

Diurnal patterns of lower atmospheric pollution in two urbanized valleys

Mark L. Hildebrandt
Department of Geography
Southern Illinois University Edwardsville
Edwardsville, IL 62026-1459 USA
mhildeb@siue.edu

Abstract

In this study, I compare the diurnal transport of lower atmospheric pollution in Phoenix, Arizona (USA) with the daily variability of air pollution in another urbanized valley, Kathmandu, Nepal. I find evidence that the physical setting of Kathmandu partially accounts for the diurnal variability of pollutant levels in the capital city of the Kingdom of Nepal. I also suggest that other factors, such as vehicular traffic, industrial emissions, and the use of kerosene stoves account for some of the variability in Kathmandu.

Introduction

Past studies have investigated the climatic conditions that promote high pollution levels in Phoenix, Arizona, USA (Ellis et al., 2000; Hildebrandt, 2000). Likewise, scientists have examined the anthropogenic and natural factors that partially account for daily concentration variability and the transport of air pollutants throughout the Phoenix Valley area (Ellis et al., 1999; Hildebrandt, 2000).

In several respects, Kathmandu, Nepal is similar to Phoenix - both are affected by distinct monsoon seasons with high summer temperatures and moderate winters, both are densely populated, both have a high reliance on personal motor vehicles, and both lie within large, urbanized valleys. While Phoenix is nearly surrounded by mountains and the effects of the topography on air pollution transport are well documented (e.g. Berman et al., 1995; Ellis et al., 1999, 2000; Hildebrandt, 2000), there is little such documentation for Kathmandu. In fact, few quantitative studies have been performed in Kathmandu to examine the climatic conditions that promote high levels of air pollution (URBAIR, 1997; Hildebrandt and Pokhrel, 2002), and no studies have been performed to examine the influence of the local topography on the transport of air pollution in and around Kathmandu Valley.

PM₁₀ is defined as particulate matter (PM) with a diameter less than 10 micrometers (μm). PM₁₀ is therefore very small and remains suspended in the air for periods of time, and is easily inhaled into the deep lung. Hourly measurements of atmospheric PM₁₀ are available for the Kathmandu area since 1999, providing an opportunity to characterize temporal patterns of air pollution from another urbanized valley and compare the results to temporal variations reported in Phoenix. Identifying climatic factors that control variations in urban pollution levels may further illuminate how the topography affects pollution concentrations and transport. Analyses of Kathmandu, particularly when compared to Phoenix, may expand our understanding of the dynamics of pollution levels in urbanized valleys.

Data Collection

The Kathmandu Valley, which is bowl-like in topography, stretches approximately 25 kilometers (km) from east to west and roughly 20 km from north to south. Kathmandu lies at a height of approximately 1300 meters, while the surrounding mountains range from 1500 meters to 2800 meters in height (Hildebrandt and Pokhrel, 2002). It is plausible that Kathmandu is often subject to a daytime mountain-valley mesoscale thermal circulation, similar to the patterns observed in Phoenix, Arizona (Hildebrandt and Pokhrel, 2002).

Hourly atmospheric PM₁₀ concentration, wind speed and direction measurements have been made in the Putalisadak district of Kathmandu since 1999. Putalisadak is a major commercial area located in the center of Kathmandu and is located in the central business district of the Kathmandu Valley. It is believed that the

microclimate of the site is reasonably representative of the local area within which high pollution levels are common. The data for this study were provided by Nepal's Department of Hydrology and Meteorology (D.H.M., 2000) and LEADERS Nepal (2000). Monitoring was conducted for 10 days in December 1999.

Results and Discussion

Air pollution transport in Phoenix has been shown to follow a distinct diurnal "sloshing" pattern. A "sloshing" effect is a phenomenon that occurs due to mountain-valley breezes generated by a diurnal thermodynamic circulation. Pollutants carried anabatically by winds flowing from the south, southwest and west during the day could be brought back again by katabatic winds flowing from the north, northeast and east during the night.

Hourly mean PM₁₀ concentrations in Kathmandu show a fairly similar diurnal pattern to ozone concentrations in Phoenix. Figure 1 demonstrates that PM₁₀ values peaked around 8:00 AM LST, reached their minimum during the late afternoon hours, and peaked once again at around 10:00 PM. I argue that this can be at least partially explained by wind direction shifts throughout the 24-hour period. This may be due to the fact that hourly mean wind direction measurements for December 1999 follow a distinct pattern. Similar to surface wind patterns in Phoenix (Ellis et al., 1999), winds during the morning hours are typically from the northeast while they shift to being mostly from the south and southwest during the afternoon hours, then back toward northeasterly after sunset. Hildebrandt and Pokhrel (2002) suggest that these shifts occur as the katabatic winds tend to drain cool, dense air from the higher elevations during the early morning and late evening, while the anabatic wind tends to strengthen as the south-facing slopes warm as the solar angle increases.

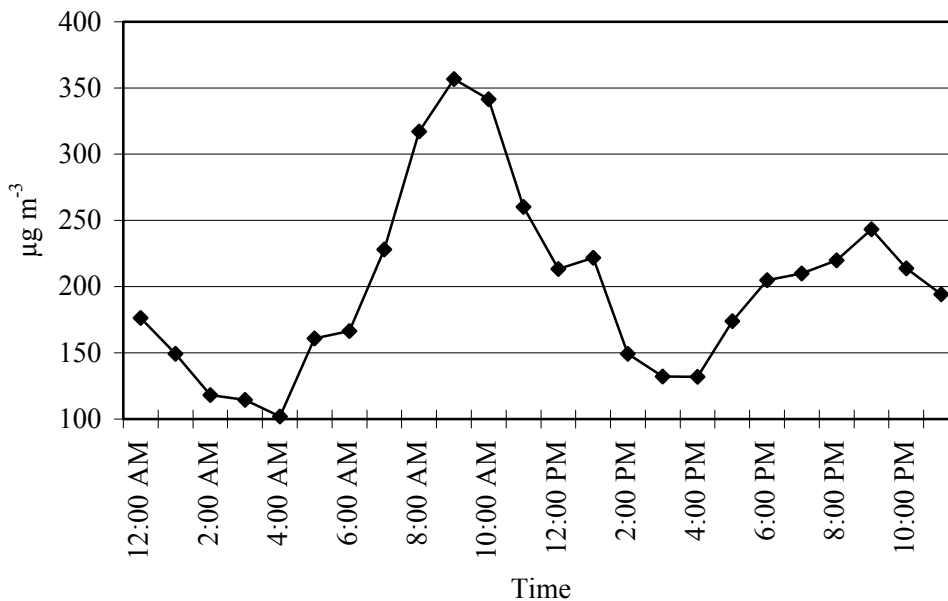


Figure 1. Hourly means of PM₁₀ (µg m⁻³) for December 1999 recorded at Putalisadak

Wind direction clearly affects PM₁₀ concentration levels. Figure 2 shows that PM₁₀ levels are highest when winds are out of the north and northeast, due to the katabatic wind at night, and when winds are from the southeast during the afternoon, likely due to the upslope transport of PM₁₀ from cement factories to the south and southeast of Putalisadak.

It should be noted that there are differences when comparing the diurnal patterns in Phoenix and Kathmandu. First of all, while ozone and PM₁₀ are both pollutants, both are formed differently. Ozone is formed indirectly from the burning of fossils but directly via the photolytic cycle, meaning it requires

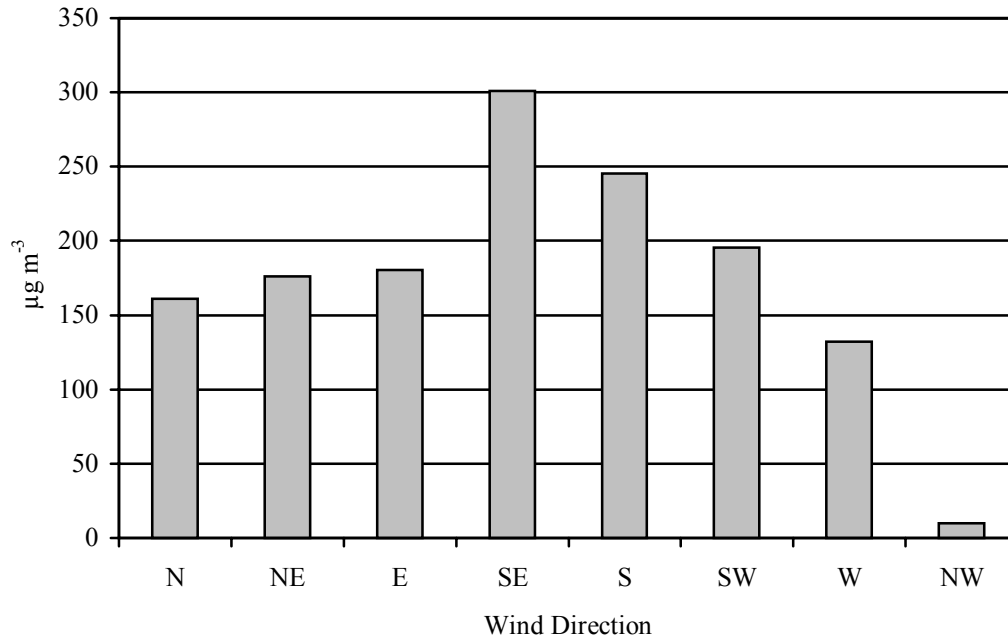


Figure 2. Mean hourly PM₁₀ (µg m⁻³) concentrations and associated wind directions for December 1999.

sunlight to form, whereas PM₁₀ does not. PM₁₀ is produced largely by industrial and automobile exhaust, and is easily re-suspended into the lower atmosphere by vehicular traffic (Devkota, 1992; Bhattarai, 1993; LEADERS Nepal, 1998; URBAIR, 1997). Unlike Phoenix, the streets in Kathmandu are not well maintained and are often laden by debris and pollutants, including PM₁₀. In addition, PM₁₀ is also partially produced by the use of kerosene-burning stoves that are used by many residents of Kathmandu (URBAIR, 1997). While PM₁₀ concentrations are affected by wind direction shifts, each of these other factors must be noted as well.

Conclusions

Generally, Phoenix and Kathmandu displays many of the same diurnal patterns and concentration variability in PM₁₀. However, Kathmandu is different from Phoenix both climatically and socio-economically, and these factors are also partially responsible for the air pollution transport.

To better understand the similarities and differences between the two cities, we compare the climatic, socio-economic, and air pollutant climatologies of Phoenix and Kathmandu. The results show that both cities lie within large urbanized valleys and the surrounding topography partially dictates the daily flow of air pollutants. We conclude that there are in fact physical similarities between the two cities and those similarities manifest themselves in similar diurnal patterns of air pollution. We suggest that differences in industrial emissions, vehicular traffic patterns, and cooking practices account for some of variability of PM₁₀ concentrations in Kathmandu.

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