Environmental Pollution 228 (2017) 92–101

Contents lists available at ScienceDirect

Environmental Pollution

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

Source characterization of urban particles from meat smoking activities in Chongqing, China using single particle aerosol mass spectrometry

Yang Chen [a, c, *], John C. Wenger [b], Fumo Yang [a, d, e, **], Junji Cao [c], Rujin Huang [c], Guangming Shi [a], Shumin Zhang [f, g], Mi Tian [a], Huanbo Wang [a]

[a] Research Center for Atmospheric Environment, Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences, Chongqing 400714, China
[b] Department of Chemistry and Environmental Research Institute, University College Cork, Cork, Ireland
[c] Key Lab of Aerosol Chemistry & Physics, Institute of Earth Environment, Chinese Academy of Sciences, Xi'an 710061, China
[d] Center for Excellence in Regional Atmospheric Environment, Institute of Urban Environment, Chinese Academy of Sciences, Xiamen 361021, China
[e] Yangtze Normal University, Chongqing 408100, China
[f] North Sichuan Medical College, Nanchong 637000, Sichuan, China
[g] Chongqing University, Chongqing 400044, China

ARTICLE INFO

Article history:
Received 14 December 2016
Received in revised form
4 May 2017
Accepted 7 May 2017

Keywords:
Biomass burning
Meat smoking
Chongqing
SPAMS
$PM_{2.5}$
Biofuel smoldering

ABSTRACT

A Single Particle Aerosol Mass Spectrometer (SPAMS) was deployed in the urban area of Chongqing to characterize the particles present during a severe particulate pollution event that occurred in winter 2014–2015. The measurements were made at a time when residents engaged in traditional outdoor meat smoking activities to preserve meat before the Chinese Spring Festival. The measurement period was predominantly characterized by stagnant weather conditions, highly elevated levels of $PM_{2.5}$, and low visibility. Eleven major single particle types were identified, with over 92.5% of the particles attributed to biomass burning emissions. Most of the particle types showed appreciable signs of aging in the stagnant air conditions. To simulate the meat smoking activities, a series of controlled smoldering experiments was conducted using freshly cut pine and cypress branches, both with and without wood logs. SPAMS data obtained from these experiments revealed a number of biomass burning particle types, including an elemental and organic carbon (ECOC) type that proved to be the most suitable marker for meat smoking activities. The traditional activity of making preserved meat in southwestern China is shown here to be a major source of particulate pollution. Improved measures to reduce emissions from the smoking of meat should be introduced to improve air quality in regions where smoking meat activity prevails.

1. Introduction

Biomass burning (BB) emissions make a significant contribution to urban PM in China (Cao et al., 2007; Cheng et al., 2014; He et al., 2011; Huang et al., 2014; Yang et al., 2011). A range of BB activities has been identified, including forest and savanna wildfires, wood and peat burning, residential heating and cooking, as well as industrial biofuel burning (Reid et al., 2005; Simoneit, 2002). Zhang and Cao (2015) have highlighted two of the most important BB sources in China: household biofuel combustion and open agricultural waste burning in rural areas. BB particles impact considerably on urban air quality in China during periods of agricultural waste burning. For example, it has been estimated that $PM_{2.5}$ levels for the Yangtze River Delta region could be reduced by 51% if anthropogenic biomass burning is eliminated (Cheng et al., 2014). Detailed investigation of chemical composition and mixing state of atmospheric single particles can provide information on their sources, as well as the extent of aging or atmospheric processing.

* Corresponding author. Research Center for Atmospheric Environment, Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences, Chongqing 400714. China.
** Corresponding author. Research Center for Atmospheric Environment, Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences, Chongqing 400714. China.
E-mail addresses: chenyang@cigit.ac.cn (Y. Chen), fmyang@cigit.ac.cn (F. Yang).

http://dx.doi.org/10.1016/j.envpol.2017.05.022
0269-7491/

Over the last 15 years, single particle mass spectrometers have been used for determining the size-resolved chemical characterization of individual BB particles for source identification and apportionment (Pratt and Prather, 2012). Silva et al. (1999) investigated the composition and mixing state of typical wood-burning particles in southern California, while Healy et al. (2010) reported the chemical composition of freshly emitted particles from wood and peat burning in Cork, Ireland and used the data to identify the sources of ambient particles. Pratt et al. (2011) characterized the aging of BB particles in two prescribed burn smoke plumes using an aircraft-based instrument, and Pagels et al. (2013) investigated various markers of solid biofuel combustion particles. Overall, the available literature in this area indicates that BB particles are typically rich in potassium, Elemental Carbon (EC), and Organic Carbon (OC), with the latter comprised of numerous combustion products including levoglucosan, aldehydes, ketones, polycyclic aromatic hydrocarbons (PAHs), and nitrogenated organics. Aged or processed BB particles usually contain significant amounts of secondary nitrate and sulfate (Pagels et al., 2013; Pratt et al., 2011; Zauscher et al., 2013). Over the last few years, single particle aerosol mass spectrometers (SPAMS) have been used to study the size-resolved chemical characterization and mixing state of ambient PM at various locations in China. Ambient BB particle types have been reported in Guangzhou (Bi et al., 2011), Nanjing (Wang et al., 2015), Shanghai (Huang et al., 2013), Beijing (Li et al., 2014), Xi'an (Chen et al., 2016), and Mt. Huang (Chen et al., 2014). However, the characterization of single particles in urban areas of southwestern China is still limited (Chen et al., 2017).

Chongqing is a municipality in the southwestern China, with a population of 8.23 million in the main city (Chen et al., 2017). In both the urban and rural areas of Chongqing, natural gas is commonly used for residential cooking, but biofuel is still widely used in traditional restaurants and for smoking meat usually one or two months before the Chinese Spring Festival (January or February). These meat smoking activities are usually performed outdoors in areas close to residential communities, and the resulting emissions have attracted significant attention from the scientific community to general public within the wider context of particulate pollution in China. However, information on the impacts of traditional meat smoking activities on local and regional air quality is still limited and further targeted scientific studies are needed.

The aim of this study was to investigate the single particle chemical composition of ambient particles using a SPAMS in Chongqing during the traditional meat-smoking period. Measurements were made during a severe particulate pollution event that occurred in Chongqing from 25th December 2014 to 8th January 2015. Detailed analysis of the SPAMS dataset showed that the single particle population was dominated by BB types and the contribution of meat smoking was confirmed by the presence of particle types also observed in a series of controlled biomass smoldering experiments. This study thus provides a unique insight into the sources, composition, and mixing state of BB particles produced from meat smoking activities and their impact on air quality in the urban area of Chongqing. The findings are also relevant for other urban areas of China where meat smoking activities are common in winter.

2. Methods

2.1. Field measurements

The sampling site is an air quality monitoring station established in 2010 to monitor the urban air quality of Chongqing (Fig. 1). A detailed description of the sampling site is available in the literature (Chen et al., 2017). It is located on the roof of a building, 30 m above the ground (106.51°E, 29.62°N), in a typical commercial and residential area, 10 km from the city center. A range of gaseous air pollutants, including nitrogen oxides (NOx), ozone, carbon monoxide, and SO_2 is routinely monitored at this urban background site. $PM_{2.5}$ mass concentration is measured continuously using a Tapered Element Oscillating Microbalance (TEOM, 1400a, Thermo Fisher, USA). The mass concentration of Black Carbon was measured using an Aethalometer (AE33, Magee, USA) and meteorological data were collected using a weather station (Vaisala MAWS201, Finland).

In this study, a Single Particle Aerosol Mass Spectrometer (SPAMS, HeXin, China) was also deployed at the site to measure the size-resolved chemical composition of single particles during a sustained air pollution event that occurred in late December 2014 and early January 2015. A technical description of the SPAMS was provided by Li et al. (2011a). Briefly, the sampled air passes through an aerodynamic lens which transmits particles with aerodynamic diameters in the range 0.1–2.0 μm with high efficiency. The resulting particle beam is directed towards a sizing region where the vacuum aerodynamic diameter (D_{va}) is determined by the time-of-flight between two pre-positioned laser beams (Nd:YAG, 532 nm). Particles subsequently enter the mass spectrometer region and are ionized using a Nd:YAG laser operating at a wavelength of 266 nm (~1 mJ/pulse, 1×10^8 W/cm^2, UL728F11-F115, Quantel, France). The resulting positive and negative ions are analyzed in two time-of-flight mass spectrometers, yielding a positive and a negative ion mass spectrum for each single particle. The SPAMS thus provides information on the chemical composition and mixing state of single particles. It should be noted that this instrument is different from the Aerodyne Soot Particle Aerosol Mass Spectrometer (SP-AMS), which is used to measure the size, mass and chemical composition of black carbon containing particles (Onasch et al., 2012; Wang et al., 2016).

Air mass backward trajectories were calculated using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model to elucidate the origin of air masses during the pollution event (Draxler and Hess, 1998). All the trajectory calculations were performed using a height of 500 m above ground level (AGL) at 00:00 local time using GDAS1 meteorological dataset.

2.2. Controlled smoldering experiments

A number of controlled smoldering experiments were performed to simulate the emissions arising from the meat smoking activities. The traditional approach typically involves the smoldering of freshly cut pine and cypress branches (with green needles) along with dry wood for 12–48 h to smoke the meat. The oxygen supply is controlled to avoid flaming. The experiments performed here mimicked this process in a homemade oven using locally available wood combined with fresh pine and cypress branches, with the latter making up less than 30% (by weight) of the total biomass in the smoking procedure. Another set of smoldering experiments was conducted using only the fresh pine and cypress branches in order to exclude the influence of BB particles from the combustion of dry wood. The SPAMS instrument was used to sample the emissions continuously in order to obtain representative single particle mass spectra of the biomass smoke that would serve as potential markers to aid interpretation of the field data. The inlet of the SPAMS was fitted with a cyclone impactor to remove particles with a diameter >2.5 μm. Neither dilution nor relative humidity control was adopted during the SPAMS sampling.

2.3. SPAMS data analysis

A total of 1.24 million ambient particles were collected with