MAGNETIC PARAMETERS AND THEIR RELATIONSHIP WITH HEAVY METALS IN URBAN DUSTS OF MEXICO CITY

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ABSTRACT

Environmental magnetism techniques have been used as proxy for the heavy metals (HM) monitoring by its correlation with magnetic parameters due its relatively low cost and high resolution. The objective of this work was to explore the relationship between the magnetic properties and HM on urban dusts samples. The magnetic susceptibility (χ) and the saturation isothermal remanent magnetization (SIRM) were measured. The content of HM were analyzed with the X ray fluorescence technique. Discriminant analyses were used to gather the samples in groups, considering the color indexes, and were related with both magnetic parameters and HM content applying multiple regressions. Five groups of samples were classified by dust-color. Group 1 correspond to very dark dusts, group 2 to dark gray, 3 to dark reddish gray, 4 to gray and 5 to reddish. On the first four groups good multiple regressions were found between magnetic susceptibility and HM, with the following values: R² > 35%. In the case of SIRM the five groups reached values of R² > 37% and p < 0.09. In general SIRM proved to be more sensitive magnetic proxies with respect to the bulk magnetic susceptibility.

Keywords: saturation isothermal remanent magnetization; soil color; pollution

Introduction

Nowadays, evidences of the increasing concentration of fossil fuels combustion gases are being found, the same gases which causes the greenhouse effect (GHE) in our atmosphere and the global warming (Trenberth et al., 2007). Such gases from combustion and industrial residues produce dust particles with adsorbed heavy metals (HM) that are deposited on the soil (Sutherland et al., 1999). Gas emission due to fossil fuel combustion and industrial residues produce dust particles with adsorbed heavy metals (HM) that are deposited on the soil, thus, such soil can be used as short and medium term pollution indicator. This is of such importance to human health because of its relationship with cancer. Several studies indicated that particles of 2.5 microns or less are associated with higher risk of damage in human health than larger size fractions. In combustion-dominate particle fractions with smaller average size and considerably larger surface area, but also different composition, may have more impact on mortality and morbidity than larger particles (Pope III, et al., 1999; Schwartz et al., 1999; Schwartz and Neas, 2000; Schwarze et al., 2006), therefore,
is very easy for these particles to get into the human organism and its constituents start affecting systematically. First, the respiratory system by getting caught in the upper tract creating difficulty for breathing, as well, these compounds, depending on its size, can reach the circulatory system and start accumulating in the liver and muscles increasing the chances to develop cancer (Schwarze et al., 2006). Another consequence is the replacement of osteoblasts and osteoclasts in the skeleton (Andrews et al., 2011). For the mentioned reasons, dusts can be used as short and medium term pollution indicator.

Methods for environmental diagnoses about heavy metals in dust and soils imply a longer time and high costs, hereby, environmental magnetism techniques, which require physical proves only have been used as proxy for the HM monitoring by its correlation with magnetic parameters which do not require long time, great manipulation, have a lower cost and are reliable (Morton et al., 2009; Jordanova et al., 2003; Aguilar et al., 2011; Aguilar et al., 2012; Lourenço et al., 2012).

The mega cities like Mexico City are suitable for such studies because of the large amounts of urban dust emitted into the atmosphere by motor vehicles and industrial activities. The objective of this work was to explore the relationship between the magnetic properties of dusts of Mexico City and the content of HM using multivariable analysis.

**Methodology**

89 sites were distributed within Mexico City its suburbs covering the whole area showing a grid-like shape. Once the site was selected, the collection area was set at 1 m\(^2\) and marked with duct tape (fig. 1). To take the samples it was necessary to sweep the surface of the street or sidewalk and remove the dust from it with plastic, non magnetic tools such as brushes and scoops. Samples were dried in the shade, macerated in a wood mortar and weighed to obtain the densities.

The magnetic susceptibility (χ) was measured with a BARTINGTON MS2B and KAPPABRIDGE susceptibilimeter (Dearing, 1999); and the saturation isothermal remanent magnetization (SIRM), was read using a spinner JR6 AGICO magnetometer (Aguilar et al., 2011).

The elements and oxides (Cr, Ni, Cu, Zn, Pb, V, Na\(_2\)O, MgO, Al\(_2\)O\(_3\), SiO\(_2\), P\(_2\)O\(_5\), K\(_2\)O, CaO, TiO\(_2\), MnO and Fe\(_2\)O\(_3\)) were analyzed with the X ray fluorescence (XRF) technique, with a Jordan Valley EX-6600 spectrometer (Kirpichtchikova et al., 2006).

The sample color was measured with a Konica Minolta colorimeter CR400m (Wondafrash et al., 2005). The redness, saturation and hue indexes were calculated in the RGB scale of color. The decimal RBG color system (R = red, G = green, B = blue) was used to calculate the hue, redness and saturation indexes.
SI = (R-B) / (R+B) 
HI = (2* R-G-B) / (G-B) 
RI = R² / (B*G³)

Where: SI= saturation index; HI= hue index; RI= redness index, R= red, G= green; B= blue

Discriminant analyses were used to gather the samples in groups, considering the color indexes (Huerta et al., 2011). In each group of samples, multiple regressions were applied in order to relate the dependent variables (HM content) with the independent variables (each magnetic property) as Wackernagel (2003). Discriminant analysis and multiple regressions were performed with Statgraphics Plus 5.1 software.

Results

Five groups of samples were classified by dust-color, using the indexes with a 100% of correctness. Group 1 corresponded to very dark dusts, group 2 to dark gray, 3 to dark reddish gray, 4 to gray and 5 to reddish (fig. 2).

On the first four groups good multiple regressions were found between magnetic susceptibility and HM, with the following values: \( R^2 > 35\% \) and \( p< 0.08 \), and a confidence of 90% (Table 1).

<table>
<thead>
<tr>
<th>Groups</th>
<th>Dust color</th>
<th>Equations</th>
<th>( R^2 )</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>very dark grey</td>
<td>( X = -86.88 + 2.19<em>Cr - 2.50</em>Ni + 0.79<em>Cu - 0.67</em>Pb + 1.98*Zn )</td>
<td>0.65</td>
<td>0.08</td>
</tr>
<tr>
<td>Group 2</td>
<td>dark grey</td>
<td>( X = 777.68 - 9.74<em>Cr + 1.28</em>Ni + 1.32<em>Cu - 0.044</em>Zn + 1.18<em>Pb - 6.66</em>V + 6772.29<em>MnO - 1.79</em>Fe2O3 )</td>
<td>0.57</td>
<td>0.08</td>
</tr>
<tr>
<td>Group 3</td>
<td>dark reddish grey</td>
<td>( X = 643.98 - 5.38<em>Cr + 1.37</em>Cu + 1.44*Pb )</td>
<td>0.35</td>
<td>0.08</td>
</tr>
<tr>
<td>Group 4</td>
<td>gray</td>
<td>( X = 307.10 + 5.03<em>Cr + 12.65</em>Ni + 7.11<em>Cu - 4.10</em>Zn + 2.83<em>V - 74.41</em>Fe2O3 )</td>
<td>0.87</td>
<td>0.08</td>
</tr>
<tr>
<td>Group 5</td>
<td>reddish</td>
<td>( X = 840.16 - 4.90<em>Cr - 2.76</em>Ni - 3.02<em>Cu + 1.14</em>Zn + 24.46<em>V + 0.57</em>Pb - 12915.7<em>MnO - 88.22</em>Fe2O3 )</td>
<td>0.27</td>
<td>0.79</td>
</tr>
</tbody>
</table>

Table 1. Multiple regressions between magnetic susceptibility and heavy metals for each group of samples by color
Within the red dusts group the correlations between magnetic susceptibility and HM was low. The HM found on the multiple regressions were Cr, Cu, within the five groups and Cr, Cu, Pb, Zn and Ni, within only four groups. In the case of SIRM the five groups reached values of $R^2 > 37\%$ and $p < 0.09$, and a confidence level of 90% (Table 2). The HM found on the multiple correlations, in some cases, were Cr, Cu, Pb and V.

<table>
<thead>
<tr>
<th>Groups Dust color</th>
<th>Equations</th>
<th>$R^2$</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 1</strong> very dark grey</td>
<td>$SIRM = 76.79 - 0.408<em>Cr + 0.31</em>Cu - 0.004*Pb$</td>
<td>0.46</td>
<td>0.09</td>
</tr>
<tr>
<td><strong>Group 2</strong> dark gray</td>
<td>$SIRM = 27.21 - 0.42<em>Cr + 0.10</em>Cu + 0.054<em>Pb + 0.70</em>V$</td>
<td>0.37</td>
<td>0.07</td>
</tr>
<tr>
<td><strong>Group 3</strong> dark reddish gray</td>
<td>$SIRM = 22.99 + 0.028<em>Zn + 0.12</em>Pb- 2985.71<em>MnO + 3.91</em>V$</td>
<td>0.43</td>
<td>0.08</td>
</tr>
<tr>
<td><strong>Group 4</strong> gray</td>
<td>$SIRM = 13.52 + 0.47<em>Cr + 1.46</em>Ni + 0.81<em>Cu - 0.45</em>Zn + 0.13*V$</td>
<td>0.80</td>
<td>0.08</td>
</tr>
<tr>
<td><strong>Group 5</strong> reddish</td>
<td>$SIRM = 53.96 - 0.53<em>Cr + 0.047</em>Pb + 0.10<em>Ni + 1.81</em>V - 385.17<em>MnO - 9.42</em>Fe_2O_3$</td>
<td>0.50</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Table 2. Multiple regressions between SIRM and heavy metals for each group of samples by color

**Conclusions**

The most significant heavy metals found in the Mexico City samples were Cr, Cu, Pb and V. The gathering of samples by color was proved suitable because it allowed identifying SIRM as most sensitive magnetic proxy related with the heavy metals rather than the bulk magnetic susceptibility.

**Acknowledgements**

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**References**

