Lead contents and magnetic susceptibility in alluvial soils of the Štiavnica brook

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A b s t r a c t: The results of field and laboratory research showed that lead contents in soils gradually decreased with increasing distance regardless of the increase in soil organic matter and clay fraction contents. The same trend was observed for the changes in magnetic susceptibility values, which highly correlates with lead contents in monitored soils. The obtained results indicate that the measurement of magnetic susceptibility in the alluvium of the Štiavnica brook can be a very perspective method for soil survey aimed by the identification and mapping of soils highly contaminated at heavy metals.

Key words: magnetic susceptibility, lead, soil contamination, alluvial soils

1. Introduction

Surveys carried out since 1960 have indicated that soils in many parts of the world, especially in urban and industrial areas, contain anomalously high concentrations of heavy metals. A need for rapid and inexpensive methods of outlining areas, exposed to increased pollution by heavy metals of industrial origin, caused scientists in various fields to use and validate different non-traditional (or non-chemical) techniques *(Negri and Hinchman, 1996; Florek et al., 2001; Shilton et al., 2005).* Among them, a soil magnetometry seems to be a suitable tool, at least in some cases. Soil magnetometry is

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based on the knowledge that detected higher values of magnetic susceptibility of soils' samples above background indicate higher concentration of heavy metals in soil *(Chan et al., 1998; Ďurža, 1999; Kapička et al., 2000; Magiera and Strzyszcz, 2000).*

2. Heavy metals in soil

Heavy metals are important in several ways: many are used industrially in technologically advanced countries, some are physiologically essential for plants and animals - and thus have a direct bearing on human health and agricultural productivity - and many are significant as pollutants in ecosystems throughout the world.

Heavy metals in soils have received increasing attention in recent years *(Chan et al., 1998; Ďurža, 1999; Kapička et al., 2000; Magiera and Strzyszcz, 2000).* It was recommended by *Mikľajev and Žogolev (1990)* to use soil magnetometry as a preliminary method that enables to outline zones of "increased geochemical activity", to bring down a bulk of works and to change flexibly the method of mapping but also in study of surface sediments *(Brandau and Urbat 2000; Milička et al., 2002)* and pedological study of paleosols and loess *(Cocuaud et al., 1998; Ďurža et al., 2004)* .

There are two sources of heavy metals: natural – geochemical and anthropogenic. Campbell et al. (1983 in *Mejeed 1997)* compared natural and anthropogenic quantities of heavy metals in atmosphere and declared that men emitted 15-times more Cd, 100-times more Pb, 13-times more Cu and 21-times more Zn in comparison with natural sources.

Environmental pollution, especially by chemicals, is one of the most effective factors in the destruction of the biosphere components. Among all chemical contaminants, heavy metals are believed to be of a specific ecological, biological, or health significance. While geological and biological alterations of the earth's surface have been very slow, changes introduced and/or stimulated by man have accumulated extremely quickly in recent years.

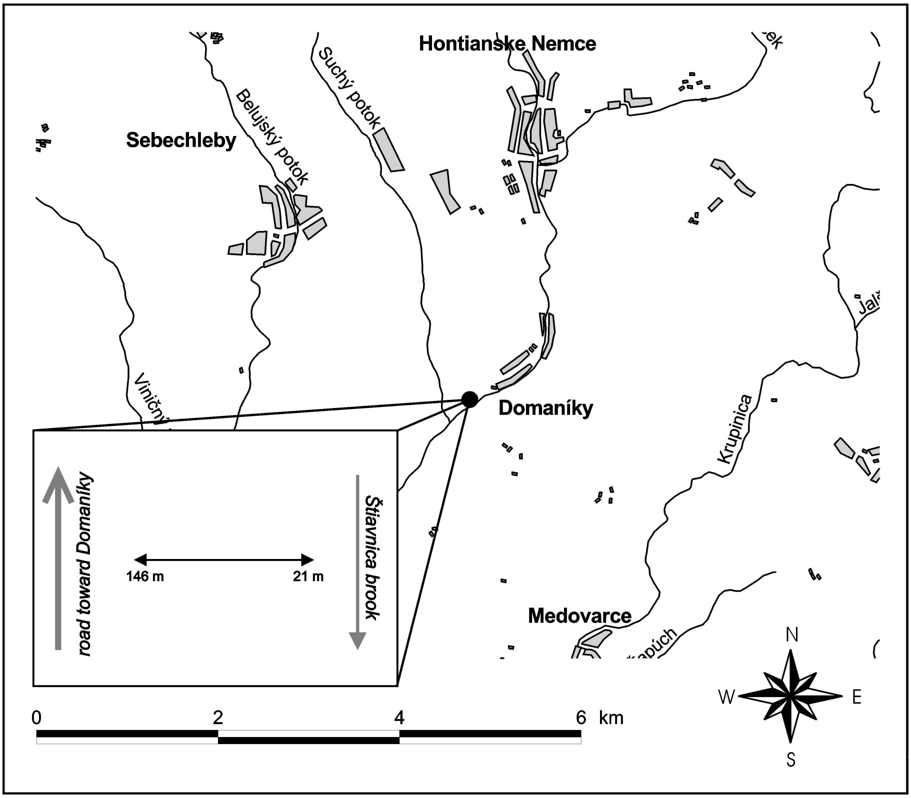

Fig. 1. Schematic presentation of the study site location.

3. The origin of magnetic particles in the soil

Magnetic particles in the soil may be derived geologically from atmospheric sources, anthropogenic, if they are derived from industrial emissions, or biogenic in nature. The strong correlation between magnetic susceptibility and several heavy metal concentrations suggests a significant contribution to the magnetism from anthropogenic sources in the topsoil *(Chan et al., 1998)*.

Ferrimagnetic iron oxide particles (mainly magnetite and maghemite) in fly ashes, originating during high-temperature combustion of fossil fuels, are potentially the most significant source of anthropogenic ferrimagnetics found in the upper soil horizons. Except for small amounts of magnetite in coal, the main source of ferrimagnetics is pyrite, the concentration of which reaches up to 15% of inorganic fraction in hard coal (Kuhl, 1961; in *Magiera and Strzyszcz 2000).* Pyrite and other iron sulphides are oxidized during the coal combustion process. The sulphur is liberated as gas, whereas iron is converted into ferrimagnetic minerals, which are emitted into the atmosphere together with other dusts. The anthropogenic ferrimagnetics are transported as dusts and aerosols over variable distances to settle on the soil surface. Deposition of atmospheric particulates represents one of the most important contributions to environmental stresses.

The correlation between magnetic susceptibility and heavy metal content reveals a causal relation between ferric oxide and heavy metals. Previous studies *(Alloway and Ayres, 1993; Chan et al., 1998)* have shown that certain heavy metals, such as Pb, Cu and Zn, are preferentially adsorbed onto the exterior surface of fly ash and aerosols from industrial emissions, which often contain significant amount of Fe and Mn oxides *(Chan et al., 1998).* The relative order of correlation for these metals with magnetic susceptibility can be explained in terms of the selectivity of clay minerals and hydrous oxide absorbents for the metal, which generally follows the order Pb>Cu>Zn>Cr *(Alloway and Ayres, 1993).*

4. Alluvial soils of the Štiavnica brook

The region of Banská Štiavnica is geologically comprised of volcanic rocks (andesites, ryolites, basalts). This region is known by polymetallic ores, which have been mined almost one millennia. In the course of mining history hundreds of mines were digged and millions of cubic meters of rocks with the different content of sulphides (mostly pyrite FeS_2, galenite PbS, sphalerite ZnS and chalcopyrite $CuFeS_2$). In aerated zones of rocks with sulphides content acid sulphatic weathering with sulphuric acid take place. Clastogene material together with dissolved species were transported to the drainage system of Štiavnica brook. This transporting processes have caused the formation of anomalous concentration of heavy metals in alluvial soil and sediments. The highest concentration relates to Pb and Zn, with accompanied heavy metals: Cd, Cu, Ag, Hg, Se and Cr *(Forgáč and Streško,*

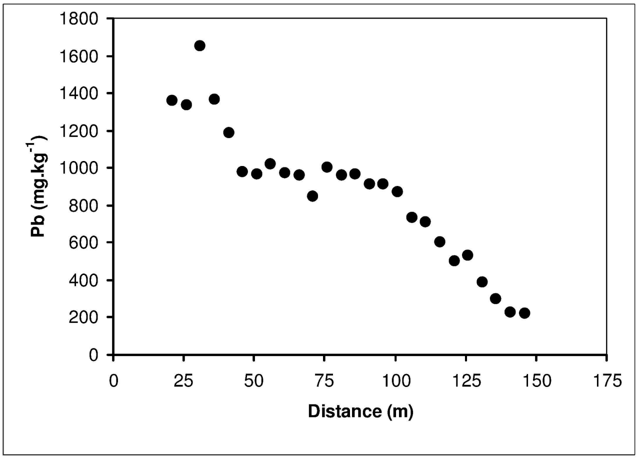

Fig. 2. The change of Pb content in dependence to the distance from Štiavnica brook.

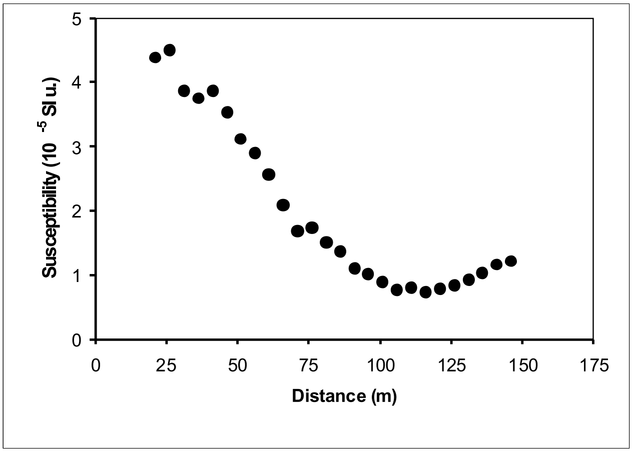

Fig. 3. The change of magnetic susceptibility values in dependence to the distance from Štiavnica brook.

1999).

Studied area is near Domaníky village (Fig. 1). The highest contents of

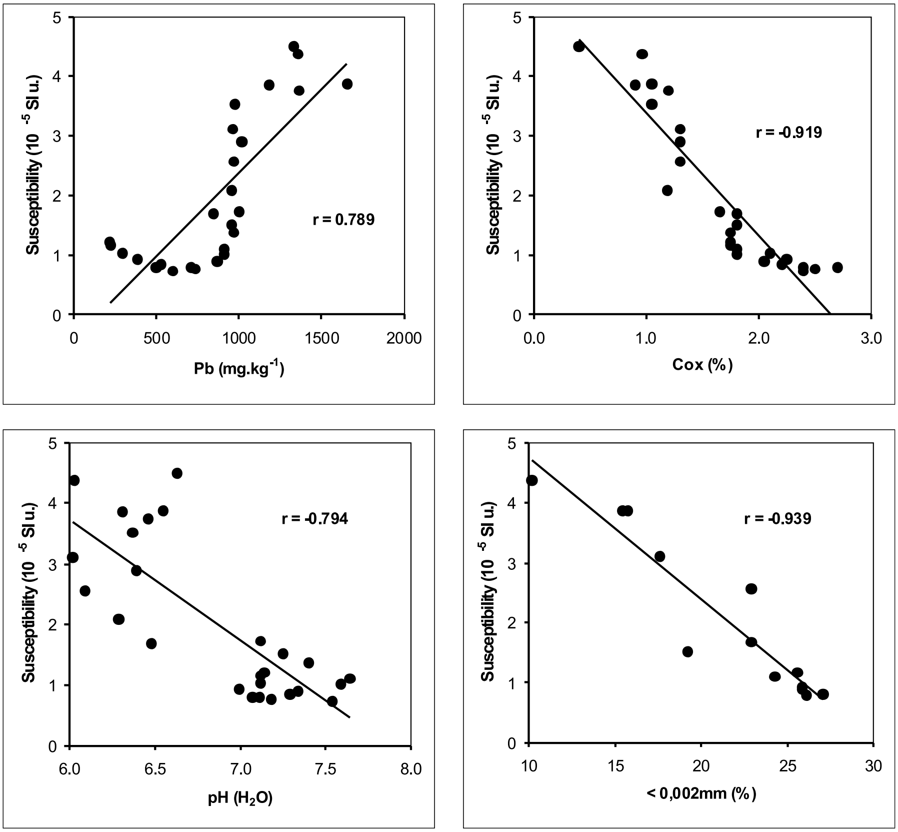

Fig. 4. The relationships between magnetic susceptibility and basic soil properties (total lead content - Pb, organic carbon content – Cox, soil pH, and clay fraction content - <0.002 mm).

lead were found in alluvial soils close to the stream (Eutric Fluvisols) and they gradually decreased with increasing distance (Fig. 2) regardless of the increase in soil organic matter and clay fraction contents (Mollic Fluvisols and Fluvic Gleysols). This tendency clearly shows evidence of contamination contribution by the flow from the area where mining activity used to take place in the past. The same trend was observed for the changes in magnetic susceptibility values (Fig. 3).

Correlation diagrams presented in Fig. 4 show relationships between magnetic susceptibility and soil properties. From the diagrams it is clear the only dependence of magnetic susceptibility on total lead content in soils showed strong positive correlation (r = 0.789). This fact together with unexpected negative correlations with soil organic matter content (Cox) and clay fraction content (<0.002 mm) indicate the selectivity of the used magnetometry method for indirect measurements of soil contamination.

5. Conclusions

The soil survey together with magnetometry measurements in the environmentally stressed area along Štiavnica brook near Domaníky village gave valuable information about contamination of agricultural soils. The highest contents of lead were found in alluvial soils close to the brook. Lead contents gradually decrease with increasing distance from the Štiavnica brook. The same trend was observed for the changes in magnetic susceptibility values. The obtained results indicate that the measurement of magnetic susceptibility in the alluvium of the Štiavnica brook can be a very perspective method for soil survey aimed at the identification and mapping of soils highly contaminated by heavy metals.

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References

Alloway B. J., Ayres D. C., 1993: Chemical Principles of Environmental Pollution. Blackie Academic and Professional, London, 291 p.

Brandau A., Urbat M., 2000: Rock Magnetic Signature of Sediment near the Active Dead Dog Mound, Juan De Fuca Ridge. XXV EGS General Assembly, Geophysical Research Abstract, **2**, CD Rom.

Chan L. S., Yeung C. H., Yim W. W., Or O. L., 1998: Correlation between Magnetic Susceptibility and Distribution of Heavy Metals in Contaminated Sea-floor Sediments of Hong Kong Harbour. Environmental Geology, **36**, 1-2, 77–86.

Cocuaud F., Roussaeu D. D., Antoine P., 1998: Rock Magnetism as a Paleoclimate Proxy in the Loess at Nussloch, Germany. Annales Geophysicae, Part I, Suplement I, **15**, C 101.

Ďurža O., 1999: Heavy Metals Contamination and Magnetic Susceptibility in Soils around Metallurgical Plant. Phys. Chem. Earth (A), **24**, 6, 541–543.

Ďurža O., Dlapa P., Klátiková K., Milička J., 2004: Interpretation of the Magnetic Susceptibility Record of Senec Brickyard Loess/Paleosol Sequence. Contr. Geophys. Geod., **34**, 4, 381–386.

Florek M., Frontasyeva M., Maňkovská B., Oprea K., Pavlov S., Sýkora I., 2001: Present state and tendency in air-pollution by heavy metals and radionuclides in Slovakia. In: 9th International Seminar. Forgáč J., Streško V., 1999: Soil pollution in the alluvial plain of the Štiavnický potok brook. Miner. Slov., **31**, 2, 117–130 (in Slovak).

Forgáč J., Streško V., 1999: Soil pollution in the alluvial plain of the Štiavnický potok brook. Miner. Slov. **31**, 2, 117–130 (in Slovak).

Kapička A., Jordanova N., Petrovský E., Ustjak S., 2000: Magnetic Stability of Power Plant Fly-ash in Different Soil Solutions. Phys. Chem. Earth (A), **25**, 5, 431–436.

Magiera T., Strzyszcz Z., 2000: Ferrimagnetic minerals of anthropogenic origin in soils of Polish national parks. Water air and soil pollution, **124**, 1-2, 37–48.

Mejeed S. Y., 1997: Heavy metals in soil. Manuscript. Department of Geochemistry, Faculty of Natural Sciences, Comenius University, Bratislava, 41 p. (in Slovak).

Mikľajev J. V., Žogolev S. L., 1990: The link anomalies of magnetic susceptibility and lithogeochemical aureoles of metal elements. Vest. Leningr. Un-ta, **7**, 14, 26–33 (in Russian).

Milička J., Vass D., Pereszlényi M., 2002: Organic matter study from the late miocene sediments of Lučenecká kotlina Depression, Southern Slovakia. Miner. Slov., **34**, 2, 93–98 (in Slovak).

Negri M. C., Hinchman R. R., 1996: Plants that remove contaminants from the environment. Laboratory Medicine, **27**, 1, 36–40.

Shilton V. F., Booth C. A., Smith J. P., Giess P., Mitchell D. J., Williams C. D., 2005: Magnetic properties of urban street dust and their relationship with organic matter content in the West Midlands, UK. Atmospheric Environment, **39**, 20, 3651–3659.