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Particulate air pollution in six Asian cities: Spatial and temporal distributions, and associated sources

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Abstract

A monitoring program for particulate matter pollution was designed and implemented in six Asian cities/metropolitan regions including Bandung, Bangkok, Beijing, Chennai, Manila, and Hanoi, within the framework of the Asian regional air pollution research network (AIRPET), coordinated by the Asian Institute of Technology. As uniform the methodologies as possible were intended with an established QA/QC procedure in order to produce reliable and comparable data by the network. The monsoon effects and seasonal changes in the sources/activities require long-term monitoring to understand the nature of air pollution in the cities. During phase 1 (2001–2004) of the AIRPET around 3000 fine and coarse particulate matter samples were collected from characteristic urban sites, which provide insight into temporal and spatial variations of PM in the cities. In all six cities, the levels of PM_{10} and $PM_{2.5}$ were found high, especially during the dry season, which frequently exceeded the corresponding 24 h US EPA standards at a number of sites. The average concentrations of $PM_{2.5}$ and PM_{10} in the cities ranged, respectively, 44–168 and 54–262 $\mu g\,m^{-3}$ in the dry season, and 18–104 and 33–180 $\mu g\,m^{-3}$ in the wet season. Spatial and temporal distribution of PM in each city, the ratios of $PM_{2.5}$ to PM_{10}, and the reconstructed mass were presented which provide useful information on possible PM sources in the cities. The findings help to understand the nature of particulate matter air pollution problems in the selected cities/metropolitan regions.

Keywords: Monitoring; Particulate matter; Contributing sources; Asian cities; AIRPET

1. Introduction

Atmospheric particles can cause multiple effects on human health and the environment. Particles with the size less than 10 μm (PM_{10}) have long been

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implicated in causing adverse health effects and increased mortality (Dockery and Pope, 1994) whereas fine ($PM_{2.5}$) and ultrafine particles impose even higher risk (Donaldson et al., 1998; Schwartz and Neas, 2000; Ostro et al., 2006). Atmospheric particles also interact directly and/or indirectly with the Earth's radiation energy balance and can subsequently affect the global climate (IPCC, 2001; Liu and Daum, 2002). The recently discovered atmospheric/Asian brown cloud, which contains suspended particles as the major component, is believed to cause multiple effects on regional air temperature, precipitation, agriculture, air quality, and health (UNEP and C[4], 2002). Due to their ability to absorb and scatter solar radiation the atmospheric particles, especially fine ones, effectively reduce visibility (Watson, 2002; Kim et al., 2001).

There has been a growing concern on monitoring and characterization of size-segregated ambient particulate matter (PM) in the recent years. Efforts and resources are being spent to understand its nature and to develop mechanisms that would help control this harmful pollutant. In many developing countries, however, information on levels of fine particles in the ambient air is still scarce. Until recently, total suspended particulate matter (TSP) was the most monitored and is still a regulated pollutant in most developing countries. However, with the increased awareness of their harmful effects on human health and the environment, there is a tendency toward monitoring fine particles in the ambient air. Fragmented data available in some Asian developing countries suggest high ambient levels of fine particles. A study in Beijing shows that the weekly $PM_{2.5}$ in 1999–2000, at two sites, ranged from 37 to 357 $\mu g\,m^{-3}$ (He et al., 2001). In Vietnam, the averaged level during 1996–1998 for PM_2 and PM_{10-2}, at a site in Ho Chi Minh city, was 16 and 32 $\mu g\,m^{-3}$, respectively (Hien et al., 2001), while for a site in Hanoi the corresponding levels, averaged for 1998–1999, were 35 and 50 $\mu g\,m^{-3}$, respectively (Hien et al., 2002). In Bangkok, Thailand, records show that in the years of 2000, 2001 and 2002, the PM_{10} levels at curbside stations exceeded the 24 h Thai National Ambient Air Quality Standard (120 $\mu g\,m^{-3}$) with a frequency of 12.8%, 10.5%, and 3.8%, respectively, while at ambient sites the corresponding exceedance frequency was 2.1%, 0.3%, and 0.39% (PCD, 2001, 2002, and 2003). Limited published $PM_{2.5}$ data for Bangkok show that 24 h $PM_{2.5}$ in busy parts of the city may be as high as 100 $\mu g\,m^{-3}$ (Ostro et al., 1999).

There are no systematic and long-term published records of PM mass and composition, which are regionally compatible, in the Asian developing countries. Such records, especially with focus on fine particles, will help to create and enhance scientific knowledge necessary to address the worsening particulate air quality in these countries. In particular, the data will help to understand the nature of the particulate pollution in a city in relation to local sources, long-range transport and atmospheric transformation processes, which is essential for the formulation of effective air quality management strategies.

To partly fill up the gap, the Asian regional air pollution research network, or AIRPET, (http://www.serd.ait.ac.th/airpet), has designed a monitoring program to collect such data. AIRPET, now in phase 2, has one of the main research objectives in providing a comprehensive assessment of PM pollution. The focus is on $PM_{2.5}$ and PM_{10}/$PM_{10-2.5}$ levels and composition with the spatial and temporal distribution in six involved cities/metropolitan regions in Asia, namely, the Bangkok Metropolitan Region (BMR, Thailand), Bandung (Indonesia), Beijing (China), Chennai (India), Metro Manila Region (Philippines), and Hanoi Metropolitan Region (Vietnam). The network is mainly funded by the Swedish International Development Cooperation Agency (Sida) through the Asian Regional Research Program in Environmental Technology (ARRPET) and is coordinated by the Asian Institute of Technology (AIT). This paper presents some findings on levels, composition and possible source contributions of the PM in the six cities during AIRPET phase 1, 2001–2004.

2. Methodology

2.1. Monitoring program design

Six research institutions (NRIs) are involved in this network, including AIT; Institute of Technology of Bandung; Research Centre for Eco-Environmental Sciences/Beijing Normal University, Beijing; Manila Observatory; Hanoi University of Science; and Indian Institute of Technology, Madras. Each institution conducts monitoring for one city/metropolitan region in a country.

The selected cities/regions are different in terms of topography, meteorology, population, energy use, industry, and vehicular mix and density. The climate of the region is dominated by monsoon with