > Lead > Chromium > Nickel > Cadmium in residential areas, Iron >>>Zinc > Manganese > Lead > Copper > Chromium > Nickel > Cadmium in commercial area and Iron > >Zinc > Manganese > Lead > Copper > Chromium > Nickel > Cadmium in industrial area. Minimum concentration values of all the metals have been found along the residential area road dusts which experiences the less traffic density and no industrial activity. Maximum concentration values of all metals except nickel found in the road dusts of the industrial areas because of emissions from various industrial activities like fuel combustion, waste dumping and vehicular emissions. From the Fig 2, it can be concluded that the average concentrations of metal are more correlated in the industrial activity. The scatter plots of Ternary show that the emissions of metal through commercial activity are less as followed by residential and Industrial activities.

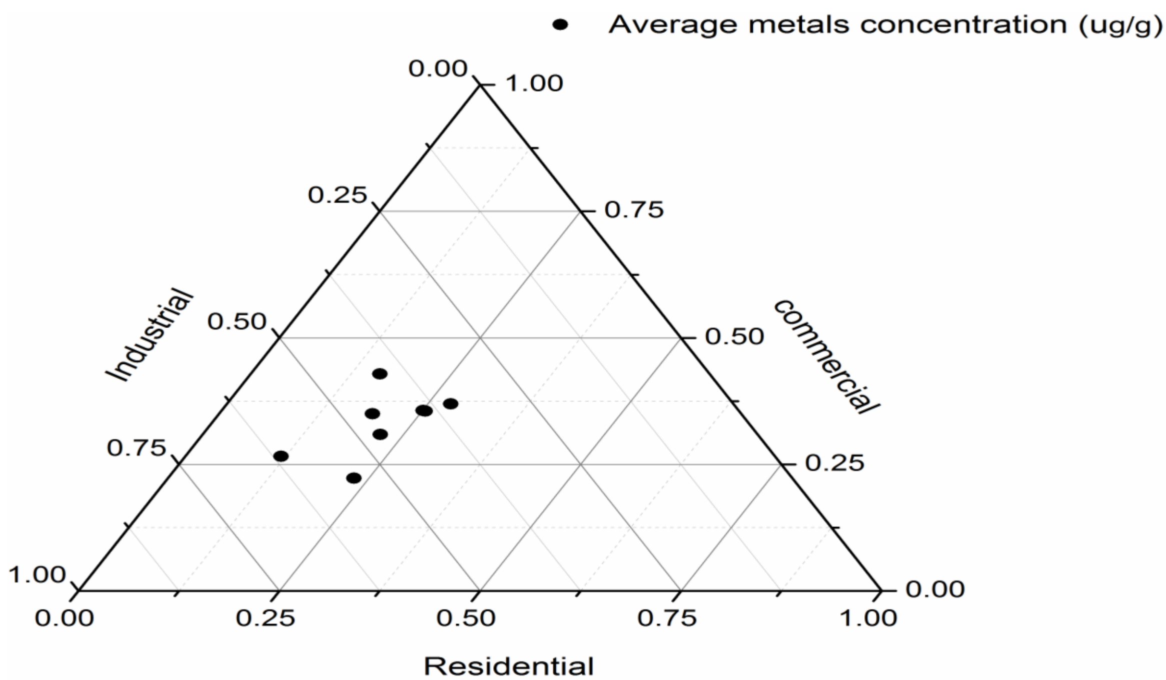

Figure 2. Ternary plot showing the concentration of metals in different land use

Correlation Coefficient Analysis

Correlation coefficient analysis was conducted to evaluate the inter element relationships in the road dusts. From Table 3 we have observed that almost all metals are positively correlated with each other. High positive correlation found between zinc and lead($r = 0.77$, $p<0.01$), lead and copper ($r = 0.74$, $p<0.01$), chromium and lead($r = 0.77$, $p< 0.01$), nickel and chromium ($r =0.83$, $p<0.01$). Moderately correlated between zinc and magnesium ($r = 0.62$, $p<0.01$), lead and magnesium ($r = 0.62$, $p<0.01$), nickel and magnesium ($r = 0.50$ $p<0.01$), chromium and magnesium($r = 0.56$, $p<0.01$) zinc and copper($r = 0.57$, $p<0.01$), lead and nickel ($r = 0.56$, $p<0.01$) and copper and chromium($r = 0.66$, $p<0.01$). The positive correlation indicates that dust metals were probably well mixed through transportation by winds and by vehicle wheels in this study area. The high positive correlations of dust zinc, copper, chromium might have come from a common metal source from the road intersection.

Table 3. Correlation matrix for road dust samples

Metal	Mn	Zn	Pb	Cu	Ni	Cd	Cr	Fe
Mn	1	0.62**	0.62**	0.35	0.50**	0.32	0.56**	0.03
Zn		1	0.77**	0.57**	0.37*	0.30	0.49**	0.47**
Pb			1	0.74**	0.56**	0.32	0.77**	0.26
Cu				1	0.46*	0.08	0.66**	0.24
Ni					1	0.35	0.83**	0.27
Cd						1	0.32	-0.15
Cr							1	0.18
Fe								1

**** Correlation is significant at the 0.01 level (2-tailed**
*** Correlation is significant at the 0.05 level (2-tailed**

Contamination Factor

The contamination factor (CF) for each heavy metal at each land use type was calculated according to the equation previously described and presented in table 4. Table indicate that in residential locations most of the metals are moderately contamination category except Cd, Zn and Cu which are considerable contamination category. In commercial locations Fe, Mn & Pb are moderately contamination category, Zn, Cd, Cr and Cu are in considerable contamination category and Ni comes under high contamination category. Zn and Cu are mostly comes from tyre abrasion, break pad wear whereas Cr, Cd, Ni and Fe comes from engine wear and corrosion of metal parts. Lead is banned from last few years but still some concentration found in fuel and engine oil. In industrial locations Fe and Mn comes under moderate contamination category, Pb and Cr are in considerable contamination category, Zn, Cu, Cd & Ni are in high contamination category. In industrial area heavy duty vehicle are common for loading and unloading of goods. Many small scale metal related workshops, construction activities and waste from battery manufacturing industry are common source of Cd, Cu and Ni.

Table 4. Contamination Factor of heavy metals in roadside dusts in different types of land uses

Land use type	Fe	Mn	Zn	Pb	Cu	Cr	Ni	Cd
Residential	1.0	1.8	3.9	2.1	3.1	2.2	2.8	4.0
Commercial	2.0	2.6	5.4	2.7	3.0	4.0	7.6	5.6
Industrial	2.5	2.8	8.2	4.1	7.3	5.3	7.3	6.1

Pollution load index in different types of land uses

To effective compare whether the three land use types suffer contamination or not, the pollution load index (PLI) described earlier was applied. The PLI is aimed at providing a measure of degree of the overall contamination at the sampling sites along the various land use types. Figure 3 shows results of the PLI for the eight metals studies at the various land use types i.e. residential, commercial and industrial. Based on the results presented in figure 3, the overall degree of contamination is of the order industrial> commercial > residential. Industrial area show strong signs of pollution or deterioration of site quality, whereas residential and commercial exhibited signs of less pollution comparatively.

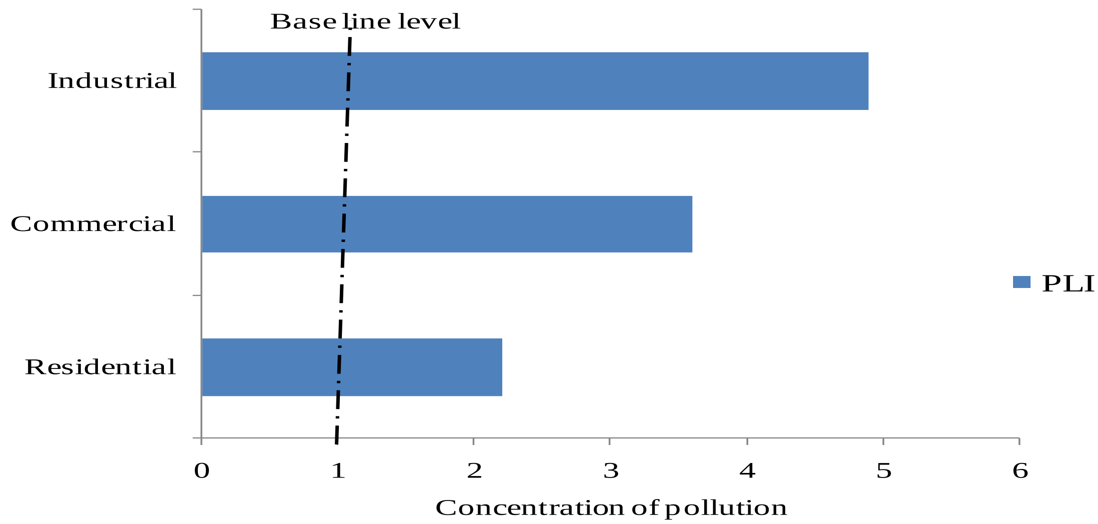

Figure 3. Pollution Load Index of different land use

Relatively high PLI values at industrial and to some extent commercial area suggest input from anthropogenic sources attributed to industrial activities and vehicular emissions.

Commercial areas have a number of commercial centres and shops and having heavy population. Heavy vehicular density, frequent stop start pattern of vehicles, road congestion is also responsible for heavy pollution. Industrial areas having many large scale industries and apart from that many road side storage houses, small industries, storage houses, construction activities and many road side motor workshops also contributed to increase heavy metal pollution. Heavy vehicular density especially heavy duty vehicles are increasing heavy metal pollution on road side dust.

Land use type	PLI
Residential	2.42
Commercial	3.99
Industrial	5.47

Principal component analysis (PCA)

In the present study, a principal component analysis (PCA) with Varimax normalization algorithm was applied for dataset of eight heavy metal. The results of PCA analysis are displayed in table 5.

Table 5. Total variance explained and component matrix for heavy metal content

Elements	**Principal component**	
	PC1	**PC2**
Fe	0.348	0.784
Mn	0.726	-0.269
Zn	0.802	0.230
Pb	0.916	0.043
Cu	0.755	0.229
Cr	0.878	-0.112
Ni	0.767	-0.128
Cd	0.411	-0.675
Eigenvalues	4.228	1.278
% of variance	52.856	15.980
Cumulative %	52.856	68.836

Table 6. Comparisons of mean concentrations (μg/g) of metals of road dusts in different areas

City	Fe	Zn	Mn	Pb	Cu	Cr	Ni	Cd	Reference
Present study	**6161.87**	**177.68**	**109.36**	**25.89**	**24.97**	**10.77**	**8.02**	**0.42**	
Delhi, India	-	3700	-	150	1300	9000	980	-	Banerjee (2003)
Anand city, India	-	66	-	87	83	-	65.6	-	Bhattacharya et al. (2011)
Ottawa	-	112.5	-	48	65.84	43.3	15.2	0.37	Rasmussen et al. (2001)
Islamabad,pakistan	-	116	-	104	52	-	23	-	Faiz. et al. (2009)
Dhaka bangladesh	-	169	-	54	105	136	35	-	Ahmad F, Ishiga H (2006)
Birmingham , UK	-	534	-	48	466		41	1.62	Charlesworth et al. (2003)
Beijing , China	-	214	-	61	42	85	-	1.20	Taner et al. (2008)

As a consequence; heavy metals could be grouped into a two-component model that accounts for 68.8% of all the data variation. In the component matrix, the first PC (PC1, variance of 52.8 %) included Pb, Cr, Zn, Ni and Cu while the second PC (PC2, variance of 15.9%) was constituted by Fe. PC1, including Pb, Cr, Zn, Ni, and Cu can be defined as an anthropogenic component due to its high-vehicular density observed in the present study. In the sampling sites, higher content of Zn might have come from the abrasion of tyre wear and break wear. However, Zn and its compounds are also used in different manufactured goods (e.g., paints, cosmetics, batteries and electrical apparatus). Lubricant oil, engine oil in dense traffic is the main source of Pb contents found in some road dusts. Cu and Cr come from tyre abrasion, lubricants and industrial & incinerator emissions. The source of Ni, Cd and Cr in street dust is believed to be due to corrosion of vehicular parts and chrome plating of some motor vehicle parts .Copper is mainly released from the wear of brake linings which are also an important source of lead and zinc. Fe which could be considered as a natural component and its distribution had lithogenic control and this metal was included in the second principal component (PC 2). It can be concluded that Pb, Cr, Zn, Ni and Cu in soil of study area were generally play a significant role in contamination whereas Fe play a second level contamination level in soil. The sources of Mn and Cd in road dust is not very clear but may be comes from vehicular and industrial activities.

Conclusions

The concentration of heavy metals Fe, Mn ,Zn ,Pb ,Cu ,Cr ,Ni ,Cd and their contamination level in road dusts from different land use types collected in the Lucknow city have been studied in this work. Two contamination indexes namely contamination factor (CF) and pollution load index (PLI) were used in the assessment of level of metal contamination in the study area. Heavy metal concentration found higher in industrial areas followed by commercial areas. High concentration of heavy metal reflected the significant influence of high vehicular density, fossil fuel burning, industrial processes and re-suspension of soil/dust. Statistical analysis results showed that Zn, Cr, Cu, Ni & Pb are positively correlated and may have same pollution sources i.e. vehicular sources. Zn, Cr, Cu, Ni mainly comes from fuel combustion, tyre abrasion, break pad wear, degradation of paint and chrome plating while Fe was controlled by original materials and therefore interpreted as natural sources.

References

Adachi, K. and Tainosho, Y., 2004. Characterization of heavy metal particles embedded in tire dust, ***Environment International***, 30: 1009-1017.

Ahmed, F. and Ishiga, H., 2006. Trace metal concentrations in street dusts of Dhaka City, Bangladesh, ***Atmospheric Environment,*** 40: 3835–3844.

Akbar, K.F., Hale, W.H.G., Headley, A.D. and Athar, M., 2006. Heavy Metal Contamination of Roadside Soils of Northern England, ***Soil and Water Research***, 4: 158-163.

Bai, J., Cui, B., Wang, Q., Gao, H. and Ding, Q., 2009. Assessment of heavy metal contamination of roadside soils in Southwest China, ***Stochastic Environmental Rsearch and Risk Assessment,*** 23: 341-347.

Banerjee, A.D.K., 2003. Heavy metal levels and solid phase speciation in street dust of Delhi, India, ***Environmental Pollution***, 123: 95-105.

Bhattacharya, T., Chakraborty, S., Fadadu, B. and Bhattacharya, P., 2011. Heavy Metal concentration in Street and Leaf deposited dust in Anand City, India, ***Research Journal of Chemical Sciences***, 1: 61-66.

Charlesworth, S., Everett, M., McCarthy, R., Ordóñez, 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: 563–573.

De Miguel, E., Iribarren, I., Chacón, E., Ordoñez, A. and Charlesworth, S., 2007. Risk-based evaluation of the exposure of children to trace elements in playgrounds in Madrid (Spain), *Chemosphere*, 66: 505–513.

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.

Ferreira-Baptista, L. and De Miguel, E., 2005. Geochemistry and risk assessment of street dust in Luanda, Angola: a tropical urban environment, ***Atmospheric Environment***, 39: 4501–4512.

Habil, M., Massey D.D. and Taneja, A., 2013. Exposure of children studying in schools of India to PM levels and metal contamination: sources and their identification, ***Air Quality Atmosphere & Health***, 6: 575–587.

Han, Y., Peixuan, D., Junji, C. and Posmentier, E.S., 2006. Multivariate analysis of heavy metal contamination in urban dusts of Xi'an, Central China, ***Science of the Total Environment***, 355: 176–186.

Hjortenkrans, D., Bergback, B. and Haggerud, A., 2006. New metal emission patterns in road traffic environments, ***Environmental Monitoring and Assessment***, 117: 85–98.

Khan, S., Cao, Q., Zheng, Y.M., Huang, Y.Z. and Zhu, Y.G., 2008. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China, ***Environmental Pollution***, 152: 686–692.

Laidlaw, M.A.S., Mielke, H.W., Filippelli, G.M., Johnson, D.L. and Gonzales, C.R., 2005. Seasonality and children's blood lead levels: developing a predictive model using climatic variables and blood lead data from Indianapolis, Indiana, Syracuse, New York, and New Orleans, Louisiana (USA), ***Environmental Health Perspectives***, 113: 793–800.

Lu, X., Wang, L., Lei, K., Huang, J. and Zhai, Y., 2008. Contamination assessment of copper, lead, zinc, manganese and nickel in street dust of Baoji, NW China, ***Journal of Hazardous Materials***, 161: 1058-1062.

Manasreh, W.A., 2010. Assessment of trace metals in street dust of Mutah City, Kurak, Jordan, ***Carpathian journal of earth and environmental sciences***, 5: 5-12.

Meza-Figueroa, D., De La O-Villanueva, M. and De La Parra, M.L., 2007. Heavy metal distribution in dust from elementary schools in Hermosillo, Sonora, Mexico, ***Atmospheric Environment***, 41: 276-288.

Mmolawa, K. B., Likuku, A.S. and Gaboutloeloe, G.K., 2011. Assessment of heavy metal pollution in soils along major roadside areas in Botswana, ***African Journal of Environmental Science and Technology***, 5: 186-196.

Nasr, S.M., Okbah, M.A. and Kasem, S.M., 2006. Environmental Assessment of Heavy Metal Pollution in bottom Sediment of Aden Port, Yemen, ***International Journal of Ocean & Oceanography***, 1: 99-109.

Oliva, S. and Espinosa, A., 2007. Monitoring of heavy metals in topsoils, atmospheric particles and plant leaves to identify possible contamination sources. ***Microchemical Journal***, 86: 131–139.

Okunola, O.J., Uzairu, A., Ndukwe, G.I. and Adewusi S.G., 2008. Assessment of Cd and Zn in Roadside Surface Soils and Vegetations along Some Roads of Kaduna Metropolis, Nigeria. ***Research Journal of Environmental Science***, 2: 266-274.

Rasmussen P.E., Subranmanian, K.S. and Jessiman, B.J., 2001. A multi-element profile of house dust in relation to exterior dust and soils in the city of Ottawa, Canada, ***Sci. Total Environ.***, 267: 125-140.

Sharma, S. and Prasade, F.M., 2010. Accumulation of Lead and Cadmium in Soil and Vegetable Crops along Major Highways in Agra (India), ***Journal of Chemistry***, 7: 1174-1183.

Shi, G.T., Chen, Z.L., Xu, S.Y., Zhang, J., Wang, L. and Bi, C.J., 2008. Potentially toxic metal contamination of urban soils and roadside dust in Shanghai, China. ***Environmental Pollution***, 156: 251–260.

Shi, G.T., Chen, Z.L., Chunjuan Bi, C.J., Wang, L., Teng, J.Y. and Li, Y.S., 2011. A comparative study of health risk of potentially toxic metals in urban and suburban road dust in the most populated city of China, ***Atmospheric Environment***, 45: 764–71.

Taner, P.A, Ma H.L. and Yu, P.K.N., 2008. Fingerprinting metals in urban street dust of Beijing, Shanghai and Hong Kong. ***Environmental Science and Technology***, 42: 7111-7117.

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

Thomilson, D.C., Wilson, D.J., Harris, C.R. and Jeffrey, D.W., 1980. Problem in heavy metals in estuaries and the formation of pollution index, Helgol, ***Wiss Meeresunlter***, 33, 566–575.

Wei, B. and Yang, L., 2010. A review of heavy metal contamination in urban soils, urban roadside and agricultural soils from China, ***Microchemical Journal***, 94: 99–107.

Wong, C.S.C., Li, X. and Thornton, I., 2006. Urban environmental geochemistry of trace metals, ***Environmental Pollution***, 142: 1-16.

Wu, S., Zhou S. and Li, X., 2011. Determining the anthropogenic contribution of heavy metal accumulations around atypical industrial town, Xushe, China, ***Journal of Geochemical Exploration***, 110: 92–97.

Zehetner, F., Rosenfellner, U., Mentler, A. and Gerzabek, M., 2009. Distribution of road salt residues, heavy metals and polycyclic aromatic hydrocarbons across a highway-forest interface, ***Water, Air, and Soil pollution***, 198: 125–132.