

Full Length Research Paper

Biomonitoring of particulate matter by magnetic properties of *Ulmus carpinifolia* leaves

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Biomonitoring of the particulate matter (PM) helps us to find out quantity and quality of vegetation in different parts of the city and create sustainable urban landscape. This study explains the results of an air pollution biomonitoring in Isfahan (Iran) with regards to the magnetic properties of tree leaves of Elm (*Ulmus carpinifolia*). Isothermal remanent magnetization (IRM₃₀₀ mT) of *U. carpinifolia* leaves was determined. Data collection apparatus was a magnetometer. Four stations in different areas of green space, including, one park, one square, one street and one control station were determined and the tree leaves of *U. carpinifolia* from two meter height were collected. Ten leaves from each tree were separated and ten repetitions were achieved for each station. Leaves were placed in a special box to measure magnetic field with magnetometer. Comparison of magnetic properties of Elm tree leaves before and after washing was done. Magnetic properties showed that high concentrations were seen in trees found in squares and streets. Also, rainfall and washing decreased the magnetic properties of the leaves.

Key words: Particulate matter, green area, magnetic properties, biomonitoring.

INTRODUCTION

Magnetic mineral provides a compositional tool, which is reliable, rapid, non-destructive, inexpensive and sensitive to low detection levels (Walden et al., 1999). This has promoted its suitability for aiding biomonitoring of air quality (Maher and Matzka, 1999; Hanesch et al., 2003; Moreno et al., 2003; Urbat et al., 2004). Magnetic particles have long been recognized to be associated with atmospheric particulates (Hunt et al., 1984). Magnetic minerals in aerosols may be derived from combustion processes related to industry, domestic heating or vehicles, as well as from abrasion products from street surfaces and brake systems (Petrovsky and Elwood, 1999). Therefore, magnetic parameters, notably magnetic susceptibility, are possible proxies to monitor the regional distribution of air particulate matter (PM) pollution or relative changes in area overtime. In the past, magnetic properties have been used to identify atmospheric industrial and traffic pollution in cities by studying dust directly collected on roads (Goddu et al., 2004) or gathered in filters (Gillies et al., 2001) and on tree leaves

(Urbat et al., 2004). Section leaves with large surface areas per unit of weight and favorable surface properties having waxy coating and long lifespan, are considered to be good accumulators of PM from the atmosphere (Alfani et al., 2000; Freer-Smith et al., 1997). In the atmosphere, magnetic minerals are derived from combustion, such as industrial, domestic or vehicle emissions (Hunt et al., 1984; Flanders, 1994) or from abrasion products from asphalt and from vehicles brake (Hoffmann et al., 1999). In biomonitoring studies, the spatial mapping of PM loads via environmental magnetic techniques is shown to be quick, non-destructive and inexpensive (Maher and Matzka, 1999; Jordanova et al., 2003; Gautam et al., 2005).

Studies related to the use of magnetic properties of tree leaves are not new. The isothermal remanent magnetization (IRM) showed leaves of Birch (*Betula pendula*) found in urban and suburban area (Maher and Matzka, 1999). The study was done around the city of Norwich (UK), as a proxy of traffic pollution. Relevance of both

susceptibility and IRM of dust loaded leaves of deciduous trees (*Platanus* sp. and *Quercus ilex*) for mapping vehicular traffic emissions in Rome in Italy was shown (Moreno et al., 2003). The potential of susceptibility and IRM to susceptibility ratio of maple tree leaves was described in and around an Austrian industrial site in Leoben for monitoring short-term (up to several months) dust deposition (Hanesch et al., 2003). Biomonitoring of traffic air pollution in Rome indicate that magnetic properties of *Quercus ilex* and *Platanus* sp. leaves in green area and roads have a clear difference (Moreno et al., 2003). Polycyclic aromatic hydrocarbons (PAHs) were determined in the leaves of *Q. ilex* L. as biomonitor of the degree of pollution (Alfani et al., 2000). Mapping dust distribution around the industrial city of Leoben in Austria was achieved by measuring magnetic parameters of maple leaves (Hanesch et al., 2003). Many studies suggested a relationship between distribution of magnetic particles and scattering of heavy metals around industrial sites (Strzyszczyk et al., 1996; Heller et al., 1998). The results showed that a magnetic survey of tree leaves, which is rapid and cheap, may be used for air quality monitoring to identify polluted area. Significant correlations between the organic matter content of urban street dust and certain mineral magnetic properties were studied (Shilton et al., 2005). Some researches on spatial variation in vehicle-derived metal pollution were identified by magnetic and elemental analysis of roadside tree leaves achieved (Maher et al., 2008). The magnetic properties of particles deposited on *Platanus x hispanica* leaves in Madrid, Spain were studied (McIntosh et al., 2007). Another study focused on magnetic properties of atmospheric PM from automatic air sampler stations in Italy (Sagnotti et al., 2006).

The presence of a permanent magnetic field B_a in the soil where plants were growing caused a change of optical and physiological characteristics of the green leaves. The magnetic field causes the change of fluorescent spectra of the plant's leaf and this change is manifested in the appearance of red shift of both fluorescent peaks (Jovanic and Jevtovic, 2002). A new protocol for magnetic susceptibility measurements is proposed, in order to account for changes due to water evaporation in the leaves as a function of time after collection of the samples. Additional magnetic analyses, such as acquisition of artificial remanences and hysteresis properties, were used to characterize the mineralogy and grain size of the magnetic PM. The results indicated that the population of ferrimagnetic phases has a homogenous composition and grain size throughout the investigated area (Szonyi, 2008). The present study describes the results of air pollution biomonitoring in Isfahan, Iran with regards to the magnetic properties of tree leaves of *U. carpinifolia*. The principal objectives were to test the ability of the leaves to capture and preserve a magnetic signal.

MATERIALS AND METHODS

The leaves were collected from four different sites in Isfahan (Iran). Isfahan is situated in Iran and lies at 32° 39' 35" N latitude and 51° 40' 17" E longitude as shown in Figure 1. The climate in Isfahan is generally semi arid with temperature between 24 and 39°C in July. Leaves were collected from one species of *U. carpinifolia* trees to avoid differences in dust absorption. Samples are close to Azadi Square, Mellat Park, Bozorgmehr Street and a site outside the city as control. Leaves were collected within a distance of 2 m from the road. At each site, 5 to 10 leaves were detached from the tree on the refuges (protection in the middle of street and between street and pavements for planting trees and shrubs) of the site about 1.5 to 2 m above the ground at the lower section of the crown. Only the oldest leaves of the newest twig growth was collected. The leaves were placed in 8 cm³ cubic plastic boxes, specifically designed for sampling of paleomagnetic specimens. All samples were collected in June 2011. Magnetic parameters were determined the day after sampling. This study measured susceptibility with a magnetometer. The samples were magnetized with a pulsed magnetic field of 300 mT, the isothermal remanent magnetization (IRM300 mT) was measured with CCL cryogenic magnetometer having the sensitivity of 10⁻¹⁰ Am²; the weakest leaf samples had magnetizations of 10⁻⁹ Am². After measurement of 2-D magnetization, the leaves were washed with water to determine their background magnetization.

RESULTS AND DISCUSSION

Magnetization of leaves of *U. carpinifolia* at different sites is shown in Table 1. Results indicate that observed t at $p \leq 0.05$ level is higher than the table critical amount; therefore, the mean difference between 2-D magnetization, before and after cleaning of the leaves in Mellat Park, Bozorgmehr Street, Azadi Square and Mountain Park is meaningful. On the other hand, variance analysis indicated that observed F at $p \leq 0.05$ level is higher than table critical amount.

The magnetization values are least for park trees and much higher for square and street trees. Maximum 2-D values were for *U. carpinifolia* leaves close to Bozorgmehr Street and Azadi Square and minimum 2-D magnetization for those close to Mellat Park and Rural Mountain Park. Cleaning with detergent removes between 64 and 78% of the magnetization.

The results show that the observed t is higher than table critical value at the level of $p \leq 0.05$, therefore the difference of average amount of magnetism leaves of Elm trees before and after washing in Mellat Park, Bozorgmehr Street, Azadi Square and Rural Mountain Park is meaningful. However, analysis of variance showed that observed F at the level of $p \leq 0.05$ is larger than the critical value of the table, therefore, there are significant difference between the mean of magnetic properties of Elm leaves in the Mellat park, Bozorgmehr Street, Azadi Square and Rural Mountain Park.

This research analyzed the magnetic properties of dusts adhering to leaf surfaces as a pollution indicator. The magnetic properties of roadside tree leaves are due to magnetic particles present in road dust. These particles are primarily non-spherical and comes from rust

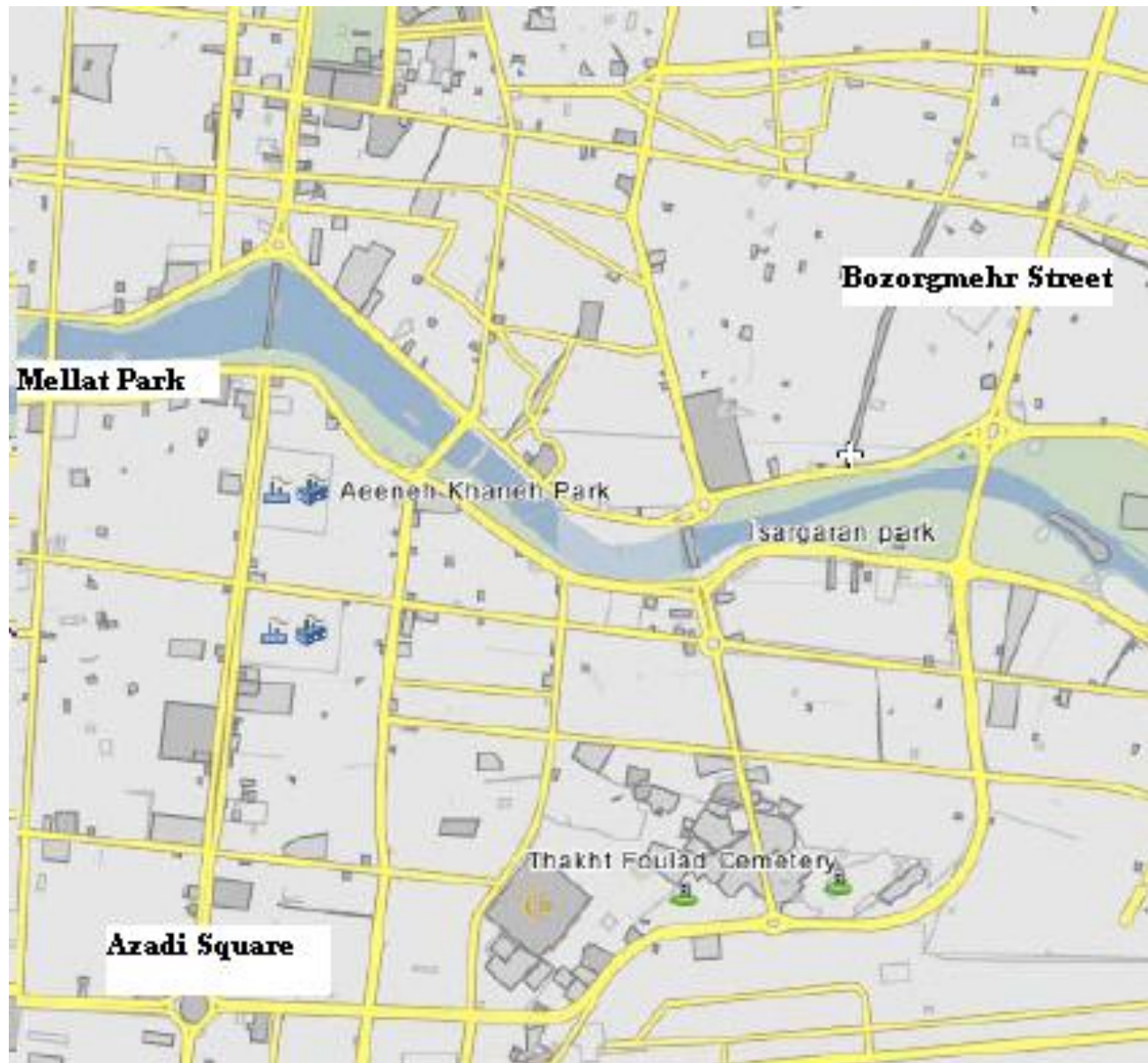


Figure 1. Map of the study area, source: Wikimapia.

and attrition of vehicles, pipes and other iron and steel surfaces (Flanders, 1994). Thus, roads having high traffic density would re-suspend more road dust leading to higher magnetization of tree leaves. The required magnetic field to demagnetize IRM300 mT is greater than 40 mT, which indicate that the size of magnetic particle ranges from 0.03 to 0.3 μm (Heider et al., 1996). This magnetic pattern matches total dust interception by roadside trees. Maximum 2D-magnetizations were encountered for a sample taken between traffic lanes of major road (Impens and Delcarte, 1979).

As shown by the results, highest leaf magnetizations was found beside the square and street, suggesting a

combustion and exhaust related source of the magnetic particles. The least magnetizations for rural mountain park trees suggest that vehicle and road derived particles are the cause of leaf magnetization.

Magnetic survey of tree leaves is recommended as an inexpensive and rapid tool for surveying air pollution in urban areas.

Rainfall and washing decreases the magnetic properties of the leaves. Precipitation is usually thought to remove air-borne particles and so is expected to be associated with increased deposition. An additional effect, though, is the washing of leaf surfaces, leading to particle removal and a reduction in magnetic concentration.

Table 1. IRM₃₀₀ mT values of sampled leaves of *U. carpinifolia* and background IRM300 mT of the subsequently washed leaves.

Sampling location	2-D magnetization before cleaning of the leaf (10 ⁻⁶ A)		2-D magnetization after cleaning of the leaf (10 ⁻⁶ A)		Magnetization removed by washing (%)	t test	F
	Mean	SD	Mean	SD			
Mellat Park	9.56	0.556	3.45	0.247	63.91	31.78	385.60
Azadi Square	64.15	0.541	14.12	0.331	77.98	249.77	
Bozorgmehr Street	51.27	0.396	11.32	0.349	77.92	158.09	
Rural Mountain Park	5.68	0.500	3.19	0.164	43.83	14.97	

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