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# Impact Analysis of Brick Kilns on the Air Quality in Dhaka, Bangladesh

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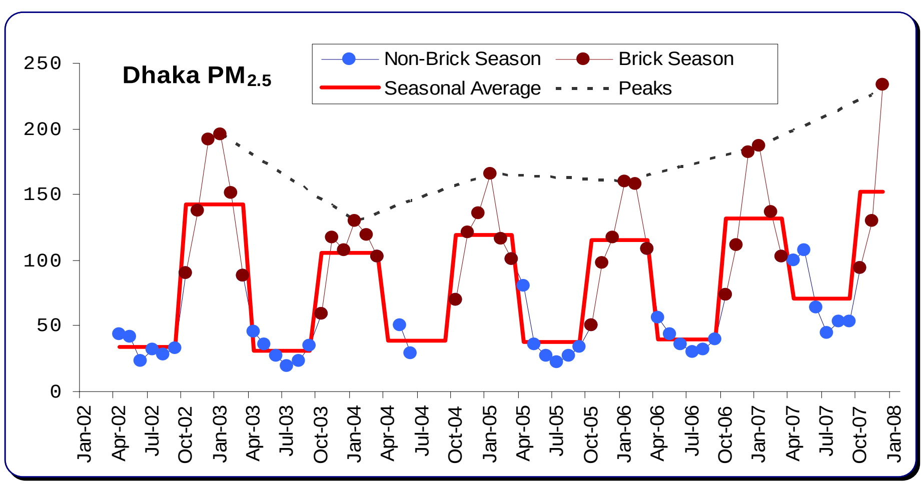


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# Impact Analysis of Brick Kilns on the Air Quality in Dhaka, Bangladesh[1]

Dhaka is among the six South Asian cities with at least 15 million inhabitants and included as 20 mega cities of the world. The other cities are Kolkata, Mumbai, Delhi, Karachi and Lahore. Other notables include Chennai, Bangalore, Hyderabad, Islamabad, Colombo, and Kathmandu, and all these cities are facing air pollution problems.

Dhaka city is expanding in all directions - east to west, north to south. The population, energy and infrastructure demands are increasing but the amenities (including environmental) can not keep pace with the growing demand. A recent study in 2008 concluded that an estimated 15,000 premature deaths, as well as several million cases of pulmonary, respiratory and neurological illness are attributed to poor air quality in Dhaka[2]. **Figure 1** presents an overview of the measured monthly average $PM_{2.5}$ concentrations at the Sansad Bhavan (Parliament).

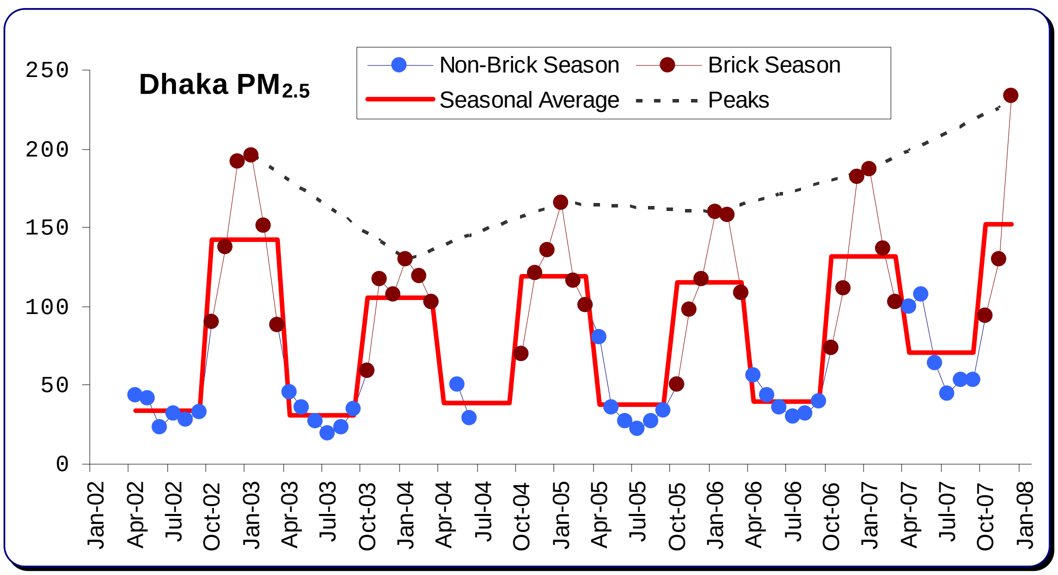


**Figure 1: Monthly average $PM_{2.5}$ measurements in Dhaka city[3]**

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[1] The analysis presented in this paper was conducted as part the training program at the Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh, supported by the World Bank and the Task Team Leader (TTL), Dr. Sameer Akbar. The final report (including the financial analysis of possible interventions) was prepared by the BUET staff (Dr. Ijaz Hossain and his students, of the Department of Chemical Engineering) using the US EPA's ISC3 modeling system. The author acknowledges the support of BUET staff who conducted the surveys and prepared the necessary inputs for the emissions inventories, which are utilized to conduct this ***parallel study***.
The final report and the program details are available with the TTL (Contact: sakbar@worldbank.org for details).

[2] The Daily Star, March 27th, 2008, "Inhaling poisonous air every day" @ http://www.thedailystar.net/pf_story.php?nid=29461
IRIN, April 3rd, 2009, "Air Pollution Choking Dhaka" @ http://www.irinnews.org/Report.aspx?ReportId=83772

[3] The measurement data is provided by Dr. Zia Wadud, Department of Civil Engineering @ BUET (May, 2009)

The air quality in the Dhaka city has deteriorated over the last decade due to a rapid change in the vehicular fleet, increased congestion, and a large increase in the industrial activity (in and around the city)[4]. The annual average concentrations for $PM_{2.5}$ are ~100 μg/m$^3$, above any of the standards for clean air and better health[5].

In the city, transport dominates as an air pollution source. Among the industries, the brick kilns are the major source, especially during the manufacturing season of October to March, depending on the monsoonal rains. In **Figure 1**, the $PM_{2.5}$ concentrations are split between the brick making season and the rest, clearly presenting a distinct change in the pollution trends. The seasonal averages have shifted over the years and during the brick manufacturing season, pollution peaks measured ~230 μg/m$^3$ in January 2008.

A majority of the brick kiln clusters are to the North of the city, presented in **Figure 2** and the measured peak values represent the worst case scenario of the maximum wind blowing towards the city (the red line boundary). The clusters account for ~700 brick kilns.

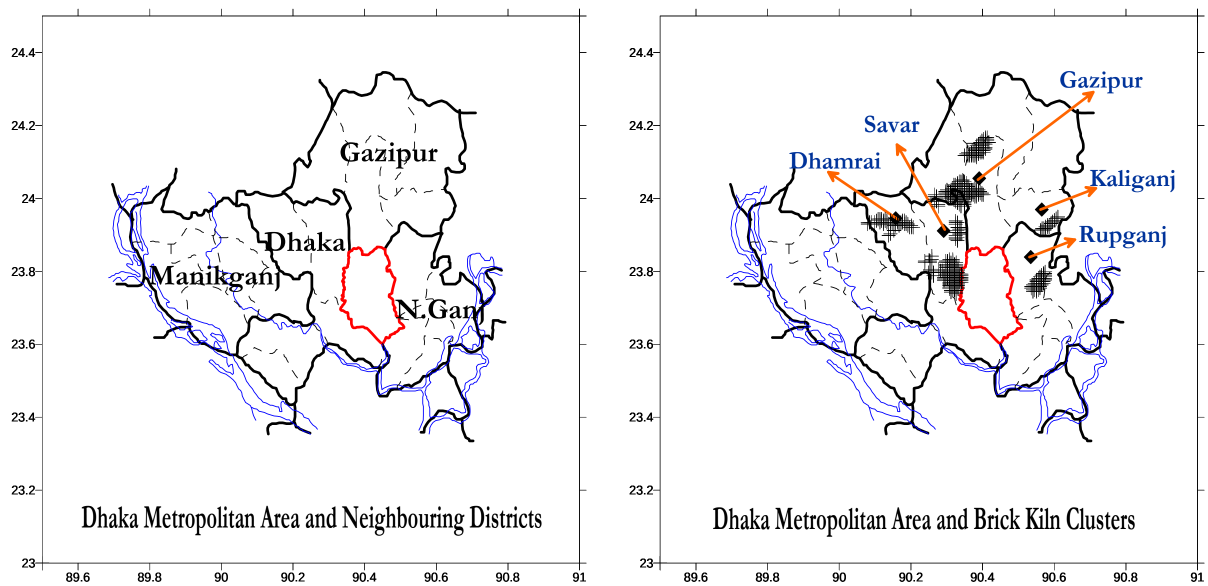


**Figure 2: Dhaka metropolitan area and brick clusters**

The analysis presented in this study focuses on the review of the current source apportionment studies (**Annex 1**) quantifying the share of the brick kiln emissions affecting the air pollution in the Dhaka city and modeling of the impacts of the brick kiln clusters. Discussion of the other sectors (transport, domestic, or other industries) is not included in this paper.

[4] Bangladesh News, March 21st, 2009, "City's air quality back to square one" @ http://www.bangladeshnews.com.bd/2009/03/21/citys-air-quality-back-to-square-one/

[5] Recent notes from WHO suggest that there is no threshold for PM pollution below which no health impacts are registered. However, the concentrations of 15 μg/m$^3$ are concentrations a health standard, and the pollution levels in Dhaka are several times above the standards

## Dhaka Air Pollution Source Apportionment

Based on the source apportionment studies, listed in **Annex 1**, during the dry season (October to March) - vehicular emissions, particularly motor cycles, diesel trucks and buses (most dominant of the sources in both fine and coarse mode); soil and road dusts arising from civil construction, broken roads, and open land wind erosion; biomass burning in the brickfields and city incinerators (to the fine mode) are the major sources of PM pollution. **Figure 3** presents a summary of the source apportionment study conducted by the Bangladesh Atomic Energy Center, Dhaka, Bangladesh[6] for fine and coarse mode[7] particulates at two stations – Farm gate and the Dhaka University premises.

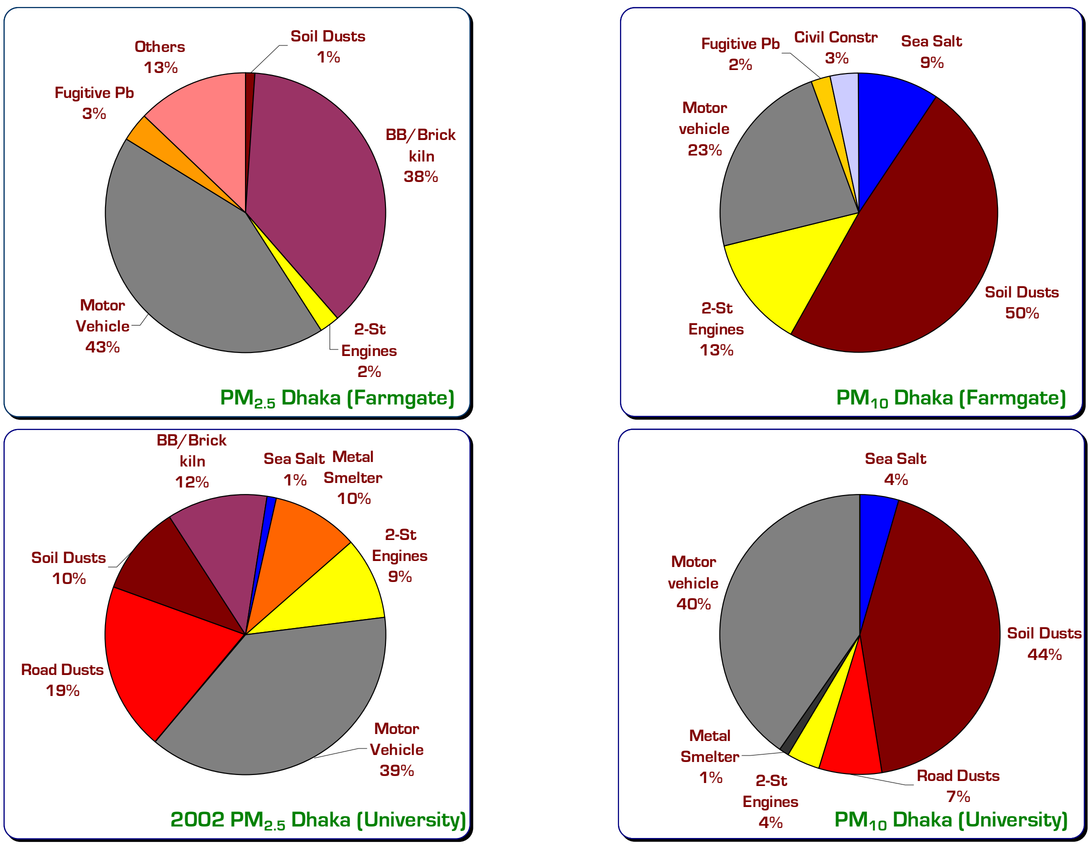


**Figure 3: Source apportionment results for Dhaka**

The analysis was conducted using 'GENT' stacked filter samplers, followed by analysis of the filter samples using PIXE and receptor modeling using PMF[8]. The study included development of city specific source profiles, which provide the necessary information on the

[6] Contact person for the source apportionment studies is Dr. Swapan Biswas. Email - sbiswas@baec.org.bd. See **Annex 1** for latest publications and reports.

[7] Fine PM = particulates with less than 2.5 micron aerodynamic diameter and coarse PM = particulates between 10 and 2,5 micron aerodynamic diameter. The fine PM is considering more harmful to human health, because of its capacity to travel deeper into the respiratory systems, resulting in premature mortality and respiratory ailments.

[8] For details on various methodologies for methodologies to conduct source apportionment, refer to the working paper SIM-16-2009 @ http://urbanemissions.info/simair/simseries.html

biomarkers to identify sources, analyze the measured samples, and estimate the percentage contributions of various sources. It is important to note that the source apportionment results cannot be generalized to the whole city, but they do provide a basis for further analysis and an understanding of the mix of sources contributing to the air pollution, especially around the hot spots. The process of source apportionment, applied in this study, is expensive, which prohibits inclusion of many measurement points, unlike a mobile monitoring station which can be used to measure multiple points, but cannot be used to calculate source contributions.

[9]The motor vehicles are a known and visible source of particulate pollution in Dhaka, which require interventions ranging from technical (emission standards) to institutional (inspection and maintenance). The dust, due to the resuspension on the roads, an indirect source of motor vehicle activity, is a major cause of air pollution (in the coarse mode of PM), due to lack the sufficient infrastructure (paved roads) to support the growing fleets and congestion on the roads[10]. The study estimates at least 50 percent of the coarse PM is linked to the resuspension of the road dust, followed by the industrial smelters.

The clusters of brick kilns lying north of Dhaka contribute ~40 percent of the measured fine PM pollution[11]. Growing construction activity (also contributing to the fugitive dust) is leading the demand for brick kilns and burning of biomass and low quality coal is resulting in pollution[12].

Similar source apportionment studies were conducted in other Bangladeshi cities, e.g. Rajshahi, Chittagong and Khulna. Results from the preliminary work conducted at Rajshahi station are presented **Figure 4**. Similar to Dhaka, the results suggest the brick kiln industry dominates the fine PM pollution in Rajshahi.

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[9] IRIN, April 3rd, 2009, "Air Pollution Choking Dhaka" @
http://www.irinnews.org/Report.aspx?ReportId=83772
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The Daily Star, June 14th, 2008, "Can't we check the decline of Dhaka city?" @
http://www.thedailystar.net/story.php?nid=40999
The Daily Star, June 14th, 2008, "To solve the transportation problem of Dhaka metropolitan area" @
http://www.thedailystar.net/pf_story.php?nid=41017

[10] Energy Bangla, March 3rd, 2008, "Integrated planning for Dhaka City" @
http://www.energybangla.com/index.php?mod=article&cat=SomethingtoSay&article=28

[11] The Nation, October 20th, 2008, "Brick-kilns severely affect Dhaka's environment" @
http://nation.ittefaq.com/issues/2008/10/20/news0717.htm

[12] Energy Bangla, April 26th, 2009, "Coal Mining Challenges in Bangladesh" @
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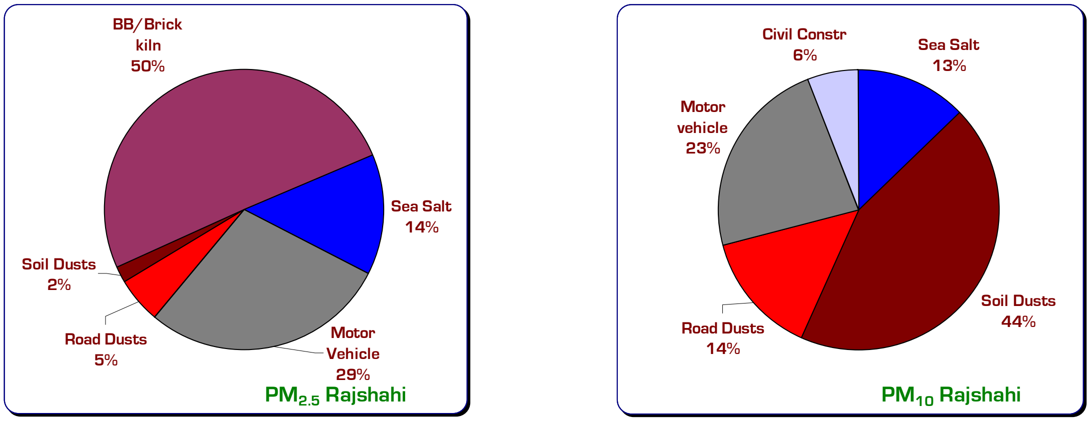


**Figure 4: Source apportionment results for Rajshahi**

With the seasonal fine PM averages of ~150 μg/m$^3$ (**Figure 1**) a 40 percent share of ~60 μg/m$^3$ presents a tremendous opportunity for air pollution control from the brick kilns in and around Dhaka.

## Dispersion of Brick Kiln Emissions

The source apportionment studies, due to their limitation of not able to analyze multiple stations, a bottom up analysis of the energy consumption, emissions analysis, and dispersion is necessary to better understand the physical extent of the impact of these brick kiln emissions on Dhaka's air quality.

Note that this study was conducted for the brick kiln emissions only and it is NOT a representation of the Dhaka's entire air quality. The results are compared to the known source apportionment results for consolidation of the two methodologies and make way for further analysis and introduction of effective interventions for brick kiln emissions control.

### ATMoS – Dispersion Model

A number of modeling systems exist with varying capacities to analyze industrial, urban, regional, and global scale air quality[13]. For Dhaka, the air pollution dispersion was conducted using the Atmospheric Transport Modeling System (ATMoS), a meso-scale three-layer forward trajectory lagrangian puff-transport model. The model schematics are presented in **Figure 5**.

The model was developed for sulfur pollution modeling, as part of the Regional Air Pollution Information System for Asia (RAINS-Asia)[14]. The model was, since, extensively applied for sulfur and particulate modeling studies in Asia for regional, national, and urban scale studies[15].

[13] Modeling tools for air pollution analysis and management @ http://urbanemissions.blogspot.com/2009/01/tools-for-air-pollution-analysis.html

[14] Developed and distributed by International Institute of Applied Systems Analysis (IIASA), Laxenburg, Austria @ http://www.iiasa.ac.at

[15] See **Annex 2** for the supporting documents and case studies (regional and urban) of ATMoS Applications

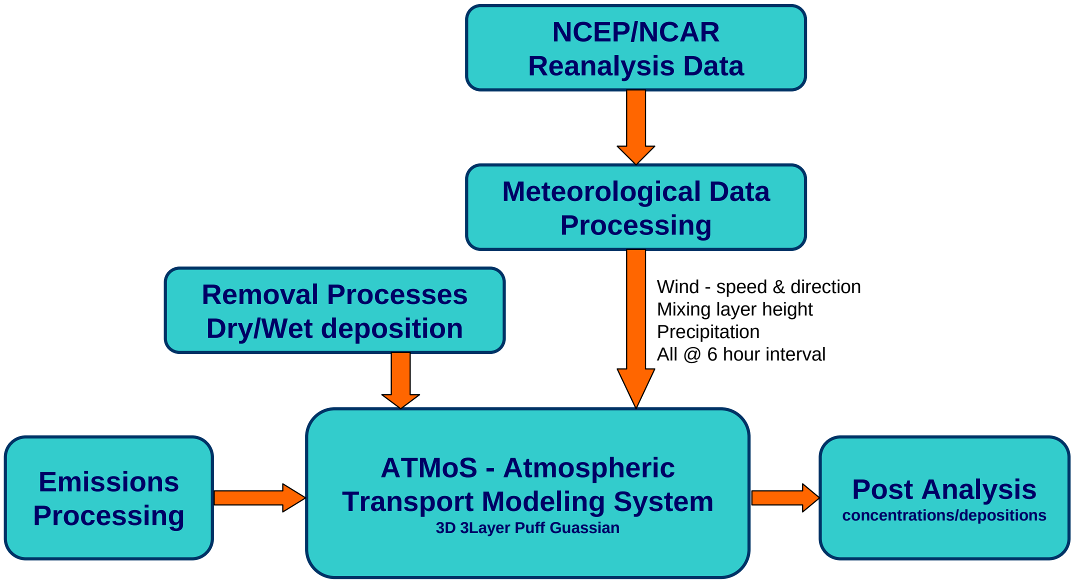


**Figure 5: Schematics of ATMoS Modeling System**

In the ATMOS/UrBAT model, the emissions are modeled as puffs released every 3 hours or every hour respectively, for regional and urban simulation. Each puff is assigned a mass proportional to the source strength and uniformly mixed in the assigned vertical layer and diffused along a Gaussian distribution in the horizontal direction. Individual emission puffs are tracked for 120 hours (5 days) or until the mass falls below a cut-off value of 0.1 percent of the emission source strength or puffs fall out of the simulation domain. Puffs transported beyond the modeling domain are no longer tracked.

The model separates the vertical dimension into two layers during the day and three layers at night. The day layers are the boundary and upper layer. The night layers are the surface, boundary, and upper layers (see **Figure 6**). The night surface layer extends from ground to 300 meters. The boundary and upper layers are separated by the critical inversion, which determined from the vertical temperature profile. The maximum height for the model is 6000 meters.

The model has flexible temporal and spatial resolution. The horizontal spatial resolution can be varied from 1000 meter for an urban scale study to 1° x 1° (approximately 90 km) for a regional scale study. However, using this model for analysis of episodic analysis is not recommended, due to the applied advection schemes, which tend to simply the interaction between the horizontal and vertical layers. The model is applicable for the regional and urban scale studies, analyzing the seasonal and annual air quality for long term trends and evaluating "what-if" scenarios[16].

[16] "Quantifying the health impacts of power and industrial interventions in Shanghai" (2004), "Co-benefits of air pollution action plan in Hyderabad" (2008), and "Urban air pollution analysis in Ulaanabaatar" (2007). All the reports and study details are available @ http://www.urbanemissions.info

For modeling purposes, the emissions are emitted at the center of the grid point for area sources and at the exact locations for elevated sources (in hundredths of a degree). Area emission sources (small industries, incinerators, boilers and mobile sources) are released into the boundary layer during the day and into the surface layer at night, and the elevated sources (large point sources, LPS's) are released into the boundary layer during the day and above the surface layer at night. Volcanic sources are released into the upper layer at all times.

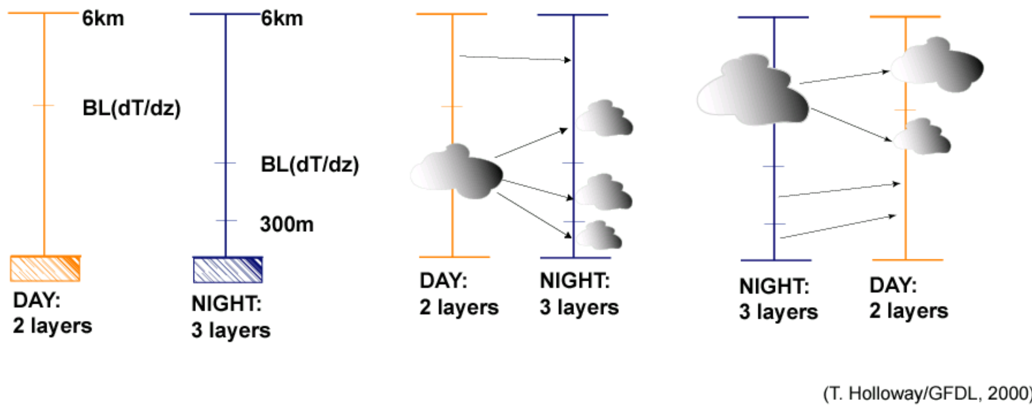


**Figure 6: Vertical mixing of pollutants in ATMoS model**

The released puffs expand and follow their own trajectory, depending on the prevailing meteorological conditions. However, during day to night and night to day transitions the puff branches into multiple puffs. This action is performed to simulate vertical wind shearing of the puff. Furthermore, the mixing height acts to trap urban surface emission and magnify their influence. The model uses a time-step of 1 hour on which advection and surface processes (wet and dry deposition) are calculated and averaged over the desired time period.

The model is run separately for sulfur, nitrogen, and particulate pollution. For particulates, due to physical and chemical differences in $PM_{10}$ and $PM_{2.5}$, two separate bins are distinguished with varying dry and wet deposition functions. In addition, sulfate and nitrate concentrations are added to the $PM_{10}$ and $PM_{2.5}$ fractions to reflect the contribution of the secondary particles.

## Meteorological Data

The ATMoS model uses the meteorological data from the NCEP/NCAR (National Center for Environmental Prediction) Reanalysis Data[17]. The global dataset is available at 2.5° by 2.5°, from which is the grid cells containing the Dhaka city is extracted. The meteorological input data includes six hourly precipitation, mixing height, and wind vector information. **Figure 7** presents the seasonal average windrose functions for the year 2004.

[17] NCEP Reanalysis Data @ http://www.cdc.noaa.gov/cdc/reanalysis/reanalysis.shtml

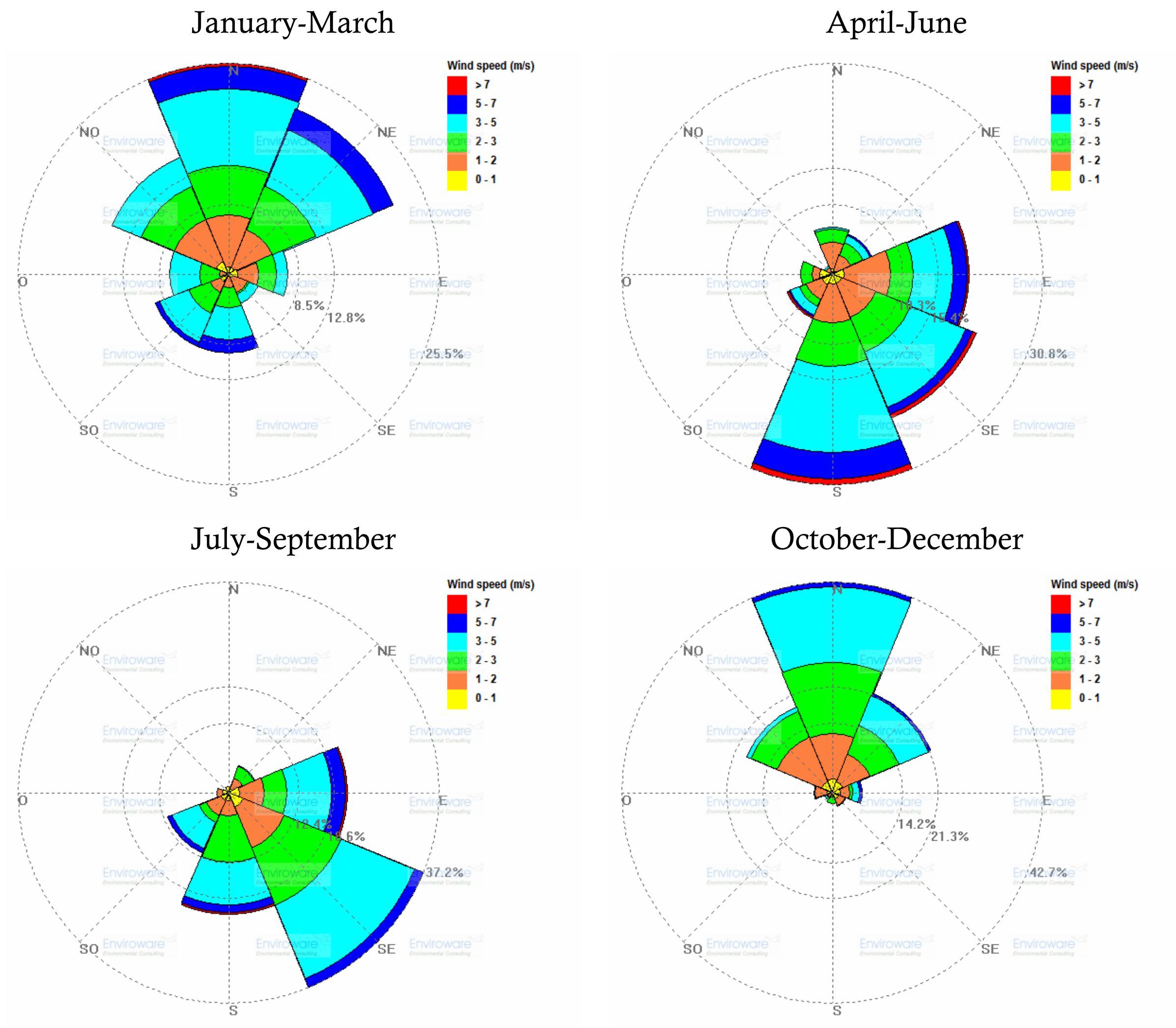


**Figure 7: NCEP reanalysis fields for Dhaka city in 2004**

The brick kiln manufacturing season runs from October to March, during which the northerly winds enhance the contribution of their emissions to the Dhaka air quality. The precipitation and mixing heights information is not presented here. All the calculations are conducted using the meteorological data from 2004.

### Brick Kiln Emissions

The emissions analysis and data on the physical location of the brick kiln clusters was collected by the team from BUET. The details (latitudes and longitudes) are presented in their final project report. At the brick kilns, measurements included an emission rate of 44 gm/sec of TSP. The emission rates were converted to $PM_{10}$ (using a ratio of 0.3 to TSP) and to $PM_{2.5}$ (using a ratio of 0.3 to $PM_{10}$). This amounts to a total of 108 ktons of $PM_{10}$ for 180 days of operating 530 brick kilns presented in **Figure 2**.

## Impact of Brick Kiln Emissions

The **Figure 8** (left panel) presents the seasonal (October to March) average contribution of brick kiln emissions, followed by the modeled monthly maxima over the Dhaka metropolitan area. It is important to note the contribution of the brick kilns is incremental to the daily vehicular, domestic, and industrial activities during these months. It is evident in the **Figure 1**, which demonstrates the dramatic increase in the $PM_{2.5}$ levels measured in the city premises.

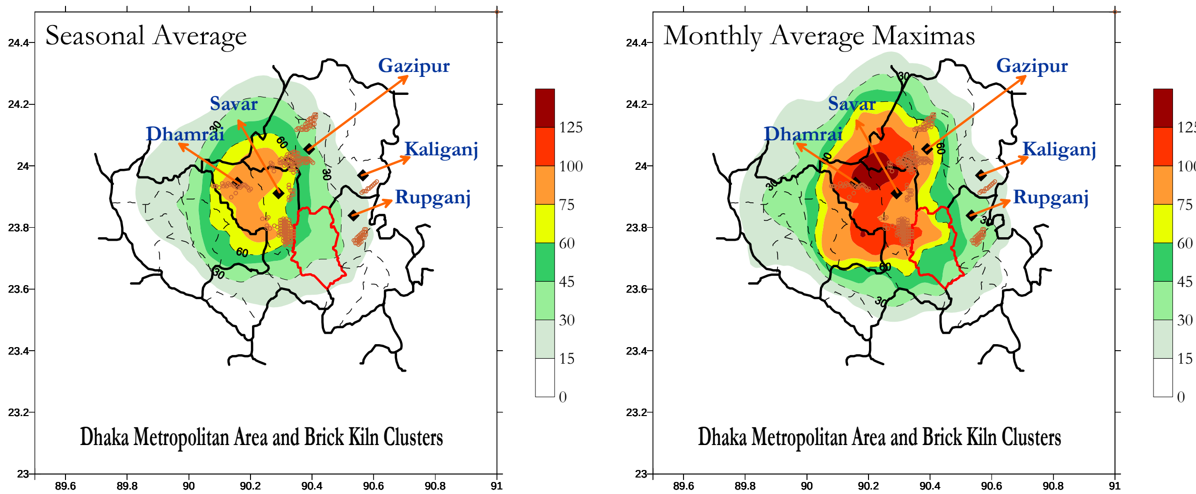


**Figure 8: Seasonal average and monthly maxima of modeled $PM_{2.5}$ (μg/m$^3$) due to the brick kiln emissions**

The seasonal averages estimate a contribution of 15-60 μg/m$^3$ of $PM_{2.5}$, which translates to 30-40 percent of the measured $PM_{2.5}$ concentrations in **Figure 1**, which corresponds to the estimated source contribution of brick kilns in **Figure 3** (via source apportionment). The monthly maxima (right panel) correspond to the worst case scenario of heavy northerly winds and possible maximum modeled contribution of 30-100 μg/m$^3$ of $PM_{2.5}$ over the season.

**Figure 8** presents monthly average contributions of brick kilns for the 6 months of operation.

The calculations presented in this paper should not translate to undermining the influence of the other sectors on Dhaka's air quality. At the ground level, the transport sector (the direct vehicle exhaust, road dust due to resuspension, and idling emissions) contributes more to the exposure levels than the long range transport of the emissions from outside the city.

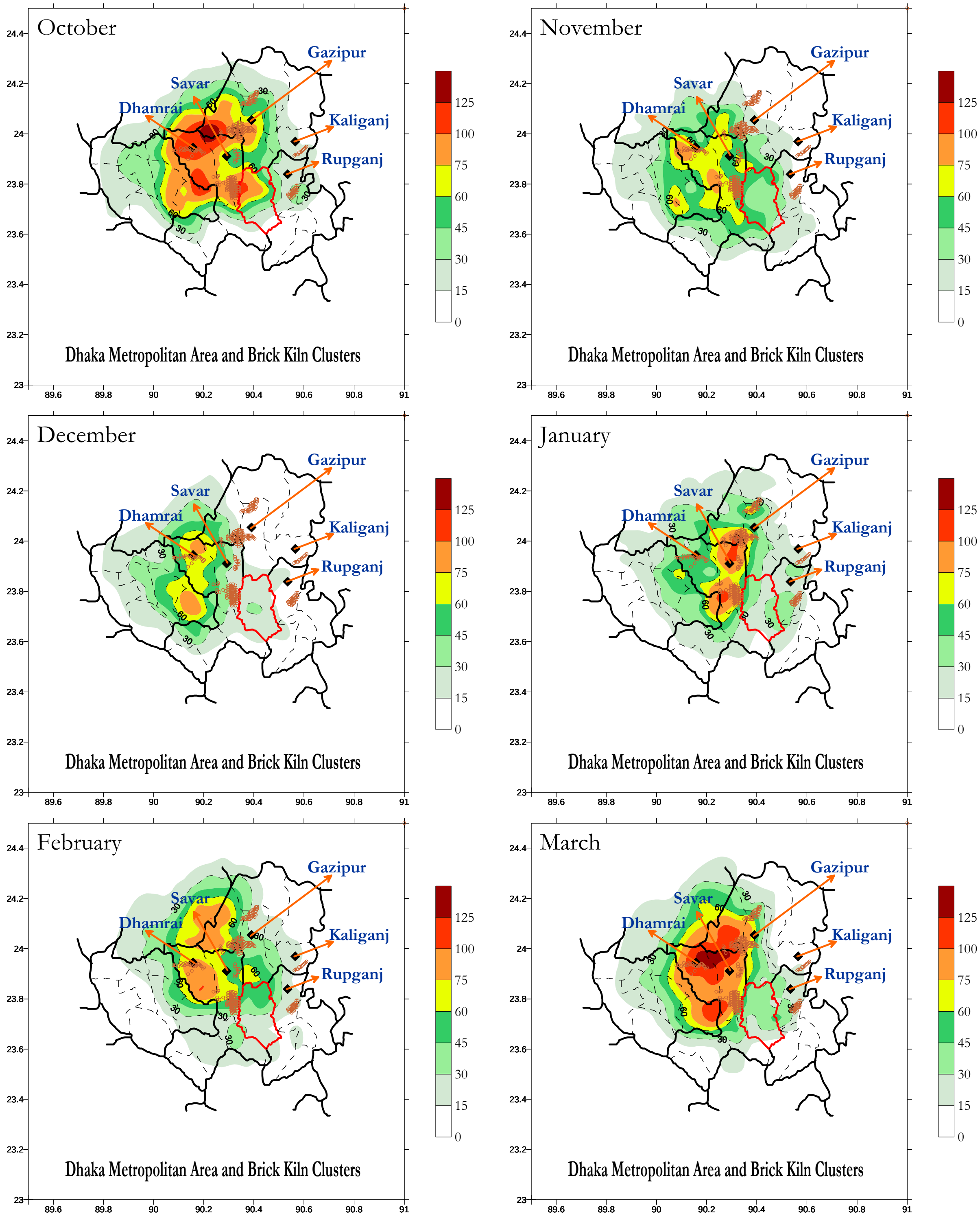


**Figure 9: Monthly average modeled $PM_{2.5}$ ($\mu g/m^3$) due to brick kiln emissions**

## In Conclusion

The main objective of this analysis was to demonstrate the schematics of the modeling approach in understanding the contribution of brick kiln emissions in Dhaka, the characteristics of the air pollution dispersion, and the physical extent of the influence of these emissions on public health.

The brick kilns contribute significantly to the Dhaka air pollution problems, especially during the heightened manufacturing season and requires stringent interventions to reduce their incremental impact of the local air quality and health.

For example, the incremental pollution of 40 $\mu g/m^3$, due to the brick kilns in the north, translates to an increase in ~5,000 premature deaths annually in the Dhaka city[18].

A final report was prepared by the BUET (followed by ISC3 modeling of the impact of Brick Kiln emissions) and the World Bank team, focusing on the interventions to improve the combustion technologies, the financial implications, and possible reductions on Dhaka air quality. Those details are not presented here and the reader should contact the project team for further information.

[18] Based on the methodology presented in SIM-06-2008, "Estimating health impacts of urban air pollution" @ http://www.urbanemissions.info

# Annex 1: Air Pollution Studies in Bangladesh

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## Annex 2: Applications & Publications Utilizing ATMoS Modeling System


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