Latinmag Letters, Volume 3, Special Issue (2013), OD06, 1-5. Proceedings Montevideo, Uruguay

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

Francisco Bautista[1], Rubén Cejudo[1], Gonzalo Zapata-Carbonell[1,2], José Luis Cortés[1], Patricia Quintana[3], Daniel Aguilar[3], Bertha Aguilar[4], Juan Morales[4] y Avto Gogichaishvili[4]

[1] Laboratorio Universitario de Geofísica Ambiental (LUGA), Centro de Investigaciones en Geografía Ambiental, Universidad Nacional Autónoma de México. Michoacán, México. Antigua Carretera a Pátzcuaro No. 8701 Col. Ex-Hacienda de San José de La Huerta, C.P. 58190, Morelia, Michoacán, México. leptosol@ciga.unam.mx, leptosol@yahoo.com

[2] Licenciatura en Ingeniería Ambiental, Universidad de Quintana Roo.

[3] Centro de Investigación y de Estudios Avanzados- Unidad Mérida.

[4] Laboratorio Universitario de Geofísica Ambiental, Instituto de Geofísica campus Morelia, Universidad Nacional Autónoma de México.

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: $R^2 > 35\%$. In the case of SIRM the five groups reached values of $R^2 > 37\%$ 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.

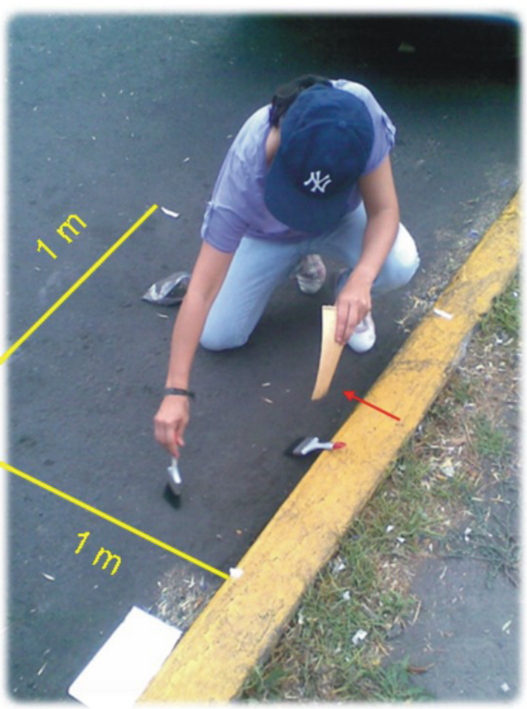

Figure 1. Sampling 1 m^2 of urban dust on Mexico City

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_2O, MgO, Al_2O_3, SiO_2, P_2O_5, K_2O, CaO, TiO_2, MnO and Fe_2O_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.

$$SI = (R-B) / (R+B)$$
$$HI = (2* R-G-B) / (G-B)$$
$$RI = R^2 / (B*G^3)$$

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).

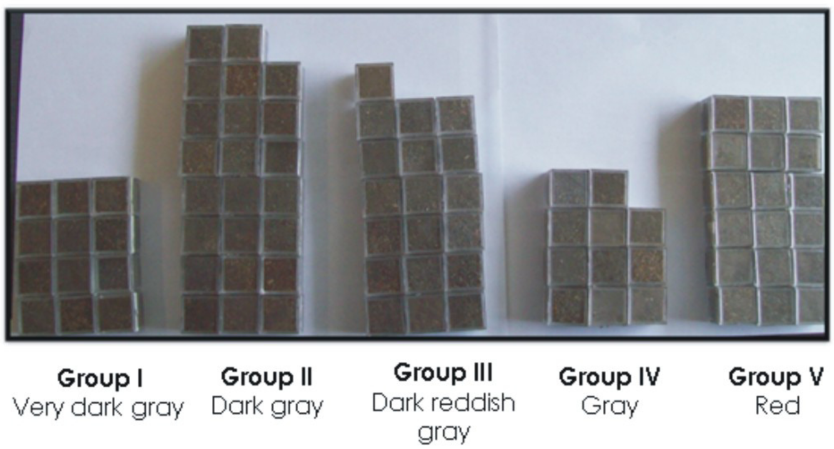

Figure 2. Groups of urban dust by color

Groups Dust color	**Equations**	**R²**	**P-value**
Group 1 very dark grey	X = -86.88 + 2.19*Cr- 2.50*Ni + 0.79*Cu- 0.67*Pb + 1.98*Zn	0.65	0.08
Group 2 dark gray	X = 777.68 - 9.74*Cr + 1.28*Ni + 1.32*Cu - 0.044*Zn + 1.18*Pb - 6.66*V + 6772.29*MnO - 1.79*Fe2O3	0.57	0.08
Group 3 dark reddish gray	X = 643.98 - 5.38*Cr + 1.37*Cu + 1.44*Pb	0.35	0.08
Group 4 gray	X = 307.10 + 5.03*Cr + 12.65*Ni + 7.11*Cu - 4.10*Zn + 2.83*V - 74.41*Fe2O3	0.87	0.08
Group 5 reddish	X = 840.16 - 4.90*Cr- 2.76*Ni- 3.02*Cu + 1.14*Zn + 24.46*V + 0.57*Pb - 12915.7*MnO - 88.22*Fe2O3	0.27	0.79

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.

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

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

We thank the Consejo Nacional de Ciencia y Tecnología for the financial support to projects “Las propiedades magnéticas de los suelos y sus aplicaciones: contaminación, clasificación, cartografía y uso del fuego en la agricultura” (CB-2011-01-169915); and the project CONACYT-153289. Also DGAPA-PAPIIT National Autonomous University of Mexico supported the project financially IN 223110.

References

Aguilar, B., Cejudo, R., Martínez-Cruz, J., Bautista, F., Goguitchaichvili, A., Carvallo, C., Morales J., 2012. Ficus benjamina leaves as indicator of atmospheric pollution: a reconaissance study, *Stud. Geophys. Geod., 56*, 879−887.

Aguilar, B.; Bautista, F.; Goguitchaichvili, A., y Morton, O., 2011. Magnetic Monitoring of Top Soils of Merida (Southern Mexico), *Stud. Geophys. Geod., 55*, 377-388.

Andrews, R. E.; Shah, K. M.; Wilkinson, J. M. and Gartland, A., 2011. Effects of cobalt and chromium ions at clinically equivalent concentrations after metal-onmetal hip replacement on human osteoblasts and osteoclasts: Implications for skeletal health. *Bone, 49*, 717-723.

Dearing, J., 1999. Environmental Magnetic Susceptibility, London.

Huerta, E., Brown, G., Bautista, F., 2011. Macroinvertebrados del suelo y lombrices de tierra: Análisis de datos (cap 15)' Bautista, F., Palacio, J. L., Delfín H. (eds) Técnicas de Muestreo para Manejadores de Recursos Naturales. Morelia, UNAM.

Jordanova, N., Jordanova, D., Veneva, L., Yorova, K., Petrovsky, E., 2003. Magnetic Response of Soils and Vegetation to Heavy Metal Pollution; A Case Study, Environ. *Sci. Technol., 37*, 4417-4424.

Kirpichtchikova, T. A.; Manceau, A.; Spadini, L.; Panfili, F.; Marcus, M. A., and Jacquet, T., 2006. Speciation and solubility of heavy metals in contaminated soil using X-ray microfluorescence, EXAFS spectroscopy, chemical extraction and thermodynamic modeling, *Geochim. Cosmochim. Ac., 70*, 2163-2190.

Lourenço, A. M.; Rocha, F., and Gomes, C. R., 2012. Relationships between magnetic parameters, chemical composition and clay minerals of topsoils near Coimbra, central Portugal. *Nat. Hazards Earth Syst. Sci., 12*, 2545–2555.

Morton, O., Hernandez, E., Martinez-Pichardo, E., Soler-Arechalde, A. M., Lozano, R., Gonzalez-Hernandez, G., Beramendi-Orosco, L., Urrutia-Fucugauchi, J., 2009. Mexico City topsoils: Heavy metals vs. magnetic susceptibility, *Geoderm., 151*, 121–125.

Pope III, C. A.; Hill, R. W., Villegas, G. M., 1999. Particulate air pollution and daily mortality on Utah's Wasatch Front., *Environ Health Perspect., 107*, 567-73.

Schwartz, J.; Norris, G.; Larson T.; Sheppard, L.; Claiborne, C. and Koenig, J., 1999. Episodes of high coarse particle concentrations are not associated with increased mortality. *Environ. Health Perspect., 107*, 339-42.

Schwartz, J. and Neas, L.M., 2000. Fine particles are more strongly associated than coarse particles with acute respiratory health effects in schoolchildren, *Epidemiology, 11*, 6-10.

Schwarze P. E.; Øvrevik, J.; Låg, M.; Refsnes, M.; Nafstad, P.; Hetland, R. B., Dybing, E., 2006. Particulate matter properties and health effects: consistency of epidemiological and toxicological studies, *Hum. Exp. Toxicol*., *25*, 559–579.

Sutherland, R. A.; Tolosa, C. A.; Tack, F. M. G., Verloo, M. G., 1999. Characterization of Selected Elements Concentrations and Enrichment ratios in Background and Anthropogenically Impacted Roadside Areas, *Environ. Contam. Toxicol., 38*, 428-438.

Trenberth, K. E.; Jones P. D.; Ambenje, P.; Bojariu, R.; Easterling, D.; Klein Tank A.; Parker, D., Rahimzadeh, F.; Renwick J. A.; Rusticucci, M.; Soden, B., and Zhai, P., 2007. Observations: Surface and Atmospheric Climate Change. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S.; Qin, D.; Manning, M.; Chen, Z., Marquis, M.; Averyt, K. B., Tignor M., and Miller, H. L. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Wackernagel, H., 2003. Linear Segression and Simple Krigin: Multiple Linear Regression (cap 3) Springer-verlag (ed) Multivariate Geostatistics: An Introduction with Applications*.* Berlin Heidelberg.

Wondafrash, T.; Sancho, I.; Gomez-Miguel, V.; Espejo-Serrano, R., 2005. Relationship between soil color and temperature in the surface horizon of mediterranean soils: A laboratory study, *Soil Science, 5*, 495-503.