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Original article

Seasonal size distribution and possible health implications of atmospheric aerosols collected from a rural site of eastern central India

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ABSTRACT

This paper contributes for the first time the seasonal mass size distribution of atmospheric aerosols and their possible health implications in a rural area of eastern central India. Size-segregated atmospheric aerosols were collected from July 2012 to June 2013 at rural site near Mahanadi riverside basin of Rajim (20° 59′N and 81°55′E), Chhattisgarh, India using nine-stage cascade impactor. Bimodal size distribution was found with stable peaks at 0.4–0.7 μm (fine mode) and 4.4–5.8 μm (coarse mode) during monsoon, winter, spring and summer seasons at study site. The mass median aerodynamic diameter of total impactor particle sizes was shifted from lower particle size in winter to higher particle size in summer. High concentrations of size-segregated aerosols were found during winter season with 45%, 55% and 36% of $PM_{2.5-10}$, $PM_{2.5}$ and PM_1, respectively of the total PM_{10} aerosol. One unique observation was that the mass concentration of particulate matter increases abruptly in May and June during summer season, which was due to in situ burning of rice crop residues. The concentrations of upper respiratory tract and lungs particles were found to be highest during winter whereas respiratory airways particles showed maxima during summer season. The highest numbers of unfavorable days (i.e. value of air quality index > 101) were also observed during winter followed by summer season. The significant positive correlations found among particle in fine size bins (<0.43–2.5 μm) during winter and summer season was mainly due to the biomass burning activities during the study period at a rural site in eastern central India.

1. Introduction

The seasonal variations on mass concentration of size-segregated aerosols such as PM_{10}, $PM_{2.5-10}$, $PM_{2.5}$ and PM_1 have been extensively documented in various atmospheric conditions (Elbir et al., 2007; Odabasi et al., 2010; Zhang et al., 2010; Xu et al., 2015). However, less information is available for the size distribution of atmospheric aerosols. Measuring the aerosol particle size distribution in the rural site will give an indication about particle transformation processes that act on the particles on their way from the emission sources to atmospheric aerosols (Singh et al., 2003a,b; Engling et al., 2009; Godec et al., 2012; Verma et al., 2012; Singh et al., 2013). Particulate matters influence climate directly by absorbing and scattering incoming solar emissions, and indirectly by acting as cloud condensation nuclei (CCN), and thus affecting the cloud microphysical and optical properties, as well as the precipitation rate and clouds lifetime (Oanh et al., 2001; Elbir et al., 2007; Akyuz and Cabuk, 2009; Odabasi et al., 2010).

Moreover, the concentration of respirable particulate matter (RSPM) in the atmosphere has become a topic of considerable importance over current years in relation to public health (Kulshrestha et al., 2004; Pant et al., 2006; Majumdar and Nema, 2011; Prakash et al., 2013). The epidemiological studies have revealed that exposure of particulates with aerodynamic diameters < 10 μm (PM_{10}) and <2.5 μm ($PM_{2.5}$) induces an increase of lung cancer, morbidity and cardiopulmonary mortality whereas

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coarse particle ($PM_{2.5-10}$) can also initiate asthma attacks, coughing and sneezing, exacerbation and cancer (Singh et al., 2004; Pope et al., 2011; Pipalatkar et al., 2012; Yaman et al., 2015). Even though there is still a fundamental requirement of understanding the underlying mechanisms of their toxicity, one of the widely accepted hypotheses is that toxicity of aerosols dependent on their chemical composition and penetration towards the human respiratory system is dependent on their aerodynamic diameter (Singh et al., 2003a; Sharma and Maloo, 2005; Kaya et al., 2012; Saha et al., 2014). The information about the seasonal variability of mass concentration and size distribution is of great attention to constrain global and regional modeling and to investigate the processes involved in particle formation and sinks (Tsai et al., 2005; Tiwari et al., 2009; Sharma et al., 2011; Aydin et al., 2014). In this paper, we report the seasonal size distribution and mass concentration of size-segregated aerosols and their possible health implications over rural area of eastern central India during July 2012 to June 2013.

2. Material and method

2.1. Study area and prevailing meteorological parameters

Rajim (20°59′N and 81°55′E) is located in eastern central region of India and 45 km away from Raipur, the state capital of Chhattisgarh, as shown in Fig. 1. The sampling site was positioned at height of about 281 m above the sea level. The study area is bordered by housing, restrained traffic discharge, frequent agricultural and extreme biomass burning activities. The location is considered to be representative for a rural site and is highly influenced by local anthropogenic emission characterized by intense biomass burning in almost all seasons.

The months of the year are combined into four seasons, namely monsoon (July–September), winter (October–January), spring (February–March) and summer (April–June). Meteorological data including ambient temperature, relative humidity, vapor pressure, wind speed and wind direction was obtained at the study site from the local meteorological sub-station of Indira Gandhi Agriculture University, Raipur, Chhattisgarh. The mean temperature throughout the study period was found to be 25.5 °C with lowest temperature of 13.7 °C during winter (12 January 2012) and highest of 39.2 °C during summer (25 May 2013) (Table 1). The relative humidity ranged from 15.4% during summer (23 May 2013) to 98.0% during monsoon (04 August 2012) with an average of 64.8% during the study period. As shown in Fig. 2, the total rainfall was found to be 1932 mm throughout a year with a highest rainfall recorded during monsoon (80% of the total rainfall) followed by summer (15% of total rainfall). The vapor pressure was observed to be 23.9 ± 1.6 kPa in monsoon, 13.7 ± 4.9 kPa in winter, 12.5 ± 2.3 kPa in spring and 17.3 ± 5.3 kPa in summer with an annual average of 16.6 ± 5.9 kPa. The wind speed was 7.4 ± 3.8 m s^{-1}, 1.6 ± 1.2 m s^{-1}, 2.3 ± 1.1 m s^{-1} and 7.8 ± 4.1 m s^{-1} during monsoon, winter, spring and summer, respectively. The annual average wind speed was 5.1 ± 3.3 m s^{-1} during the study period. The prevailing wind directions were south-west and north-east during the study period over the observation site.

2.2. Aerosol collection

The nine-stage cascade impactor sampler (TE 20-800, USA) was installed on the rooftop of double-storied building at Rajim, Chhattisgarh, India. The sampling campaign was performed from July 2012 to June 2013 by using nine-stage cascade sampler operating at a flow rate of 28.3 ± 0.3 L min^{-1}. The cascade sampler collect the atmospheric aerosols with cutoff points at 10.0 μm (stage 0), 9.0 μm (stage 1), 5.8 μm (stage 2), 4.4 μm (stage 3), 2.5 μm (stage 4), 2.1 μm (stage 5), 1.0 μm (stage 6), 0.7 μm (stage 7), 0.4 μm (stage 8) and <0.4 μm (stage 9 - backup stage). The initial and final flow rate of vacuum pump was checked by dry gas meter (Model 12393959, Invensys TM) purchased by Thermo Fisher Scientific and flow rate was found to be within ±1% L min^{-1}. A total 120 sets of size-segregated aerosols were collected during the study period. Aerosol samples were collected (for 24 h) using quartz fiber filters pre-combusted at 450 °C for 6 h. We also collected field blanks ($N = 24$) consisting of sampling media taken into the field and handled as regular samples (but not exposed to a Sampling Event), then returned to the laboratory for gravimetric analysis.

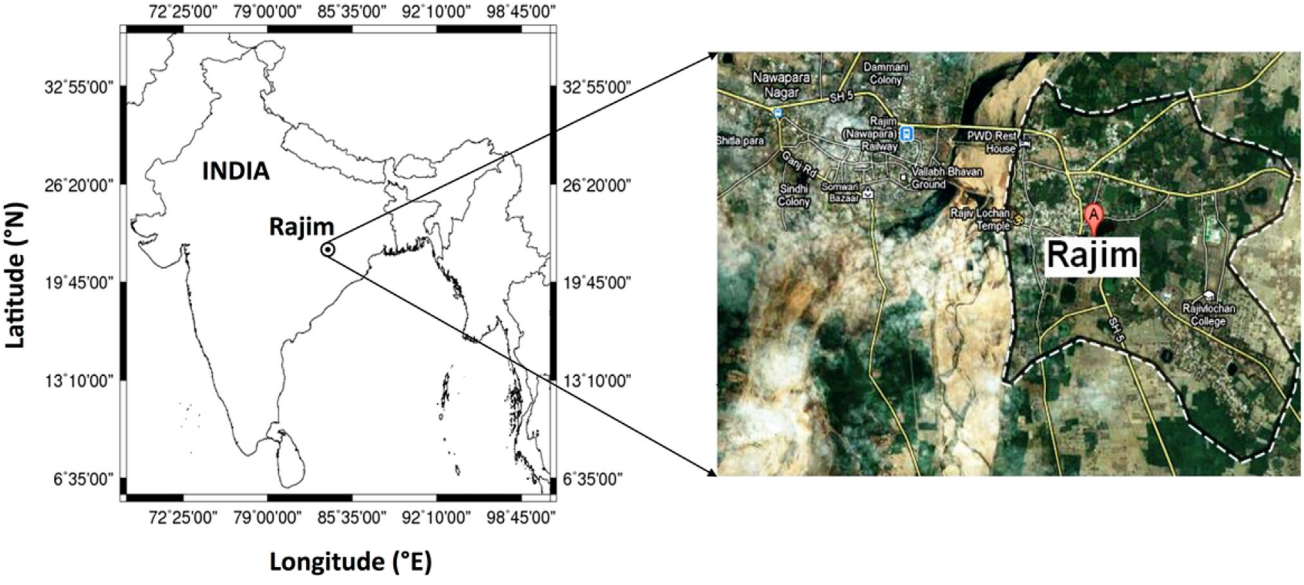

Fig. 1. A map showing the location of sampling site in India.