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A comparative study of metals in roadside soils and urban parks from Hamedan metropolis, Iran

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ABSTRACT

A total of 25 roadside and 25 park soils have been sampled from six major streets and seven urban parks of the city of Hamedan (Iran) and analyzed for Pb and Cd. Metal pollution and spatial distribution maps were carried out using the pollution index(PI), integrated pollution index(IPI) and ordinary kriging with Geographic Information Systems. High levels of Cd and Pb were observed with average concentrations of Cd and Pb in the urban roadside soils being 1.57 ± 0.53, and 164.04 ± 50.08 mg/kg, respectively. However, the concentrations in urban park soils (1.16 ± 0.62, and 105.4 ± 46.47 mg/kg, respectively), were significantly lower. Vehicle traffic has resulted in a significant enrichment of Cd and Pb in the roadside soils with the highest concentrations found in the city center. The spatial distribution pattern of Cd and Pb in urban soils of Hamedan indicated that the concentration of metals in the central and northern parts of Hamedan is high, due to the human activities. Findings of metals in soils of major streets and urban parks indicated that metal contamination in urban roadside soils was higher than urban parks showing suitability of these soils than urban parks as indicators of metal contamination in urban areas.

1. Introduction

Soil pollution by metals is a worldwide environmental concern. Rapid industrialization and urbanization has led to increased soil and water pollution, and a direct influence on public health (Lu et al., 2007). Urban soil receives a large number of pollutants and metals inputs from many sources, therefore urban soils are an important indicator of urban environmental quality (Christoforidis and Stamatis, 2009; Luo et al., 2012). In urban environment, intensive human activities (such as disposal of municipal and industrial wastes, domestic heating, industrial emissions and energy production) and heavy traffic are the main sources of metals that pollute parks and roadside lawns (Santorufo et al., 2012; Rizo et al., 2013). Therefore, it is important to gain understanding of the concentration, distribution and possible sources of metals in urban soils. In the recent decades, the study of metals in urban soils, developed in the late 1960s (Purves, 1967), have been welcomed by many researchers (Albanese and Cicchella, 2012; Filippelli et al., 2012; Szolnoki et al., 2013; Santorufo et al., 2012; Rizo et al., 2013; Du et al., 2013; Al Obaidy and Al Mashhadi., 2013; Hamad et al., 2014; Karim et al., 2014; Argyraki and Kelepertzis 2014; Doležalová Weissmannová et al., 2015; Liu et al., 2016).

Among metals in the urban soil, Cd and Pb have been receiving more attention in researches (Massadeh 2004; Rodrigues et al., 2013; Li et al., 2014; Wu et al., 2015; Solgi, 2016). Metals such as Cd and Pb are common contaminants in urban soils and have been shown to be very useful traces of environmental pollution (Manta et al., 2002). The high concentration of Pb and Cd in urban areas are mainly related to automobile exhaust, particularly from leaded gasoline, motor vehicle tires, and lubricant oils (Sharma and Prasad, 2010). Since, there is a difference in pollutant concentrations in soil from different urban land uses, the study of metals concentrations in different types of land use of urban soils is desirable in order to establish the source of metals contamination of soils and prevent accumulation up to levels which may be considered as toxic for human health (Xia et al., 2011).

With regard to population growth and industrial development, the percentage of population living in Hamedan is increasing significantly and, as a result, assessing the quality of the urban environment especially monitoring of urban soils pollution essential for human health. Also, Hamedan is the largest city and capital of Hamedan province in Iran, nevertheless, no information is available on heavy metals level in Hamedan urban soils. This research assessed the concentration and sources of Cd and Pb in park and roadside soils from Hamadan city, The main objectives of this

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research were: (1) to determine the total concentration of Pb and Cd in urban roadside and park soils in Hamedan city, (2) to assess the degree of pollution of Pb and Cd in urban soils by comparison with those from other cities around the world, and the maximum permissible limits, and (4) to evaluate the spatial distribution pattern of Cd and Pb using GIS approaches.

2. Material and methods

Hamedan city (34°48′N, 48°31′E) is the center of Hamedan province of Iran and located in the middle part of Hamedan County (Balmaki and Aldin Niknami, 2012) (Fig. 1). Hamedan is the official and political center of Hamedan province, with a history of over 2500 years. Hamedan is one of the oldest cities of Iran and the resident of more than 500,000 people. Also in February 2010, Hamedan was considered as a metropolis (Shojaeimehr and Zakerhaghighi, 2013). Geographically, Hamedan city is located in the foothills of the Alvand Mountain and is 1813 m above sea level (Shojaeimehr and Zakerhaghighi, 2013). Based on the Emberger climate classification (reference), the climate is cold semi-arid and average annual rainfall is 330 mm and the annual mean temperature is 11° C. Hamedan city is located between two valleys, Abas-abad valley and the Moradbeig valley and also is located between Bahar and Kaboodarahang from the north and northwest, and Malayer and Toyserkan from the east and south. In Hamedan the prevailing wind is from the southwest.

In the present research, the scope of the sampling area is limited to the urban area of Hamedan, which has an area of 60 km^2. Seven different urban parks and six major city streets were selected in this study. A total of 50 surface soil samples (0–20 cm depth) were collected from roadside (n = 25 samples) and urban parks (n = 25 samples). The sampling location coordinates were recorded with a GPS and the location of sampling points is shown in Fig. 1. Composite samples were obtained by mixing subsamples from five random points within each sampling site. All collected soils were kept in sealed polyethylene bags and labeled for subsequent sample preparation and analysis laboratory. The urban soils were air dried at room temperature and passed through a 2 mm plastic sieve. The samples were ground to pass through a 0.15 mm nylon sieve for analysis. Each sample weighing about 0.5 g was digested using HCl, HNO_3 and $HClO_4$ for determining Pb and Cd concentrations. The concentration of Pb was determined using Flame Atomic Absorption Spectrometry (F-AAS), whereas Cd was analyzed by Graphite Furnace Atomic Absorption Spectrometry (GF-AAS). An AAS instrument (Varian. Spectra AA 220) equipped with the graphite furnace was applied for the measurement of heavy metals. The important parameters applied for Pb measurement were: a wavelength of 283.3 nm, a lamp current of 3.0 mA, and slit width of 0.2 nm. The parameters for Cd analysis were a wavelength of 228.8 nm nm, a current of 3.0 mA, and slit width of 0.2 nm. The calibration standard solutions for Cd and Pb were prepared with a standard solution of 1000 mg/L of these metals. The LOD of Cd and, Pb were 0.004, and 0.5 mg/kg, respectively. Also, the LOQ of these heavy metals were 0.01, and 1.6 mg/kg, respectively. Because of the absence of standard reference material (SRM) for the soil samples, the accuracy of the digestion method was evaluated by performing spike recovery test. A good agreement was obtained between the added and measured analyte amounts that approve the accuracy of the procedure. The obtained recoveries were between 93%–104.2%. The precision of analytical procedures was expressed as relative standard deviation (RSD). Each solution was replicated three times and the relative standard deviation (RSD) of the repeated analyses for each metal ranged from 5 to 8%. Also as a quality assurance blank sample without soil was included in the sample batches.

For each sample, about 5 g of sieved soil was weighted for determining the soil pH and electrical conductivity (EC). Both pH and EC were measured in a suspension at 1:5 soil:deionized water ratio after shaking for 2 h with a calibrated pH-meter and conductivity-meter respectively.

Statistical analysis of data was done using SPSS V18.0 for Windows and Microsoft Excel Analysis. Confidence levels were calculated using 95% limits. A Pearson's correlation test was used to evaluate the relationships among metal concentrations and soil properties. The Shapiro–Wilks test for normality was employed. Analysis of variance (one way ANOVA) was applied to compare the mean metal concentrations among the sites. Leven's test was done to evaluate homogeneity of variances. Further evaluation was performed via Dunnett's T3 test in case of no homogeneity. The pollution index (PI) and integrated pollution index (IPI) were calculated for measuring the degree of pollution in soils. These indices have been applied by many researchers to evaluate the environment quality of the contaminated soils (Chen et al., 2005; Sun et al., 2010; Rizo et al., 2011; Belabed et al., 2014). The PI of each metal was calculated as the ratio of the metal concentration in the soil to the background (reference) value for the metal. This index is computed with the following formula:

$$\mathrm{PI} = C_i/S_i$$

Where PI is the assessment score for each sample, Ci is the measured concentration of metal i and Bi is the background concentration of the metal i in soil. In this study, the background concentrations are based on earth crust values (Taylor, 1964). IPI is expressed as the mean values for all the Pollution Indexes (PI) of all regarded metals (Rizo et al., 2011). IPI is measured by the following equation:

$$\mathrm{IPI} = \frac{1}{\mathrm{n}}\sum_{\mathrm{i=1}}^{\mathrm{n}}\mathrm{PI_i}$$

Where, n is the number of metals (two in this study). The PI was classified as: PI ≤ 1 low pollution; 1 ≤ PI < 3 moderate pollution and PI > 3 while IPI was classified as: IPI ≤ 1 low level of pollution; 1 < IPI ≤ 2 moderate level of pollution; IPI > 2 high level of pollution (Wei and Yang 2010; Rizo et al., 2011; Salah et al., 2013).

The Cd and Pb concentrations were used as the input data for a contour map to study the spatial distribution of theses metals in the urban topsoil. The spatial distribution maps were produced using GIS software ArcGIS 9.3.

3. Results and discussion

The descriptive statistics of Cd and Pb concentrations in urban park and roadside soils are shown in Table 1. Concentration of Cd and Pb in urban park soils was found in the range of 0.23 to 2.30 mg kg^{-1} with a mean value of 1.16 mg $kg^{-1}$and 30.9 to 190 mg kg^{-1} with a mean value of 105.38 mg kg^{-1}, respectively. Also the concentrations of two hmetals (Cd and Pb) in roadside soils varied between 0.59–2.50 mg kg^{-1} (mean = 1.56 mgkg^{-1}) and 87–265 mg kg^{-1} (mean = 164 mg kg^{-1}), respectively. According to Kabata-Pendias (2000), the typical normal ranges of Pb and Cd in soil are 0.5–1.0 and 10–30 mg $kg^{-1}$of dry weight respectively. In addition, cadmium concentrations over 0.5 mg kg^{-1}could reflect the impacts of human activities on soil contamination (McBride, 1994). Because of the mean concentrations of Cd and Pb reported in this study are higher than the typical levels in soils, likely an anthropogenic source are the responsible for the presence of these metals in urban soils.

There are no universally established allowed limits or MCLs (Maximum Contaminant Levels) for assessing the state of Cd and Pb pollution in soils. Different guidelines are used in different