CROSS-VARIOGRAMS OF GEOCHEMICAL, VERTICAL AND SURFACE MAGNETOMETRIC MEASUREMENTS IN AREAS WITH STRONG ANTHROPOGENIC PRESSURE

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Introduction

Determination of soil pollution is usually done by measurements of a concentration of Potentially Toxic Elements (PTE) in soil. However, chemical analyses are frequently supplemented by fast and inexpensive geophysical methods that are intensively developed. One of such methods is a field magnetometry that aim at the measuring the magnetic susceptibility of top soil layers. Numerous studies performed so far, confirmed the existence of statistically significant correlation between soil magnetic susceptibility and the concentration of pollutants. However, in these studies the relationship between magnetometric and chemical measurements was mostly investigated using simple statistical measures such as Pearson's and Spearman's correlation coefficients. The goal of this study was to investigate the correlations between geochemical, surface and vertical magnetometric using more advanced methods. In particular, geostatistical measure of spatial correlations, specifically cross-variograms, were used.

Methods

Study sites were selected in Poland and in Norway, in the areas with a strong anthropogenic pressure. In Poland, three neighboring sites were located in the park, forest, and arable field to the south of Katowice agglomeration. Next large site was located in the direct vicinity of Katowice steelworks, in the complex area that included park, large reservoir, and habited regions. Additional sites were located in the Izery Mountains, and these sites were subjected to the pollution related to glasswork, and long-range pollution from Czech Republic. In Norway, 9 sites were located in forested areas, in different distance to the large iron mine Bjornevatn, and nickel smelters in Nikel town.

Soil magnetic susceptibility (κ) was measured using the Bartington MS2D loop sensor. At selected location 10 to 15 single readings of soil magnetic susceptibility were made in the circle with a radius of 2 m, to obtain the average value, representative for the measured point.

Additionally, soil cores were collected in the field that were later used to measure the magnetic susceptibility in soil profile using MS2C Bartington device.

Values of soil magnetic susceptibility and a concentration of PTEs measured at sample points were used to calculate experimental cross-variograms that were modeled using spherical, exponential or Gaussian model, which parameters, such as a nugget effect, a range of correlation, and a sill were determined.

Chemical measurements were carried out using sub-samples that were cut from the collected soil cores. In particular the top 10 cm of the soil core was used, because it was the maximum penetration depth of the MS2D sensor. Soil sub-samples were dried in room temperature, and after that sieved through a 1 mm sieve. After the soil samples were digested the BCR sequential extraction procedure was used to determine the concentration of PTEs in soil.

Results

For each of the study areas cross-variograms of PTE and κ were modeled using spherical model that was the most suitable one. Determined nugget effects and parameters of spherical models, such as a range of correlation and a sill were analyzed in details.

For most of the analyzed PTEs it was possible to fit the linear model of coregionalization that suggested that it would be possible to integrate magnetic susceptibility measured on the soil surface and parameters of a distribution of magnetic susceptibility in soil profile using cokriging.

Conclusions

Geostatistical tools such as cross-variograms can be very useful when analyzing the correlation between soil magnetic susceptibility and a concentration of elements in soil. Apart from the determination of strength of correlation between magnetometric and geochemical measurements at sample points, it was also possible to determine how the strength of these correlation changed along with a distance.

Key finding was that despite of the small number of chemical samples it was possible to model cross-variograms between geochemical and magnetometric measurements using, if necessary, expert-knowledge. It made it possible to analyze spatial correlation in local scale when the number of chemical samples was limited.

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