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Original paper

Rock-magnetic properties of topsoils and urban dust from Morelia (>800,000 inhabitants), Mexico: Implications for anthropogenic pollution monitoring in Mexico's medium size cities

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Resumen

En el presente trabajo, investigamos la correlación entre algunos parámetros magnéticos y el nivel de contaminación por metales pesados en suelos urbanos de la ciudad de Morelia, en el occidente de México. El estudio magnético fue llevado a cabo en 98 muestras urbanas provenientes de diferentes tipos de uso de suelo. La mayoría de las muestras contienen minerales ferrimagnéticos como responsables de la magnetización, pertenecientes probablemente a las soluciones sólidas de las titanomagnetitas/titanomaghemitas. Esto es inferido a partir de las mediciones de susceptibilidad en función de la temperatura y de los experimentos de magnetización remanente isotérmica (MRI). Estas mediciones indican además, que la mayoría de las muestras se saturan casi completamente antes de los 300 mT. Adicionalmente, los valores S_{-200} (S_{-200} = IRM_{-200}/SIRM, donde IRM_{-200}= magnetización a campo inverso de 200 mT después de la saturación magnética) se encuentran entre 0.7 y 1.0, característicos de minerales de baja coercitividad magnética. Las curvas promedio de magnetización remanente isotérmica de saturación (SIRM) pueden ser usadas como un indicador del nivel de contaminación, ya que estas curvas muestran diferentes valores de saturación de acuerdo al nivel de contaminación por metales pesados: Cu, Ni, Cr y Sr. Estas asociaciones de (titano)magnetitas con metales pesados fueron observadas bajo el Microscopio Electrónico de Barrido, revelando algunos agregados complejos en lugar de las esférulas detectadas comúnmente.

Palabras clave: ambientemetría, magnetismo de rocas, metales pesados, contaminación urbana, agregados magnéticos.

Abstract

In this work, we investigate the correlation between some magnetic parameters and the level of contamination by heavy metals in urban soils from Morelia city, western Mexico. The magnetic study was carried out on 98 urban soils samples belonging to distinct land uses. Most of analyzed samples contain ferrimagnetic minerals as the responsible for magnetization, most probably corresponding to the titanomagnetites/titanomaghemites solid solutions. This is inferred from the susceptibility *vs.* temperature measurements and the isothermal remanent magnetization (IRM) experiments. These measurements also indicate that most of samples are almost completely saturated before 300 mT. Additionally, the S_{-200} values (S_{-200} = IRM_{-200}/SIRM, where IRM_{-200}= Back-field of 200 mT after magnetic saturation) are between 0.7 and 1.0, characteristic of low coercivity magnetic minerals. The averaged saturation isothermal remanent magnetization (SIRM) curves can be used as an indicator of pollution level, as these curves show different saturation values according to the level of contamination by heavy metals: Cu, Ni, Cr and Sr. These associations of (titano)magnetite with heavy metals were observed by Scanning Electron Microscope revealing some complex aggregates rather than commonly detected spherules.

Key words: environmetrics, rock-magnetism, heavy metals, urban pollution, magnetite aggregate.

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Introduction

Urban areas represent potential sources of magnetic pollution due to human activities: vehicle usage, industrial activity, and emissions from burning of fossil fuel, domestic and industrial. Other source includes power stations and metallurgic works (Chaparro *et al*., 2002; Goluchowska, 2001; Hullet *et al*., 1980; Hunt, 1986; Kapička *et al*., 1999; Kim *et al*., 2007; Kukier *et al*., 2003; Petrovský and Elwood, 1999; Strzyszcz *et al*., 1996; Sutherland, 2003; Thompson and Oldfield, 1986; Vassilev, 1992). Among these activities, the vehicles are used throughout the entire city, representing a source of widespread and growing pollution.

The magnetic particles derived by vehicular combustion are due to Fe impurities in fuel (Abdul-Razzaq and Gautam, 2001) as well as wear and friction of engine components. The fine magnetic particles (< 10 mm: PM10) represent a great danger when they are inhaled because they are easily absorbed into the human body, causing serious health problems such as cardiovascular diseases and respiratory illnesses (Becher *et al*., 2001; Donaldson *et al*., 1998; Gómez *et al*., 2002; Kim *et al*., 2003; Muxworthy *et al*., 2001). Additionally, the ultrafine particles (<0.1 mm, PM0.1) are proven to have worse health effects than fine particles (<2.5 mm, PM2.5) (Harrison and Yin, 2000; Lu *et al*., 2008; Wichmann and Peters, 2000). Furthermore, these particles can lodge in their structure other toxic metals like Pb, Zn, Ba, Cd and Cr (Harrison and Jones, 1995; Maher *et al*., 2008; Muxworthy *et al*., 2003) probably due to the affinity of Fe oxides with trace metals (Gautam *et al*., 2005; Hunt *et al*., 1984; Lu *et al*., 2007; Ma and Rao, 1997; Meena *et al*., 2011). In particular, Pb, Cu and Zn and ferromagnetic minerals are commonly associated with industrial activity and traffic pollution (Beckwith *et al*., 1986; Hanesch and Scholger, 2002; Li *et al*., 2001; Lu *et al*., 2005).

Therefore, the concentration of magnetic minerals may reflect not only magnetogenic pollutants but the content of toxic metals in urban soils and other environmental samples (Bityukova *et al*., 1999; Magiera *et al*., 2006, Maher *et al*., 2008). The magnetic method has been developed to provide a fast and inexpensive alternative for monitoring anthropogenic pollution.

Several studies have reported a good correlation between magnetic susceptibility and the heavy metal content (Bityukova *et al*., 1999; Desenfant *et al*., 2004; Ďurža, 1999; Fialova *et al*., 2006; Hanesch and Scholger, 2002; Hoffmann *et al*., 1999; Lecoanet *et al*., 2003; Muxworthy *et al*., 2003; Petrovský *et al*., 2000). These studies are generally site specific and correlations are linked to evidence of fly ash, pollution products from traffic and metallurgic plants.

In most of cases, it is very difficult to interpret the result because of soil composition and other factors which can have an influence on this magnetic property (Ruiping and Cioppa, 2006) such as biological activity in soils and the diamagnetic mineral content. A good correlation has been reported between the saturation isothermal remanent magnetization (SIRM) and heavy metals content in urban dust (Maher *et al*. 2008; Mitchell and Maher, 2009).

This study reports the results of magnetic measurements obtained for 98 samples of soils and urban dusts from Morelia, Mexico. The objective is to correlate the magnetic properties with heavy metal content, and to establish a relative level of pollution in each point referred to a natural background. In our case, this reference is a natural reserve located in the southeast of the city. We show that SIRM has a strong correlation with the metal content, for soil samples as well as urban dust, showing the different degrees of pollution according to the IRM acquisition curves. The magnetic particles have been identified trough SEM observations under spherical shapes and irregular aggregates of < 2 mm.

Methods

Description of the city

Morelia is situated on a valley in northeast of the state of Michoacan in central part of Mexico, at an altitude of 1900 m.

Morelia is the most populated city on the state of Michoacan and the twentieth of the whole country. The metropolitan area has 806822 inhabitants (INEGI, 2010). 597511 of them are concentrated in Morelia. The main economic activity includes services, among them financial, real estate and tourism, followed by the construction industry, manufacturing industry and ultimately the primary sector activities.

Morelia city has an average temperature of 17.5 ° C, and annual precipitation of 773.5 mm, with a subhumid climate. The prevailing winds come from southwest and northwest; the intensity varies 2.0 to 14.5 km / h in July and August.

The rock basement of the city is composed of rhyolite (commonly known as "cantera"), as well as unconsolidated volcanic materials, which is called "tepetate". The principal soils groups, in agreement with World Reference Base for Soil Resources are Luvisols, Andosols, Vertisols, Acrisols and Leptosols. The municipality has 69,750 ha of land, of which 20,082 are cultivated