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PM_{10} characterization and source apportionment at two residential areas in Bogota

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ABSTRACT

Bogota is the largest city in Colombia and is considered one of the most ones polluted in Latin America. The annual average PM_{10} concentration in the city is 55 $\mu g/m^3$, being as high as 90 $\mu g/m^3$ in the western region of the city. In this study, two sites in the western region were selected to assess the PM_{10} contribution from different sources. Two sets of fifty five 24–hour PM_{10} samples were taken at each site on quartz and Teflon filters. Chemical analysis of these samples was conducted to determine the ion, metal, and organic and elemental carbon concentrations. Ionic balance and mass closure were performed to check the consistency of chemical analysis. Positive Matrix Factorization (PMF) was then applied to determine the source contributions. Mobile sources and fugitive windblown dust were found to be the most significant sources of PM_{10} at both sites. An ion factor and a secondary aerosol source factor were identified at one site, whereas industry–related factors were identified at the other site, as expected in an area with a high density of small and medium industrial facilities. While it is true that source apportionment studies have been conducted worldwide, this is the first time that the Positive Matrix Factorization (PMF) model is applied in Bogota using full PM_{10} chemical speciation data, including carbonaceous materials, metals and ions. It is also the first time that a receptor model is applied simultaneously in two sites of the city. We aim that the results from this study will support environmental authorities in designing effective air pollution abatement measures in the city.

Keywords:
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1. Introduction

As a result of its economic growth, Bogota's air is among the most polluted in Latin America, with particulate matter (PM) the pollutant of most concern (Maggiora and Lopez–Silva, 2006). Results from the Bogota Air Quality Monitoring Network (BAQMN) show that the annual average PM_{10} concentration in the city for 2008 was 55 $\mu g/m^3$ when average over all the monitors but there are significant differences among areas of the city. The annual average PM_{10} concentration measured at Puente Aranda, Kennedy, Fontibon and Suba air quality monitoring stations, located in the western region of the city, is in the range of 60 to 90 $\mu g/m^3$, much higher than in the eastern and northeastern regions, 30–50 $\mu g/m^3$ (Figure 1). Several small and highly polluting industries and mobile sources impact the southwestern stations whereas the Suba station is located in an exclusively residential and commercial area and near the rural limits of the city.

Particulate matter, e.g. measured as $PM_{2.5}$ or PM_{10}, impacts health (Dockery et al., 1993; Holgate et al., 1999; Dominici et al., 2007) and thus environmental agencies set air quality standards for this pollutant. For the case of Bogota, it has been observed that an increase of 10 $\mu g/m^3$ in the PM_{10} concentration is associated with an increase of at least 8% in the number of hospital visits for respiratory illness in children less than 14 years old (Solarte et al., 2002) and it is also associated with a 4% increase in the number of hospital admissions for acute respiratory infections (ARI) (Arciniegas et al., 2006).

It is important for policy makers to identify the sources of PM so that they can design regulations and strategies to reduce its emissions. The most recent air pollutant emission inventory for Bogota (Fandino and Behrentz, 2009; Rodriguez and Behrentz, 2009) estimates that point sources account for 1 440 tons/year of total suspended particles (TSP) (based on isokinetic sampling data) and mobile sources for 1 100 tons/year of $PM_{2.5}$. This inventory, however, does not include source information detailed enough to develop local air pollution abatement strategies for the most polluted areas of the city, which is the interest of this work.

Previous studies have addressed PM_{10} chemical analysis in Bogota. Pachon et al. (2008) analyzed samples for organic carbon (OC) and elemental carbon (EC) by thermal gravimetric analysis (TGA) and thermal optical transmittance (TOT), and water soluble ions (SO_4^{2-}, NO_3^-, NO_2^-, $HCOO^-$, Cl^-, NH_4^+, Ca^{2+}, K^+, Na^+) by ion chromatography (IC). They concluded that the carbonaceous fraction (EC + OM, assuming a ratio of OM/OC = 1.4) was approx–imately 60% of the total PM_{10}, the coarse fraction accounted for between 25 and 45% and that secondary aerosol (mainly in the form of NH_4NO_3) could contribute between 9% and 17% of the PM_{10}. Rivera and Behrentz (2009), using chemical characterization of PM_{10} and $PM_{2.5}$ samples, applied Principal Component Analysis (PCA) to identify emission sources for three sites in Bogota. They analyzed ions (Cl^-, NO_3^-, SO_4^{2-} and PO_4^{-3}, Na^+, NH_4^+, K^+, Mg^{2+} and Ca^{2+}) by IC and metals (Fe, Al, Mg, Ca, K, Mn, Ga, Ba, Na, Cr, Ni, Zn, Cu) by Inductively Coupled Plasma Mass Spectroscopy (ICP–MS), but did not analyze for carbonaceous material. They found that the ionic fraction contributed between 4% and 8% of the total PM_{10},

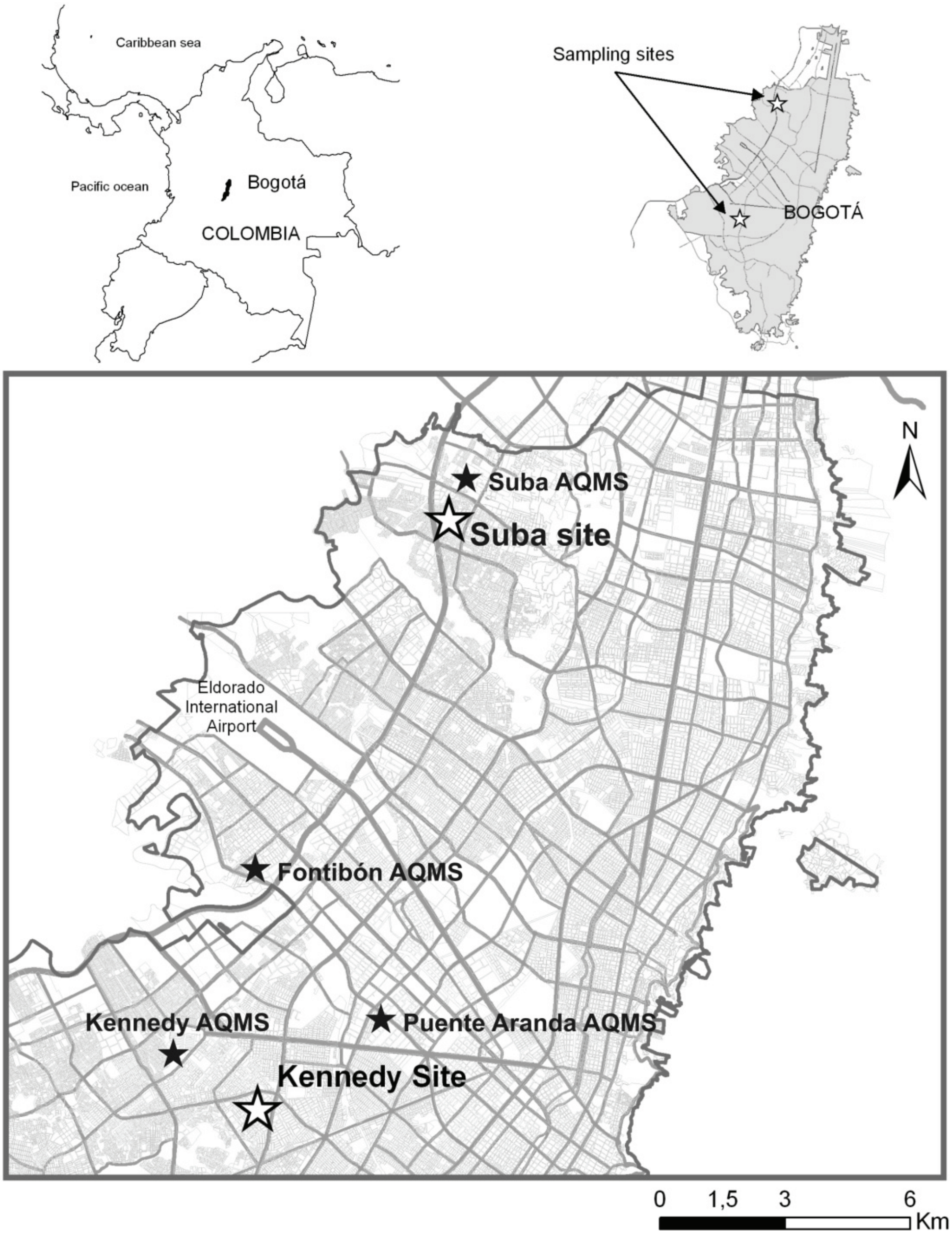

Figure 1. *Location of Kennedy and Suba sampling sites and neighboring air quality monitoring stations (AQMS). Although both sites are located in areas with high PM_{10} concentrations the Suba site is located in a residential and commercial area whereas the Kennedy site is surrounded by small but highly polluting industries using coal as fuel.*

and the metals apportionment was between 7% and 10% of PM_{10} (without correction for crustal compounds). The apportionment for factors identified in that work were different at every site ranging 42–60% for resuspended dust associated with vehicular activities, 1–17% for industry and 3–29% for automobile exhaust.

PMF analysis of PM composition has been used in different cities around the world to identify source impacts (Hopke,2003; Begum et al., 2004; Kim et al., 2004; Zhao and Hopke, 2004; Morishita et al., 2006; Zhao and Hopke, 2006; Quin et al., 2006; Begum et al., 2007; Rizzo and Scheff, 2007; Vecchi et al., 2008; Mazzei et al., 2008). For PM_{10} studies the largest factor is often soil or dust (Chueinta et al., 2000; Begum et al., 2004; Hedberg et al., 2005) ranging between 20% and 64%. Other important factors are secondary pollutants and carbonaceous fractions (Mazzei et al., 2008).

In order to better understand the origin of PM_{10} in the western and northwestern regions of Bogota, PMF is applied to two sets of PM_{10} samples, from two sites in the western region of the city. This is the first time that a full PM_{10} chemical analysis, including carbonaceous compounds, metals and ions, together with PMF is used for source contribution purposes in Bogota. The authors hope that these results will be useful for policy makers in the design of strategies to effectively curb air pollution in this city.

2. Methods

2.1. Sampling and chemical characterization

Ambient PM_{10} samples were collected at two sites in the western part of Bogota: Kennedy and Suba (Figure 1). Kennedy (4°36’57” N, 74°08’37” W) is an urban site located in a residential area with a significant number of small tanning industries and foundries that burn coal as fuel. The area has both paved and unpaved roads and its surroundings are urban. Suba (4°44’36” N, 74°06’09” W) is an urban site located in a residential area with commercial activities and paved and unpaved roads. There are no