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# Characteristics and applications of size-segregated biomass burning tracers in China's Pearl River Delta region

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## HIGHLIGHTS

- First report of size distributions of biomass burning tracers in the PRD.
- Origins of biomass burning aerosols were identified using multiple tracer method.
- Biomass smoke contributed significantly to ambient aerosol in the PRD region.

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## ABSTRACT

Biomass burning activities in China are ubiquitous and the resulting smoke emissions may pose considerable threats to human health and the environment. In the present study, size-segregated biomass burning tracers, including anhydrosugars (levoglucosan (LG) and mannosan (MN)) and non-sea-salt potassium (nss-$K^+$), were determined at an urban and a suburban site in the Pearl River Delta (PRD) region. The size distributions of biomass burning tracers were generally characterized by a unimodal pattern peaking in the particle size range of 0.44–1.0 μm, except for MN during the wet season, for which a bimodal pattern (one in fine and one in coarse mode) was observed. These observed biomass burning tracers in the PRD region shifted towards larger particle sizes compared to the typical size distributions of fresh biomass smoke particles. Elevated biomass burning tracers were observed during the dry season when biomass burning activities were intensive and meteorological conditions favored the transport of biomass smoke particles from the rural areas in the PRD and neighboring areas to the sampling sites. The fine mode biomass burning tracers significantly correlated with each other, confirming their common sources. Rather high ΔLG/ΔMN ratios were observed at both sites, indicating limited influence from softwood combustion. High Δnss-$K^+$/ΔLG ratios further suggested that biomass burning aerosols in the PRD were predominately associated with burning of crop residues. Using a simplified receptor-oriented approach with an emission factor of 0.075 (LG/TC) obtained from several chamber studies, average contributions of biomass burning emissions to total carbon in fine particles were estimated to be 23% and 16% at the urban and suburban site, respectively, during the dry season. In

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contrast, the relative contributions to total carbon were lower than 8% at both sites during the wet season.



## 1. Introduction

Atmospheric particulate matter (PM) exerts significant influence on cloud formation, radiation budget and air quality, and ultimately affects global climate and human health (Pöschl, 2005; Seinfeld and Pandis, 2006). Recently, there has been growing public concern about the high PM levels and reduced visibility in Asia, especially in China. Facing severe air pollution problems, the Chinese government has recently revised the national ambient air quality standard, which will be implemented countrywide in 2016. This is the first standard in China that sets a critical level for $PM_{2.5}$ (particulate matter with aerodynamic diameters smaller than 2.5 μm). Therefore, an understanding of source contributions to $PM_{2.5}$ and its major components in various regions of China is urgently required to provide scientific evidence for establishing pollutant control policies and strategies.

Inorganic ions and carbonaceous species are major chemical components of PM (Jimenez et al., 2009). The dominant inorganic ions include sulfate, nitrate, ammonium and basic cations. Their sources and formation mechanisms are generally well understood (Alexander et al., 2005; Michalski et al., 2003; Zhang et al., 2008a). Strict emission control policies have been established in China for controlling the gaseous precursors forming sulfate and nitrate. However, knowledge of source contributions to carbonaceous species is still limited. An early study on global emission inventories suggested that biomass burning was the largest source of primary organic carbon (POC) and elemental carbon (EC) (Bond et al., 2004). About 31 TgC $yr^{-1}$ POC and 5.0 TgC $yr^{-1}$ EC were produced from biomass burning processes, accounting for 93% and 62% of the total global EC and POC emissions, respectively. Although biomass burning is a significant source of carbonaceous matter as well as $PM_{2.5}$ in general, little attention has been paid to this source by policy-makers due to the dominant influence of urban and industrial activities on $PM_{2.5}$.

Both source-oriented and receptor-based approaches have been used to quantify biomass burning contributions to $PM_{2.5}$ (e.g., Zhang et al., 2010a). Source-oriented methods rely on emission inventories and meteorological parameters to estimate the impact of particular sources. However, large uncertainties exist in the biomass burning activity data, and emission factors also vary greatly under different combustion conditions (Tian et al., 2008). Over the past decade, receptor-oriented methods have become the primary impact assessment tool for biomass burning, especially studies based on the measurements of source-specific tracers (Ho et al., 2014; Zhang et al., 2013a, 2010a; Zheng et al., 2002). The most commonly used biomass burning tracers are anhydrosugars (i.e., LG, MN and galactosan), of which LG is the single most abundant component in biomass burning smoke. Anhydrosugars are the pyrolysis products of cellulose and hemicellulose and have not been found in other types of combustion processes (Simoneit, 2002). Although the emission factors of anhydrosugars have been found to vary significantly with biomass types and burning conditions (Sullivan et al., 2008), they have been used extensively to estimate biomass burning contributions to $PM_{2.5}$ and carbonaceous species masses (Harrison et al., 2012; Zhang et al., 2008b, 2010b). Water-soluble potassium is also regarded as a reliable tracer for biomass burning, although corrections are needed due to the contributions from other potential sources such as soil and sea-salt (Duan et al., 2004).

The Pearl River Delta (PRD) region is one of the most developed areas in China and has long been suffering of serious PM pollution (Chan and Yao, 2008). An increasing demand for cleaner air from the public drives the government and the scientific community to better understand PM sources, formation mechanisms and control strategies. The PRD region also plays a leading role in the establishment of China's air pollution control and prevention policies, and the experience gained in this region will benefit other parts of the country. From the emission inventory studies for the PRD region, biomass burning has been recently identified as an important source of $PM_{2.5}$ in the PRD region, producing 0.03 Tg or 15% of the total $PM_{2.5}$ (He et al., 2011; Zheng et al., 2009). As suggested by Zhang et al. (2010b), biomass burning aerosols generated in the rural areas of the PRD and Guangdong province can be transported to the urban areas resulting in serious biomass burning episodic events. Biomass burning activities are common in the surrounding areas of the PRD region, although there is still very limited knowledge regarding the major type of biomass burning aerosols influencing the PRD region and other parts of China.

The purpose of the present study is, therefore, to identify the sources of biomass burning aerosols and quantify the contributions of biomass burning activities to the total carbon (TC) content in $PM_{2.5}$ in the PRD region. This is achieved through measurement of multiple biomass burning tracers in size-segregated aerosol samples at an urban and a suburban site within the PRD during typical dry and wet seasons. Knowledge gained from this study will also benefit other regions of China, where biomass burning activities are common practice, e.g., in the region of the Sichuan basin and North China (Tao et al., 2013).

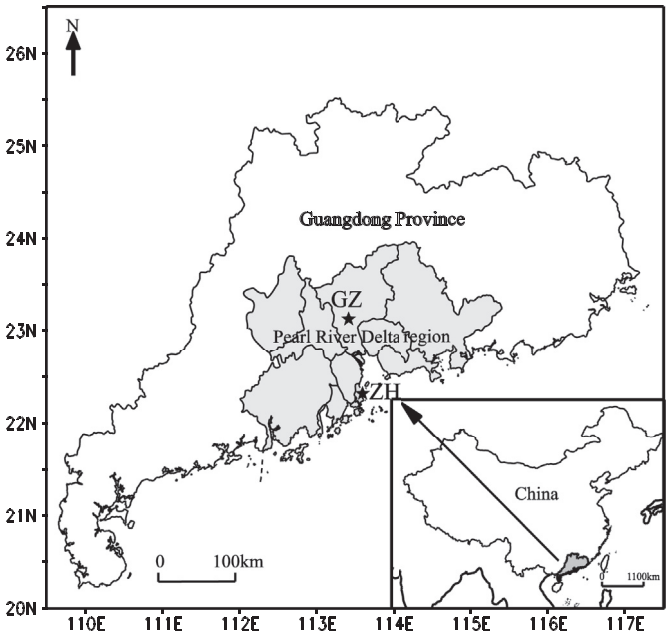


**Fig. 1.** Location of the sampling sites.