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Measurement of the atmospheric aerosol particle size distribution in a highly polluted mega-city in Southeast Asia (Dhaka-Bangladesh)

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HIGHLIGHTS

- ► Aerosol particle size distributions were measured in Southeast Asia Mega city (Dhaka, Bangladesh).
- ► Elevated concentrations of the number, surface and mass distributions were observed in Dhaka, Bangladesh.
- ► Fine particles (0.5–1.0 μm) were dominating the aerosol particles number concentrations.
- ► Remarkable daily, monthly, seasonal variations were observed.
- ► Aerosol particle concentrations showed significant correlation with the traffic peak and off hours.

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ABSTRACT

Aerosol particle size distribution was measured with an aerodynamic particle sizer (APS) spectrometer continuously from January 21 to April 24, 2006 in Dhaka, Bangladesh. Particles number, surface and mass distributions data were stored automatically with Aerosol Instrument Manager (AIM) software on average every half an hour in a computer attached to the APS. The grand total average of number, surface and mass concentrations were $8.2 \times 10^3 \pm 7.8 \times 10^3$ particles cm^{-3}, $13.3 \times 10^3 \pm 11.8 \times 10^3$ μm^2 cm^{-3} and 3.04 ± 2.10 mg m^{-3}, respectively. Fine particles with diameter smaller than 1.0 μm aerodynamic diameter (AD) dominated the number concentration, accounted for 91.7% of the total particles indicating vehicular emissions were dominating in Dhaka air either from fossil fuel burning or compressed natural gas (CNGs). The surface and mass concentrations between 0.5 and 1.0 μm AD were about 56.0% and 26.4% of the total particles, respectively. Remarkable seasonal differences were observed between winter and pre-monsoon seasons with the highest monthly average in January and the lowest in April. Aerosol particles in winter were 3.79 times higher for number, 3.15 times for surface and 2.18 times for mass distributions than during the pre-monsoon season. Weekends had lower concentrations than weekdays due to less vehicular traffic in the streets. Aerosol particles concentrations were about 15.0% (ranging from 9.4% to 17.3%) higher during traffic peak hours (6:00am–8:00pm) than off hours (8:00pm–6:00am). These are the first aerosol size distribution measurements with respect to number, surface and mass concentrations in real time at Dhaka, Bangladesh.

1. Introduction

Air pollution has a large impact on human health, climate change, agriculture and on the natural ecosystems (Mayer et al., 2000; Molina and Molina, 2004). Epidemiological studies have indicated a strong association between the elevated concentration of inhalable particles and increased mortality and morbidity (Lin and Lee, 2004; Namdeo and Bell, 2005). Fine particles have serious health impact as they can easily enter in the alveoli of the human respiratory system, and also have a climate effect by absorbing and scattering solar radiation. Characterizations of fine particles have been becoming very important to governments, regulators and researchers (IPCC, 2001). Aerosol particle size distribution has been measured at many urban locations in developed countries, e.g., USA, UK, Germany and Finland (Hämeri et al., 1996; Shi et al., 2001; Longley et al., 2003). Only limited studies were done in Asia, especially in the Southeast and South Asia (Delhi, Dhaka, Karachi, Kolkata, Manila, and Shanghai, etc.) (Faiz

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and Sturm, 2000), even though the air quality situation is very severe in these regions, exceptions are the Arabian Sea and Indian Ocean experiments (e.g., Krishnamoorthy and Saha, 2000; de Reus et al., 2001; Kamra et al., 2003).

Dhaka, Bangladesh is a densely populated mega-city in the world. About 16 million inhabitants are living within an area of 360 square kilometers. Air quality situation has been degrading due to unplanned growth, increasing vehicles, severe traffic jams, brick kilns, industries, construction, and also long range transport (Azad and Kitada, 1998; Salam et al., 2011). A rapidly growing number of vehicles has worsened the air quality in spite of major policy interventions, e.g., ban of two-stroke and three-wheeled vehicles, phase out of 20 years old vehicles, conversion to compressed natural gas (CNGs), etc. Introduction of CNGs to reduce air pollution was not the solution for fine particles at all, as evidence shows that CNGs and diesel engines are the major sources of fine particles (Kittelson, 1998; Ristovski et al., 2000). A high concentration of air pollutants in Dhaka city such as carbonaceous species (black and organic carbon) has already been reported (Salam et al., 2011). Most of the measurements (e.g., Azad and Kitada, 1998; Begum et al., 2004; Salam et al., 2003, 2008) carried out in Dhaka were based on filters for particulate mass. The literature revealed that the adverse health effect is not dependent on the particulate mass but rather on the number concentrations (Seaton et al., 1995; Peters et al., 1997). High concentrations of ultra fine particles might be an explanation for the observed health effects (Seaton et al., 1995), which was supported by epidemiological studies (Peters et al., 1997). Moreover, particles size distribution is one of the most important factors for the determination of transport, life-time and also the optical properties of the aerosol particles in the atmosphere (Qin et al., 2010). Unfortunately, there is no measurement of the aerosol particle size distribution in real time at Dhaka until now.

We have measured the aerosol particle number, surface and mass concentrations with an aerodynamic particle sizer (APS) spectrometer (TSI 3321, USA) between 0.5 and 20 μm AD from January 21 to April 24, 2006 in Dhaka, Bangladesh. We discuss here the spatial and temporal variations of the aerosol particles size distribution.

2. Experiment

2.1. Sampling location, Dhaka-Bangladesh

Bangladesh is situated in the eastern part of South Asia. It is surrounded by India on the west, the north and the northeast, Myanmar on the southeast, and the Bay of Bengal on the south (Fig. 1[A]). Dhaka (23′76°N, 90′38°E, 8 m a.s.l.), the capital of Bangladesh, is the center of commerce and industries for the country (Salam et al., 2003, 2011). Dhaka is growing rapidly and faces all the problems associated with a mega-city. Dhaka is situated on flat land surrounded by rivers. The exact sampling location is situated on the 2nd floor of the Soil, Water and Environment Department (SWED) in the most eastern side of Curzon Hall area, Dhaka University (DU) campus (Fig. 1[B]). The distance of the APS spectrometer from the adjacent College Street (High Court-Bongobazar-Fulbaria connecting road) was about 20 m. The traffic intensity was medium during daytime and very low from midnight to early morning.

2.2. Meteorological conditions

The climate in Bangladesh is characterized by high temperature and high humidity most of the year with a distinct seasonal variation of precipitation. The year can be divided into four seasons, pre-monsoon (March–May), monsoon (June–September), post-monsoon (October–November) and winter (December–February) in Bangladesh (Salam et al., 2011). The average temperature was 14.2 °C in January, 25.8 °C in February, 28.1 °C in March, 28.5 °C in April, 2006 with 4-month average of 25.8 °C. Rain was observed in March for 2 days and in April for 13 days. The average wind speed is 1.39 meters second^{-1} (m s^{-1}) in January, 1.93 m s^{-1} in February, 2.01 m s^{-1} in March and 3.04 m s^{-1} in April, 2006 with a four months average of 2.1 m s^{-1}. Wind direction in Dhaka city is mainly from west and south-west direction at pre-monsoon, and from north and north-west at winter (Begum et al., 2004). The meteorological data was obtained at Kurmitola airport meteorological station (Source: Bangladesh Meteorological Department).

2.3. Aerodynamic particle sizer (APS) spectrometer

The aerodynamic particle sizer (Model TSI 3321, USA) is a high performance particle spectrometer that measures both aerodynamic diameter and light-scattering intensity. It is a widely used instrument for aerosol measurements with accurate size distributions in real time (Salam et al., 2006). Model 3321 provides accurate count size distributions of particles with aerodynamic diameters (AD) from 0.5 to 20 μm (μm). It is a time-of-flight spectrometer that measures the velocity of particles in an accelerating air flow through a nozzle, where particles are confined to the centerline of the sheath air. Particles then pass through two broadly focused laser beams, scattering light as they do so. Side-scattered light is

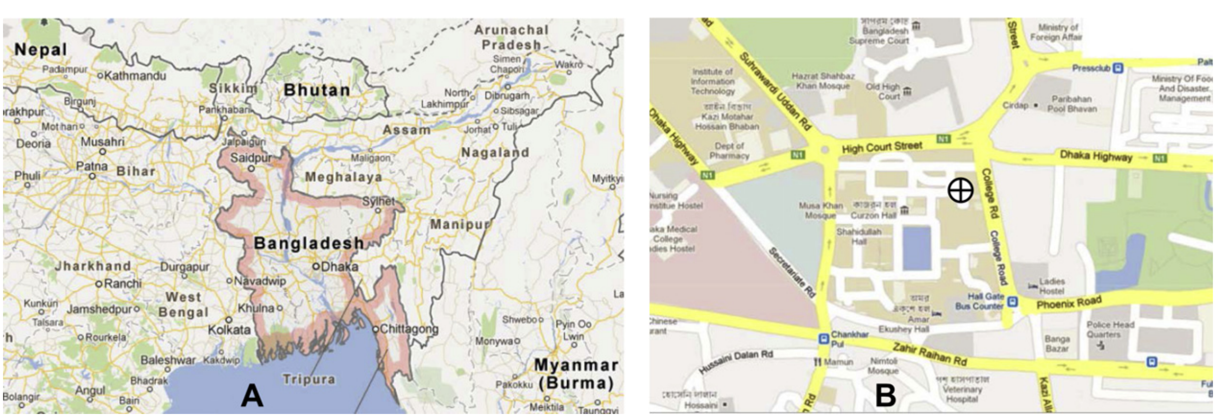

Fig. 1. [A]. Bangladesh in Southeast Asia, [B]. shows the exact sampling location in Soil, Water and Environment Department (SWED), Curzon Hall area, Dhaka University (DU), (Source: Google).