Science of the Total Environment 579 (2017) 860–870

Contents lists available at ScienceDirect

Science of the Total Environment

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

Source apportionment of size-fractionated particles during the 2013 Asian Youth Games and the 2014 Youth Olympic Games in Nanjing, China

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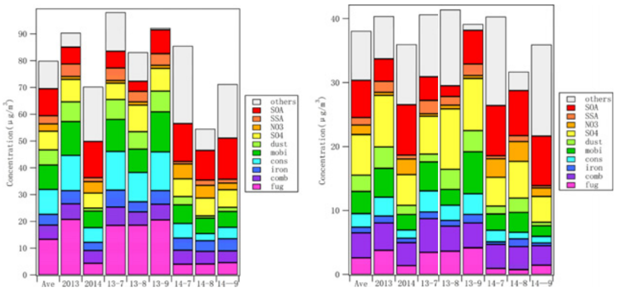
HIGHLIGHTS

- Source apportionment of size-fractionated particles during Youth Olympic Games.
- Fugitive and construction dust decreased significantly in YOG than AYG.
- Find out that control measures made obvious effects in reduction of particles.

GRAPHICAL ABSTRACT



(a) $PM_{2.1}$ (b)PM_{10}

The Figure shows CMB source contribution estimates during the Asian Youth Games (July to September 2013) and the Youth Olympic Games (July to September 2014). We could find that first, the concentrations of $PM_{2.1}$ and PM_{10} were much lower in YOG than AYG; secondly, both in AYG and YOG concentrations of particles were much lower in the during-Games period (August) than before-Games period (July) and after-Games period (September); finally, fugitive dusts, construction dusts and secondary sulfate aerosol decreased obviously in YOG, which means mitigation measures have played an effective role in reduction of particulate matter.

ARTICLE INFO

Article history:
Received 18 September 2016
Received in revised form 2 November 2016
Accepted 2 November 2016
Available online 22 November 2016

Editor: D. Barcelo

Keywords:
Size-fractionated particulate matter
Source apportionment
CMB model
Youth Olympic Games
Asian Youth Games

ABSTRACT

In this study, samples of size-fractionated particulate matter were collected continuously using a 9-size interval cascade impactor at an urban site in Nanjing, before, during and after the Asian Youth Games (AYG), from July to September of 2013, and the Youth Olympic Games (YOG), from July to September of 2014. First, elemental concentrations, water-soluble ions including Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, K^+, Na^+ and Ca^{2+}, organic carbon (OC) and elemental carbon (EC) were analysed. Then, the source apportionment of the fine and coarse particulate matter was carried out using the chemical mass balance (CMB) model. The average PM_{10} concentrations were 90.4 ± 20.0 $\mu g/m^3$ during the 2013 AYG and 70.6 ± 25.3 $\mu g/m^3$ during the 2014 YOG. For $PM_{2.1}$, the average concentrations were 50.0 ± 12.8 $\mu g/m^3$ in 2013 and 34.6 ± 17.0 $\mu g/m^3$ in 2014. Investigations showed that the average concentrations of particles declined significantly from 2013 to 2014, and concentrations were at the lowest levels during the events. Results indicated that OC, EC, sulfate and crustal elements have significant monthly and size-based variations. The major components, including crustal elements, water-soluble ions and carbonaceous aerosol accounted for 75.3–91.9% of the total particulate mass concentrations during the sampling periods. Fugitive dust, coal combustion dust, iron dust, construction dust, soil dust, vehicle exhaust, secondary aerosols and

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http://dx.doi.org/10.1016/j.scitotenv.2016.11.014

sea salt have been classified as the main emissions in Nanjing. The source apportionment results indicate that the emissions from fugitive dust, which was the most abundance emission source during the 2013 AYG, contributed to 23.0% of the total particle mass. However, fugitive dust decreased to 6.2% of the total particle mass during the 2014 YOG. Construction dust (14.7% versus 7.8% for the AYG and the YOG, respectively) and secondary sulfate aerosol (9.3% versus 8.0% for the AYG and the YOG, respectively) showed the same trend as fugitive dust, suggesting that the mitigation measures of controlling particles from the paved roads, construction and industry worked more efficiently during the YOG.

1. Introduction

Located in the downstream Yangtze River drainage basin, Nanjing has always been one of China's most important cities, with eight million people within a 6600 km^2 territory. It is also the second largest city in the Yangtze River Delta, with a large number of industrial enterprises. As the economic and political centre of the Jiangsu Province, Nanjing is a representative city with rapid urbanization and industrialization accompanied by air pollution issues. The Asian Youth Games (AYG) in 2013 and the Youth Olympic Games (YOG) in 2014 were held in Nanjing, which made the city more international and popular. It is well known that good air quality is one of guarantees for successfully hosting these Games. So the government made significant efforts towards improving the air quality of the city, especially reducing particulate matter, which was the main air pollutant in Nanjing.

Particulate matter (PM) in the atmosphere, such as PM_{10} (airborne particles with an aero-dynamic diameter less than or equal to 10 μm) and $PM_{2.5}$ (airborne particles with aero-dynamic diameter less than or equal to 2.5 μm), is a criteria air pollutants regulated by the Ministry of Environmental Protection of the People's Republic of China because of its adverse effects on public health, visibility and atmospheric environment (Agudelo-Castaneda and Teixeira, 2014; Cheng S.-H et al., 2011a; Cheng Y. et al., 2011b; Chen and Lippmann, 2009; Künzli et al., 2006; Grivas et al., 2008; Teixeira et al., 2013; Teixeira et al., 2015; Sun et al., 2011; Tsai et al., 2012; Viana et al., 2008; Wagner, 2010; Wagner et al., 2008).

Source apportionment has been a conventional technique for seeking the emission sources of particulate matter. There are many ways to investigate the source of particles, such as receptor models, emission inventories, trajectory analysis, dispersion models, photochemical models and source models. Receptor models were shown to be an effective tool for source apportionment. As one of the most popular receptor models, the chemical mass balance (CMB) model estimates the sources contribution rate based on chemical characteristics of the size fractionated ambient and source samples. The effective variance weighting for the least squares calculations have been applied to the CMB model (Watson, 1984; Watson et al., 1984). This calculation contains the effects of random uncertainties in both the receptor and the sources with transcendental equations for the unknown source contribution variables, providing a more accurate estimate. Receptor models have been used to assess source contributions of particulate matter all around the world, such as Western Europe, America, and East Asian (Balachandran et al., 2012; Bove et al., 2014; Bullock et al., 2008; He et al., 2001; Hu et al., 2013; Karanasiou et al., 2009; Long et al., 2014; Song et al., 2012; Tian et al., 2014; Xu et al., 2012; Xu et al., 2015). Recent studies on the source apportionment of particulate matter are summarized in Table 1 (Kong et al., 2010; Cheng S.-H et al., 2011a; Cheng Y. et al., 2011b; Song et al., 2007; Wang et al., 2006; Choi et al., 2013; Masiol et al., 2014; Antony Chen et al., 2010;Tositti et al., 2014; Contini et al., 2014; Cao et al., 2005; Aldabe et al., 2011; Yatkin and Bayram, 2008; Dutton et al., 2010; Pandolfi et al., 2008; Lee et al., 2008).

By comparing chemical species in ambient particulate matter samples to primary particulate matter emissions, fractional source profiles were made to describe the abundance of different compositions. These profiles can be used to create chemically speciated emissions inventories (Cass and McRae, 1983; Kuykendal et al., 1989) and to apportion airborne particulate concentrations to source profiles with a CMB model. Several studies have been conducted to identify chemical source profiles (Chow and Watson, 1994; Houck, 1991; Watson and Chow, 2001; Watson et al., 1994a) and to use the chemical source profiles in source apportionment studies (Watson et al., 1990a; Watson et al., 1990b; Chow and Ono, 1992).

Types of emission sources that might contribute to PM_{10} in Nanjing, China are: (1) fugitive dust from unpaved and paved roads and construction; (2) soil dust mainly including geological material; (3) motor vehicle exhaust from gasoline and diesel automobiles such as passenger cars, buses, and trucks; (4) industrial emissions from steel works (local large-scale iron and steel enterprises); (5) combustion dust from coal-fired power plants; (6) secondary inorganic aerosols (i.e., ammonium nitrate and ammonium sulfate particulate matter that form from gaseous ammonia, oxides of nitrogen, and sulfur dioxide emissions); (7) sea salt aerosols (i.e., the waves droplet breakage); and (8) secondary organic aerosol.

Table 1
Studies on aerosol source apportionment in recent years around the world.

Study area	Study concerns and models	Reference
Xi'an, China	Source apportionment of organic and elemental carbon	Cao et al., 2005
Shanghai, China	Ion chemistry and sources of $PM_{2.5}$ and TSP aerosol	Wang et al., 2006
Beijing, China	Source apportionment of $PM_{2.5}$ by PMF	Song et al., 2007
Atlanta, U.S.	Source apportionment of $PM_{2.5}$ by CMB and PMF, and model comparison	Lee et al., 2008
Eastern Spain	Comparison source apportionment results of multi-year ambient PM_{10} by CMB, PMF and PCA	Pandolfi et al., 2008
Izmir, Turkey	Source apportionment of $PM_{2.5}$ and PM_{10} by CMB and PMF	Yatkin and Bayram, 2008
U.S.	Source apportionment of combined $PM_{2.5}$ from long-term networks by CMB	Antony Chen et al., 2010
Denver, U.S.	Source apportionment of daily $PM_{2.5}$ by PMF	Dutton et al., 2010
Tianjin, China	Source apportionment of $PM_{2.5}$, PM_{10}, TSP by PCA and CMB	Kong et al., 2010
Navarra, Spain	Source apportionment of $PM_{2.5}$ and PM_{10} by PMF at rural, urban and traffic sites	Aldabe et al., 2011
Korea	Source apportionment of $PM_{2.5}$ at coastal area by PCA and PMF	Choi et al., 2013
Ulsan, Korea	Source apportionment of size-fractionated PM at an industrial city by cluster analyses	Lee and Hieu, 2013
Bologna, Italy	Source apportionment of particles in a large city by PMF	Tositti et al., 2014
Venice, Italy	Source apportionment of $PM_{2.5}$ by PMF	Masiol et al., 2014
Lecce, Italy	Source apportionment of size-segregated particles based on water-soluble ions by PMF	Contini et al., 2014