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Ambient particulate pollution during Chinese Spring Festival in urban Lanzhou, Northwestern China

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ABSTRACT

The effect of firework displays on ambient particulate pollution in a typical valley city in Northwestern China was evaluated based on high temporal resolution atmospheric particle size distribution (10–10 000 nm) data and particle mass concentrations in different sizes obtained during 25th January – 24th February, 2013. Firework displays have significant impact on particle number concentrations in accumulation mode (100–1 000 nm), especially in 200–500 nm, as well as PM_1 mass concentrations. The hourly mean number concentration in 200–500 nm and PM_1 mass concentration during the peak hour of firework displays were 11 800.2±2 548.0 cm^{-3} and 214.1±31.2 μg m^{-3}, which are approximately 6 times and 2 times of that before the festival, respectively, with a maximum10–min mean number concentration in size range 100–1 000 nm reaching 3.8×10^4 cm^{-3} on the New Year's Eve (00:10 BT 10th February, 2013). It was estimated that local emissions and firework displays contributed 74.6% and 37.0%, respectively, to the number concentration of particles less than 1 000 nm. On short–time scale, the contribution of firework displays on local particulate pollution is obvious and should not be ignored, especially on fine particulate pollution.

Keywords: *Particulate pollution, fireworks, Lanzhou, Spring Festival*

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1. Introduction

With the development of economy, more attention is paid to short–term air quality degradation events and their negative impact on human health. Firework set off can cause notable short–term particulate and gaseous pollution during festivals all over the world, especially particulate air pollution, which poses a serious threat to human health. During Chinese Spring Festival, generally occurs in January or February, one of the most attractive activities is the nationwide firework displays. In particular, the most intensive firework events occur on the Chinese New Year's Eve in most cities and rural areas, which can lead to a slight and dramatic increase in gaseous pollutants (Ravindra et al., 2003) and atmospheric particulate matter concentrations (Jin et al., 2007; Zhao et al., 2011) in a short time period, respectively. The short–term air quality degradation caused by fireworks may result in serious health hazards (Ravindra et al., 2001; van Kamp et al., 2006) and a reduction in visibility for hours (Vecchi et al., 2008).

Considering the adverse impacts of fireworks on air quality and human health, since the 1990's some researchers studied the atmospheric particle size distributions and mass concentrations during firework displays and some important results were obtained at different places over the world (Wehner et al., 2000; Drewnick et al., 2006; Rissler et al., 2006; Moreno et al., 2007; Barman et al., 2008; Vecchi et al., 2008; Croteau et al., 2010; Joly et al., 2010; Singh et al., 2010; Thakur et al., 2010; Agrawal et al., 2011). Wehner et al. (2000) indicated that the most affected particles by fireworks was in the accumulation mode range, i.e. D_p>100 nm. Vecchi et al. (2008) observed an increase of particle number concentrations up to 6.7 times in 1 h in the size of 500<D_p<1 000 nm during a firework episode. Few studies have been carried out describing the particle concentrations and their size distributions during Chinese Spring Festival (Hong et al., 2003; Li et al., 2006; Jin et al., 2007; Wang et al., 2007; Li et al., 2008; Zhang et al., 2008; Zhang et al., 2010; Wang et al., 2011; Zhao et al., 2012), with most of them focused on economically developed regions in central or eastern China and developed coastal cities. For example, Zhang et al. (2010) studied particle number concentration and their size distribution properties by measuring particles in 10–1 000 nm using a Wide–range Particle Spectrometer at 20 m above the ground level during firework events in Shanghai. Their results indicated a clear contribution of firework activities to number concentration of accumulation mode particles and PM_1 mass concentration. Li et al. (2006), Jin et al. (2007), and Zhang et al. (2008) explored changes of particulate pollution and their impacts on air quality before and after the official firework prohibition in Beijing and showed the significant increase of fine particulate concentration by firework displays in urban area. Wang et al. (2007) analyzed chemical compositions of atmospheric aerosols during the Lantern Festival in Beijing in 2006 and showed that chemical compositions, such as Ba, K, Sr, SO_4^{2-} and NO_3^-, during bonfire night were five times higher than those during other nights. Until now, there is limited amount of literature describing the effects of firework displays on atmospheric particle concentration in cities in Northwestern China. Wang et al. (2008) found a greater short–term contribution of firework displays to near ground pollutant concentrations than other pollution sources by studying the spatial–temporal characteristics of particle mass concentrations during Spring Festival in urban and suburban Xi'an in Northwestern China. Shi et al. (2011) investigated the influence of firework events on perchlorate in PM_{10} and $PM_{10–100}$ in Lanzhou and Yuzhong during Chinese Spring Festival and found the levels of perchlorate during firework displays was 5.8–25.2 times higher than that during the period of no or limited firework displays. There have been no relevant reports on the effects of firework displays on submicron particle size distributions in northwestern China. In this study high resolution particle size distributions in 10–10 000 nm were analyzed to better understand the effect of short–term firework displays on particle concentrations in different size ranges and changes in aerosol particle size distribution properties during firework events.

The objective of this study is to investigate the effect of short–period firework events on urban air quality, especially particle concentrations and their size distributions using in situ observations, and quantify the contribution of firework emissions to urban particle concentrations in different size ranges.

2. Methods

2.1. Sampling site

Lanzhou (36.05°N, 103.88°E), located at the intersection of Qinghai–Tibet Plateau, the Inner Mongolian Plateau and the Loess Plateau, has an average elevation of 1 520 m and is surrounded by mountains and hills rising to 500–600 m. It is the capital of the Gansu province, with an area of 13 thousand square kilometers and a population of 2.58 million. The area has a semi–dry climate, with an annual average temperature of 8.9 °C, and an annual average precipitation of 331 mm. Figure 1 shows the location of Lanzhou and the sampling site. There are two major roads with traffic volume of more than 2 000 cars per hour near the sampling site, one of which is 20 m from the sampling site (Donggang West Road in Figure 1), and the other is about 300 m west of the sampling site (Tianshui Road in Figure 1). The sampling site was on the roof of a 32 m high research building of the Cold and Arid Regions Environmental and Engineering Research Institute (CAREEI), Chinese Academy of Sciences, located in the eastern part of the Lanzhou urban area. The main activities in its surroundings are residential and commercial. A study by Imhof et al. (2005) indicated that at 30 m above ground the background concentration was attained. So, our instrument captured the particle concentrations and size distributions representing Lanzhou urban environment.

2.2. Measurement

Continuous particle size distributions (10–10 000 nm) were measured using scanning mobility particle sizer (SMPS model 3936, TSI, USA) and aerodynamic particle sizer (APS model 3321, TSI, USA) during 25th January to 24th February, 2013. The SMPS and APS measure the size distribution of aerosols in the size range 10–1 000 nm and 500–10 000 nm, respectively. The SMPS measures the particle size distribution using an electrical mobility detection technique, which uses a bipolar charger in the Electrostatic Classifier to charge the particles to a known charge distribution. The particles are then classified according to their traverse ability in an electrical field, and the number of particles in a specified size range is counted by Condensation Particle Counter (CPC). The APS is a time–of–flight spectrometer that measures the velocity of particles in an accelerating airflow through a nozzle. Aerosol is drawn into the inlet and is immediately split into a sample flow (1 L/min) through the inner nozzle, and a sheath flow (4 L/min) through the outer nozzle. In the present study, in order to combine particle size distributions measured with the two instruments, particle sizes from SMPS and APS were binned into 107 and 37 channels in the size range 10–800 nm and 800–10 000 nm with a time resolution of 5 min per scan, respectively. Furthermore, the mobility diameters measured by SMPS were converted into aerodynamic diameters measured by APS. The fundamental equation relating aerodynamic diameter d_a to mobility diameter d_m is:

$$d_a = d_m \left(\frac{\rho_p}{\chi \rho_0} \right)^{\frac{1}{2}} \tag{1}$$

where ρ_p is the particle density, ρ_0 is the reference density 1 g cm^{-3}, and χ is a dynamic shape factor. In this study χ is taken as 1, and ρ_p is calculated using integral particle volume concentrations in 10–2 500 nm and the corresponding $PM_{2.5}$ mass concentration.

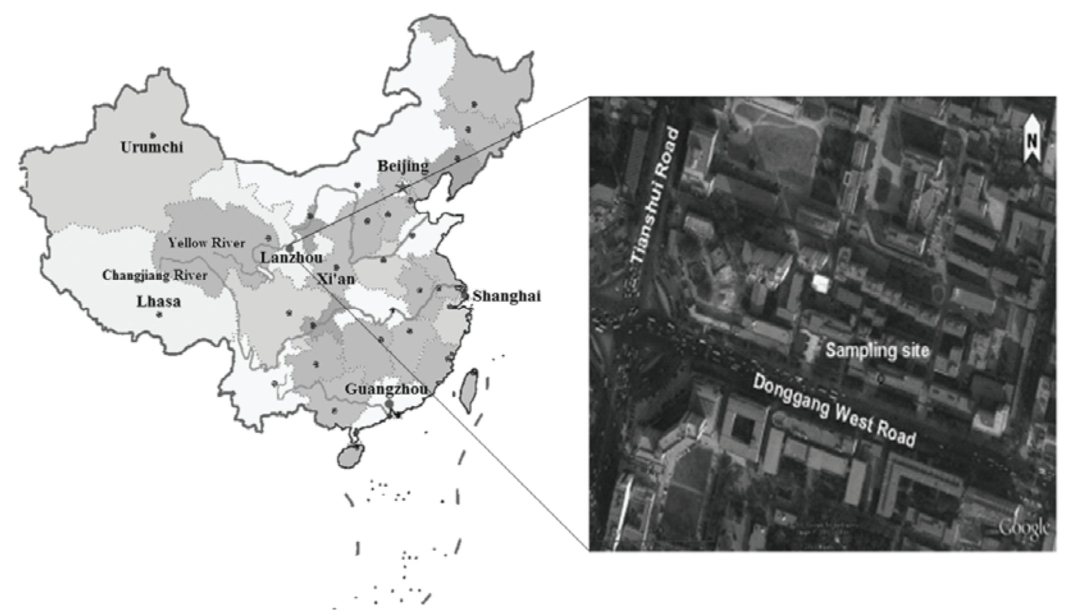

Figure 1. *A map of China and sketch map of sampling site.*