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Lead isotope composition and risk elements distribution in urban soils of historically different cities Ostrava and Prague, the Czech Republic

Ivana Galušková [a,*], Martin Mihaljevič [b], Luboš Borůvka [a], Ondřej Drábek [a], Manfred Frühauf [c], Karel Němeček [a]

[a] Department of Soil Science and Soil Protection, Czech University of Life Sciences Prague, Faculty of Agrobiology, Food and Natural Resources, Kamýcká 129, 165 21 Prague 6, Czech Republic
[b] Institute of Geochemistry, Mineralogy and Mineral Resources, Charles University in Prague, Faculty of Science, Albertov 6, 128 43 Prague 2, Czech Republic
[c] Institute of Geosciences, Martin Luther University HalleWittenberg, Von-Seckendorff-Platz 4, 061 20 Halle (Saale), Germany

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ABSTRACT

The impact of intensive industry and other human activities on urban soil pollution and the origin of these pollutants were studied in industrial Ostrava and residential Prague. The concentrations of fourteen risk elements and lead isotopic compositions were assessed in soil samples of urban parks. Prague was characterised by elevated concentrations of As (median 22 mg·kg^{-1}), Se (0.7 mg·kg^{-1}), Cu (50 mg·kg^{-1}), Pb (67 mg·kg^{-1}) and Ni (27 mg·kg^{-1}), while Ostrava by Cd (median 0.8 mg·kg^{-1}), Zn (152 mg·kg^{-1}), Mn (828 mg·kg^{-1}) and Cr (43 mg·kg^{-1}), where Cd reached on average two times higher values compared to Prague parks. Significantly higher concentrations of risk elements were found in both cities in sites under tree crowns compared to open areas. A more considerable trend was observed in Ostrava, a city affected by strong airborne deposition. Differences in Pb isotopic composition between both cities were proven despite their having similar values. Lower $^{206}Pb/^{207}Pb$ ratios of 1.164–1.206 (median 1.174) were found in Prague, compared to Ostrava with the ratios 1.159–1.198 (median 1.180). The broad range of isotopic ratios in cities corresponds to a combination of different pollution sources and a long term accumulation of pollutants in the soils. One of the lowest ratios ($^{206}Pb/^{207}Pb$ 1.172, mean calculated from all samples of the park — Karlovo náměstí in Prague) was assessed in a park which is significantly influenced by traffic.

Contents

1. Introduction

The urban environment represents one of the most endangered areas by pollutants due to intensive anthropogenic activities where a large number of inhabitants are contemporaneously exposed to a health risk (Li et al., 2004; Madrid et al., 2008).

Soils in cities are often contaminated from a broad range of sources (Bretzel and Calderisi, 2006; Manta et al., 2002) by both organic and inorganic pollutants. As stated in the study by Li et al. (2004) soils of different sectors (industrial, commercial etc.) are characterized by elevated contents of specific metals. The main risks posed by inorganic contaminants arise due to their non-biodegradability and accumulation in soils resulting in a long period of exposure (Lee et al., 2006). Urban soils do not present an immediate threat to health with respect to entrance of contaminants to food production. However, they can enter

* Corresponding author. Tel.: +420 224 382 758.
E-mail address: galuskova@af.czu.cz (I. Galušková).

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the human body via dust ingestion, dermal contact or inhalation. Children are particularly exposed to a high threat as they play on the ground and then place their fingers covered by dust and soil into their mouths (Biasioli et al., 2006; Madrid et al., 2006).

Lead isotopes are commonly used as tracers of environmental pollution sources, where the $^{206}Pb/^{207}Pb$ ratio is the most preferred because it can be precisely determined (Komárek et al., 2008). Lead originating from different sources of pollution is characterized by different ratios (Watmough et al., 1999). Various components of the environment can convey information about the history of contamination. Peat and sediments have been used in many studies for the evaluation of several millennia of Pb contamination and for the study of Pb origin (Novák et al., 2003; Renberg et al., 2001), while soil and plants have been used for the assessment of several decades and centuries old contamination (Conkova and Kubiznakova, 2008; Sucharová et al., 2011b; Watmough et al., 1999). The isotopic composition of prevailing anthropogenic Pb sources and polluters have been mapped in detail on a European scale (Hamester et al., 1994; Hansmann and Köppel, 2000; Véron et al., 1999) and specifically for the Czech Republic (Ettler et al., 2004; Mihaljevič et al., 2006, 2009; Novák et al., 2003; Sucharová et al., 2011b). In the Czech Republic higher ratios were found in the industrial north ($^{206}Pb/^{207}Pb = 1.17–1.19$) while the rural south area with sparse industrial activities showed lower ratios ($^{206}Pb/^{207}Pb = 1.12–1.16$). This information can now be used to detect the source of Pb contamination in problematic areas such as metropolitan zones, where a mixture of polluters exists; and also to monitor the Pb load development in the future. The aim of the paper is to study the sources of pollution, the impact on park soil and the distribution of contaminants in historically different metropolises in Central Europe.

2. Materials and methods

2.1. Sampling and sample preparation

Soil samples were collected in urban parks and green spaces of two important cities of the Czech Republic (Fig. 1), Prague (13 parks) and Ostrava (9 parks) in June and August, respectively, of 2006. At each locality composite soil samples were collected at a site under trees and in an open area at depths of 0–10, 10–20 and 20–30 cm. The total number of samples was 78 in Prague and 54 in Ostrava. The soil samples were afterward air-dried, ground and passed through a 2 mm sieve (Galušková et al., 2011).

2.2. Analytical procedures

Active pH was determined potentiometrically (pH meter inoLab pH Level 1 WTW) using soil/ water ratio of 1:10 (Westerman, 1990), soil organic carbon (SOC) content was determined by a modified oxidimetric Tyurin method (Pospíšil, 1964) and humus quality was determined as the ratio of pyrophosphate soil extract absorbance at wavelengths 400 and 600 nm (A_{400}/A_{600}) according to Pospíšil (1981); soil texture was determined by laser-diffraction analysis (Malvern Mastersizer 2000 with wet cell Malvern Hydro 2000S). Risk elements and metals were extracted by a mixture of concentrated HCl/HNO_3 (aqua regia) according to ISO 11466:1995 (pseudototal content). Risk element contents and Pb isotopic ratios were assessed by inductively coupled plasma mass spectrometry (ICP-MS, Xseries^{II} ThermoScientific). Detailed analytical conditions of Pb isotope measurements are given in Ettler et al. (2004). Mass bias correction of isotopic ratios was done using NIST SRM 981.

Data were treated statistically using Statgraphics (version 5.0) software.

3. Results and discussion

3.1. Soil characteristics

Basic soil parameters did not differ significantly between Prague and Ostrava (see Table 1). However, there were statistically significant differences of basic soil characteristics between parks in both cities. The lower pH values observed under tree crowns can be partially explained by the interception of acidic atmospheric particulates by tree leaves or needles and their subsequent entrance into the soil following precipitation (Augusto et al., 2002). All the soil samples analysed in 0–30 cm depth were identified as silt loam (USDA classification).

3.2. Risk elements in soils

Prague and Ostrava rank among cities in the Czech Republic with highly deteriorated air quality. The main cause of pollution in Prague is from traffic, followed by burning of solid fuels and waste. Ostrava is one of the most polluted cities in the Czech Republic and Europe. As a result of heavy industry, coal processing and burning, waste incineration in households and traffic, the concentration of fine particles (PM10) in the atmosphere annually exceeds year-long limits. Park soils in both cities showed elevated concentrations of risk elements

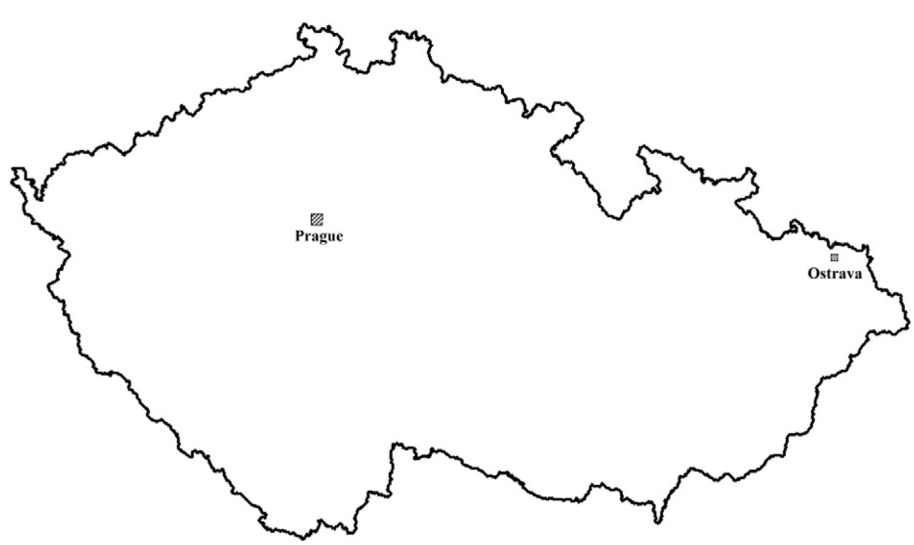

Fig. 1. Location of Prague and Ostrava in the Czech Republic.