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Concentrations and source apportionment of particulate matter in different functional areas of Shanghai, China

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ABSTRACT

Concentrations of atmospheric particulate matter with different sizes and 9 metallic elements (Al, Ca, Mg, Fe, Cu, Mn, Ni, Pb and Zn) were measured in two sampling sites of Baoshan District and Putuo District from July 2009 to September 2010, to investigate the size distribution and the possible sources of particulate matter. The results showed that in these two sampling sites, crustal elements mainly distributed in coarse mode and heavy metals all distributed in fine mode. Source apportionment results by enrichment factor and principal component analysis indicated that in Baoshan sampling site, $PM_{0.43-2.1}$ was mainly from industrial metallurgical processes, while $PM_{2.1-10}$ was mainly from re–suspended soil dust. Local road traffic source was the dominant contributor to $PM_{0.43-2.1}$ and $PM_{2.1-10}$ in Putuo sampling site.

Keywords: *Particulate matter, size distribution, seasonal variation, source apportionment, different functional areas*

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1. Introduction

Particulate matter (PM) in the atmosphere are complex mixtures of elemental and organic carbon, mineral dust, trace elements and water (Lim et al., 2010). They originate from both the natural (involving sea–salt particles, wind–blown sand, volcanic ash, etc.) and anthropogenic sources (industrial processes, traffic sources, fuel combustion, etc.) (Lim et al., 2010). Particulate matter has negative effects on human health, air quality, visibility as well as global climate change (WHO, 2006; IPCC, 2007; Colette et al., 2008; Chen et al., 2010). And the pollution caused by particulate matter is not only related to its concentrations, but also associated with particle sizes. In general, particulate matter with smaller sizes can adsorb more pollutants (toxic heavy metals, acidic oxides, organic pollutants, large amounts of bacteria and viruses, etc.) and deposits in the lungs and reaches the alveoli (Samet et al., 2000). In addition, fine particulate matter has a longer atmospheric residence time for several days or weeks and is transported through atmospheric circulation, affects the surrounding atmospheric environment more significantly (Harrison and Pio, 1983).

In recent years, in most cities of China, particulate matter has been the primary pollutant in the atmosphere, and there is no exception for Shanghai. From 2005 to 2010, the annual average concentration of $PM_{2.5}$ (particle aerodynamic diameter less than or equals to 2.5 μm) in Shanghai is between 44 μg m^{-3} and 53 μg m^{-3}, which exceeds the new National Standard II of Air Quality (annual average of 35 μg m^{-3}). In 2010, the total deaths of circulatory system disease and cardiovascular disease caused by $PM_{2.5}$ in Shanghai were 2 980 and which also resulted in economic losses of about 390 million dollars (Pan et al., 2012).

Considering the adverse effects of particulate matter pollution in Shanghai, many related investigations have been carried out, mainly including chemical compositions (Shen et al., 2002), physical characteristics (Yang et al., 2007), variations of particulate matter concentrations (Lu et al., 2008) and source apportionment (Yao et al., 2010). However, the former studies focused on the pollution property and source apportionment of PM_{10} (particle aerodynamic diameter equals to or less than 10 μm) or $PM_{2.5}$, and did not consider the pollution properties of particulate matter in different sizes, nor did they conduct comparative studies of different functional areas. The aim of the present study is to (1) investigate the size distribution of particulate matter; (2) discuss the differences of particulate matter and 9 associated elements (Al, Ca, Mg, Fe, Cu, Mn, Ni, Pb and Zn) among four seasons; (3) identify the possible sources of particulate matter with different sizes in different functional areas.

2. Materials and Methods

2.1. Sampling sites

Shanghai is located in 30°23′–31°27′N, 120°52′–121°45′E. It belongs to subtropical monsoon climate, prevails northwest wind in winter and southeast wind in summer. Its annual average temperature is about 16 °C, and the annual average rainfall is about 1 125 mm, while 60% of the total rainfall occurs in spring, summer and autumn.

The sampling site in the industrial area is located on the roof of a building in Yuepu Town, Baoshan District, which is 9 m above the ground. The site is close to Baoshan Iron and Steel Group and Shidongkou Power plant and both industrial sectors are coal–fired. The residential–commercial sampling site is located on the roof of an office building in Changfeng Community of Putuo District, which is also 9 m above the ground. This site is surrounded by many commercial malls and supermarkets, with heavy traffic of Jinshajiang Road (Figure 1).

2.2. Sampling and analysis

From July 2009 to September 2010, atmospheric particulate matter samples were collected using Ambient Eight Stage Non–Viable Cascade Impactor Sampler (TE–20–800, BGI/TISCH, America) at a rate of 28.3 L m^{-1}, with stages 0 to 7 representing the aerodynamic equivalent diameters of 9.0–10 µm, 5.8–9.0 µm, 4.7–5.8 µm, 3.3–4.7 µm, 2.1–3.3 µm, 1.1–2.1 µm, 0.7–1.1 µm and 0.43–0.7 µm, respectively. The sampling medium was 81 mm glass fiber filter (TE–20–301). Before and after sampling, the glass fiber filters were conditioned in an oven for 48 h (25 °C, 40±5% relative humidity), and then they were weighted. In Baoshan sampling site, 14 groups of samples were collected, and each group of 8 samples with a total 108 valid filter samples (excluding 4 missing samples). In Putuo sampling site, 12 groups of samples were collected, a total of 94 valid filter samples (excluding 2 missing samples).

The filters were shredded using plastic scissors and transferred to a PTFE (polytetrafluoroethylene) tank. 2 mL of HNO_3, 3 mL of HF, and 1 mL of $HClO_4$ were added to the tank to digest the samples. Then they were heated in an oven at 180 °C for 5 h. After digestion and cooling, the tank was moved to an electro–thermal board at 130 °C in order to drain the remaining acid. Sample was cooled again and the final volume was adjusted to 25 mL with 2 mL HNO_3 (Wang et al., 2013). Subsequently, the concentrations of metallic elements (Al, Ca, Fe, Mg, Cu, Mn, Ni, Pb and Zn) were determined by a 710–ES Inductively Coupled Plasma–Emission Spectrometer. Two blanks and two reference materials (soil standards, GSS–6) were used for quality assurance and quality control. The recovery of the analyzed elements was between 80% and 110%.

3. Results and Discussion

3.1. Mass concentrations and size distribution of particulate matter and metallic elements

The aerodynamic equivalent diameter of 2.5 µm is always regarded as the boundary of coarse particulate matter ($PM_{2.5–10}$) and fine particulate matter ($PM_{2.5}$) (Chaloulakou et al., 2003). Since the sampler does not have a cut–off head of 2.5 µm, 2.1 µm was regarded as the boundary of coarse and fine particulate matter in this study. Particulate matter with diameter of less than 2.1 µm was classified as fine particulate matter ($PM_{0.43–2.1}$), particulate matter with diameter greater than 2.1 µm and less than 10 µm was classified as coarse particulate matter ($PM_{2.1–10}$). The monthly average concentrations of particulate matter in different sizes were displayed in Table 1. In the two sampling sites, monthly average concentration of $PM_{9.0–10}$ was the highest and the concentration of $PM_{0.43–0.7}$ was the lowest. The monthly average concentrations of particulate matter with different sizes in Baoshan sampling site were all higher than those in Putuo sampling site, which suggesting that industrial processes were significantly associated with the high concentrations of particulate matter in the atmosphere.

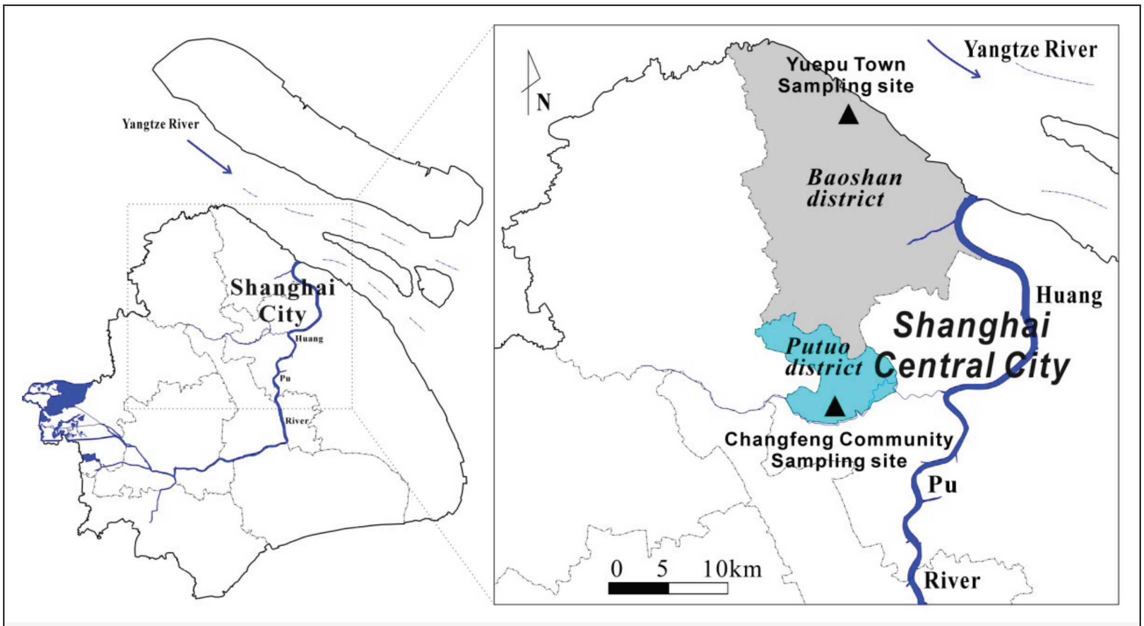

Figure 1. *Sampling sites.*

Table 1. *Monthly average concentrations (mean±SD) of particulate matter with different sizes in different sampling sites (µg m^{-3})*

Sampling sites	$PM_{0.43–0.7}$	$PM_{0.7–1.1}$	$PM_{1.1–2.1}$	$PM_{2.1–3.3}$	$PM_{3.3–4.7}$	$PM_{4.7–5.8}$	$PM_{5.8–9.0}$	$PM_{9.0–10}$
Baoshan	13.98±11.91	25.77±31.18	25.77±27.11	14.25±8.67	18.20±10.90	25.29±32.97	26.26±16.99	47.98±31.62
Number of samples	12	13	14	13	14	14	14	14
Putuo	8.14±5.82	14.19±11.12	15.87±12.00	10.63±7.02	14.43±10.56	13.51±7.25	23.40±11.44	35.43±16.25
Number of samples	11	12	12	12	12	11	12	12