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Distribution of chemical elements in an old metallurgical area, Zenica (Bosnia and Herzegovina)

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ABSTRACT

The objective of this work is to study the distribution of chemical elements in topsoil and subsoil, focusing on the identification of anthropogenic (human-made) and geogenic (natural) element sources in a former metallurgical industrial area. Samples of topsoil (0–5 cm depth) and subsoil (20–30 cm depth) were collected from 60 different sites in a 52 km^2 area around the town of Zenica, Bosnia and Herzegovina. The study was based on comparisons of statistical parameters, spatial distribution of selected elements, and the results of cluster and factor analyses. Two natural geochemical associations and one anthropogenic association were identified. The natural geochemical associations (Al, Ce, K, La, Li, Nb, Rb, Sc, Ta, Ti Th, V, and Y and Co, Cr, Na, Ni, and Mg) are predominantly influenced by lithological factors, whereas the anthropogenic association (Ag, Bi, Cd, Cu, Hg, Mo, Pb, Sb, and Zn) is the result of past iron metallurgy in the study area. Although Zenica was the largest ironwork in former Yugoslavia, the observed level of contamination is rather low when compared to the iron and steel industry in Bosnia, Herzegovina and Slovenia.

1. Introduction

In the territory of present day Bosnia and Herzegovina, mining and metallurgy are considered among the oldest forms of industry. The earliest recorded evidence dates back to the Neolithic Age, but major mineral exploration and mine development began during medieval times and the Austro-Hungarian occupation of Bosnia. The mines attracted foreign entrepreneurs who established settlements, colonies, and caravan parks. By the end of nineteenth century, three coal mines (Raspotočje, Drivuša, and Stara Jama) had been opened. Under the post World War II communist government, the industrialization of Bosnia and Herzegovina increased further. The environmental impact of the long term operation of mines, ironworks, and smelters in this region was the major source of contamination with metals (Alijagić and Šajn, 2006; Duran, 1997).

Construction of the iron and steel works in Zenica began in 1892; upon completion the operation produced about 3700 tons of rolled products. Through the years new facilities were built and the production was dramatically expanded. By 1986 it had reached 1.72 million tons of pig iron and 1.91 million tons of crude steel. After the end of the Bosnian War (1992–1995), plant operations continued, although at a lower capacity (Monography, Faculty of Metallurgy and Material Science of Zenica, 1961–2001, 2001). The rapid growth in coal, iron, and steel production (1.4 million tons of steel, 924000 tons of coal by 1990) over a long period of time left significant trace metal contamination throughout the area (Serdarević et al., 1987).

Metal contamination in urban areas has recently become a subject of many studies (Borůvka et al., 2005; Bretzel and Calderisi, 2006; Chen et al., 2005; Moller et al., 2005; Wang et al., 2005). Contamination of soil occurs mainly in industrial regions and within major settlements where factories, motor vehicles, and municipal wastes are the most important sources of trace metals (Kabata-Pendias and Pendias, 2001). Previous researches in the study area have usually considered the most common metals such as Cd, Cu, Fe, Pb, Zn, and Hg (Goletić and Redžić, 2003; Ivetić, 1991).

The objectives of this work have been: (a) to study the distribution of chemical elements in topsoil and subsoil; (b) to define by statistical methods the main geochemical groups and their spatial distribution in soil; (c) to identify the distribution of the elements in the survey area as either geogenic or anthropogenic; and (d) to determine the spatial contamination in topsoil and subsoil.

2. Material and methods

2.1. Description of the study area

The town of Zenica (170000 inhabitants) is situated in the Bosna River valley, surrounded by mountains and hills. The climate is moderate continental, with warm summers and cold winters. Mean temperatures in January are under 0 °C, whereas the mean temperatures in July are between 19 °C and 23 °C. The mean annual precipitation is 800 mm (Bosnia and Herzegovina, Federation of

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Bosnia and Herzegovina, Federal Office of Statistics, 2009). The study area is in central Bosnia and Herzegovina and covers an area of 52 km^2 (7 km W–E × 9 km S–N) (Fig. 1). The area of the different land uses is: urban area 12.9 km^2 (settlements: 9.2 km^2, industrial zone 3.7 km^2); cultivated land, meadows, and pastures 26.2 km^2; forests 11.8 km^2; and surface water (mostly the river Bosna) 1.1 km^2. About 23 km^2 of the study area lies below a height of 400 m above sea level, and the built-up areas of the city are situated on the lowlands (Fig. 2). Spatial data were acquired by digitization of existing topographical maps (Topographic Map of Bosnia and Herzegovina, 1977), Google Earth maps, and SRTM 90 m digital elevation data with additional reambulation of data.

The geological information of the study area is taken from the Basic Geological Map of the Socialist Federal Republic of Yugoslavia (SFRY), scale 1:100 000, sheet Zenica (Živanović et al., 1975). The oldest rocks are found in the N and NW of the study area, and are represented by the Jurassic–Cretaceous flysch — Vranduk series (^{2}JK, marly limestone, calcarenites, detritic limestone with rare nodules of hornfels, marls, and sandy claystones). Cretaceous formations are mostly of Senonian massive limestone and limestone breccias (K_2^3) that occur as discontinuous belts between the Jurassic–Cretaceous flysch and the Oligo-Miocene complex (clastite and marl complex). On the left bank of the river to the S and SW of the study area are the Miocene clastic carbonate series ($M_{2,3}$). In the Lašva zone, the dominant bedrocks are conglomerate, with alternating layers of sandstone, marls, and limestones. Between the Lašva zone and the Oligo-Miocene complex occurs the Miocene principal coal zone (M_2), within which the coal mines Drivuša, Raspotočje, Stara Jama, and Podbrežje are situated. The quaternary sediments are represented by the Holocene river terraces and the recent alluvial planes. Younger Quaternary layers are found along the present watercourse in the gravel-conglomerate terraces (Fig. 3).

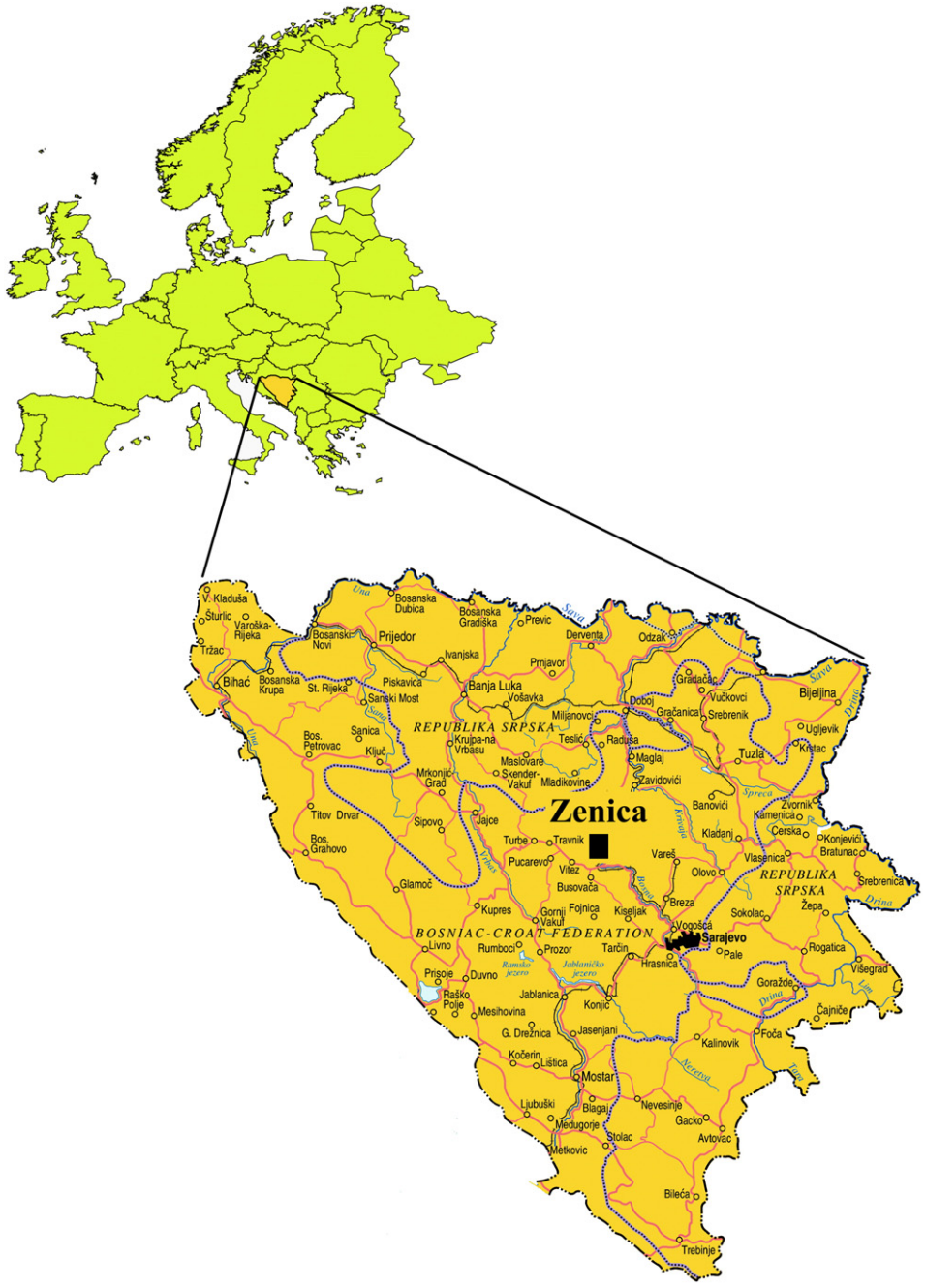

Fig. 1. Location of study area in Bosnia and Herzegovina.