Geophysical Research Abstracts
Vol. 14, EGU2012-1218, 2012
EGU General Assembly 2012

Magnetic mineralogy of heavy metals-contaminated soils

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Soils around mine and in urban areas are often contaminated by heavy metals derived from industrial and human activities [1, 2]. These contaminated soils are often characterized by a magnetic enhancement on topsoils. Many studies demonstrated that there are significant correlations between heavy metals and various magnetic parameters in contaminated soils, indicating a strong affinity of heavy metals to magnetic minerals. The magnetic particles in contaminated soils were separated by a magnetic separation technique. The rock magnetism, XRD, field emission scanning electron microscopy equiped with an energy-dispersive X-ray analyzer (FESEM/EDX) were used to characterize their magnetic mineralogy.
Results of XRD analysis indicated that the magnetic particles separated from heavy metal-contaminated soils are composed of quartz, magnetite, and hematite. Based on the X-ray diffraction peak intensity, the Fe3O4 was identified as the predominant magnetic mineral phase. The high-temperature magnetization (Ms-T) curves of magnetic particles extracted from contaminated soils show a sharp Ms decrease at about 580C (the Curie temperature of magnetite), suggesting that magnetite is the dominant magnetic carrier. The hysteresis loops of contaminated soils are closed at about 100-200 mT which is consistent with the presence of a dominant ferrimagnetic mineral phase. The FESEM analysis showed a great variety of shapes of magnetic particles in contaminated soils. The most common morphology are observed in the form of spherules, with the sizes ranging from 20 to 100 um. The chemical composition of magnetic particles consist mainly of Fe, Si, Al, and Ca with minor heavy metal elements (Cu, Zn, Hg, and Cr). The semi-quantitative Fe content identified by FESEM/EDX ranged from 40 to 90%. Combined studies of rock magnetism, XRD, and FESEM/EDX indicated that magnetic mineral phases responsible for the magnetic enhancement of contaminated soils are anthropogenic origin which are coarse-grained multi-domain (MD) ferrimagnetic minerals.
These spherical magnetic particles in contaminated soils are most likely related to airborne particles from coal combusition and industrial activities. Coal burning, metallurgical and industrial dusts contain a significant fraction of ferrimagnetic minerals. The magnetic particles in fly ash from coal-burning power plant have a typical spherical morphology, ranging from 10 to 100 [U+F06D]m. Vehicle emissions have been suggested to be another source of magnetic particles. These anthropogenic ferrimagnetic mineral phases are directly responsible for the magnetic enhancement in the contaminated soils. Therefore, the strong magnetic signature in contaminated soils can be used as an effective tool for identifying pollution sources and quantifying pollution level of heavy metals.

Acknowledgements: This research was supported by National Nature Science Foundation of China (No. 41171182 and 40971131) and the Ph.D. Programs Foundation of Ministry of Education of China (20090101110088).

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