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Full Length Research Paper

Distribution of lead, cadmium, copper and zinc in roadside soil of Sari-Ghaemshahr road, Iran

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This study was conducted to investigate the concentration of lead, cadmium, copper and zinc in different site of the Sari-Ghaemshahr road in Iran. The soil samples were collected along the sampling section at the distances of 4, 8, 16, 32, 64 and 100 m from the road edge of both sides of the road, while sampling depths were 0 to 5 and 5 to 15 cm from the surface. The concentrations of Cu, Zn, Pb and Cd were measured by flame atomic absorption and the data obtained was statistically analyzed using SPSS 16 software. Results showed that all the three heavy metals except Cd were significantly different ($p<0.01$) in the distance of 4 m. Pb concentration obtained in 4 m was 2.95 mg kg^{-1}, this value decreased to 1.76 mg kg^{-1} at 64 m and then again increased at 100 m from the road. The amounts of Cd in all distances were not significantly different. At first, the distance of Cu concentration was 1.91 mg kg^{-1} but later dropped to 1.48 mg kg^{-1} at a distance of 16 m, then increased to 2.02 mg kg^{-1} at 32 m distance from the road, then decreased again to 1.25 mg kg^{-1} at 100 m. Zn concentration at the nearest distance of the road was 3.66 mg kg^{-1}, then decreased to 0.81 mg kg^{-1} at 64 m distance from the road and later increased at 100 m distance from the road. Similar findings were obtained for Pb, Cu and Zn concentration in south side of the road. The highest value in nearest distances could be because of emissions from vehicle exhausts. In addition Pb, Cu and Zn concentrations in two sides of the road at the same distance were not found to be close to each other.

Key words: Cadmium, copper, lead and zinc concentration, vehicular emission.

INTRODUCTION

Heavy metals are considered as one of the main pollutants responsible for environmental contamination (Jozic et al., 2009) due to their high toxicity and persistency in the environment. Vehicular emissions, industrial discharge and other manmade activities are considered to be the main sources of heavy metals in the urban environments (Morton-Bermea et al., 2009; Irvine et al., 2009). The pollution caused by traffic activities is a great threat to urban environment (Li et al., 2001) and transportation causes air contamination particularly with Pb and Cd together with other toxic pollutants (Sanchez-Martin et al., 2000). Children and adults living in urban areas where surface soils are contaminated with Pb may become exposed through indoor and outdoor inhalation of Pb in dust and ingestion of Pb deposited within houses and outdoor surfaces (Laidlaw et al., 2005). Previously, it was investigated that Pb can cause various health risks like anemia and neurological disorders, hyperactivity and enzyme changes in humans (Marsden, 2003). In addition, lead poisoning causes permanent neurological, developmental and behavioral disorders, particularly in children. Similarly, Cd poisoning can affect lungs, kidneys, bones and reproductive systems (Godt et al., 2006). Zinc is ubiquitous in the environment. Zinc is a component of tires, which is released as they wear (Doss et al., 1995). Although Zn is an essential element for higher plants, it is phytotoxic at elevated concentrations, and consequently can reduce crop yields and soil fertility (Alloway et al., 1990). Also, it is known that Cu is an essential element, yet it may be toxic to both humans and animals when its concentration exceeds the safe limits and its concentration in some human tissues, such as

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Table 1. Selected physiochemical properties of soils collected from the study area.

Location	pH	Soil texture		
		Sand (%)	Silt (%)	Clay (%)
		(0.05 to 2 mm)	(0.02 to 0.05 mm)	(<0.02 mm)
Northern side	7.17	29.6	54.2	16.2
Southern side	7.08	51.6	42.4	6.2

thyroid can be changed depending on the tissue state including cancerous or non-cancerous (Yang et al., 2002; Yaman and Akdeniz, 2004). In general, when heavy metals are present in high concentrations in the environment, they result in health hazards by adversely affecting the nervous, blood forming, cardiovascular, renal and reproductive systems. They also result to reduction in intelligence, attention deficit and behavioral abnormality, as well as contribute to cardiovascular disease in adults. In recent years, there has been a growing concern for the potential contribution of ingested dust to metal toxicity in humans (Chirenje et al., 2006; Inyang and Bae, 2006). The dispersion of contaminants is influenced by meteorological conditions like wind (Piron-Frenet et al., 1994), rainfall, profiles (Bennouma, 1988) or traffic intensity (Garcia and Millan, 1998). The concentrations of metals in the roadside soil are influenced by the same factors (Garcia et al., 1996; Othman et al., 1997; Garcia and Millan, 1998) and by soil parameters. This study determined the distribution of heavy metal concentration within various distances from two sides of one of the main roads that have high traffic load and was full of farming lands.

MATERIALS AND METHODS

The present study investigated the emission of Pb, Cd, Cu and Zn from both sides of Sari-Ghaemshahr highway. It is a busy road in the north of Iran with the latitude, longitude and elevation of 36°.56', 53°.05' and 52 m, respectively. According to Hansen classification, this area has mid-warm climate. The average annual precipitation and temperature are about 724 mm and 14.4°C, respectively. On August, 2010, soil samples were collected along the sampling section at the distances of 4, 8, 16, 32, 64 and 100 m from the road edge and depths of sampling were 0 to 5 and 5 to 15 cm from the surface. To compare variations of pollution in surface and subsoil, two different depths of sampling were selected. At each sampling site, in both sides of road, a line parallel to the edge road was laid and four samples were equally distributed along the line and samples were thoroughly mixed and finally, 1 kg soil was used for laboratory analysis. Efforts were made to avoid other sources of contamination at each site, such as industrial waste, dumpsite garbage, wastewater effluents, or compost that might mask the effects of motor vehicle emissions. Each soil sample was air-dried, any clods and crumbs were removed, and the sample was mixed uniformly by coning and quartering. Soils were sieved through a 2-mm sieve to remove coarse particles before sub-sampling for chemical analysis. The available heavy metals (Cu, Zn, Pb and Cd) were measured by DTPA extraction method, developed by Reed and Martend (1996) and by flame atomic absorption spectrophotometer (Varian AA10 spectr). Some physical and chemical properties of the sample soils such as pH and soil texture were examined in the laboratory. pH was determined using a hydrogen selective electrode with soil paste using deionized water (Salinity Laboratory Staff. 1954) and soil texture was detected by hydrometer method (Gee and Bauder, 1986).

Data analysis

The data obtained was statistically analyzed using SPSS 16 software. The variations in Pb, Cd, Zn and Cu concentrations between different distances from the road for the two sides of the road and two depths were calculated using general liner model (univariate and multivariate) method.

RESULTS

Table 1 summarizes the basic properties of soils collected from both sides of the road (north and south).The pH values of the soils ranged from 7.17 to 7.08 and did not vary significantly along the selected roads. But texture differed between north and south side. Hence these differences could influence the amounts of heavy metals concentration in the two sides of the road.

Heavy metal concentrations and distance from the road

Tables 2 and 3 show the results of statistical analyses. According to these tables, all three heavy metals except Cd were significantly different at various distances of road edge and also in different depth of soil. Table 4 shows the concentration of Pb, Cd, Cu and Zn in the soil sample collected from different distances from two sides of the road. Soil samples for the two sides of the road were collected from the upper soil layer of 0 to 5 cm which is more influenced by the road traffic. Results show that all the three heavy metals except Cd were significantly different ($p<0.01$) in different distances from road. In north side of the road, Pb concentration in the nearest distance (4 m from the road) was 2.95 mg kg^{-1}, with increasing distance of the road to 64 m, this value decreased to 1.76 mg kg^{-1} and then again increased at 100 m from the road. The amounts of Cd in all distances were not significantly different and because of their low amounts, road traffic was not the main source of Cd (Table 4). Cu also followed the same trend of Pb distance from the road. Cu concentration first decreased with

Table 2. Tests of between-subjects effects (northern side).

Fixed factor	Dependent variable	Sum of squares	df	Mean square	F	Significance
Distance	Pb	6.816	5	1.363	944.683	0.000
	Cd	0.013	5	0.003	1.717	0.156
	Cu	1.773	5	0.355	284.753	0.000
	Zn	31.832	5	6.366	7.543	0.000
Depth	Pb	0.012	1	0.012	8.363	0.006
	Cd	0.007	1	0.007	4.292	0.046
	Cu	0.431	1	0.431	345.832	0.000
	Zn	1.126	1	1.126	1.334	0.000
Distance x depth	Pb	1.916	5	0.383	265.603	0.000
	Cd	0.006	5	0.001	0.823	0.541
	Cu	2.326	5	0.465	373.634	0.000
	Zn	1.132	5	0.226	268.235	0.000
Error	Pb	0.052	36	0.001		
	Cd	0.055	36	0.002		
	Cu	0.045	36	0.001		
	Zn	0.030	36	0.001		
Total	Pb	314.710	48			
	Cd	0.646	48			
	Cu	142.137	48			
	Zn	157.295	48			

Table 3. Tests of between-subjects effects (southern side).

Fixed factor	Dependent variable	Sum of squares	df	Mean square	F	Significance
Distance	Pb	134.751	5	26.950	3.794	0.000
	Cd	0.043	5	0.009	82.168	0.000
	Cu	16.554	5	3.311	8.030	0.000
	Zn	13.752	5	2.750	4.183	0.000
Depth	Pb	3.945	1	3.945	5.553	0.000
	Cd	0.000	1	0.000	2.842	0.100
	Cu	0.051	1	0.051	123.351	0.000
	Zn	1.245	1	1.245	1.894	0.000
Distance x depth	Pb	11.901	5	2.380	3.350	0.000
	Cd	0.014	5	0.003	26.526	0.000
	Cu	2.549	5	0.510	1.236	0.000
	Zn	0.199	5	0.040	60.519	0.000
Error	Pb	0.026	36	0.001		
	Cd	0.004	36	0.000		
	Cu	0.015	36	0.000		
	Zn	0.024	36	0.001		
Total	Pb	587.142	48			
	Cd	1.121	48			
	Cu	233.494	48			
	Zn	232.433	48			

Table 4. Heavy metal concentration of different distances from the two sides of the road.

Distance from road	Heavy metal (mg kg^{-1})							
	North (mean±SD)				South (mean±SD)			
	Pb	Cd	Cu	Zn	Pb	Cd	Cu	Zn
4	2.95±0.05	0.11±0.01	1.91±0.07	3.66±0.05	7.83±0.0 5	0.16±0	3.59±0.01	3.55±0.01
8	2.63±0.03	0.13±0.01	1.51±0.03	2.23±0.01	3.51±0.0 1	0.11±0.01	2.38±0.01	2.11±0.01
16	2.29±0.01	0.12±0.01	1.48±0.03	1.37±0.01	2.38±0. 01	0.11±0.01	1.58±0.01	1.99±0.02
32	2.63±0.02	0.12±0	2.02±0.03	1.31±0.01	1.69±0.01	0.13±0.01	1.23±0.01	1.73±0.01
64	1.76±0.02	0.13±0.02	1.38±0.01	0.81±0.02	2.34±0.01	0.17±0.1	2.03±0.03	2.16±0.02
100	2.75±0.03	0.13±0.02	1.25±0.04	1.13±0.03	2.03±0 .01	0.19±0.01	1.65±0.11	2.16±0.01

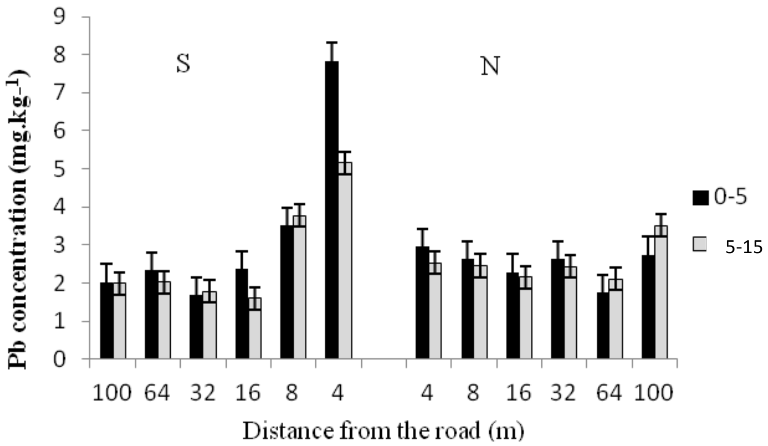

Figure 1. Pb concentration of soils of both sides (S and N) and both depths (0 to 5 and 5 to 15 cm) of the road with standard errors at different distances from the road. S: southern side, N: northern side of the road.

increasing distance from the road and in specific distance, it increased again. At first, the distance of Cu concentration was 1.91 mg kg^{-1} at 16 m distance from the road and then dropped to 1.48 mg kg^{-1} and later increased to 2.02 mg kg^{-1} at 32 m distance from the road, after which it then decreased again to 1.25 mg kg^{-1} at 100 m. Zn concentration at the nearest distance of the road was 3.66 mg kg^{-1}, but it then decreased to 0.81 mg kg^{-1} at 64 m distance and later increased at 100 m distance from the road. Similar findings were observed for Pb, Cu and Zn concentration in the south side of the road. However, their peak locations were not the same. In addition, Pb, Cu and Zn concentrations in the two sides of the road were not found to be close to each other at the same distance.

Lead

Figure 1 shows the variation of Pb concentration in different distances from both sides of the road (northern and southern). In addition, the amounts of Pb concentration in samples of two depths of soil (0 to 5 and 5 to 15 cm) were compared in this figure. Pb concentrations in the two sides of soil decreased with increasing distance from the road (Christoforidis et al., 2008; Swaileh et al., 2001).

It can be seen from Figure 1 that in most distances, Pb concentration in southern side was higher than that of the northern side. This result can be described with different soil texture. As can be observed in Table 1, the amount of clay (%) in southern side was lower than that of the northern side. So, Pb element with positive charge could be easier released in the southern side than in the northern side, therefore its amount in analyzed southern samples extracts were more. Bakirdere and Yaman (2008) in their study reported that soil properties such as soil texture could influence amounts of heavy metals concentration. In addition, the differences in directions and strength of winds could have efficacy. Figure 1 also show differences of Pb concentration for the two depths of soil (0 to 5 and 5 to 15 cm). It is clear that in most

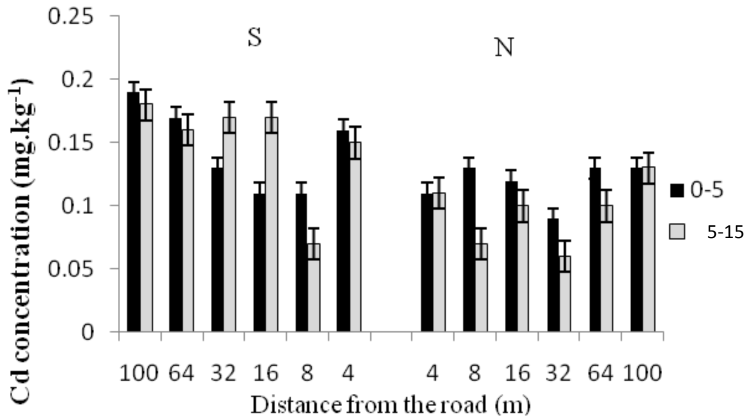

Figure 2. Cd concentration of soils of both sides (S and N) and both depths (0 to 5 and 5 to 15 cm) of the road with standard errors at different distances from the road. S: southern side, N: northern side of the road.

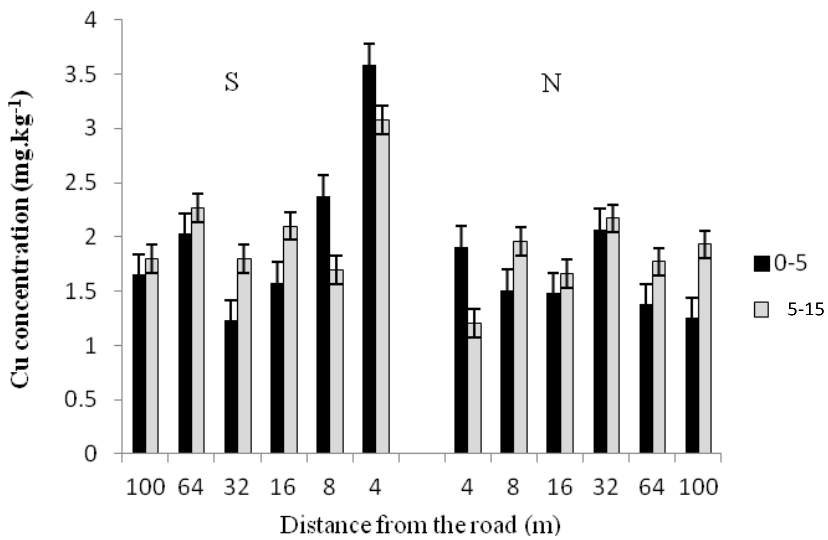

Figure 3. Cu concentration of soils of both sides (S and N) and both depths (0 to 5 and 5 to 15 cm) of the road with standard errors at different distances from the road. S: southern side, N: northern side of the road.

distances, Pb concentration in upper soil was higher than others.

Cadmium

As reported above, no significant differences were observed for Cd concentration in different distances from the road. Abechi et al. (2010) reported that among all metals (Mn, Fe, Cu, Pb, Zn and Cd), only Cd did not show significant difference with others. Irregular Cd concentrations in different distances are also shown in Figure 2.

Copper and zinc

Significant variation ($p<0.01$) was found for Cu and Zn concentrations in different distances of the road which was clearly expressed by the variation of Cu concentration in the two sides of the road, especially in the upper layer of the soil (Figures 3 and 4). As shown in the figures, Cu concentration in the two sides of the road decreased at first and then increased but a new improvement of Cu concentration occurred in different distances. Variation of Zn concentration also showed similar results (Figure 4). However, the results showed that the effect of distance from the road is more evident

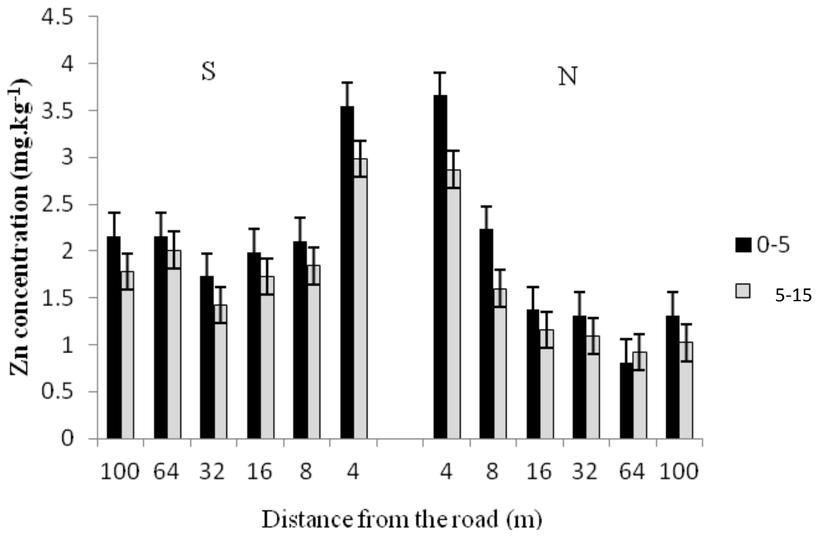

Figure 4. Zn concentration of soils of both sides (S and N) and both depths (0 to 5 and 5 to 15 cm) of the road with standard errors at different distances from the road. S: southern side, N: northern side of the road.

for zinc and a high concentration of zinc was observed in samples taken from sites close to the road edge. No such trend was observed for copper. This result is consistent with that of Fatoki (1996).

DISCUSSION

This study demonstrated that roadside soil could be influenced by emissions from vehicle exhausts (Christoforidis and Stamatis, 2009; Faiz et al., 2009; Li et al., 2001). The most common heavy metals released from vehicles on road are cadmium (Cd), copper (Cu), lead (Pb) and zinc (Zn). Pb particles in the environment could be from vehicle emissions where lead gasoline is used in such areas as in this study. Tire wear is also another source of lead and cadmium in roadside environment (Ozkan et al., 2005). Cadmium is used in accumulators of motor vehicles or in carburetors as alloys and is released after combustion. Zinc is a component of tires, which is released as they wear, so these heavy metals could influence the environment around roads because roads convey high density of motor vehicles.

The concentrations of Pb, Zn and Cu in soils were the highest at the railroad edge, decreased quickly with the distance from the railroad, increased again and formed a secondary peak at certain distances from the railroad and then decreased with the increase of distance. It indicated that the migration and accumulation of heavy metals in roadside soils did not decrease linearly with the distance from railroad, but followed a more complex pattern. The distributive patterns of the heavy metals in railroad-side soils are obviously related to the exhaust gases released from the vehicle. The exhaust gases can migrate with airflow and be deposited in railroad-side soils. Thus, different heavy metals may be adsorbed onto the particles of different sizes. The larger particles are deposited mainly close to the railroad edge, while the smaller particles can stay in the air for a rather long time and be deposited at the sites far away from the railroad. Particles of various sizes may be deposited where the secondary peaks form. No liner decline pattern for heavy metals concentration was also found in Jian-Hua et al. (2009) study. This study also showed that there were differences between heavy metals concentration of the two sides of the road because of differences in directions and strength of winds in these regions. Direction of wind in this area is NS (north to south) which could help remove heavy metal particles from northern to southern side. Bakirdere et al. (2008) reported the same effect. In addition, results showed significant differences of heavy metals concentration in the two depths of soil samples. It was because of sediments of heavy metals in upper layer of soil, so this layer was more influenced than deeper layers. Al-Chalabi et al. (2000) reported that heavy metal emissions were deposited on upper layer and influenced it. All lead, cadmium, copper and zinc concentrations were lower than critical limit reported by ICRCL (1987). This study focused on comparing the heavy metals concentrations in different distances from the road. Low concentration could be due to the age of the road which was not old enough to be much contaminated.

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