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Chemical composition of rainwater collected at a southwest site of Mexico City, Mexico

A. Báez *, R. Belmont, R. García, H. Padilla, M.C. Torres

Laboratorio de Química Atmosférica, Centro de Ciencias de la Atmósfera, Universidad, Nacional Autónoma de México, Circuito Exterior, Ciudad Universitaria, México D.F. 04510, Mexico

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Abstract

Measurements of the trace metals Cd, Cr, Mn, Ni, Pb, V and Al in soluble and insoluble rain fractions and SO_4^{-2}, NO_3^-, Cl^-, HCO_3^-, Ca^{2+}, Mg^{2+}, Na^+, K^+, NH_4^+ and H^+ in soluble fractions were performed in rainwater collected at a southwest site of Mexico City during the rainy seasons of 2001 and 2002. Aluminum presented the highest volume-weighted mean concentration (VWMC) in both insoluble and soluble fractions. In the insoluble fractions, the VWM of the other trace metals decreased in the order Mn, Pb, Ni, V, Cr and Cd, and in the soluble fractions in the order Mn, V, Ni, Pb, Cd and Cr. Ammonium presented the higher VWMC, followed by SO_4^{2-}, NO_3^-, HCO_3^-, Ca^{2+}, Cl^-, H^+, Na^+, Mg^{2+} and K^+. Air mass back trajectories were associated to the concentrations of trace metals and of SO_4^{2-}, Ca^{2+}, Mg^{2+}, NH_4^+ and H^+ observed during each rainy day. Trace metal concentrations were not clearly related to wind direction. Enrichment factors related to the relative abundance of elements in crustal material were calculated using Mg as reference. The high enrichment factors (EF_c) suggested that, in general, trace metals and major ions had an anthropogenic origin. Aluminum, K^+, and Ca^{2+} were the only elements that had a significant crustal source. Factor analysis (Principal Component Analysis) with Varimax normalized rotation grouping the elements analyzed into three factors. Factor 1 indicated a crustal contribution for Ca^{2+}, K^+, Mg^{2+} and anthropogenic sources for SO_4^{2-}, NH_4^+ and V. Factor 2 indicated a high loading for Al, Ni and Mn, that indicate possible contribution of anthropogenic sources but with a significant crustal contribution for Al. Factor 3 indicated an anthropogenic origin for H^+ and NO_3^-. Pearson's correlations show that Al correlated with all the metals, including Ca^{2+} and Mg^{2+}. The solubility of trace metals did not depend on rainwater pH. As it was expected, Al presented the highest wet deposition flux.

Keywords: Heavy metals; Wet precipitation; Major ions; Natural and anthropogenic sources; Enrichment factor; Mexico City

1. Introduction

Precipitation chemistry has been exhaustively studied in urban and rural areas (Lee et al., 2000; Lara et al., 2001; Kulshrestha et al., 2003; Astel et al., 2004; Khare et al., 2004; Mouli et al., 2005) and some researchers have included the study of trace metals (Tanner and Wong, 2000; Luo, 2001; Roy and Négrel, 2001; Al-Momani et al., 2002; Hu and Balasubramanian, 2003; Al-Momani, 2003; Migliavacca et al., 2004).

The study of trace metals in wet and dry precipitation has increased in the last decades because of their adverse environmental and human health effects. Some metals such as Pb, Cd and Hg, among others, accumulate in the biosphere and may be toxic to living systems (Galloway et al., 1982; Barrie et al., 1987). Anthropogenic sources

* Corresponding author. Tel.: +52 55 5622 4071; fax: +52 55 5622 4050.

E-mail address: barmando@atmosfera.unam.mx (A. Báez).

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have substantially increased trace metal concentrations in atmospheric deposition. In addition, acid precipitation favors the dissolution of many trace metals, which enhances their bioavailability. If the concentrations are too high, many of the trace metals can harm human health through the consumption of drinking water and/or aquatic organisms. Trace metals from precipitation can also accumulate in surface waters and soils where they may cause harmful effects to aquatic life and forest ecosystems (Howard et al., 2004).

Trace metals are deposited by rain, snow and dry fallout. Rainout and washout are the predominant processes of deposition by rain (Seinfeld and Pandis, 1998). Usually over 80% of wet deposited trace metals are dissolved in rainwater, reaching the vegetation canopy in the most favorable form for uptake (Valenta et al., 1986). Atmospheric transport and deposition processes are important in the global recycling of trace metals.

Since the atmosphere of Mexico City is one of the most polluted cities in the world, it was considered important to analyze the trace metals Al, Cd, Cr, Pb, Ni, Mn, and V in soluble and insoluble rain fractions and the major ions SO_4^{-2}, NO_3^-, Cl^-, Ca^{2+}, Mg^{2+}, Na^+, K^+, NH_4^+ and alkalinity (HCO_3^-) only for the soluble fractions. Báez et al. (1980) determined the concentration of Pb, Cd and Cr in rainwater in several regions of Mexico. The results obtained in the Universidad Nacional Autónoma de Mexico (UNAM) in 1980 were 133, 0.88, and 4.54 μg l^{-1} for Pb, Cd and Cr, respectively. Since the government enforced the reduction of lead in fuels, we considered that it was important to investigate present lead levels in the atmosphere after this reduction took place. The values obtained in this study, 22.7, 4.62 and 2.57 μg l^{-1}, in the same order, were noticeably lower than those obtained in 1980. However the 1980 results can not be compared with recent values because both the collection and the analytical methods were much different that the present techniques, for instance, rainwater sampling was made base on 30 days bulk precipitation, now it is made daily or in event bases collection, and the analytical instruments have had many improvements.

2. Materials and methods

2.1. Sampling site

The Atmospheric Sciences building at UNAM campus, located in southern Mexico City at 2200 m above sea level (masl) at 19°19.57′ N latitude and 99°10.55′ W longitude (Fig. 1). Buildings surrounded by green areas with moderate to high traffic density characterize the UNAM campus. Mexico City is located on a volcanic high plateau. Volcanic rocks plus alluvial, fluvial and lacustrine deposits overlie limestones. A detailed description of the geological setting of Mexico City Basin

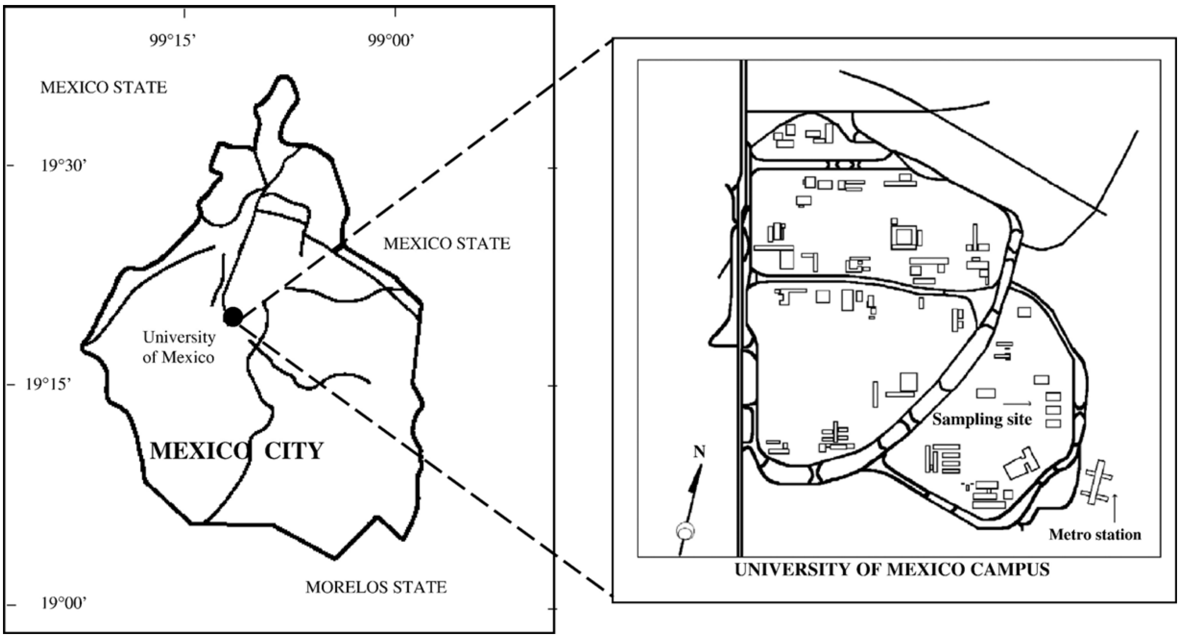

Fig. 1. Sampling site location.