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Seasonal PM_{10} dynamics in Kathmandu Valley

Rupak Kumar Aryal [a], Byeong-Kyu Lee [b,*], Rahul Karki [c], Anup Gurung [c], Jaya Kandasamy [a], Bipin Kumar Pathak [a], Suman Sharma [d], Nirita Giri [e]

[a] Institute for Water and Environmental Resource Management, Faculty of Engineering, University of Technology, Sydney, Australia
[b] Department of Civil and Environmental Engineering, University of Ulsan, San 29, Mugeo2-dong, Nam-gu, Ulsan 680-749, Ulsan, Republic of Korea
[c] Department of Environmental Science and Engineering, Kathmandu University, Kavre, Nepal
[d] Ministry of Population and Environment, Kathmandu, Nepal
[e] Environment and Public Health Organization, Kathmandu, Nepal

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ABSTRACT

Data on ambient PM_{10} levels from six locations in the Kathmandu Valley recorded by means of continuous sampling using low volume air samplers from October 2002 to March 2007 were used to investigate PM_{10} concentration dynamics in the valley. Monthly average data of the urban areas, which have much higher concentrations than the rural areas, even exceeded the daily standard level of PM_{10}, in Nepal, 120 $\mu g\,m^{-3}$. Repetitive peaks and troughs each year indicated annual patterns. Monthly average showed seasonal patterns are different between rural area and urban sites. The highest monthly average concentration was observed in February, the end of winter in urban areas where as in rural found in spring, and the lowest concentration was observed in July (monsoon period). The continuous increase in PM_{10} concentration from December to February in urban areas showed accumulation of PM_{10} in the ambient air during the wintertime. Rainfall in June and September, during the monsoon period, caused a PM_{10} concentration decrease, demonstrating that precipitation is effective in removing PM_{10} from the valley. Cross correlation analyses among the PM_{10} levels measured simultaneously at the sampling stations showed a poor relationship in winter; however, there were good relationships in the monsoon and post-monsoon seasons. Both the PM_{10} concentration and the air-mixing environment in the valley were closely associated with the temperature and wind speed.

1. Introduction

Thoracic ambient particulate matter (PM_{10}) is defined as particles less than 10 μm in aerodynamic diameter. It is well-documented that increased exposure to thoracic PM is associated with various adverse health effects, such as respiratory diseases, cardiovascular mortality, morbidity, and probably, malignant lung diseases (Donaldson and MacNee, 2001; Kan and Chen, 2003; Chang et al., 2005; Goldberg et al., 2006; Ostro et al., 2006). Ambient PM_{10} represents a complex mixture of anthropogenic and naturally occurring airborne particles. There is increased evidence that most of the harmful components in PM_{10} are particles formed from incomplete combustion of fossil fuels and pyrolysis of organic materials. A plethora of chemicals has been identified in contaminated ambient air, including polycyclic aromatic hydrocarbons (PAHs) and their nitro- and oxy-derivatives, strong acids and toxic metals (Fang et al., 2000; Lin et al., 2005). There have been many studies of the association between the prevalence of different air pollutants and adverse human health outcomes. PM_{10} appears to be one of the most useful single measures of air pollution in a given area (US EPA, 1996; Kunzli et al., 2000; Schwartz, 2001). Most PM_{10} studies have been conducted

* Corresponding author. Tel.: +82 52 259 2864; fax: +82 52 259 2629.
E-mail address: bklee@ulsan.ac.kr (B.-K. Lee).

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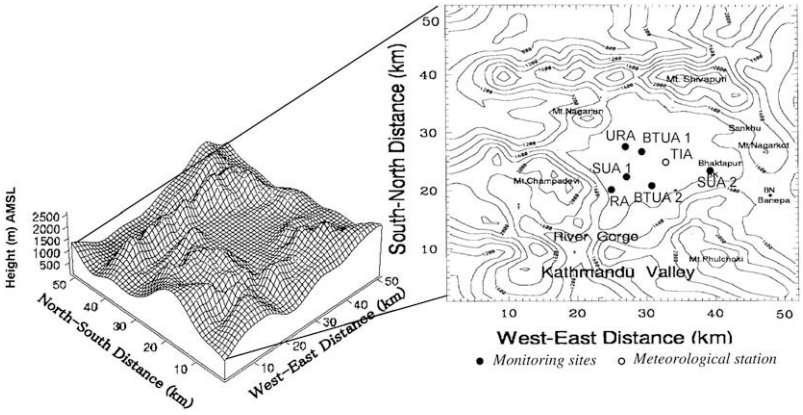

Fig. 1. 3-D topographic view of Kathmandu Valley (adopted from Regmi et al., 2003) and six PM_{10} monitoring locations (right). Where, RA = rural area, SUA = sub-urban area, URA = urban residential area, BTUA = busy traffic urban area, TIA = meteorological station.

in developed countries, with only a small number of studies conducted in Asia (Health Effects Institute, 2004). There is a need for studies in cities of developing countries, where outdoor air pollution characteristics, such as air pollution level, meteorological conditions and socio-demographic status of local residents, may be different from developed countries.

The accumulation of pollutants in any location is mainly defined by the existing sources, the surrounding geology and meteorology. Pollution levels and dispersion features within mountain regions are more complex (Banta et al., 1997; Rega et al., 2001; Jazcilevich et al., 2005). Mountain ranges surrounding valleys block or reroute prevailing winds and thus alter the atmospheric thermal structure, which may create local winds and change the meteorology within a short distance. To understand the influence of surrounding mountains, several studies have been conducted in valley cities throughout the world (Baumgardner et al., 2000; Clements et al., 2000; Chazette et al., 2005; Jazcilevich et al., 2005; Shaw et al., 2005). This research has shown that the accumulation and dispersion of pollutants are influenced by the complex and time-varying interplay of local and regional winds with temporal and spatial emission patterns.

The Kathmandu Valley in Nepal is completely surrounded by rather steep mountains and hills, ranging from 500 to 3000 m above the valley floor (Kitada and Regmi, 2003). Being surrounded by high hills and mountains, the horizontal movement of air pollutants without vertical dispersion is limited (Sapkota and Dhaubadel, 2002). According to a recent report by Regmi and Kitada (2003), 48% of the population living in the Kathmandu Valley is exposed to annual PM concentrations from 20 to 40 $\mu g\,m^{-3}$, and 33% of the population experiences annual PM concentrations higher than 60 $\mu g\,m^{-3}$. Based on their short term observation for 3 weeks using passive sampler, Regmi and Kitada reported that a significant number of patients suffer from respiratory symptoms related to high PM exposure. For example, our recent survey at 3 different hospitals in the valley during winter in 2007 showed increase of 25–30% in outpatient number related to respiratory problems. According to the report by Kitada and Regmi (2003), the total suspended particles in the valley originated from a long-range transport of 9%, industrial sources of 46%, domestic sources of 28% and resuspension of 17%. The aim of our research was to evaluate the longer term PM_{10} concentration in different locations of the Kathmandu Valley (rural, urban background and traffic hotspots) using continuous sampling, to assess seasonal characteristics, and to determine the influence of meteorological conditions on PM_{10} concentration.

2. Materials and methods

2.1. Study area

The Kathmandu Valley is an oval shaped tectonic basin located in the middle section of the Himalayan range and is surrounded by ranges of green mountains. The valley has two narrow river gorges in the southwest and northwest edges and low hills on the southwest edge, connecting the neighboring Banepa Valley (Fig. 1). The central part of the valley is flat, with an elevation of 1300 m above sea level. The valley winds usually enter from the southwest and the northwest gorges and exit over the low southeastern hills to the neighboring valley. Kathmandu Valley experiences four distinct seasons during the year: pre-monsoon, monsoon, post-monsoon and winter. During the past three decades, the Kathmandu Valley's population has increased greatly and become more urbanized. Sharp population increase with an annual average growth rate above 4.5% (Central Bureau of Statistics, Nepal, 2001) and associated activities in the valley has worsened the air pollution (Sharma, 1997; Sapkota and Dhaubadel, 2002).

2.2. Measurements

Recognizing the air quality deterioration in the valley, the Ministry of Population and Environment of Nepal installed air pollution monitoring stations at six different locations. Ambient PM_{10} data for a period of 4 years and 6 months, from October 2002 to March 2007, were obtained from six monitoring sites located within 15 km of one another