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Assessment of Pb and Ni contamination in the topsoil of ring roads' green spaces in the city of Hamedan

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ABSTRACT: Due to rapid industrialization and urbanization, environmental pollution has become a major concern in developing countries; therefore, the main objective of the current study is to determine heavy metal contents of Pb, and Ni for 42 topsoil samples, collected from 14 green spaces along the 1st and 2nd ring roads in Hamedan City in 2016. For this purpose, after determining some chemical properties as well as acid digestion of soil samples, Pb and Ni concentrations have been found in the soil samples with ICP-OES. All statistical analyses have been conducted, using SPSS 18.0 statistical package, with the results showing that the metal levels in soil samples, collected from green space of 1st and 2nd ring road, have been 34.86±10.28 and 41.57±10.08 mg/kg for Pb and 14.0-20.33 and 14.0-20.0 mg/kg for Ni, respectively. Also the mean concentration of Pb and Ni have been lower than MPL. According to heavy metal concentration maps, the spatial distribution patterns of Pb, and Ni contents in the soil samples are generally similar along the 1st and 2nd ring road. Due to the fact that traffic volume in the 2nd ring was higher than the 1st one, there has been a significant difference in the mean contents of Pb between the topsoil samples, collected from the 1st and 2nd ring roads; therefore, it is recommended to keep environmental health in order to control the anthropogenic sources, causing the pollutants discharge into the environment is recommended.

Keywords: green space, heavy metals, roadside, soil contamination, spatial distribution.

INTRODUCTION

Human activities such as urbanization and urban development, emission from thermal power stations and industrial plants, mining, agricultural activities, waste disposal, vehicle traffic/road infrastructures, and soil amendment can significantly boost the accumulation of metallic elements in terrestrial environments (soils and sediments) (Hursthouse et al., 2004; Karbassi et al., 2005; 2006; Alizamir & Sobhanardakani, 2016). It has been proven that under certain environmental conditions, pollutants, especially the heavy metals, may accumulate up to toxic levels, causing ecological damages (Sobhanardakani & Jafari, 2015). Some heavy metals like Cu, Fe, Mn, Ni, and Zn are known as essential metals, since they play an important role in biological systems, whereas nonessential metals, including As, Cd, Hg, and Pb, are toxic, capable of posing significant health-related risks to men and other living organisms, even in low levels (Hursthouse et al., 2004; Sobhanardakani & Jafari, 2015). It should be noted that essential metals can also have toxic and adverse health effects at high concentrations (Sobhanardakani & Jafari, 2015); therefore, nowadays, due to the ability of heavy metals

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to accumulate in the biota as well as their toxicity potentials and adverse health effects even at low contents, the presence of heavy metals in the environment have caused global concerns (Morillo et al., 2002; Alizamir & Sobhanardakani, 2016).

In urban areas, soil acquires new functions such as aesthetic and recreational ones, playing a distinct environmental role, especially by contributing to the preservation of biodiversity. In this regard, since in an urban environment soil can more easily come into contact with humans and be transferred via the metabolic chain, either as re-suspended dust or through direct contact, they can directly influence public health (Ferguson, 1999; Hursthouse et al., 2004).

As the most common environmental metal poison, lead can pose the most common environmental health risk. Men are exposed to this element, mainly through inadvertent ingestion of Pb-based paint as well as inhalation of traffic exhaust fumes, not to mention consumption of Pb-contaminated foods (Adekunle & Akinyemi, 2004; Şireli et al., 2006).

Nickel is regarded as a hazardous agent, due to its adverse health effects such as hematotoxic, hepatotoxic, immunotoxic, genotoxic, nephrotoxic, neurotoxic, pulmonary toxic, and carcinogenic potentiality. Nickel exposure leads to the formation of free radicals in various tissues of living organisms, in turn resulting in altered calcium and sulfhydryl homeostasis, various modifications of DNA bases, and enhanced lipid peroxidation (Das et al., 2008; Sobhanardakani et al., 2016).

A ring road is a road or a series of connected roads, encircling a town or city with high rates of vehicle traffic, resulting in the discharge of a variety of pollutants, especially heavy metals, into their surroundings, e.g. soil, water, and air environment (Al-Shayeb & Seaward, 2001; Farzan & Sobhanardakani, 2016). In this regard, other studies have reported that there is a positive correlation between the heavy-metal content of urban soils and some intensive urbanization metrics such as population density, percentage of urban land use, length of urban roads and highways, and particularly traffic volume (Pouyat et al., 2008).

Literature review shows the relation between heavy metals contamination in topsoil along the ring roads and traffic density. In this regard, contamination of roadside environments with heavy metals has been shown by many researchers, including Yousefi et al. (2015), Aslam et al. (2013), Tanee and Albert (2013), Shashank and Prasad (2010), Ezer (2009), Bakirdere and Yaman (2008), Nabulo et al. (2006), Fakayode and Olu-Owolabi (2003), Al-Shayeb and Seaward (2001), Pagotto et al. (2001), and Al-Chalabi and Hawker (2000).

Obviously the huge increase in the number of motor vehicles in Hamedan is leading to increasingly high levels of some toxic heavy metals in urban environment, especially in roadside topsoil; therefore, the current study has been carried out to determine Pb and Ni contamination in the topsoil of ring roads' green spaces in Hamedan in 2016.

MATERIAL AND METHODS

The study took place in Hamedan, one of the 15 metropolitans in Iran in the western part of Iran with an average annual temperature of 11.1 °C and rainfall of 331 mm. The 1^{st} and 2^{nd} ring roads were about 5.25 and 18.18 km long respectively, with the 1^{st} one being located in the center of city and the 2^{nd} one around the city.

In accordance with Cochran's sample size formula, totally 42 topsoil samples (upper 0-15 cm depth) were collected from fourteen different locations along the 1^{st} and 2^{nd} ring roads with a hand auger. Soil samples were collected with a polyethylene scoop and got stored in plastic bags. The soil samples were air-dried and passed through a 2 mm plastic sieve in order to remove gravel and rocks, ultimately to be poured into plastic bags. Figure 1 shows the sampling stations in the study area (Sobhanardakani et al., 2016).

In order to study the heavy metals concentration and carry out the chemical analysis, all of the soil samples were poured into Teflon tubes. Then 1 g of each dried soil specimen was placed in a 250 mL Pyrex flask. The digestion was performed with a mixture of $HClO_4$-HNO_3-HCl-HF, added to the flask, which was then placed for 10 minutes in a microwave oven at 180 °C. Finally, the metal levels of the soil samples were determined with an inductively-coupled plasma-optical emission spectrometry (Varian 710-ES, Australia), while the standard solutions were made from stock solutions (1000 ppm) of all elements, supplied with Sigma-Aldrich (Spain) (Kelepertsis et al., 2001; Hayzoun et al., 2014; Sobhanardakani et al., 2016). All instrumental conditions, applied for Pb, and Ni content determinations, were adjusted in accordance with general recommendations (the wave length for Pb and Ni being 220.3 nm, and 231.6 nm, respectively).

Apart from heavy metals, soil pH was determined, too. For this purpose, 10 g of soil sample was weighed into a clean beaker, and then 25-ml double-distilled water (1:2.5) was added. The obtained mixture was stirred with a clean glass rod, and the soil slurry was allowed to equilibrate for 30 min. What is more, wet and dry sieving techniques as well as the pipette method was used for soil particle size analysis (sand, silt, clay) (Dantu, 2010). Also, the electrical conductivity (EC) was measured after preparing the extracts (the ratio of soil and water quality is 1:5) with a conductivity/ TDS meter (Jenway 4520, Australia) (Lyu & Chen, 2016). The spatial distribution maps of heavy metals in soil were prepared with Inverse Distance Weighting (IDW) interpolation method by means of ArcGIS v.10.2.2, since the number of sampling points was small.

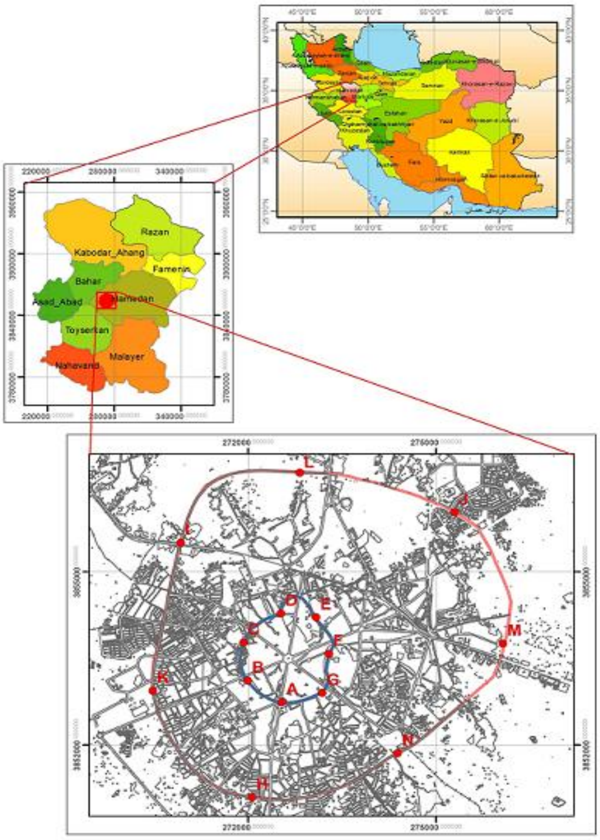

Fig. 1. The location of the study area in Iran and the soil sampling stations

The statistical analysis of the obtained results consisted in a first Shapiro-Wilk normality test, followed by the study of the variance homogeneity, using an ANOVA parametric test with a DMS post hoc and Duncan's multiple comparison tests at the 0.05 significance level. The mean levels of the heavy metals were compared with WHO maximum permissible limit, using a one-sample test. The mean contents of heavy metals for 1st and 2nd ring roads were compared with each other, using independent t test. Also, Pearson correlation analysis was employed to measure the correlations between the mean concentrations of metals and chemical properties of the soil, with the statistical calculations carried out by means of SPSS version 18.0 (SPSS Inc., Chicago, IL, USA) statistical package.

RESULTS AND DISCUSSION

Table 1 shows the descriptive statistics of Pb and Ni concentrations in the topsoil samples, collected from the green space of ring roads in Hamedan City, as well as the chemical properties of the soil. The data in Table 1 shows that the percentage of metal contamination of topsoil samples reached 100%. Among the analyzed topsoil samples, Pb was detected to range between 20.0 and 52.0 and Ni from 14.0 to 20.33 mg/kg.

Comparison of heavy-metal concentrations in the studied topsoil samples with the maximum permissible limits (mg/kg) (140.0 for Pb and 50.0 for Ni), established by WHO, USEPA, and CCME (CCME, 2007; Xia et al., 2011), showed that the mean concentration (mg/kg) of Pb and Ni were 38.21±10.55 and 17.58±2.33, respectively, both lower than MPL; therefore, Pb and Ni content in topsoil samples of green space of ring roads in Hamedan City was not hazardous to Human Health.

Table 1. Heavy metal concentration (mg/kg) in topsoil samples of ring roads in Hamedan City

Sampling station	Pb	Ni	pH	EC (µS/cm)
		1st ring road		
A	25.0^{a}	15.0^{ab}	7.36^{a}	0.52^{a}
B	36.0^{bcd}	16.0^{abc}	7.45^{bcd}	0.57^{a}
C	31.0^{b}	14.0^{a}	7.56^{cde}	0.51^{a}
D	50.0^{fg}	18.5^{cde}	7.62^{ef}	0.53^{a}
E	45.0^{ef}	19.0^{cde}	7.49^{bcd}	0.54^{a}
F	37.0^{cd}	17.0^{abcd}	7.56^{def}	0.62^{a}
G	20.0^{a}	20.33^{e}	7.60^{def}	0.59^{a}
Min	20.0	14.0	7.36	0.51
Max	50.0	20.33	7.62	0.62
Mean	34.86	17.12	7.52	0.55
SD	10.28	2.28	0.09	0.04
		2nd ring road		
H	24.0^{a}	20.0^{de}	7.66^{ef}	0.66^{a}
I	32.0^{bc}	19.0^{cde}	7.58^{def}	0.55^{a}
J	45.0^{ef}	20.0^{de}	7.63^{ef}	0.63^{a}
K	52.0^{g}	20.0^{de}	7.39^{ab}	0.53^{a}
L	48.0^{fg}	18.0^{bcde}	7.43^{abc}	0.57^{a}
M	41.0^{de}	15.33^{ab}	7.69^{ef}	0.60^{a}
N	49.0^{fg}	14.0^{a}	7.61^{f}	0.62^{a}
Min	24.0	14.0	7.39	0.53
Max	52.0	20.0	7.69	0.66
Mean	41.57	18.05	7.57	0.59
SD	10.08	2.94	0.11	0.05

* The letters (a, b, c, d, …) represent statistical differences (statistical grouping) among different topsoil samples, based on the mean concentration of metals and mean amount of chemical properties of soil, according to Duncan multiple range test (p= 0.05)

The results of independent t-test showed that there was only a significant difference (p= 0.039) in the contents of Pb, among topsoil samples of 1st and 2nd ring roads in Hamedan City, whereas for the levels/amounts of Ni, pH, and EC there was no statistically significant difference (p= 0.260, 0.217, and 0.068, respectively) for the samples, collected from the 1st and 2nd ring roads.

Pearson's correlation analysis showed that there were no significant correlations between Pb and Ni, Pb and pH, Pb and EC, Ni and pH, and Ni and EC values in topsoil samples (Table 2).

Table 2. The correlation between the total contents of heavy metals and chemical properties in topsoil samples

Elements/Parameters	Pb	Ni	pH	EC
Pb	1			
Ni	0.061	1		
pH	0.051	0.067	1	
EC	0.084	0.231	0.273	1

Lead, which is known as a non-essential element, can cause oxidative stress and disrupt the delicate antioxidant balance of the cells especially in mammals. High levels of this element in the body lead to some adverse health effects, such as headache, colic, brain damage, anemia, and central nervous system disorder (Shah et al., 2013). It has been proven that the contents of Pb in surface soils of roadside are strongly related to the combustion of fuels that contain $(CH_3CH_2)_4Pb$, traffic density, traffic signals, driving mode, meteorological parameters, and distance from roadside (Al-Shayeb and Seaward, 2001; Aslam et al., 2013). The results of the current study reveal that the mean concentration of Pb (mg/kg) in topsoil samples, collected from the green spaces of 1st and 2nd ring road in Hamedan City were 34.86±10.28 and 41.57±10.08, respectively. In this regard, Chow (1970), Lagerwerff and Specht (1970), Wheeler and Rolfe (1979), Harrison et al. (1981), Ndiokwere (1984), Ward (1990), García and Millán (1994), Piron-Frenet et al. (1994), and Ho and Tai (1998) found Pb contamination in surface soil samples, collected from the roadside. Soil contamination of the roadside's surface with Pb has been shown by many researchers, presented in Table 3.

Nickel, an essential element for living organisms such ass plants and animals, is necessary in a small quantity for the formation of red blood cells along with regulation of lipid contents in tissues. However at high levels, this metal is toxic, causing severe diseases like skin irritation, loss of vision, loss of body weight, and heart and liver failures (Shah et al., 2013). The experimental data revealed that Ni content (mg/kg) in topsoil samples, collected from the green spaces of 1st and 2nd ring roads, occurred within a range of 14.0-20.33 and 14.0-20.0, respectively. Nickel contents (mg/kg) in the literature have been reported to range between 13.31 and 98.13 in surface soil samples, collected from the roads with more than two traffic signals and between 18.29 and 59.36 in surface soil samples, collected from roads with only one traffic signal (Shah et al., 2013). Table 3 compares the present mean values of Ni in surface soil samples with other studies.

As shown in Figures 2 and 3, the spatial distribution patterns of Pb, and Ni contents in the soil samples were generally similar along the 1st and 2nd ring road of Hamedan City. Both concentrations of Pb and Ni showed a decreasing trend as the distance from the road got higher, and especially in case of Pb, the concentration of this element in roadside soil samples had a positive correlation with traffic density, which was in agreement with the research results, reported by Nabulo et al. (2006). Also, the results showed that the high contents or hotspots for Pb and Ni mainly existed within the 2nd ring road, while, the levels of these elements in other parts of the study area were relatively low.

Table 3. Comparison of Pb and Ni contents (mg/kg) in topsoil samples of urban green spaces of ring roads with the corresponding values of other studies

Location	Pb	Ni	Source
Iran (Asadabad)	20.72	-	Solgi (2016)
Iran (Khorramabad)	7.38	-	Solgi & Konani (2016)
New Zealand (Auckland)	36.0	21.0	Curran-Cournane et al. (2015)
Iran (Semnan)	22.1	28.2	Mirzaei (2015)
Serbia (Belgrade)	-	61.5	Kuzmanoski et al. (2014)
Ukraine (Berehove)	29.8	30.5	Vince et al. (2014)
China (Xiamen)	36.0	8.4	Luo et al. (2012)
China (Beiging)	30.0	24.6	Xia et al. (2011)
China (Guangzhou)	159.6	7.3	Dong-sheng & Peart (2006)
Hong Kong	39.6	5.3	Lee et al. (2006)
China (Beiging)	66.2	22.2	Chen et al. (2005)
Italy (Torino)	158.0	193.0	Hursthouse et al. (2004)
Scotland (Glasgow)[57]	971.0	58.0	Hursthouse et al. (2004)
Spain (Seville)[58]	150.0	22.5	Madrid et al. (2002)
This study	38.21	17.58	-

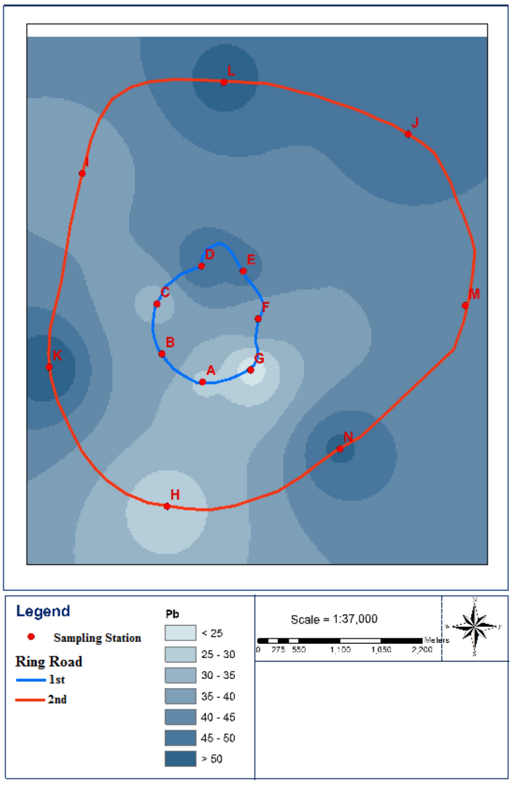

Fig. 2. Map of Pb distributions in green space topsoil of ring roads in Hamadan City

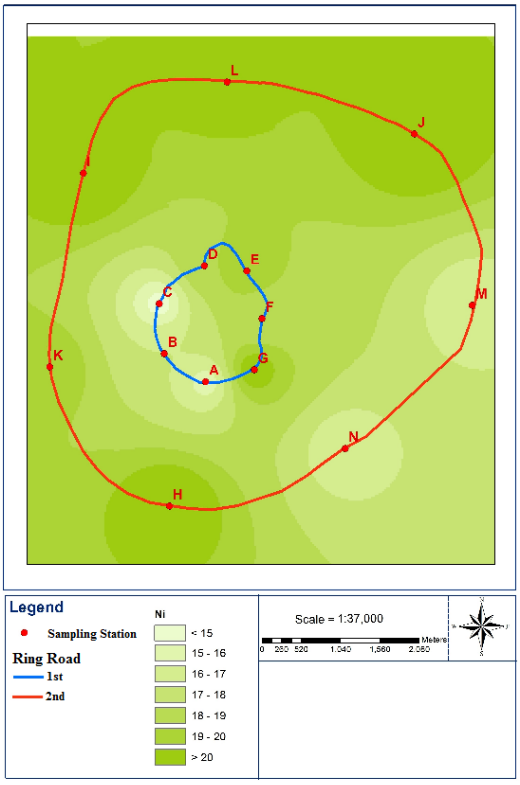

Fig. 3. Map of Ni distributions in green space topsoil of ring roads in Hamadan City

CONCLUSION

Green spaces are covered by different biological products; therefore, they play a main role in human life. In this respect urban green spaces provide a suitable living environment, hence it is essential to monitor the quality of this land use. The present study analyzed and compared the contents of Pb and Ni in topsoil samples, collected from the green spaces of 1st and 2nd ring road in Hamedan City. Based on the results, due to the movements of heavy-duty vehicles along with the connection of main roads network to the 2nd ring road, the traffic volume in this ring road was higher than the 1st one, indicating a significant difference in the mean contents of Pb among the topsoil samples, collected from both 1st (34.86±10.28 mg/kg) and 2nd (41.57±10.08 mg/kg) ring roads. Therefore, according to the results of this study, it can be concluded that the contents of heavy metals in topsoil are significantly influenced by the location of green spaces within an urban setting at any point of time.

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