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Magnetic evidence of anthropogenic dust deposition in urban soils of Shanghai, China

Guan Wang[a,b], Feifan Ren[c], Jiao Chen[a], Yuan Liu[d], Fangzhou Ye[d], Frank Oldfield[e], Weiguo Zhang[b], Xiaodong Zhang[a,*]

[a] School of Environment and Architecture, University of Shanghai for Science and technology, Shanghai 200093, China
[b] State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai 200062, China
[c] Key Laboratory of Geotechnical and Underground Engineering of the Ministry of Education, Tongji University, Shanghai 200092, China
[d] Department of Geography, East China Normal University, Shanghai 200062, China
[e] School of Environmental Sciences, University of Liverpool, Liverpool, UK

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ABSTRACT

The magnetic particulates from anthropogenic activities can be detected by magnetic methods rapidly and cost-effectively. This study focused on the investigation of vertical variations in magnetic properties in soil profiles and magnetic enhancement originating in Baoshan, Shanghai. Also the feasibility of using arable and urban park soils as a new context for magnetic monitoring was explored. A combination of magnetic and scanning electron microscopic (SEM) techniques was applied to three soil profiles. Non-pedogenic magnetic enhancement in topsoil was recorded at all three sites accompanied by coarsening of magnetic grain size. The dominant magnetic properties reflect multi-domain (MD) and pseudo-stable single domain (PSD) ferrimagnetic minerals. Both of magnetic concentrations and grain size decrease with the depth, depending on the pollutant input, soil type and degree of vertical mixing. SEM images confirmed the presence of anthropogenic particulates fly-ash. It was concluded from this study that topsoil magnetic enhancement arising from atmospheric contaminants was readily identifiable in both arable fields and urban parks, thus broadening the scope of magnetic research on urban and industrial pollution.

1. Introduction

Magnetic enhancement of topsoil is caused by either natural pedogenic, or anthropogenic (industrial dust, vehicle exhaust and other atmospheric pollutant) processes. The anthropogenic impact on soil profiles can be easily separated from pedogenic enhancement (Lecoanet et al., 2003; Magiera and Zawadzki, 2007; Blaha et al., 2008; Blundell et al., 2009; Kim et al., 2009; Łukasik et al., 2014), since anthropogenic magnetic particles are characterized by specific morphology and coarser magnetic grain size compared with the fine-grained superparamagnetic (SP) and single domain (SD) grains of pedogenic origin (Mullins, 1977; Lecoanet et al., 2001; Ska et al., 2004; Fialov et al., 2006; Lu and Bai, 2006; Magiera et al., 2006; Magiera et al., 2007; Blaha et al., 2008; Magiera et al., 2008; Muxworthy et al., 2002; Łukasik et al., 2014).

Owing to the significant correlation between magnetic susceptibility (MS) and heavy metal contamination in soils (Georgeaud et al., 1997; Xie et al., 2001; Robertson et al., 2003; Desenfant et al., 2004; Gautam et al., 2005; Lu et al., 2007; Yang et al., 2014), non-destructive and rapid magnetic techniques have been increasingly used to detect environmental pollution of soils, sediments and dusts in many studies (Hay et al., 1997; Strzyszcz and Magiera, 1998; Moreno et al., 2003; Boyko et al., 2004; Fialov et al., 2006; Lu and Bai, 2006; Blaha et al., 2008; Sharma and Tripathi, 2008; Zhang et al., 2008; Blundell et al., 2009; Morton-Bermea et al., 2009; Wang et al., 2008; Wang et al., 2012; Pietrodangelo et al., 2013; Yang et al., 2014).

With the rapid industrialization and urbanization, dust pollution is a widespread phenomenon in urban areas. As a result, farmland and parkland soils around industrial areas and transportation lines are becoming increasingly susceptible to atmospherically derived pollution, which may pose serious threats to

* Corresponding author at: School of Environment and Architecture, University of Shanghai for Science and Technology, Shanghai 200093, China.
E-mail address: fatzhxd@126.com (X. Zhang).

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food production and human health. Due to the up-to-down migration characteristics of the dust pollution in the topsoil, the study on soil profiles can provide information on anthropogenic dust input, which may be useful for pollution control and management.

Baoshan District, an industrial zone surrounded by arable land in Shanghai, has suffered varying amounts of soil pollution by a wide range of metal concentrations. Hu et al. (2007) reported that the magnetic susceptibility (MS) of topsoils in Baoshan was significantly correlated with heavy metal concentrations. However, few studies on soil profile pollution have been reported. In addition to magnetic susceptibility, additional magnetic parameters can provide detailed information on magnetic particles in terms of concentration, grain size and type. The aims of the present study are to investigate how magnetic properties vary with soil depth and land use, and to explore their linkage to atmospheric dust input.

2. Samples and methods

2.1. Study area and samples

Located in the northern part of Shanghai city (Fig. 1), Baoshan District, has also been heavily affected by rapid urbanization in recent years. In this district, many heavy industries are sited, such as, Baosteel, Shanghai No. 1 Iron and Steel Company, Shanghai Ferroalloy Company, Shanghai Chemical Plant, Shanghai Cement Plant, Shanghai Iron Smelting Plant. The predominant wind direction in this region is northeast in winter and southeast in summer. The land in Baoshan District mainly locates on the deltaic deposits of the Yangtze River Estuary, and may be classified as Entisols (Hu et al., 2007). In order to study the impacts of urbanization and industrial airborne particulate matter on the soil environment, three short soil cores (40 cm in length) were collected from Linjiang Park (LJ), Yuepu Park (YP) and arable land (AL), respectively (Fig. 1). To prevent any possible contamination, the outer ring of the core was removed before subsampling. The soil cores were sectioned at 2 cm interval, and the samples were oven dried at 40 °C before laboratory analysis.

2.2. Methods

2.2.1. Magnetic measurement

About 4–5 g soil was packed tightly into 8 ml plastic boxes and fixed for routine isothermal magnetic measurements. MS (χ) was measured on samples at low frequency (0.47 kHz) (χ_{lf}) and high frequency (4.7 kHz) (χ_{hf}) using a Bartington MS2 meter. Anhysteretic Remanent Magnetization was induced in a steady field of 0.04mT imposed on a peak AF field of 100 mT using a DTECH 2000 demagnetizer. Values have been normalized for the DC bias field and expressed as χ_{ARM}. Isothermal Remanent Magnetization (IRM) was grown in fields of 1 T, −100 mT and −300 mT using a Molspin pulse magnetizer and all remanences were measured in a Molspin low-speed spinner magnetometer. Magnetic hysteresis loops and Curie Temperatures were measured on selected samples using a variable field translation balance (Petersen Instruments, MMvftb). Magnetic parameters are expressed as mass-specific values and inter-parametric quotients have also been calculated in order to give quantitative and qualitative information of magnetic particulates. The properties recorded include MS (χ_{lf}), χ_{ARM}, SIRM (SIRM = IRM_{1000mT}), HIRM (HIRM = [(SIRM + IRM_{-300})/2]), χ_{fd}% ($\chi_{fd}\% = [\chi_{LF}-\chi_{HF}]/\chi_{LF} \times 100$), χ_{ARM}/χ_{lf}, χ_{ARM}/SIRM, SIRM/χ_{lf} and S-ratio (IRM_{-300}/SIRM). The magnetic susceptibility χ_{lf} indicates the total contribution of magnetic minerals represented by the concentration of ferrimagnetic minerals in the sample. χ_{ARM} and SIRM are also magnetic parameters related to magnetic minerals concentrations. HIRM estimates antiferromagnetic components in a sample. χ_{fd}% relates to the superparamagnetic (SP) ferrimagnetic component, while χ_{ARM}/χ_{lf}, χ_{ARM}/SIRM ratios can indicate ferrimagnetic minerals grain size. SIRM/χ_{lf} and S-ratios are often employed as grain size and type indicators for magnetic minerals. Further information on the interpretation of these measurements and quotients can be found in Chen et al. (Chen et al., 1995) and Walden et al. (Walden et al., 1999).

2.2.2. SEM analysis

For each soil profile, three samples from the top, middle and bottom part of the core were selected for SEM (Scanning Electronic

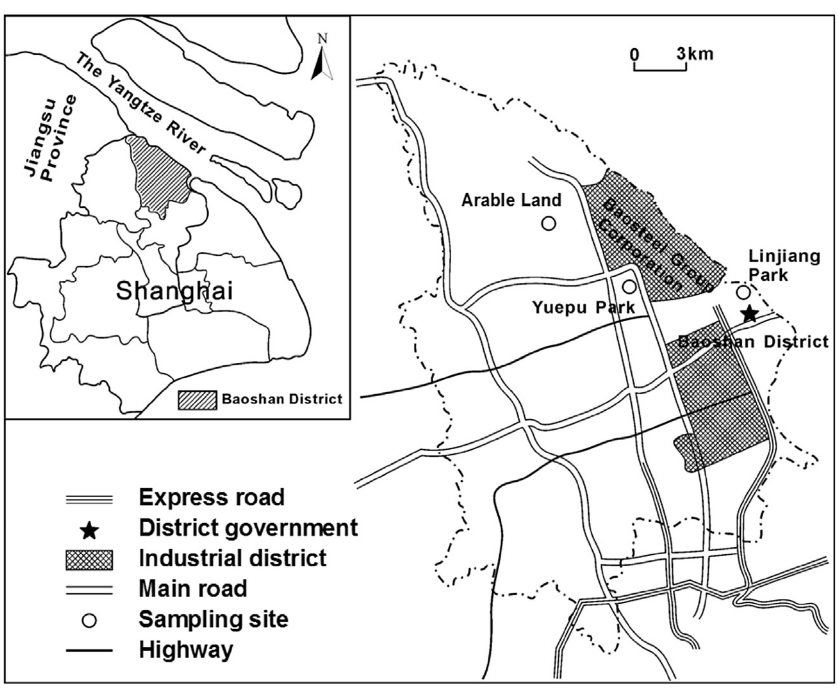

Fig. 1. Maps of Shanghai and soil core sampling.