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Effect of short-term regional traffic restriction on urban submicron particulate pollution

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ABSTRACT

During the 2013 and 2015 Lanzhou International Marathon Events (LIME1 and LIME2), the local government made a significant effort to improve traffic conditions and air quality by implementing traffic restriction measures. To fill the gap in information on the effect of short-period (several hours) traffic control on urban air quality, submicron particle size distributions and meteorological data were measured simultaneously during June 2013 and June 2015 in urban Lanzhou. The number and surface area concentrations of particles in the 100–200 nm range declined by 67.2% and 65.0% for LIME1 due to traffic control, while they decreased by 39.2% and 37.1% for LIME2. The impact of traffic restriction on air pollution near the sampling site lagged behind the traffic control period for LIME2. In addition, the effect of traffic restriction on air pollution near the sampling site was dependent on the distance between the relative orientation of the sampling site and traffic-restricted zones, as well as meteorological conditions such as wind direction. The influence of traffic restrictions on the particle concentrations differed for different particle sizes. The size range most affected by traffic restriction was 60–200 and 60–300 nm for number and surface area concentrations in the urban environment, respectively, while for the particle volume concentration it was the 100–600 nm range. This study will provide a basis for implementation of future urban traffic-induced particulate pollution control measures.

Introduction

Urban air quality is of increasing concern due to its significant climatic, environmental and health effects. In recent years, some short-term or long-term air pollution events have been reported frequently in many Chinese cities (Chai et al., 2014; Chan and Yao, 2008; Chen and Xie, 2014; Cheng et al., 2013; Li et al., 2014; Qu et al., 2010; Wang et al., 2008), especially the long-lasting haze-fog episodes in central and eastern China in January 2013 (Guo et al., 2014; Han et al., 2014; Huang et al., 2014; Wang et al., 2014; Zhang et al., 2014). Atmospheric particles, especially the fine fractions originating from direct emissions from motor vehicles and gas-to-particle conversion of vapor-phase precursors, are one of the most important pollutants affecting urban air quality. It has been estimated that 90% of urban air pollution in fast-growing cities in developing countries can be attributed to vehicle emissions (UNEP, 2010). Many studies have investigated the effect of traffic on ambient particulate matter pollutants near major roads or highways (Boogaard et al., 2010; Zhang et al., 2004, 2005) and near bus terminals (Cheng et al., 2011). The particle number concentration near busy freeways is three times higher than the background level in an urban environment (Boogaard et al., 2010), and it decreases rapidly with increasing

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distance from the roadside (Buonanno et al., 2009; Zhu et al., 2002). Emission controls by traffic management, as the primary measure to improve air quality and solve traffic congestion, have been adopted during several recent important events in China *e.g.* the 2008 Beijing Olympic Games, 2010 Shanghai World Exposition and Guangzhou Asian Games, and 2013 Nanjing Asian Youth Games, and have been shown to be an effective measure for emission reduction (Hao et al., 2011; Li et al., 2010; Schleicher et al., 2011, 2012; Wang and Xie, 2009; Wang et al., 2010; Worden et al., 2012; Zhou et al., 2010). While the benefit of traffic management lasting for tens of days or several months is generally appreciated, until now the impact of local short-period (several hours) traffic restriction on urban air quality has been largely unknown despite its potential to be a mitigation measure for air pollution, especially for alleviating air pollution under adverse meteorological conditions.

As a typical fast-growing city in northwestern China, the rapid urban expansion in Lanzhou has resulted in a sharp increase in vehicle ownership and traffic congestion. Like many cities in northern China, particulate matter is one of the most prevalent pollutants in Lanzhou. Although some actions have been taken over the years to reduce emissions of aerosol particles, the particulate pollution remains severe (Yu et al., 2010). In an attempt to improve air quality, large-scale road infrastructure projects and temporary traffic control measures are currently underway in Lanzhou. Presently, many studies on the impact of motor vehicle emissions on particle concentrations in China focus on economically developed areas such as Beijing, Shanghai and Guangzhou (Cheng et al., 2008; Hao et al., 2011; Schleicher et al., 2011, 2012; Shen et al., 2011; Wang et al., 2010; Witte et al., 2009; Zhang et al., 2011), with much less attention to northwestern cities (Zhao et al., 2014), regardless of their very different economic development level and energy structure. During the 2013 and 2015 Lanzhou International Marathon, strict traffic restriction measures were implemented by the local government on 15 June 2013 and 13 June 2015 for 7 hr. Fig. 1 shows the traffic-restricted zones and the routes of the two Lanzhou International Marathon Events, which provide a unique opportunity to study the effect of short-term traffic control on urban air quality in a heavily congested and densely populated valley city in northwest China.

The objective of this study is to investigate the impact of short-period traffic control on urban air quality, especially submicron particle number concentrations, using *in situ* observations, and quantify the contribution of on-road traffic to urban particle concentrations in different size ranges, as well as evaluate the difference in the reduction of particle concentrations between two Lanzhou International Marathon Events due to different traffic-restricted zones. The study will provide a basis for the formulation of future urban particulate pollution control measures.

1. Data and methods

1.1. *Sampling site*

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 (CAREERI), Chinese Academy of Sciences, located in the eastern part of the Lanzhou urban area. There are two major roads with traffic volume of more than 2000 cars per hour near the sampling site, one of which is 20 m from the research building (Donggang West Road in Fig. 1), and the other is about 300 m west of the building (Tianshui Road in Fig. 1). There are no large stationary pollution sources in its surroundings in summer, and the main activities are residential and commercial. The study of Imhof et al. (2005) found that the background concentration of urban particulate pollutants was attained at 30 m above ground. Our instrument did not measure the direct exhaust emissions from vehicles, but captured the particle concentrations and size distributions representing the Lanzhou urban environment. Thus particles directly emitted from combustion and their effect on the near-road environment are not within the

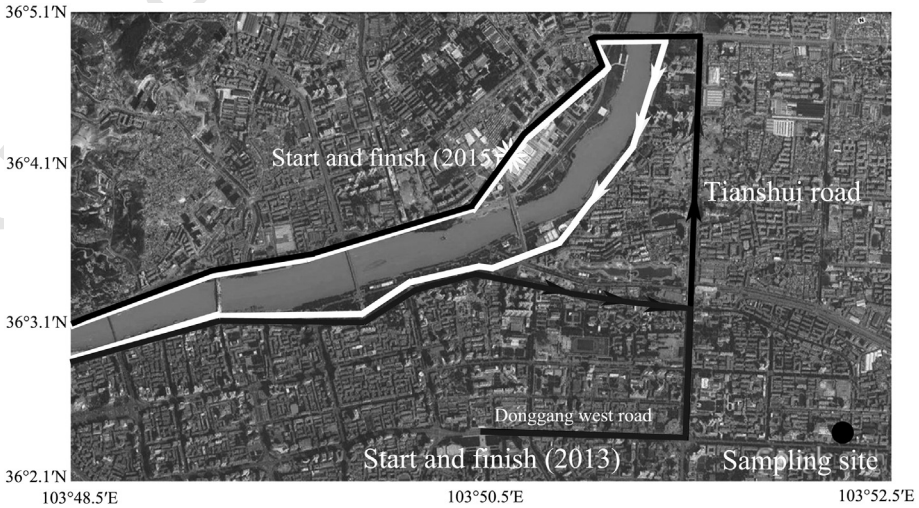

Fig. 1 – Routes of the 2013 and 2015 Lanzhou International Marathon Events (the white line represents part route of the 2015 Lanzhou International Marathon).

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