Using multivariate statistics for clarifying the element sources in soil in the area of Sisak, Croatia

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Upotreba multivarijantne statistike za određivanje porijekla elemenata u tlu na području Siska, Hrvatska

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The EuroGeoSurveys Geochemistry Expert Group initiated in 2008 the project "Urban Geochemistry in Europe (URGE) – soil, children, health" with the main aim to standardize geochemical studies in the urban areas. Thirteen cities were interested in participating in the project, among them Sisak (Croatia). The Sisak is an ancient and industrial city (SLUKAN ALTIĆ, 2004). In the former Yugoslavia in Sisak was developed heavy industry like steelworks, a thermoelectric power plant, refinery, chemical industry, etc. After 1990s almost all industry in the city collapsed.

The area of Sisak is lowland covered by fine-grained Quaternary deposits (silts, sands, clays, loess) (PIKIJA, 1987a, b). The floodplain sediments of the Sava river are composed of carbonates while those of rivers Kupa and Odra are dominated by siliciclastics. The great meander of the river Kupa is covered by loess. In the rural part of the investigated area hydromorphic soils prevail, while in the urban part technogenic soils (urban soils) predominate (HUSNJAK, 2012).

Composite samples were taken in the topsoil layer from a depth of 0–10 cm with a sampling density of 4 samples/km^2 in the urban area and 1 sample/km^2 in the rural area around the city. The sampling grid was regular and squared. The total surface of the researched area was 65.18 km^2 at which 144 samples were taken. Chemical analyses were performed by Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) for the set of 53 chemical elements in the ACME Anal. Lab., Vancouver, Canada. Soil pH was determined according to HRN ISO 10390 (2005). Quality control (QC) was maintained during sampling and analysis. The QC of the field duplicates showed great variability, this was expected since the urban geochemical data are very variable. Coefficient of variation of the precision of chemical analyses was low and the accuracy of the reference material was good.

Factor analysis (FA) of the data was carried out to reduce the observed variables in order to obtain a better understanding and to simplify its interpretation. Using this approach, the geogenic and/or anthropogenic sources of the factorized geochemical data were evaluated. In order to perform multivariate statistical analyses the analytical data was screened. The analytical data, except the pH value, were log-transformed to base 10 logarithms (log10) to approach a normal distribution of the data (REIMANN et al., 2008). The factor analysis (FA) was carried out using the statistical software IBM SPSS.

The data were adequate for factorization since the results of the KMO test is 0.763 and Bartlett's test of sphericity < 0.001 (KAISER, 1960). The 8 factors were retained (those with eigenvalues >1) which explain 84.07 of the variance. The factors were rotated by Varimax rotation to simplify its interpretation. The obtained factor scores were stored as a new variable and used for generating geochemical maps in GIS software ArcGIS™, using the extension Geostatistical Analyst. After variogram analyses, the geochemical maps of factors were generated using kriging method. The factor scores at the factor maps were classified to emphasize the highest and lowest values. Factor analysis yielded: 2 geogenic factors (FA 3 and 5), 4 anthropogenic factors (FA 1, 6, 7 and 8), 1 anthropogenic and partly geogenic (FA 4) and 1 geogenic and partially anthropogenic factor (FA 2).

The geogenic were dominantly influenced by the lithological composition of the investigated area (ŠORŠA, 2014; ŠORŠA & HALAMIĆ, 2014). The western part of the investigated area is composed of siliciclastic alluvium of Kupa and Odra rivers. The eastern part of the investigated area is covered by carbonate alluvial sediments of the Sava river. In the middle of the map is the transition zone between siliciclastic and carbonate alluviums which is additionally influenced by the urban and industrial activities. The big meander of the Kupa river is covered by loess deposits which are continued by terrace sediments with similar elements composition towards northwest.

The anthropogenic factors had the highest factor values at the south of the investigated area. They represent the influence of heavy industry and cover the area with industrial

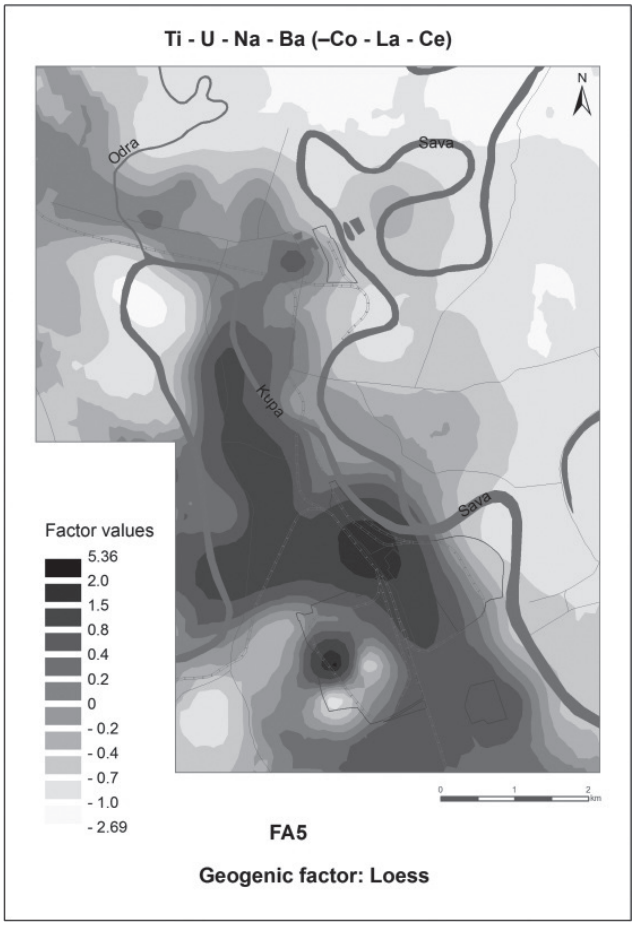

Figure 1. Geogenic factor 5.
Slika 1. Geogeni faktor 5.

facilities, neighborhood settlements and agricultural land across the Sava river. The antique part of Sisak at the north, also was influenced by industry and long-lasting urban development. Elevated factor values in the anthropogenic and partially anthropogenic factors were observed in the old part of Sisak, at some agricultural parcels, along frequent roads and in the industrial zones.

The results pointed out that main influence at the urban and rural soils composition were by parent material but the soils also are very good sink for collecting and accumulating trace elements in the long-lasting urban and industrial areas.

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