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Technogenic Magnetic Particles in Soils Around Different Pollution Sources

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A b s t r a c t

Soil magnetic properties mainly reflect the iron-mineral composition. As ferromagnetic properties sensu stricto are exhibited only by metallic iron (αFe), which is not formed under natural environmental conditions, ferrimagnetic minerals like magnetite, maghemite, pyrrhotite or greigite dominate the bulk magnetic properties of natural soils. Only if ferrimagnetic minerals are lacking, antiferromagnetic minerals such as hematite, goethite, lepidocrocite, ferrihydrite or paramagnetic iron containing aluminosilicates noticeably influence soil magnetic properties. Magnetic susceptibility (κ), which is the easiest measurable magnetic parameter in soil, even under field conditions, can be anthropogenically enhanced in areas influenced by industrial and urban dust deposition due to the presence of technogenic magnetic particles (TMPs). TMPs are defined as different mineral forms of iron that exhibit ferro- or ferrimagnetic properties and were formed during wide variety of high temperature technological processes (metallurgy, fuel combustion, ceramics, cement, coke, etc.), when iron contained in raw materials, fuels or additives was transformed into oxide forms. The results of the previous study showed that different technological processes applied in many kinds of industries are a source of very specific morphological and mineralogical forms of TMPs (Magiera *et al*. 2011, Szuszkiewicz *et al*. 2015, Szumiata *et al*. 2017). Their different internal structure is reflected in their magnetic properties, which may be useful for identification of the source of pollution and can serve as an indicator of dust origin when TMPs are found in the topsoil. During these studies we have analyzed TMPs collected from the forest topsoil or arable layer of agriculture soil around different pollution sources (iron mine, Ni-Cu smelter, iron metallurgical plant, Pb-Zn processing waste heaps). Also the topsoil samples from relatively clean area with strong magnetic background located in southern Norway were collected. The sampling areas were chosen on the base of surface magnetic susceptibility measurements using MS2D Bartington sensor. On the base of analysis of the

spatial distribution of magnetic susceptibility the magnetic anomalies were identified and topsoil cores from the uppermost 30 cm of soil were collected with application of Humax soil sampler. The vertical distribution of volume magnetic susceptibility were made at intervals of 1 cm with application of MS2C Bartington sensor and then the layers with the highest magnetic values were sampled for the further analyses. The measurements of hysteresis parameters were performed on bulk soil sample using a coercivity spectrometer (J-meter), which synchronously measures induced and remanent magnetization curves at room temperature between -1.5 and 1.5 T. The hysteresis curves were used to calculate the classical hysteresis parameters like saturation remanence (Mrs), saturation magnetization (Ms), remanence coercivity (Hcr) and coercivity (Hc). By relating the ratio Mrs/Ms to the ratio Hcr/Hc one obtains a plot which was developed to identify the average magnetic grain size within a sample. For the further analyses the magnetic fraction was concentrated using hand magnet and the magnetic fraction was divided for 2 parts. The first was used for thermomagnetic analyses and the second was sent for mineralogical analysis performed using transmission ^{57}Fe Mössbauer spectrometry at room temperature. On the Day plot the topsoil samples are grouped in different clusters showed that TMPs from different emission sources have different magnetic properties. The natural particles of geogenic origin are mostly multidomain of stoichiometric magnetite. It was confirmed by Mössbauer spectrometry, since the ratio κ of the contribution of iron ions in the octahedral positions (B) to the contribution of iron atoms in tetrahedral positions (A) is close to the theoretical value 2. The relatively large multidomines of magnetite and/or titanomagnetite are observed also in topsoil around iron mine and metallurgical plant. Close to Bjørnevatn iron mine two slightly different ferrimagnetic minerals are observed magnetite and titanomagnetite with different Ti content. The contribution of titanomagnetite in the magnetic fraction was confirmed by geochemical analyses and Mössbauer spectra (low value of κ ratio of the order of 1.3). The Mössbauer analysis revealed also the presence of magnesium ferrite. The topsoil samples collected around Mo I Rana metallurgical plant are also multidomine magnetite-like phases with good stoichiometry found by means of Mössbauer spectra analysis. The considerably finer fraction of TMPs are observed in arable soil and forest topsoils collected close to Pb-Zn wastes in Piekary Śląskie (Upper Silesia, Poland) and Ni-Cu smelter from Nikel (Kola Peninsula, Russia). The samples contain mixture of sulphides (pyrrhotite) and secondary iron oxides and hydrooxides. In some of these samples the Mössbauer spectrometry have detected the dominance of strongly defected (oxidized) magnetite and hematite, as well as noticeable contribution of goethite - FeO(OH).

Keywords: technogenic magnetic particles, iron mineralogy, Mössbauer spectrometry, hysteresis parameters, thermomagnetic analyses.

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