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Geochemistry of urban soil in the industrial town of Maribor, Slovenia

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ABSTRACT

The first systematic geochemical survey of urban soil in the old industrial town of Maribor, Slovenia, was performed in 2016. Soil properties (pH, electrical conductivity, total carbon, organic matter) and 56 aqua-regia soluble elements were determined from 118 sampling sites. A relatively clear distinction between naturally and anthropogenically distributed elements was found by inspection of the spatial distribution of their highest levels and by applying Spearman rank correlation coefficients. The median levels of Cu, Pb and Zn in the soil are significantly higher than the corresponding Slovenian median levels. Their enrichment is typically found in industrialised zones and the old town centre, suggesting that the elevated levels are historical. In addition, current industrial activities, as well as road and rail traffic contribute to increased levels. Additionally, a few isolated locations with significant enrichment of several elements were identified. Widespread diffuse contamination was not identified. Spatial distribution patterns of many elements (e.g., Co, Cr, Fe, V) are influenced by the geological setting of the area, as their highest soil levels are concentrated at the foot of the igneous-metamorphic Pohorje Mountains.

1. Introduction

Geochemical studies of urban soil are focused mainly on several potentially hazardous elements (PHEs), which are recognised as the most dangerous for ecosystems, organisms and human health. This includes the so-called '*typical urban elements*' (Cu, Hg, Pb and Zn), which are frequently enriched in urban soil throughout the world (Yang and Zhang, 2015), and other elements (e.g., As, Cd, Co, Cr, Ni and Sb). They are emitted into the environment by various human activities on a daily basis (e.g., road and rail traffic, industrial activities, and waste production). The changes in people's lifestyles, environmental awareness and economic activities have caused the introduction of some additional elements into urban environmental compartments. One such group is the Platinum Group Elements (PGEs; Pt, Pd, Rh), which are used in vehicle exhaust catalysts to reduce air pollution by gaseous pollutants (CO, NO_x, HCs). Levels of PGEs have increased significantly in the last decades in different environmental compartments, including soil (Cicchella et al., 2003; Ravindra et al., 2004; Angelone et al., 2007; Mihaljevič et al., 2013; Yang and Zhang, 2015). Another group of elements, which usage has increased in the past two decades are the Rare Earth Elements (REEs), a group of 17 elements (i.e., Sc, Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu). Their use is widespread in many common electronic devices (e.g., TVs, computers, mobile phones, cameras), batteries in electric vehicles and in other portable devices. They are used in vehicle catalysts, different alloys, magnets, fluorescent lighting, for polishing and other purposes (King, 2016). Fossil fuels contain 0.5–2% of REEs (Wong et al., 2006) and, thus, their usage also contributes to REE emissions. Despite an increasing usage of REEs, data on their levels and distribution in urban soil is scarce (Angelone et al., 2007; Giusti, 2013; Ticianelli et al., 2013). There are also other elements, which are usually neglected in urban geochemistry studies, but pose potential threat to ecosystems and human health (e.g., Ag, Ba, Mn, Se, Th). Determination of the multi-elemental composition of urban soil contributes significantly to the satisfactory assessment of the quality of the urban environment. This study provides data on aqua-regia extractable levels of 56 elements, including REEs, in topsoil of the town of Maribor, Slovenia.

The town of Maribor was one of the most important industrial centres in Slovenia and the former state of Yugoslavia and, thus, exposed to potential environmental contamination. As an old industrial town, the soil of Maribor was expected to contain elevated levels of some PHEs. Besides industry, the environmental compartments of the town are also affected by heavy traffic, because Maribor is located at road and railway junctions of local and international importance. Parts of Maribor were included in several previous national-scale geochemical surveys (Andjelov, 1994; Šajn, 2003; Zupan et al., 2008; Andjelov, 2012; Gosar et al., 2016). Only a few soil samples were included in the previous studies, which did not indicate any widespread contamination. An unpublished report of a soil survey conducted on children's playgrounds in nine kindergartens in Maribor showed the possibility of

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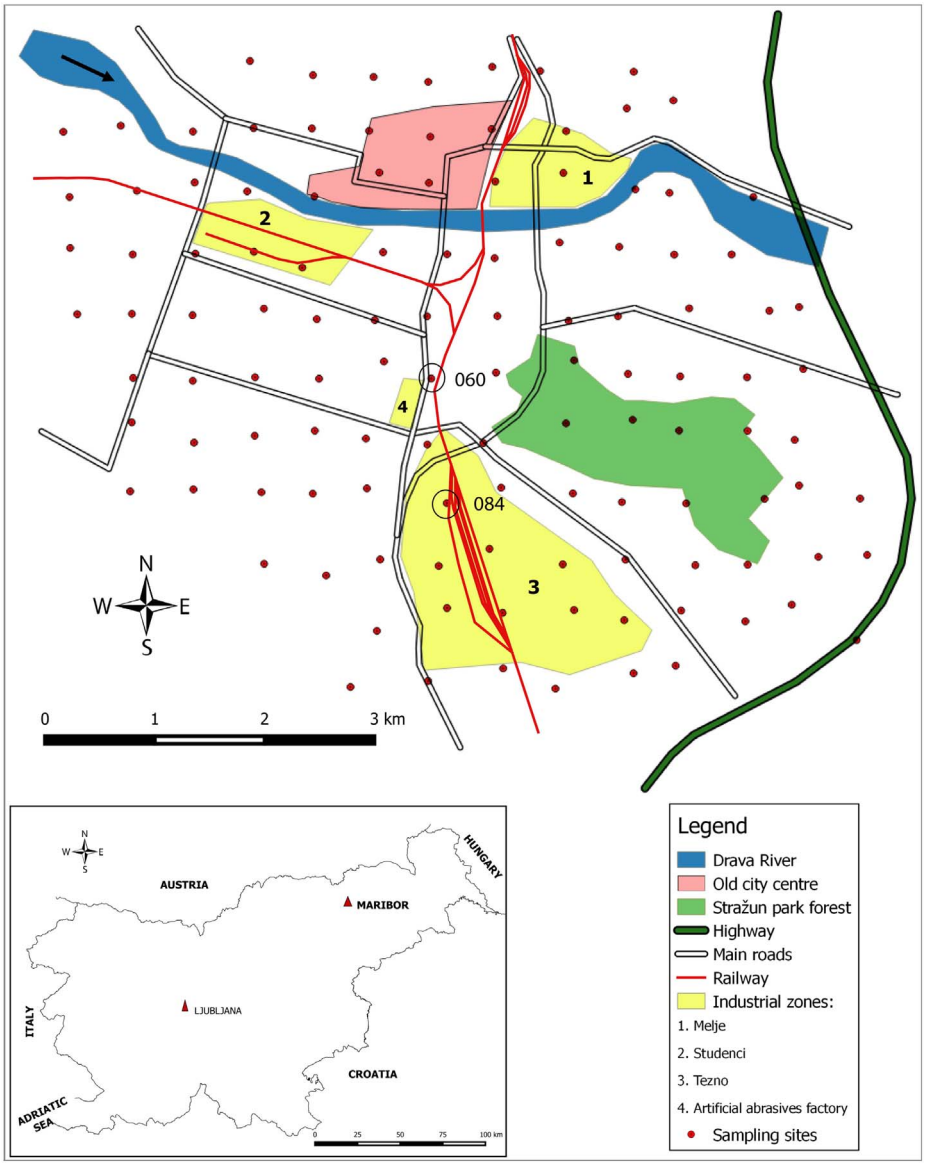

Fig. 1. Schematic map of Maribor with sampling sites (samples MBSO-060 and MBSO-084 are circled). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

slightly elevated levels of some elements in the vicinity of the old industrial zones (Grčman et al., 2008).

The aim of this paper is to present the results of the first systematic multi-element geochemical study on urban soil from the town of Maribor. The study was found necessary due to the vibrant industrial activities in the past 150 years, and the fact that Maribor is the second largest Slovenian town. The presented data will serve as a baseline for monitoring future changes in the soil chemical composition.

1.1. Study area

Maribor is the second largest town in Slovenia, with approximately 95,000 inhabitants. It is located in the north-eastern part of Slovenia (Fig. 1), close to the country border with Austria (46°33′44.94″N, 15°38′38.31″E, 275 m above sea level). It covers an area of 41 km^2. Maribor developed on the alluvial plain of the Drava River, which was one of the most important factors influencing the dissemination and development of the settlement in the past. The surroundings of the town are dominated by the hilly area of Slovenske Gorice to the east and north and by the Pohorje and Kozjak Mountains, which represent the easternmost extensions of the Alps, to the west and north-west. The Drava valley extends into a large plain area south of the town. Maribor is surrounded by intensely farmed areas. Steep slopes to the north and east are covered with vineyards; while corn and wheat fields are typical on flatter areas. The south-eastern part of the town is strongly characterised by the protected park-forest Stražun, which covers an area of about 1.5 km^2.

The climate of Maribor and surrounding area is continental, characterised by significant differences in weather conditions between different seasons. According to the Slovenian Environment Agency data (ARSO, 2016), average annual temperature in years 1961–1990 was 9.7 °C and average precipitation was 1045 mm. The climate data for 1991–2006 period show that average annual temperature was 10.7 °C and an average precipitation of 993.5 mm. The prevailing wind direction is north-west and the average wind speed is 1.8 m/s (Bertalanič, 2007).

1.2. An overview of industrial history of Maribor

The transformation of Maribor from a small settlement to an important industrial town started with the construction of Vienna-Trieste railway in the mid-19th century, which ran close to Maribor (Slavec, 1991; Oset et al., 2010). The first large industrial plant in Maribor was the railway workshop designed for repairing railway carriages