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MAGNETIC STUDIES OF LICHENS ON TREE BARK AS AIR POLLUTION BIOMONITORS

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Abstract

Several lichens were magnetically studied in order to explore their suitability as air pollution biomonitors. The lichen (on tree bark) samples were collected in urban and industrial sites from Tandil city (Argentina), as well as control (clean) sites. This vegetation involves 11 species, 8 genus and 3 families. The magnetic properties of lichen samples were determined using rock-magnetic measurements: magnetic susceptibility, anhysteretic and isothermal remanent magnetisation. The results showed that magnetite-like minerals are the main magnetic carriers for all sites and samples. However, the concentration varies between clean and polluted sites. In addition, magnetic grain size distribution showed clear differences between sites. The sites affected pollution are characterised by coarser magnetic grains (0.2-5 μm). The comparison of magnetic properties did not reveal important differences between species. Most of lichens seem to be suitable air pollution monitors, but a couple of them, i.e. *Parmotrema pilosum*, *Punctelia hipoleucites* and *Dirinaria picta* occur more frequently in the area.

Resumen

En este trabajo se estudiaron distintas especies de líquenes con el objeto de investigar su conveniencia como biomonitores de la contaminación. Las muestras de líquenes (de corteza de árboles) fueron colectadas en sitios urbanos e industriales de la ciudad de Tandil (Argentina), así como, en sitios de control. Estos vegetales involucran 11 especies, 8 géneros y 3 familias. Mediciones de susceptibilidad magnética, magnetización remanente anhistérica e isotérmica fueron realizadas para determinar las características magnéticas. Los resultados mostraron la predominancia de minerales del tipo magnetita en todas las muestras y sitios; no obstante, se observaron importantes diferencias en concentración magnética entre sitios de control y afectados por la contaminación. Además, la distribución de tamaños de granos magnéticos mostró claras diferencias entre sitios, con tamaños de granos más gruesos (0.2-5 μm) para sitios más contaminados. La comparación de propiedades magnéticas no reveló diferencias significativas entre especies recolectadas en un mismo sitio. La mayoría de los líquenes estudiados son apropiados monitores de la contaminación, no obstante, solo alguno de ellos (*Parmotrema pilosum*, *Punctelia hipoleucites* y *Dirinaria picta*) ocurren más frecuentemente en el área.

Introduction

Lichens are known to be sensitive to various pollutants and are considered a good biological indicator of the air quality and thus, they are widely used in environmental studies. Moreover, lichens are very widespread and easy to sample, although not found everywhere. Air pollution may decrease the amount of lichens available to near to zero. The sensitivity of lichens to heavy metals is species dependent and mainly influenced by morphological and structural features (Getty et al. 1999, Carreras et al. 2005).

In Environmental Magnetism, magnetic measurements have been very well accepted for mapping anthropogenic heavy metal pollution (Chaparro et al. 2006). Magnetic techniques, using natural surfaces as passive collectors of particulate pollution, are sensitive, rapid, and relatively cheap; and they require no power source or protection from vandalism (Mitchell et al. 2010). A number of studies of air pollution based on the magnetic properties of vegetation samples have been carried since the 90's. Although different vegetation species have been used as passive dust collectors in magnetometry (Moreno et al. 2003), a small number of lichen samples were only studied by Jordanova et al. (2010).
In Tandil (Argentina), studies of lichens (on rock) have been carried out by Lavornia (2009). These studies showed that richness and diversity in the saxicolous lichen communities decrease according to nearness to the city (air pollution).
In this contribution, lichens on tree bark were collected in urban and control sites. The magnetic properties of several species were measured and compared. In addition, the suitability of different species as magnetic biomonitors in this urban area is evaluated.

Methods and sampling

Sampling

Sampling campaigns were carried out in Tandil city (Buenos Aires province, Argentina), in urban, industrial and control (unpolluted or clean) sites (Table 1). A total of 29 samples of different lichens on tree bark were collected at 21 sites according the species availability. The coordinates of sites were recorded using a Garmin GPS-system. A minimum collection height at 1.5 m was considered to avoid, as possible, the influence of soil particles. Samples were not washed out, but dry cleaning was done, in order to investigate pollutants deposited and incorporated in this epiphytic organism.

Table 1. Sampling sites and classification of collected lichen on tree bark (*n*= 29)

Sample	Site [latitude; longitude]	site obs.	Species
Ca-1	37° 19.337'S; 59° 4.998'W	campus (~2 km from a factory)	*Parmotrema pilosum*
RU-1	37° 19.274'S; 59° 6.121'W	route	*Punctelia hypoleucites*
DO-1	37° 20.231'S; 59° 8.434'W	street	*Parmotrema pilosum*
Fa-1b	37° 19.376'S; 59° 6.580'W	factory, street	*Dirinaria picta*
Fa-2b	37° 19.376'S; 59° 6.580'W	factory, street	*Parmotrema pilosum*
Fa-3b	37° 19.321'S; 59° 6.515'W	factory, street	*Parmotrema pilosum*
Fa-3c	37° 19.321'S; 59° 6.515'W	factory, street	*Dirinaria picta*
Fa-4a	37° 19.295'S; 59° 6.471'W	near factory, street	*Parmotrema pilosum*
CR-2	37° 19.613'S; 59° 6.527'W	road	*Punctelia hypoleucites*
FR-1	37° 18.848'S; 59° 6.987'W	near factory, street	*Punctelia hypoleucites*
FR-2a	37° 18.762'S; 59° 7.092'W	near factory, street	*Punctelia hypoleucites*
FR-2a"	37° 18.762'S; 59° 7.092'W	near factory, street	*Punctelia hypoleucites*
FR-2b	37° 18.762'S; 59° 7.092'W	near factory, street	*Teloschistes chrysophthalmus*
PR-1	37° 18.794'S; 59° 7.032'W	factory, street	*Punctelia subpraesignis*

QU-1	37° 18.597'S; 59° 8.331'W	street	*Parmotrema pilosum*
YR-1a	37° 19.482'S; 59° 8.354'W	street	*Parmotrema pilosum*
YR-2b	37° 18.869'S; 59° 8.719'W	near factory, street	*Hyperphyscia aff coraloidea*
YR-2c	37° 18.869'S; 59° 8.719'W	near factory, street	*Dirinaria picta*
LT-1b	37° 18.748'S; 59° 8.869'W	factory, street	*Parmotrema pilosum*
LT-1c	37° 18.748'S; 59° 8.869'W	factory, street	*Dirinaria applanata*
Mu-1b	37° 18.788'S; 59° 8.717'W	near factory, street	*Parmotrema pilosum*
CAS-1a	37° 21.880'S; 59° 6.057'W	control site (~5 km from the town)	*Parmotrema pilosum*
CAS-1b	37° 21.880'S; 59° 6.057'W	control site (~5 km from the town)	*Dirinaria picta*
CAS-2	37° 21.861'S; 59° 6.064'W	control site (~5 km from the town)	*Parmotrema pilosum*
CAS-3a	37° 21.851'S; 59° 6.093'W	control site (~5 km from the town)	*Parmotrema pilosum*
CAS-3b	37° 21.851'S; 59° 6.093'W	control site (~5 km from the town)	*Flavorparmelia sorediens*
CAS-3c	37° 21.851'S; 59° 6.093'W	control site (~5 km from the town)	*Punctelia hipoleucites*
Pa-2a	37° 20.333'S; 59° 8.259'W	control site (~1 km from the town)	*Parmotrema pilosum*
Pa-2b	37° 20.333'S; 59° 8.259'W	control site (~1 km from the town)	*Punctelia hipoleucites*

Methods

Samples were carefully collected using plastic scrapers and tools in order to avoid contamination.

Lichen species were identified in the laboratory of CINEA using local keys of lichen (Adler, 1992; Calvelo, 1992), techniques of chemical analysis of substances (colour spot test) and by the analysis of morphological and anatomical characters using stereoscope and microscope.

Vegetal material was placed into standard plastic containers (~11.5 cm^3) and weighed (2.0-4.1 g).

Magnetic measurements were carried out in the laboratory of the IFAS (Tandil, Argentina). Several rock-magnetic measurements were done: magnetic susceptibility (κ), anhysteretic and isothermal remanent magnetisation (ARM and IRM) and demagnetisation. Moreover, several related magnetic parameters, ratios and plots were obtained and analysed: mass-specific magnetic susceptibility (χ), anhysteretic susceptibility (κ_{ARM}, χ_{ARM}), κ_{ARM}/κ, saturation of IRM (SIRM), S-ratio ($-IRM_{-300mT}/SIRM$), remanent coercivity (H_{cr}), ARM/SIRM and SIRM/κ ratio.

Selected samples were also examined by scanning electron microscopy (SEM), using a JEOL JSM-6460LV microscope. The composition was analyzed by x-ray Energy Dispersive Spectroscopy (EDS) investigations (EDAX Genesis XM4 - Sys 60).

Results and discussion

Lichens were identified and classified in the laboratory, they involve 11 species, 8 genus, and 3 families, such as *P. pilosum*, *P. hipoleucites*, *P. subpraesignis*, *Teloschistes chrysophthalmus*, *Hyperphyscia aff coraloidea*, *Flavorparmelia sorediens*, *D. picta* and *D. applanata*. Among them (see Table 1), *P. pilosum* (*n*= 13), *Punctelia spp.* (i.e.: *P. hipoleucites* and *P. subpraesignis*, *n*= 8) and *Dirinaria spp.* (i.e.: *D. picta* and *D. applanata*, *n*= 5) are the most available.

Magnetic measurements and parameters are shown in Fig. 1-6. The IRM studies (Fig. 1) and parameters S-ratio (0.88-0.98) reveal the predominance of ferrimagnetic mineral for all samples. The Hcr values varied in a narrow range, between 34.6 and 40.7 mT, corresponding to magnetite minerals.

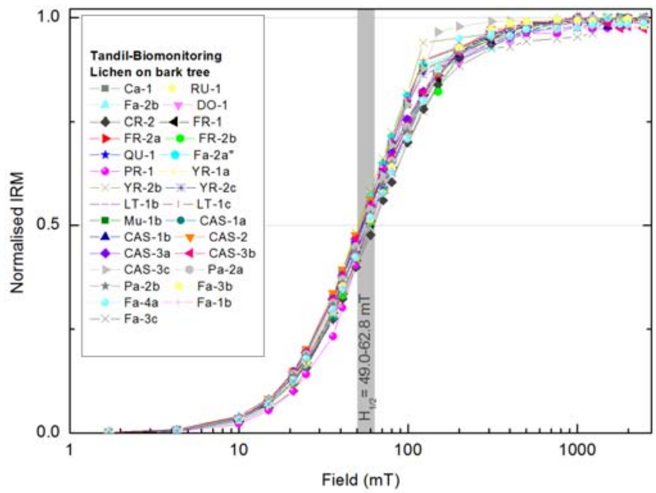


Figure 1. Measurements of acquisition IRM for all (n= 29) lichen samples.

The magnetic grain size distribution was estimated from the King's Plot (Fig. 2). Magnetic grains varied widely; samples from control sites show the finest fractions (<0.1 µm). On the contrary, samples from polluted sites have coarser sizes, between 0.2-5 µm. This conclusion was also observed from other related parameters, such as, κ_{ARM}/κ and ARM/SIRM in Fig. 3.

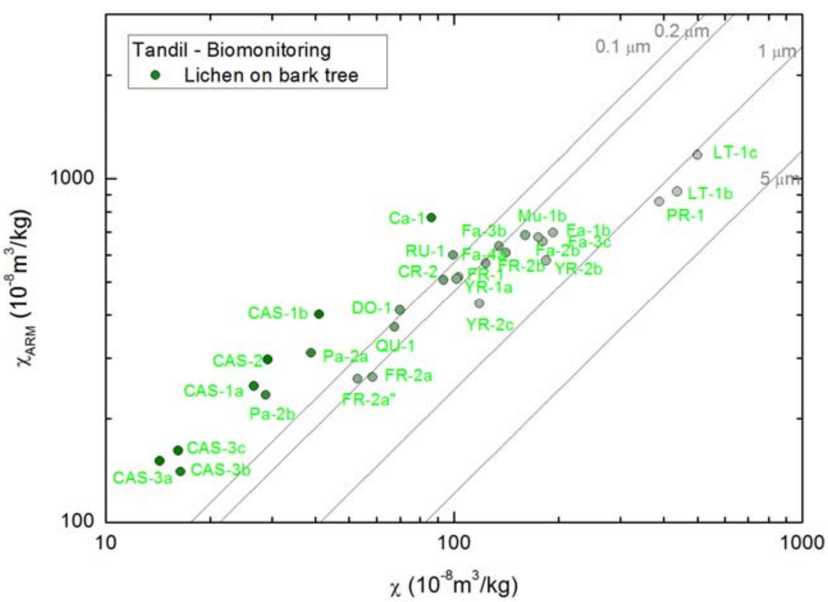


Figure 2. King's Plot (χ_{ARM} versus χ) for all lichen samples. Samples from polluted sites showed coarser magnetic grain sizes.

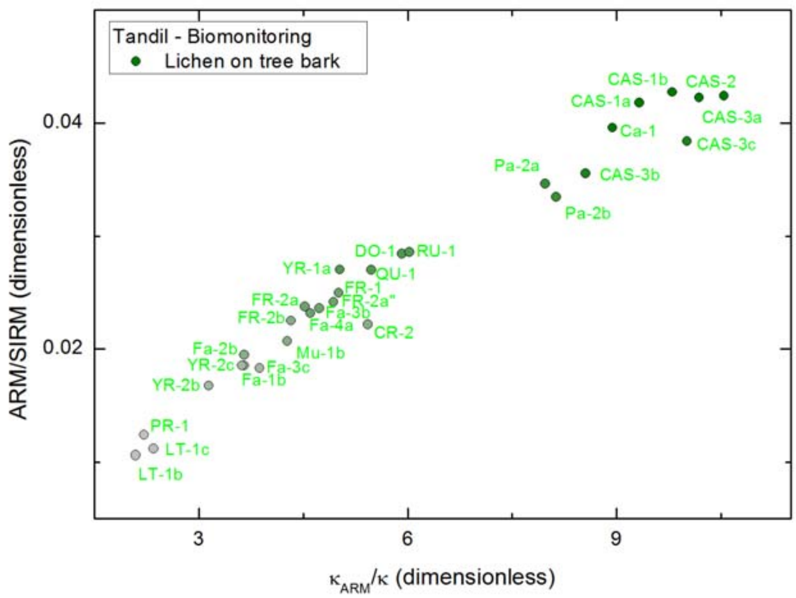


Figure 3. Biplot ARM/SIRM vs. κ_{ARM}/κ for all lichen samples.

The concentration-dependent magnetic parameters (i.e. χ and SIRM) showed a wide value range (14.3-500.0 $\times 10^{-8}$ m^3/kg and 2.5-76.3 $\times 10^{-3}$ A m^2/kg, respectively). As noted in Fig. 4, control, urban and industrial sites showed important differences, been well differentiated. Such differences are related to the load of industrial and traffic-related pollutants.

Most of the lichens samples seem to be adequate for magnetic monitoring. This can be appreciated in Fig. 5 from the magnetic properties of the most available species: *P. pilosum*, *Punctelia spp.* and *Dirinaria spp*. In addition, a comparison of lichen species in 7 sampling sites was carried out (Fig. 6). Although different lichens (*Pa*, *D*, *P*, *F*, *H* and *T*, see Fig. 6) are compared, the magnetic concentration (χ) and magnetic grain size (κ_{ARM}/κ) showed similar values at each site. This magnetic fact allows using most of the studied lichens for magnetic monitoring. However, according to the occurrence of species in Tandil, lichens *P. pilosum*, *Punctelia spp.* and *Dirinaria spp.* are convenient choices for monitoring.

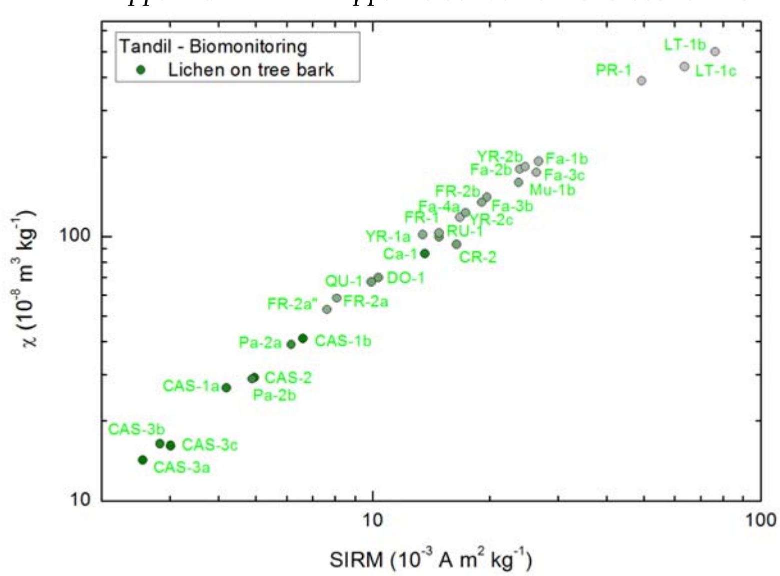


Figure 4. Measurements of χ and SIRM for all lichen samples.

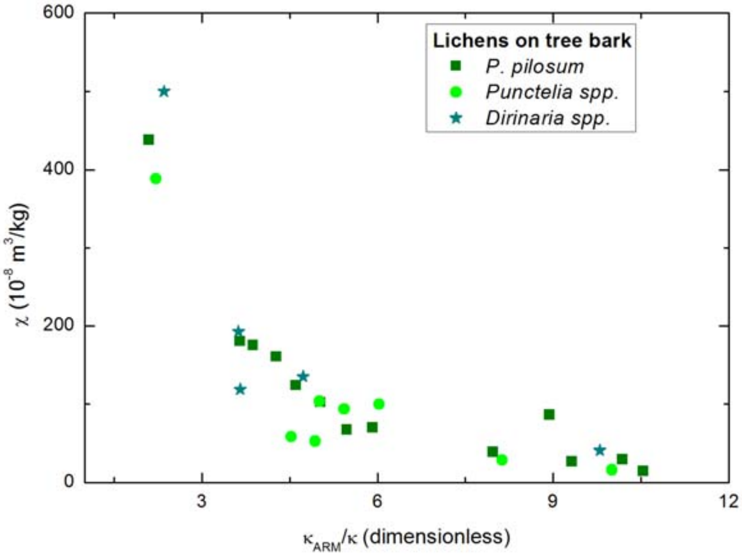
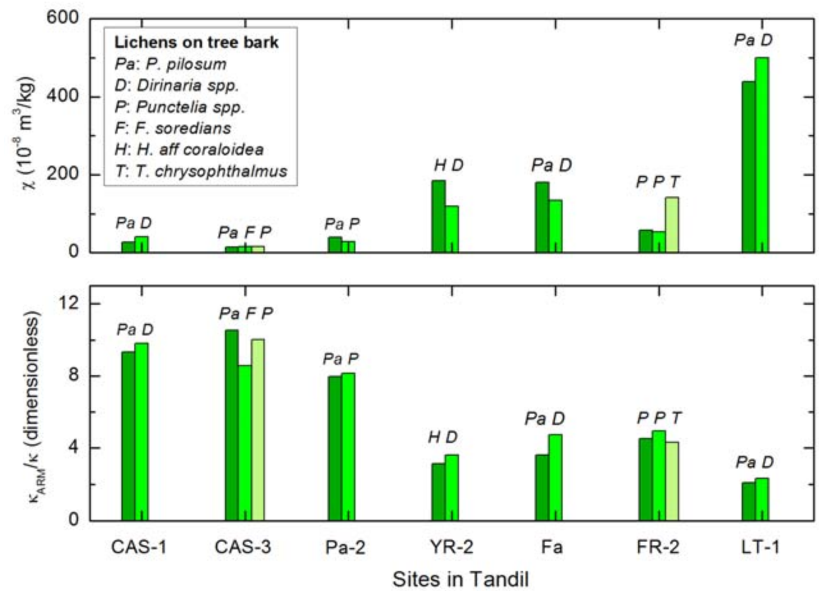


Figure 5. Comparison of magnetic properties of lichen species



Figrue 6. Comparison of magnetic properties of lichen species in 7 sampling sites.

Conclusions

The IRM studies, S-ratio and Hcr values show the dominance of magnetite-like minerals for all lichen samples. The main magnetic carrier seems to be similar between control and urban sites, but magnetic grain size varies distinctively. For example, lichens from control sites accumulated the finest magnetic fractions (<0.1 μm). On the contrary, lichens from polluted sites accumulated coarser magnetic grains (0.2-5 μm).

The magnetic concentration varies widely between clean and polluted sites, up to 20 times (e.g.: χ and SIRM). Such differences are related to the load of industrial and traffic-related pollutants.

The comparison of lichens using relevant magnetic parameters (magnetic concentration: χ and magnetic grain size: κ_{ARM}/κ) did not show important differences. Most of lichens seem to be suitable air pollution monitors, but according to the strategic distribution of species (occurring more frequently) in Tandil, lichens *P. pilosum*, *P. hipoleucites* and *D. picta* are convenient choices for monitoring.

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