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Metal pollution and its distribution pattern in the road dust of Karachi, Pakistan

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Abstract

Heavy metals are considered as one of hazardous pollutants in natural environment due to their toxicity, persistence, risk to human, and a long term damage to the environment. The main objective of the present study was to determine the possible sources, distribution pattern and the levels of heavy metals (Pb, Cd, Cu, Zn, Cr and Ni) along the major roadside of Karachi soils. In order to accomplish this task, 56 dust samples collected from the three main zones (residential, industrial and commercial) were analyzed using atomic absorption spectrophotometer. The ranges of heavy metal concentrations in the study area were 16.97-351, 2.9-4.6, 27-892, 79-689, 41-97, 26-63 mg/kg dry soil for Pb, Cd, Cu, Zn, Cr and Ni respectively. In the commercial zone significantly high concentration of Pb, Cu and Zn were observed which is mainly related to vehicle emissions, heavy traffic and commercial activities. Overall, the degree of heavy metals contamination in the Karachi soil was in following ascending order, KC >KI>KR. The study findings may provide scientific information related to heavy metal pollution in Karachi soil as it is barely monitored. Further, it may help policy makers to develop/establish an effective control strategy.

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Introduction

The fine dust particles spread out on the roads are usually termed as *road dust* (Tokalioglu and Kartal, 2006). Road dust is an important source of the heavy metal pollution (Kabadayi and Cesur, 2010). Although some heavy metals are essential for vital processes in many living organisms, including humans (Juvanovic *et al*., 1995, Lapitajs *et al*., 1995), yet these metals are generally toxic when their concentrations exceed certain thresholds (Guney *et al*., 2010). The International Agency for Cancer Research (IARC) has classified arsenic, cadmium, chromium and nickel as carcinogens (Kabadayi and Cesur, 2010). Road dust may come in contact to the human body via inhalation, ingestion and dermal contact absorption (Wei *et al*., 2008). It affects the human health including effects on the respiratory and cardiovascular systems, asthma and mortality. It's not only damaging human health, but also causing an adverse effect to the flora and fauna (Shafiq and Iqbal, 2003 and 2005).

The heavy metals are introduced to the road dust mainly through the anthropogenic sources which include traffic emission (wearing of brake lining and tyres, vehicle exhaust particles), industrial emission (power plant, coal combustion, metallurgical industry, auto repair shop, chemical plant, etc), weathering building, heating systems, corrosion of galvanized metal structures, mining activities etc. (Akhter and Madany 1993, Al-Khashman 2004, Ferreira-Baptista and De Miguel 2005, Wei and Yang 2010). Industrial metallurgical processes produce heavy metals like As, Cd, Cu, Ni and Zn (Wei *et al*., 2008). Over land, traffic is one of the major sources of heavy metals in road-deposited dust (Guney *et al*., 2009). Fossil fuel combustion (coal or petroleum products) usually produces large amounts of heavy metals such as Be, Co, Hg, Mo, Sb, Se, Sn, Ni, and V and some other pollutants like As, Cr, Cu, Mn, and Zn. In addition, tyre abrasion can also give rise to Zn (Lv *et al*., 2006). Cu is mainly released from the wear of brake linings, which is also an important source of Pb and Zn (SEHPA, 2001). Studies have also shown that another source of heavy metals in road dust is the weathering of building facades (Li *et al*., 2001, Charlesworth *et al*., 2003, Han *et al*., 2006, Tokalioˇglu and Kartal 2006; Meza-Figueroa *et al*., 2007, Xue and Wang, 2007).

The study of heavy metals in road dust and their source identification has become necessary to reduce the pollution effectively (Kabadayi and Cesur, 2010). Many researchers in various cities have well documented the presence of heavy metals in the road dust e.g., Madrid and Oslo (De Miguel *et al*., 1997), Hong Kong (Li *et al*., 2001), Birmingham and Coventry (Charlesworth *et al*., 2003), Naples (Imperator *et al*., 2003), Istanbul (Sezgin *et al*., 2003, Guney 2009), Athens, Greece (Riga-Karandinos *et al*., 2006), Brisbane (Herngren *et al*., 2006), Lahore (Jafary *et al*., 2006), Gela (Manno *et al*., 2006) and Samsun City (Kabadayi and Cesur, 2010), etc.

Karachi, a mega city of Pakistan, comprises of 3,527 square kilometers with a population > 18 million is facing tremendous environmental problems (CDGK, 2007, Qureshi 2010, CDGK 2012). It is reported that by population, Karachi is among the top ten mega cities of the world (UNDP, 2008). During the last ten years, the number of vehicles in the city has been doubled, which has increased many traffic related problems like air and noise pollution, decay of roadways, liberation of different gases due to burning of fossil fuel, decay of vehicle bodies. Although, during the last decade, major roads have been made signal free highways, yet in many road junctions and narrow commercial areas, traffic jams are the regular feature. The aim of the present study was to provide scientific information related to heavy metals pollution such as Pb, Cd, Cu, Zn, Cr and Ni in the road dust samples of Karachi city so that timely steps can be taken by regulatory bodies for its control.

Materials and methods

Study area

For this study, Karachi city was divided into three categories, i.e. residential, industrial and commercial areas. In Karachi, 4500 industrial units comprises of textile, leather, paper, marble, ceramics, rubber, plastic, glass, steel, electronics, pharmaceuticals, food products, agricultural and dairy products are situated in industrial areas like Korangi Industrial Area (KIA), Landhi Industrial Area (LIA), Export Processing Zone (EPZ), Sindh Industrial & Trading Estate (SITE), North Karachi Industrial Area (NKIA), Ahsan abad Industrial Area and F. B. Industrial Area (Qureshi, 2010). The business and commercial areas are mostly situated along the main roads of the city like Shara-e-Faisal, M. A. Jinnah Road and Shara-e-Pakistan. Although, the areas in the city have been specified for the residential, industrial and commercial activities, but massive multifunctional land use has made it difficult to differentiate between these categories. It is reported that approximately, more than 2.6 million registered vehicles in the city are moving on the roads (TPK, 2012).

Sample collection

A total of 56 surface soil samples were collected during December 2013 from the busy main roads of Karachi. Among these 56 samples, 24 samples were collected from commercial areas and16 samples each from the residential areas and industrial areas. For the background values, 8-10 inches deep soil samples were also collected within the distance of 0.5 km from each sampling site. Approximately 200 g of the road dust sample was collected from each point in a self sealing polyethylene bags by sweeping dust in a 1 square meter area using a clean plastic dustpan and a brush and then transferred to the laboratory for analysis (Wei *et al.*, 2010).

Sample treatment and analysis

In the laboratory, all samples were air dried and sieved with a nylon sieve using standard procedures (Ferreira-Baptista and De Miguel 2005, Tokalioˇglu and Kartal 2006, Wei *et al.*, 2010). For metal analysis, 1 g sample was digested in 30 ml freshly prepared aqua regia (1:3 HNO_3: HCl) on a hot plate and then diluted to 100 ml distilled water (Guo *et al.*, 2005, Liu *et al.*, 2005, Wei and Yang, 2010). Heavy metals in the soil samples were determined by the Shimadzu AAS model AA-6200 Atomic Absorption Spectrometer. To check the accuracy of analytical results, standard reference material was prepared by using MERCK stock solution. Moreover, the solvents and chemicals used in the experimental work were of analytical grade (Fluka Chemical) and the glassware was Pyrex made. To remove any adhered impurities, the glassware was washed with soap, distilled water and diluted nitric acid.

Results and discussion

The heavy metals concentration and the average values in the road dust samples collected from 56 sites along the busy roads of Karachi city are presented in Table 1 and 2. The sampling points were categorized into Karachi commercial (KC), Karachi industrial (KI) and Karachi residential (KR) areas respectively.

The results of the analysis of dust samples clearly show the adverse environmental condition due to the presence of heavy metals in the road dust of Karachi city. Overall, the minimum concentration of metal was found in the range of 2.89 mg/kg for Cd and maximum 892.14 mg/kg for Cu. The highest concentrations of metal elements were observed in the commercial areas while the residential areas had the lowest concentrations (Table 1). The details of these observations are discussed below:

Lead

Pb concentration in the road dust of Karachi ranged from 16.97 to 350.50 mg/kg with a mean of 100.38 mg/kg. It can be seen from Table 1 and Fig. 1 that the minimum concentrations of Pb were found in residential areas of Karachi city (Shafiq more, Safoora Chowrangi, PECHS Block 2, Baitul Mukaram Masjid and Ahsan abad) while the maximum concentrations were found in commercial areas (Liaquat abad No. 10, Teen Hatti, Liaquat abad P.O., Tibet Centre, Denso Hall and Regal Chowk).

Table 1. Heavy metals concentrations in the road dust samples of Karachi city.

Sample No.	Sample code	Sample Location	Pb (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Cr (mg/kg)	Ni (mg/kg)
1	KC1	Empress Market	45.52	4.19	104.45	189.56	66.87	55.56
2	KC2	Seven Day	45.61	4.56	104.66	189.74	67.12	55.77
3	KC3	Numayesh Chowrangi	44.89	4.09	103.49	187.36	64.89	53.71
4	KC4	Regal Chowk	248.30	3.26	308.90	698.12	73.47	62.85
5	KC5	Abdullah Haroon Road	238.12	3.01	299.05	688.23	68.87	58.36
6	KC6	Tibet Centre	256.31	4.20	365.79	455.36	76.24	49.54
7	KC7	Burns Road	212.11	3.11	295.13	655.21	66.56	54.67
8	KC8	Lucky Star	41.44	3.15	48.75	100.85	46.56	32.60
9	KC9	Zainab Market	59.12	4.51	51.32	110.14	51.24	39.24
10	KC10	Regent Plaza	45.32	3.61	49.34	115.21	44.34	34.25
11	KC11	Liaquat Abad P.O.	329.94	3.23	865.23	324.76	89.15	58.27
12	KC12	Liaquat Abad No 10	350.50	3.44	892.14	343.16	97.22	62.94
13	KC13	Guru Mandar	159.65	3.56	432.68	321.65	60.03	46.98
14	KC14	Golimaar	166.16	3.70	479.38	335.98	62.45	47.85
15	KC15	Patel Para	161.80	3.61	456.32	329.12	60.09	46.25
16	KC16	Tariq Road	42.38	4.09	26.66	78.59	49.13	28.34
17	KC17	Sher Shah	186.16	3.70	485.38	345.98	63.45	48.85
18	KC18	Haidery Market	41.38	3.45	36.66	88.59	45.13	26.34
19	KC19	Jama Cloth Market	130.81	3.47	86.26	219.81	74.86	49.61
20	KC20	Tower	246.31	4.15	355.79	445.36	74.14	59.54
21	KC21	Pakistan Chowk	133.61	3.67	96.26	222.61	78.69	47.18
22	KC22	Denso Hall	252.30	3.56	318.90	688.12	76.47	60.45
23	KC23	Water Pump	168.46	3.96	461.38	319.92	61.45	48.85
24	KC24	Teen Hatti	345.50	3.47	862.11	331.96	88.32	55.24
25	KI 1	Chamra Chowrangi	45.28	3.12	39.87	185.63	82.87	36.24
26	KI 2	Bilal Chowrangi	46.69	3.02	36.18	179.87	78.80	32.79
27	KI 3	Singer Chowrangi	46.12	3.09	37.96	181.60	79.56	34.47
28	KI 4	Siemen Chowrangi	85.62	3.78	88.26	145.56	89.15	57.26
29	KI 5	Habib Bank Chowrangi	80.78	3.84	79.44	130.18	85.26	49.15
30	KI 6	Shafiq More	16.97	3.13	51.00	81.97	44.52	29.08
31	KI 7	Quaid Abad	121.81	3.37	85.06	209.11	75.59	44.80
32	KI 8	Alnoor Stop (FBArea)	126.45	3.13	89.11	198.56	72.52	49.08
33	KI 9	Sohrab Goth	116.65	3.06	81.21	201.36	71.22	43.58
34	KI 10	Ghani Chowrangi	86.18	3.69	89.14	136.28	86.26	48.37
35	KI 11	Sher Shah Chowrangi	81.10	3.29	82.34	141.38	89.37	46.21
36	KI 12	Brookes Chowrangi	45.22	3.32	39.58	196.81	79.50	39.81
37	KI 13	Ahsan abad	26.24	3.23	65.23	89.14	49.32	39.21
38	KI 14	Gulshan e Meymar	36.15	3.43	75.13	96.54	56.42	49.51
39	KI 15	Daud Chowrangi	46.85	3.12	38.18	191.87	88.18	33.19
40	KI 16	New Karachi	122.45	3.23	87.21	198.43	74.42	48.18
41	KR1	Drig Road	34.27	4.55	33.71	133.52	59.54	45.69
42	KR2	Baitul Mukarm Masjid	23.30	3.96	35.41	142.78	58.16	36.43
43	KR3	Jauhar More	34.99	3.87	37.34	179.47	61.81	40.20
44	KR4	PECHS Block 2	21.40	2.89	28.19	95.08	41.23	29.45
45	KR5	Safoora Chowrangi	20.25	3.13	29.41	78.68	41.16	27.63
46	KR6	Power HouseChowrangi	26.30	3.76	39.61	132.78	59.16	38.43
47	KR7	Korangi No. 6	36.69	3.12	37.18	139.53	68.60	37.79
48	KR8	Shipowner's College	23.30	3.96	35.41	142.78	58.16	36.43
49	KR9	Hasan Square	131.01	3.19	91.31	216.12	79.23	39.87
50	KR10	Ghareeb Abad	120.81	3.27	84.06	204.11	73.59	43.80
51	KR11	Esa Nagri	125.40	3.21	87.23	211.32	76.24	41.15
52	KR12	Defence More	40.19	3.12	36.28	169.77	68.80	34.79
53	KR 13	Boat Basin	46.59	3.61	41.68	188.27	78.13	41.52
54	KR 14	Jinnah Square, Malir	43.24	3.92	41.25	191.23	74.56	49.50
55	KR 15	Gulberg Chowrangi	135.21	3.32	96.20	229.32	89.33	43.87
56	KR 16	Nagan Chowrangi	124.10	3.19	86.43	207.42	75.42	44.25

*Karachi Commercial (KC), Karachi Industrial (KI) and Karachi Residential (KR).

Table 2. Average concentrations of pH, EC, TDS and heavy metals (mg/Kg) in the road dust samples of Karachi city.

Parameters N=56	Units	Min.	Max.	Mean	SD
Pb	mg/kg	16.97	350.50	108.3805	88.85604
Cd	mg/kg	2.89	4.56	3.5298	0.42406
Cu	mg/kg	26.66	892.14	169.4934	216.49013
Zn	mg/kg	78.59	698.12	232.3546	153.29848
Cr	mg/kg	41.16	97.22	69.1575	14.03434
Ni	mg/kg	26.34	62.94	44.5530	9.49978

At commercial site (Liaquat abad), new and used electrical and mechanical items are being sold and purchased along roadside in shops as well as inside cabins. Tibet Centre is a well known place for shops of spare parts and repair of motor vehicles. It has been observed that commercially busy areas, where the traffic jams are regular features, suffered more by the lead contamination. Moreover, besides vehicular emission, commercial activities are equally responsible for the lead contamination. In comparison, the residential and the industrial areas have least level of lead contamination. The high variability in the lead concentration at various places can be observed by large standard deviation i.e. 88.86 mg/Kg (Table 2) which also verifies that vehicular emission and the commercial activities are the main causes of high lead contamination at specific places. However, when these results compared with earlier data reported by Yousufzai (1991), the average concentration of Pb was comparatively less. This can be explained by the intensive use of Compressed Natural Gas (CNG) as a fuel in the vehicles instead of leaded petrol in Pakistan which reduces the level of lead in the environment.

Cadmium

As shown in Table 2, the Cd concentration in the road dust of Karachi ranged from 2.89 to 4.56 mg/kg with a mean value of 3.53 mg/kg. The minimum concentrations of Cd were found in residential areas (PECHS Block 2, Abdullah Haroon Road and Bilal Chowrangi) while the maximum concentrations were present in commercial areas of Zainab Market, Drig Road and Seven Day (Table 1 & Fig. 2). Further, the standard deviation of Cd is very low (0.42 mg/Kg), which suggests that Cd is naturally distributed along the roads of the Karachi city due to its lithogenic occurrence rather than contributed by anthropogenic sources.

Copper

During the experimental analysis the greatest variations in the concentration of Cu were observed along the major roads of Karachi city with a standard deviation of 216.49 mg/Kg. (Table 2). The concentration of Cu ranged from 26.66 to 892.14 mg/kg with a mean of 169.49 mg/kg. Results reported in Table 1and Fig. 3 clearly show that residential areas such as Tariq Road, PECHS Block 2 and Safoora Chowrangi are the least affected areas whereas as Liaquat abad and Teen hatti, the commercial areas of Karachi suffer the most. In these areas the Cu concentration was 892.14 mg/kg and 862.11 mg/kg respectively.Whereas in Sher Shah which is located next to Liaquat abad and Teen hatti, the Cu concentration was 485.38 mg/kg. The results indicating almost half level of Cu concentration in Sher Shah when compared with the latter two places. This represents the highly contaminated situation of Liaquat abad and Teen hatti.

Zinc

Comparing with other heavy metals concentrations, the level of Zn in the road dust of Karachi city was significantly higher (232.35 mg/kg). Its concentration ranged from 78.59 to 698.12 mg/kg with a standard deviation of 153.30 mg/kg (Table 2). The high value of standard deviation shows that some commercial places like Regal Chowk, Abdullah Haroon Road, Denso Hall and Burns Road are highly contaminated with Zn metal. Where as the least polluted areas in the residential sector are Tariq road, Safoora

Chowrangi and Shafiq more. Based on results that is reported in Table 1 and shown in Fig. 4, it can be explained that enhancement of Zn contamination in the study areas is probably related to vehicular emission and commercial activities. As zinc is used in accumulators of motor vehicles or in carburetors. Moreover, zinc in soil may come from lubricating oils and tires of motor vehicles (Akhter and Madany,1993).

Chromium

The concentration of Cr in the road dust of Karachi ranged from 41.16 to 97.22 mg/kg with a mean value of 69.16 mg/kg (Table 2). The results (Table 1 and Fig. 5) showing minimum concentrations of Cr at residential areas like Safoora Chowrangi, PECHS Block 2, Reagent Plaza and Shafiq more while the maximum concentrations in commercial areas of Liaquat abad, Sher Shah Chowrangi and Gulberg Chowrangi. The low value of standard deviation (14.03) suggests that Cr is uniformly distributed in Karachi soils. However, the industrial and commercial areas are comparatively more polluted with Cr than residential areas as high concentration was observed in these areas.

Nickel

Ni concentration in the road dust of Karachi ranged from 26.34 to 62.94 mg/kg with a mean value of 44.55 mg/kg (Table 2). The minimum concentrations of Ni were found in residential areas like Haidery Market, Safoora Chowrangi and Tariq Road while the maximum concentrations were present in commercial areas i.e. Liaquat abad No. 10, Regal Chowk and Denso Hall. The results of the analysis indicate that the Nickel concentrations in all sample points remained below the natural limits (Table 1, Fig. 6). Further, the lower standard deviation value (9.50 mg/kg) suggests that Ni is uniformly present in the road dust of Karachi city due its lithogenic occurrence.

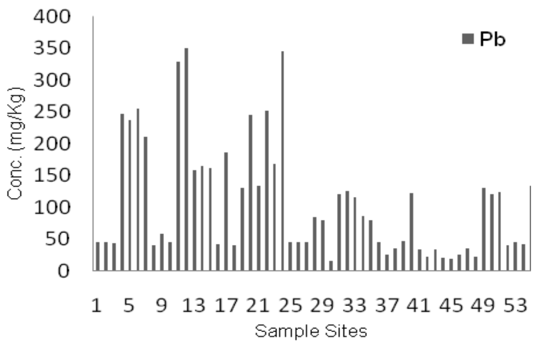

Fig. 1 Concentration of Pb in soil samples

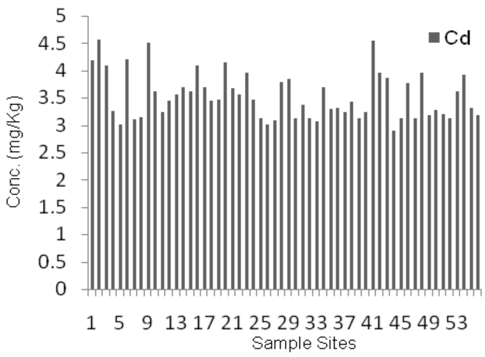

Fig. 2 Concentration of Cd in soil samples

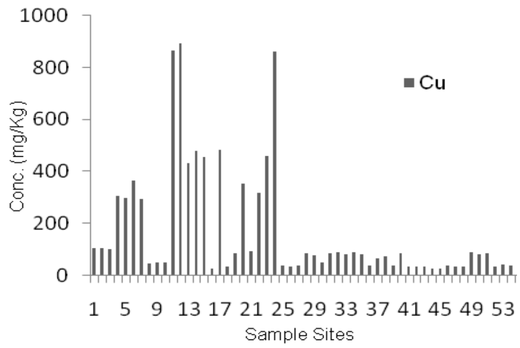

Fig. 3 Concentration of Cu in soil samples

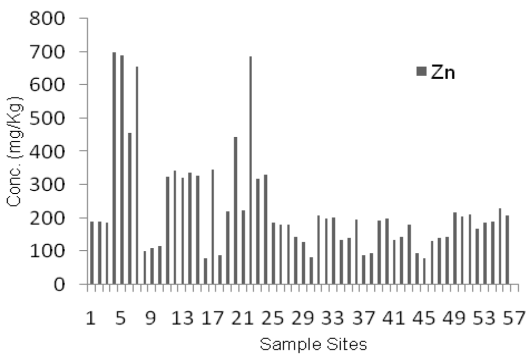

Fig. 4 Concentration of Zn in soil samples

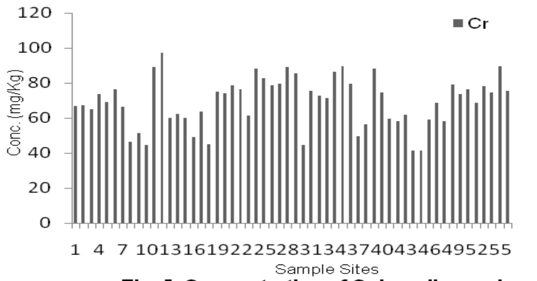

Fig. 5 Concentration of Cr in soil samples

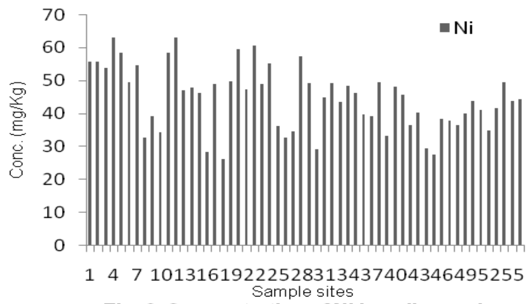

Fig. 6 Concentration of Ni in soil samples

Comparison of results with maximum allowable limits (MAL) used in different countries

As reported earlier, the mean concentration of Pb in the road dust samples of Karachi city is comparatively less than the previous studies (Yousufzai 1991, Yousufzai *et al.*, 1998, Naqvi *et al.*, 2005, Khan et. al., 2011, Hashmi *et al.*, 2012). However, its present level has reached the maximum allowable limits (MAL), when compared with the standard being used by the developed and industrial cities of the world, (Table 3). Specifically, the Cu and Zn concentrations have well exceeded the MAL. It is important to mention here that the common sources of Cu, Zn as well as Pb are the vehicle emission and the commercial activities. This might have increased the level of these elements in the soil. In contrast, the mean concentrations of Cd, Cr and Ni were within the acceptable limits.

Table 3. Concentrations of Maximum Allowable Limits (MAL) for Heavy Metals in Soil used in Different Countries.

Countries	Pb (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Cr (mg/kg)	Ni (mg/kg)
Austria	100	5	100	300	100	100
Canada	200	8	100	400	75	100
Poland	100	3	100	300	100	100
Japan	400	-	125	250	-	100
Great Britain	100	3	100	300	50	50

Source: (Fagbote and Olanipekum, 2010 & Lacatusu, 2000).

The study findings are also supported by Jiries *et al.*, (2001) who reported that Zn and Cu in the environment may be derived from mechanical abrasion of vehicles, as they are used in the production of brass alloy and it may come from brake linings, oil leak sumps and cylinder head gaskets. Moreover, the high concentration of copper in the area may be associated with electrical and mechanical working activities. Overall the three categories of sites (residential, industrial and commercial) in Karachi indicate the deteriorating quality of the environment with respect to metal pollution. At several places specifically at commercial sites significantly increased concentration of heavy metals were observed. However, the degree of contamination due to the presence of six heavy metals (Cu, Zn, Cd, Cr, Cd and Ni) in the Karachi soils follows ascending order, KC>KI>KR. Pb contamination ranked top in all the three regions and its values ranged between moderate to strong contaminated class in KI and KR. Whereas in KC the Pb concentration belongs to a strong contaminated class. The possible cause of high Pb level in the city soil linked to the extensive use of leaded petrol, the use of lead batteries, dumping of waste

Conclusions

Following conclusions are drawn from the present study:

1. The concentration of lead has decreased since 1991 (Yousufzai 1991), which might be due to the dependence on CNG fuel rather than leaded petrol.

2. The commercial areas like Liaquatabad, Teen hatti, Tibet Centre, Regal Chowk, Sher Shah etc. are

highly polluted comparable to residential and industrial areas which have low levels of heavy metal contamination.

3. The concentrations of heavy metals in the road dust of Karachi city as found in this study are lower than those found in the mega cities of the developed countries.

4. The results describe significant contamination of Pb, Cu and Zn which might be due to the vehicle emissions.

5. Region wise the degree of heavy metals contamination in Karachi soil is in order of KC>KI>KR.

6. Overall, the metal pollution in Karachi city lies in the moderate range which is alarming and steps must be taken to minimize the potential ecological risk.

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