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Impacts of geology and land use on magnetic susceptibility and selected heavy metals in surface soils of Mashhad plain, northeastern Iran

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ABSTRACT

Magnetic susceptibility is a fast, inexpensive and reliable technique for estimating and monitoring the anthropogenic contamination of soil with heavy metals. However, it is essential to determine the factors affecting magnetic susceptibility before applying this technique to environmental studies. The objectives of this study were to investigate i) the effect of parent materials and land use on the magnetic susceptibility and concentrations of Fe, Ni, Pb and Zn, and ii) capability of magnetic susceptibility as an indicator of anthropogenic heavy metals contamination of soil in Mashhad plain, northeastern Iran. One hundred seventy-eight composite surface soil samples (0–10 cm) were taken. The aqua-regia extractable concentrations of Fe, Ni, Zn and Pb were determined by atomic absorption spectroscopy. Magnetic susceptibility at low and high frequency (χ_{lf} and χ_{hf}) were measured and frequency dependent susceptibility (χ_{fd}) was calculated. The average concentrations of Fe, Ni, Pb and Zn were 22,812, 61.4, 74.1 and 31.6 mg kg^{-1}, respectively. The highest contents of Pb (69.1 mg kg^{-1}) and Zn (149 mg kg^{-1}) were observed in urban area. The highest concentration of Ni was 41,538 mg kg^{-1} observed in the soils developed from ultramafic rocks. Magnetic susceptibility varied from 20.3 on marly sediments to 311.8×10^{-8} m^3 kg^{-1} on ultramafic rocks. A positive strong correlation ($P_{value} < 0.01$, $r = 0.88$) was obtained between Ni and χ_{lf}. There were no significant relationships between Zn and Pb with χ_{lf}, therefore it seems that magnetic susceptibility has not been affected significantly by anthropogenic activities which enhanced Pb and Zn concentrations in urban soils. The results indicated that magnetic susceptibility was mainly controlled by Ni containing minerals with lithogenic origin. Therefore, in the soils studied, magnetic susceptibility could not be employed as indicator of anthropogenic contamination of soil with heavy metals.

1. Introduction

In recent decades, magnetic properties was commonly used to study soil and sediment contamination with heavy metals (Karimi et al., 2011; Morton-Bermea et al., 2009; Lu et al., 2008). Studies have indicated the relationship between heavy metals and magnetic properties and used the magnetic susceptibility as an indicator to evaluate soil pollution intensity (Liu et al., 2016; Morton-Bermea et al., 2009; Dankoub et al., 2012), determine the contamination depth (Blaha et al., 2008; Magiera et al., 2006) and discriminate lithogenic and anthropogenic sources of heavy metals (Xia et al., 2014; Wang et al., 2014; Ayoubi et al., 2014; Magiera et al., 2006).

Heavy metals and magnetic minerals are naturally ubiquitous in the soil parent materials which release to the soil by weathering and pedogenic processes. By increasing industrial activities and urbanization, considerable amount of heavy metals in association with magnetic particles have been gradually added to the soils (Karimi et al., 2011; Wang et al., 2014; Dankoub et al., 2012; Liu et al., 2016). Direct chemical measurement of heavy metal concentrations are usually accurate but costly and time consuming. Investigations have indicated the positive correlation of magnetic susceptibility with heavy metals concentrations. Considering the rapid and inexpensive measurement of magnetic susceptibility, it can be used as a suitable indicator for soil heavy metals contamination (Morton-Bermea et al., 2009; Liu et al., 2016).

Similar to heavy metals, magnetic susceptibility is affected by lithogenic and anthropogenic factors. Parent materials, weathering and pedogenic processes are among the natural factors inducing the variations in magnetic susceptibility values. Rocks and sediments have different kinds and amount of magnetic components according to their mineralogical compositions, hence, have wide range of magnetic susceptibility values. Usually igneous rocks especially mafic and ultramafic rocks have the highest and sedimentary rocks especially those containing large amount of diamagnetic materials (e.g. carbonates, gypsum and quartz) have the lowest magnetic susceptibility values

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