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Original article

Magnetic mapping of air pollution in Tandil city (Argentina) using the lichen *Parmotrema pilosum* as biomonitor

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A B S T R A C T

The lichen *Parmotrema pilosum* is sensitive to pollution and it can live accumulating airborne pollutants for long time, such characteristic allows its use as biomonitor for environmental mapping in urban areas when this epiphytic specie is available. In this work, we investigated the use of such passive collector and magnetic techniques to monitor the air pollution in Tandil, a city located in Buenos Aires province with approximately 125,000 inhabitants, 60,000 vehicles and various metallurgical factories inside the urban area. The sampling strategy was carried out following a random stratified design and measuring magnetic susceptibility, magnetic hysteresis loops, anhysteretic and isothermal remanent magnetization and thermomagnetic studies to determine the magnetic properties of airborne particles accumulated on lichen samples. Scanning electron microscopy observations show particles with different morphologies (individual particles, spherules and aggregates) and composition (Fe, Al, Ni, Cr, Ti, Cu, K and Br) produced by metallurgical factories and by gaseous/solid vehicle emissions. The magnetic mineralogy shows the predominance of pseudo-single domain magnetite-like mineral and the magnetic grain size estimations indicate the presence of fine particles (<0.1 μm) in sites with low vehicular traffic or less polluted, while sites more affected by pollution (high vehicular traffic and metallurgical industries) are characterized by coarser magnetic grain size particles, between 0.1 and 5 μm. Mass-specific magnetic susceptibility was represented in a 2-D contour map to observe in detail the distribution of magnetic particles in this urban area, giving high values (up to 1161.2×10^{-8} m^3 kg^{-1}) that are indicative of areas with high pollution loading.

1. Introduction

An organism is considered a biomonitor when provides quantitative information on the quality of the environment around it, for example air pollution. Some species are unable to adapt ecology or genetically to the altered environmental condition, so its absence is indicative of problems (Nimis et al., 2002; Lijteroff et al., 2009). Biomonitors have several advantages concerning the detection of pollution emission sources such as low costs, the possibility to register the effects of pollution for long periods of time and the possibility of monitoring many sites simultaneously (Wannaz et al., 2006). Some biomonitors can respond to pollution by altering their physiology or their ability to accumulate elements or substances (Lijteroff et al., 2009).

Lichens can be considered as biological indicators of environmental changes, they are sensitive to different pollutants and hence its utilization for environmental monitoring is increasingly common. There are recent studies presented by Jordanova et al. (2010), Salo et al. (2012) and Chaparro et al. (2013) that use magnetic

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techniques and biomonitors for anthropogenic pollution monitoring in Europe and South America. The lichen capacity to accumulate large amounts of trace elements and the sensitivity to them depends on the lichen specie and they are given by the morphological and structural characteristics thereof (Getty et al., 1999; Carreras et al., 2005).

Several studies have used the magnetic properties of deposited particles as a proxy for particulate pollution levels. Natural surfaces as passive collectors of particulate pollution require no power source or protection of vandalism (Mitchell et al., 2010). Magnetic techniques are sensitive, rapid and relatively cheap to identify differences in concentration, magnetic grain size or magnetic mineralogy between areas under study (Fabian et al., 2011).

In environmental magnetism, magnetic measurements have been accepted for mapping anthropogenic heavy metal pollution (Thompson and Olfield, 1986; Petrovský and Ellwood, 1999; Evans and Heller, 2003). For about 30 years, authors have conducted several studies using samples of plants to study their magnetic properties (Flanders, 1994; Matzka and Maher, 1999; Jordanova et al., 2003; Maher et al., 2008).

Preliminary studies show that the magnetic susceptibility parameter seems to be a suitable indicator of traffic-related pollution. The particles emitted from vehicles are soot exhaust and solid particles from tyres, brake-lining, engine corrosion and abrasion of vehicles surfaces (Marié et al., 2010). Observations made by scanning electron microscopy (SEM) on samples coming from vehicular emissions showed small individual particles or spherulites and, small aggregates in form of chains or clusters. Additionally, elements as: Na, Mg, Al, Si, S, K, Ca, Ti, Ba, Mn, Zn, Cr and Pb, were detected by X-ray energy dispersive spectroscopy (EDS, Chaparro et al., 2010).

In this contribution, the urban area of Tandil city was studied in detail using the lichen *Parmotrema pilosum* to monitor the air quality. Taking into account results obtained by Chaparro et al. (2013), where a pilot study was presented in order to evaluate the usefulness of different lichen species for studying anthropogenic pollution in urban areas, the aim of this work focuses on: 1) a detailed sampling strategy based on a random stratified design that included about 660 blocks in the city; 2) the choice and use of magnetic parameters as tools for environmental monitoring; 3) the determination of more impacted areas through concentration dependent magnetic parameters; and 4) the identification of the pollution sources from magnetic grain size dependent parameters. The use of available bioindicators in the area gives the possibility of spatial and temporal monitoring.

2. Sampling and methods

2.1. Study area

Tandil city (37° 19.5′S; 59° 08.3′W) is located in the southeast of the Buenos Aires province, in Argentina, on Tandilia belt (Fig. 1). It is a medium-size city which has an area of 22.1 Km^2, a population approximately of 125,000 inhabitants (Censo, 2010) and a number of 60,168 vehicles (Sosa, 2015), including cars, trucks and heavy transport.

Inside the urban area, few factories, such as metallurgical industries are located (0.2 per Km^2). The pollution problem is recent and seems not to be of long-range (Chaparro et al., 2002, 2013). The vehicular emissions and metallurgical factories seem to be the main sources of air pollution in this area of study.

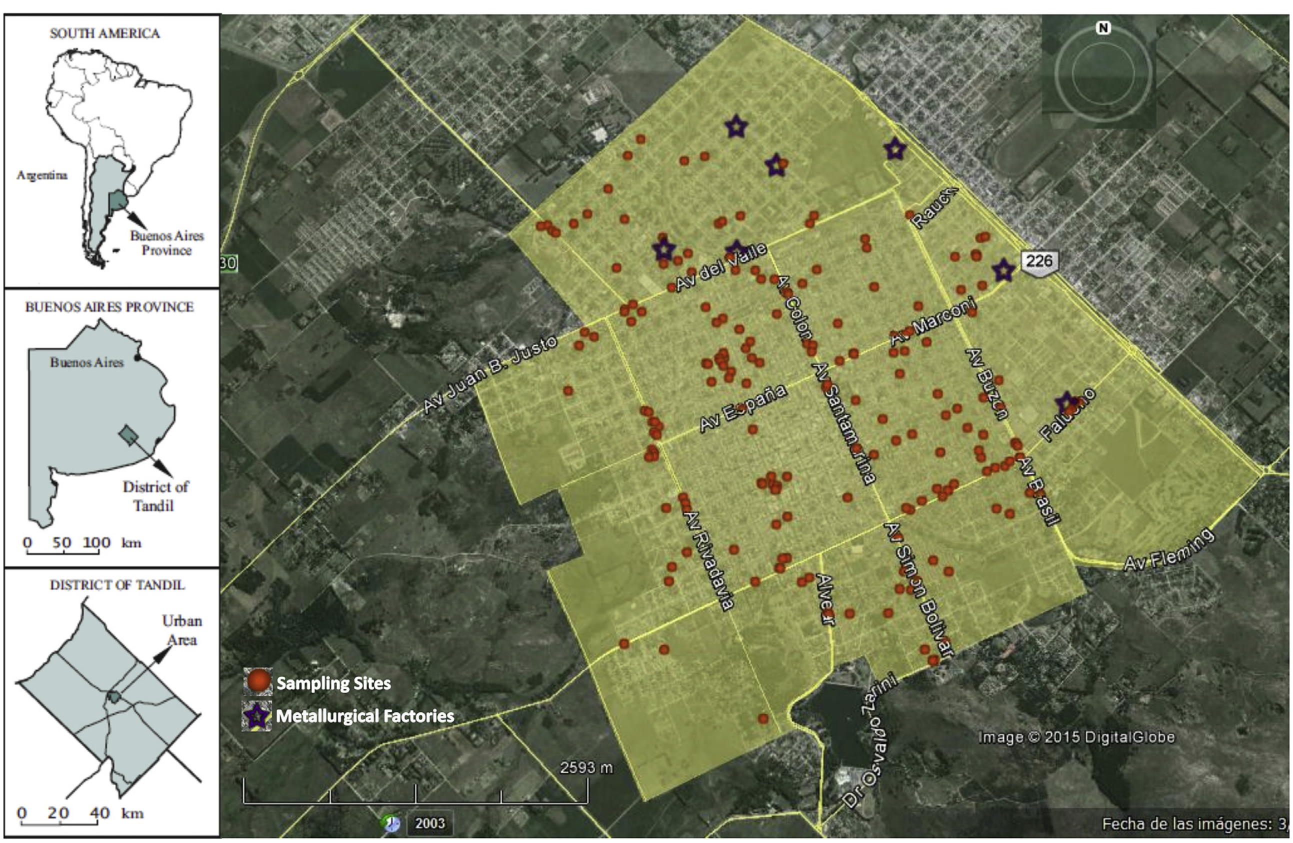

Fig. 1. Study area (Tandil City, Buenos Aires Province, Argentina), sampling points (circles), metallurgical factories (stars) and main avenues (lines in yellow) are shown. A total of 658 blocks were considered for the sampling design.