Atmospheric Research 98 (2010) 478–485

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmos

Insights into the dynamics and sources of atmospheric lead and particulate matter in São Paulo, Brazil, from high temporal resolution sampling

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ARTICLE INFO

Article history:
Received 7 December 2009
Received in revised form 18 August 2010
Accepted 24 August 2010

Keywords:
Lead Isotopes
$PM_{2.5}$
$PM_{2.5\text{-}10}$
Unleaded fuel
Megacity
Fireworks

ABSTRACT

We present the first results of a study investigating the processes that control concentrations and sources of Pb and particulate matter in the atmosphere of São Paulo City, Brazil. Aerosols were collected with high temporal resolution (3 hours) during a four-day period in July 2005. The highest Pb concentrations measured coincided with large fireworks during celebration events and associated to high traffic occurrence. Our high-resolution data highlights the impact that a singular transient event can have on air quality even in a megacity. Under meteorological conditions non-conducive to pollutant dispersion, Pb and particulate matter concentrations accumulated during the night, leading to the highest concentrations in aerosols collected early in the morning of the following day. The stable isotopes of Pb suggest that emissions from traffic remain an important source of Pb in São Paulo City due to the large traffic fleet, despite low Pb concentrations in fuels.

1. Introduction

The air quality in megacities in emerging economies such as Brazil, China, India, Egypt, etc. is threatened by rapid industrial and population growth combined with poor emission control (Bravo and Torres, 2000). Motor vehicle traffic is in general the major pollutant source for trace elements, but other sources can predominate. For example, coal combustion was identified as a major source in Beijing, especially, in the wintertime (He et al., 2001; Sun et al., 2004) and metallurgic dust, coal combustion, and cement are major pollutants in Shanghai (Zheng et al., 2004). Several investigations show a significant correlation between ambient particulate matter (PM) and cardiovascular and respiratory morbidity and mortality (e.g. Dominici et al., 2005). The distinction between fine and coarse fraction is crucial. The fine fraction ($PM_{2.5}$, aerodynamic diameter <2.5 μm) is more intensely associated with health effects because these particles penetrate deeper into the respiratory tract and affect lung function (Bourotte et al., 2007; Pitz et al., 2008). High levels in $PM_{2.5}$ are associated with combustion process from vehicular exhaust and industrial emissions. The coarse particulate matter ($PM_{2.5\text{-}10}$, aerodynamic diameter between 2.5 and 10 μm) is composed dominantly from road dust and soil resuspension (Seinfeld and Pandis 1998).

High concentrations of particulate matter lead to high toxic trace element concentrations in the atmosphere (Kandlikar and Ramachandran, 2000; Mage et al., 1996), which in turn can affect adversely human health, especially those of children and elderly people. With respect to Pb, investigations in megacities of emerging economies were conducted in Jakarta (Kondo et al., 2007), Beijing (Sun et al., 2004), Shanghai (Zheng et al., 2004), Mumbai and Delhi (Kandlikar and Ramachandran, 2000; Singh and Singh, 2006) but to date, no South American city was systematically studied.

The São Paulo Metropolitan Area (SPMA) is the third biggest urban conglomerate of the world and the largest and most industrialized area in South America with about

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doi:10.1016/j.atmosres.2010.08.016

19.2 million inhabitants (IBGE, 2007). The SPMA has one of the largest urban motor vehicles fleet of the world with almost 7 million vehicles (CETESB, 2006). Previous studies investigated the atmospheric particulate matter in SPMA (Andrade et al., 1994; Miranda et al., 2002; Orsini et al., 1986; Sanchez-Ccoyllo and Andrade, 2002; Castanho and Artaxo, 2001). Andrade et al. (1994) collected particulate matter between the 19th of June and 8th of August 1989 three times during the day (8 am, 2 pm, and 8 pm). Five sources were identified and quantified for the fine particles using absolute principal component analysis (APCA): industrial emissions, 13%; emissions from residual oil and diesel, 41%; re-suspended soil dust, 28%; and emissions of Cu and of Mg, 18%. Castanho and Artaxo (2001) collect aerosol samples in 1997 (two sampling campaign of 12 h), but suggested a significant different quantitative composition of the atmospheric pollutant sources in fine particles with light and heavy-duty vehicles accounting for 28%; re-suspended soil dust for 25%; oil combustion for 18%; sulphates for 23%; and industrial emissions for 5%. This highlights the transient nature of atmospheric pollution sources in SPMA and the importance of fuel combustion of diesel, gasoline and alcohol as one of the most important atmospheric pollutant sources. The geographical location of SPMA is unfavourable to pollutants dispersion and frequently causes diurnal thermal inversions lower than 200 m, especially in wintertime (Freitas, 2003).

Given the transient nature of atmospheric pollution sources and the rapid growth of the Sao Paulo Metropolitan Area, we conducted a high-resolution temporal sampling (3 hours interval) campaign of coarse and fine fractions over a four-day period covering weekdays, weekend and a major event. Here we report first the results for Pb given its importance to air quality in this megacity. We use its isotope composition to identify the sources and discuss its dynamic with respect to meteorological conditions. We assess in particular the importance of fuel combustion as source of particular matter and Pb, and the effect of firework on air quality in SPMA. The effect of singular short-lived pollution events on air quality has been demonstrated recently for fireworks (Kulshrestha et al., 2004; Drewnick et al., 2006; Moreno et al., 2007; Wang et al., 2007; Steinhauser et al., 2008; Vecchi et al., 2008). A significant increase in metal concentration was observed with each colour corresponding to a specific element (Steinhauser, et al., 2008). Lead has been detected as primary component during celebrations episodes (Wang et al., 2007).

2. Study Area And Experimental Methods

2.1. Study area and aerosol sampling

The SPMA covers an area of 8051 km^2 including 39 cities, among them São Paulo City (Fig. 1). The city is built on sediments. The mountain range of the *Serra da Cantareira* to the north is composed of Neoproterozoic granites. The hilly area to the south is composed of Precambrian rocks of the Embú complex (Tassinari, 1988).

Notwithstanding the control measures adopted during last years, the accentuated industrial development and the

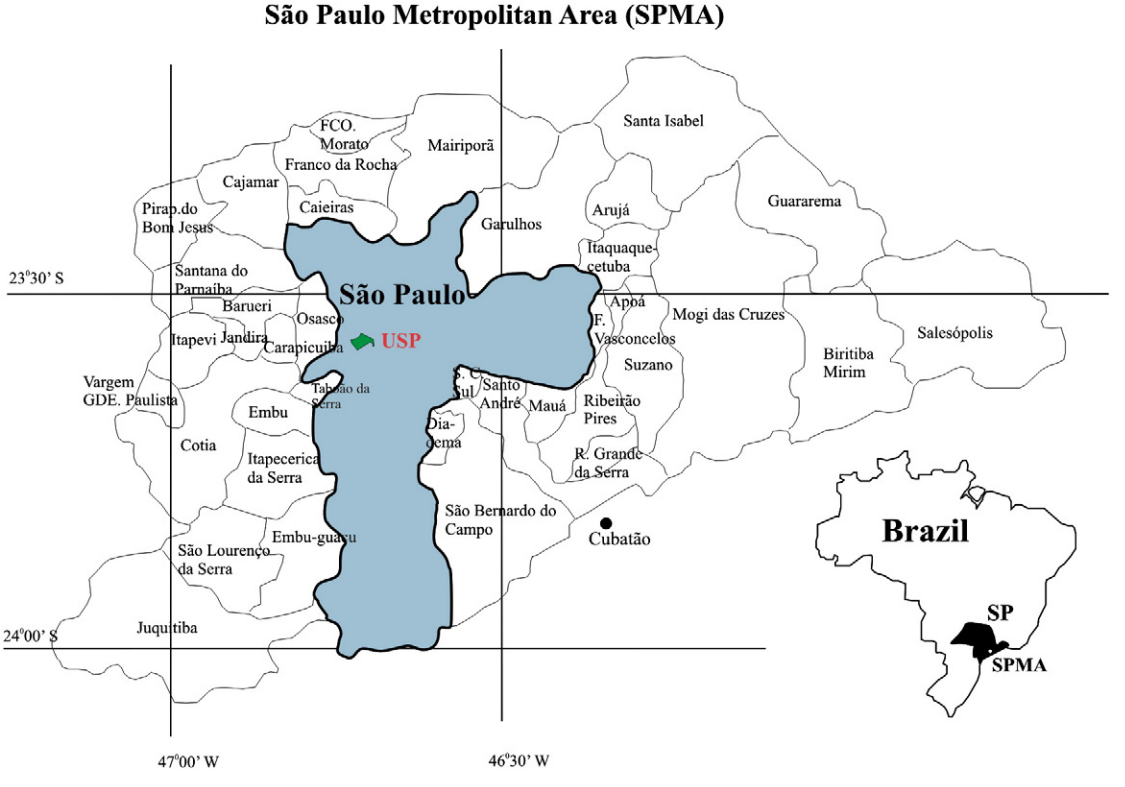

Fig. 1. Map of São Paulo Metropolitan Area (SPMA) and location of São Paulo City. Taken from Emplasa DIF/CIE - 2002. Also shown USP campus where the aerosols were sampled.