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Temporal Variation of Atmospheric Aerosol Particulate Matters and Heavy Metal Concentrations in Dhaka, Bangladesh

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Abstract

Aerosol particulate matters and heavy metal concentrations were measured for the period of August and September 2005 in Dhaka a Southeast Asian Mega City. Particulate matters (PM) of different size fractions (TSP, PM_{10} and $PM_{2.5}$) were collected on the micro fiber filters by placing the PM sampler on the roof of the Mohkarram Hossain Khundhkar Biggan Bhaban at the Department of Chemistry, University of Dhaka, Bangladesh. The overall average concentrations of TSP, PM_{10} and $PM_{2.5}$ were 68, 43 and 35 µg m^{-3}, respectively. About 82% particles were from fine fraction ($PM_{2.5}$) and 18% were from coarse fraction ($PM_{10-2.5}$), which indicates mechanical processes are one of the main sources for the particulate matters in Dhaka. Heavy metals (lead, copper, zinc, and iron) concentrations were determined by using atomic absorption spectrophotometer (AAS) for the size fraction of PM_{10} with highest concentrations recorded for iron (2360 ng m^{-3}) and lowest for copper (28 ng m^{-3}). The average concentration for lead (96 ng m^{-3}) was lower than the WHO guideline value and also lower than the previous measurements in Dhaka. The lower concentration of lead was found presumably due to the official ban of leaded gasoline in Dhaka, Bangladesh.

Key word: air pollution, particulate matter, TSP, PM_{10}, $PM_{2.5}$ and heavy metals

Introduction

Urbanization, industrialization and economic growth resulted in a profound deterioration of urban air quality [1,2]. Modernization and enhanced industrial activities led to the increased use of fossil fuels and their derivatives, particularly in developing countries like Bangladesh. Concern about atmospheric particulate pollution in urban region is getting growing importance worldwide [3]. Urban areas are mainly affected by suspended particles, which pose a serious risk to human health [4]. Several epidemiological studies have indicated a strong association between elevated concentrations of inhalable particles (PM_{10} and $PM_{2.5}$) and increased mortality and morbidity [5-7]. It also influences many atmospheric processes including cloud formation, visibility, solar radiation and precipitation, and plays a major role in acidification of clouds, rain and fog [8-10].

Particulate matter pollution in the atmosphere primarily consists of micron and sub-micron particles from the anthropogenic - motor vehicles, biomass, fossil fuel burning, and natural sources - windblown soils and sea spray [11]. The characterization of the fine particles is becoming more important to governments, regulators, and researchers due to their potential impact on human health [12], their ability to travel thousands of kilometers across countries, and their influence on climate forcing and global warming [13].

Dhaka, Bangladesh is one of the densely populated cities in the world with the population of about 14 million within 300 square kilometers. It has been estimated that air pollution is causing about 15000 premature death and several million cases of illness every year in the Dhaka city. Dhaka is congested with a large number of motor vehicles, including both public and private transportation. A high concentration of air pollutants such as black carbon in Dhaka city air has been reported [14, 15]. Vehicular emissions, as well as biomass/coal burning for cooking and the brick kilns around the Dhaka city, are the main contributor to these emissions [16].

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The objective of this work is to investigate the occurrences and characteristics of the suspended particulate matters (TSP, PM_{10} and $PM_{2.5}$) and also airborne heavy metal concentrations (lead, copper, zinc and iron) in the central part of the Dhaka city, Bangladesh. This work could be used as an incentive to perform other studies in order to develop strategies that would control and diminish the air pollution problems in this region. It is also anticipated that the study would help to develop future control strategies towards creating a pollution free environment in Dhaka, Bangladesh.

Sampling and Experimental Methods

Sampling Location

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 (Figure 1). Dhaka (23´76°N, 90´38°E, 8 m a.s. l.) is the capital of Bangladesh. It is also the center of commerce and industry of Bangladesh. Dhaka city is growing rapidly with all the problems of a mega-city. Dhaka is situated in flat land surrounded by rivers (Figure 1). The sampling locations were selected to reflect different influences from industrial and mobile sources in the highly populated central part of Dhaka. People used both motorized and non motorized vehicles for transportation.

Meteorology of Dhaka, Bangladesh

The climate of Bangladesh is characterized by high temperatures, excessive humidity and distinctly marked seasonal variation of precipitation. Meteorologically, the year of Bangladesh can be divided into four seasons, pre-monsoon (March - May), monsoon (June - September), post monsoon (October - November) and winter (December - February). Average meteorological conditions in Dhaka at different seasons were also given elsewhere [14,16]. The average temperature variation was 24°C - 35°C during the period of August and September 2005. Moderately higher temperatures were observed at the afternoon. Precipitations were observed only few times during the sampling period. The average wind velocity in August and September, 2005 at Dhaka was 1.19 m s^{-1} (source: Bangladesh Meteorological Department). Backward air trajectories studies [17] indicated that air masses were transported from south or south west to north or northwest during the sampling periods.

Particulate Matter Sampling

A respirable dust sampler (Model EnviroTech 460 NL) was used for the measurement of PM_{10}. It was also used for the measurement of non-respirable particulate matter concentration in Dhaka air. Ambient air laden with suspended particulates enters the respirable dust sampler through inlet pipe. As the air enters the cyclone, coarse, non-respirable dust is separated from the air by centrifugal forces acting on the solid particles. These coarse particulates fall through the cyclone and get collected in the sampling bottle fitted at its bottom. The air stream passing through the glass microfibre filter (Whatman, size; 20.3 cm × 24.4 cm, England) paper, which was clamped between the top cover and filter adopter assembly, carries the fine dust forming the respirable fraction (PM_{10}). A fine particulate sampler (model EnviroTech APM 550) was used for the measurement of $PM_{2.5}$ concentration in Dhaka. However, aerosol particulate matter sampling device (Model, EnviroTech 460 NL, and EnviroTech APM 550) was set up on the roof of Mohkarram Hossain Khundhkar Biggan Bhaban (MHKBB), Department of Chemistry, University of Dhaka, Bangladesh. The height of the sampling instruments is about 10 meters from the surface. The sampling time was 9:00am to 17:00pm. $PM_{2.5}$ and PM_{10} were deposited on micro fiber filters (Millipore). The particulate matters larger than PM_{10} was collected in the dust Cup Vail.

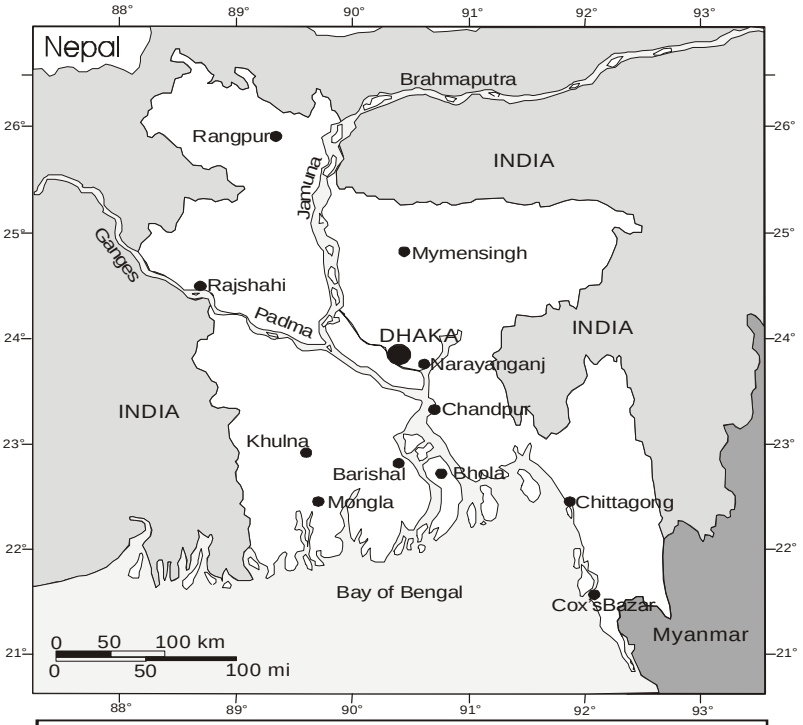
Determination of Particulate Mass (PM) Concentration

The aerosol masses for $PM_{2.5}$, PM_{10} were determined by weighing the filters before and after the exposure at ambient temperature and atmospheric pressure with OHAUS analytical balance (Model no. AR1140). Total suspended particulate (TSP) matters were determined from the sum of PM_{10} and larger than PM_{10}. Particulate matters larger than PM_{10} was determined from initial and final weight of the dust Cup Vail. Samples were transported from the sample site to laboratory and kept them in a refrigerator until analysis to minimize the volatilization. Blank corrections were done by preparing field blanks as the same procedure of the particulate matter samples.

Determination of Heavy Metals Concentration

An Atomic Absorption spectrophotometer (AAS), Shimadzu (Model AA-680), Japan was used to determine the trace elements (lead, copper, zine and iron) concentrations in PM_{10} size fraction. The particulate matters loaded filters were extracted in acid mixture to remove trace metals. Each filter was placed in 30 mL concentrated nitric acid (70%) and 10 mL of hydrogen peroxide (30%) solution into the digestion vessel. The digestion vessels were placed on a sand bath and heated at 180^{o}C for about 1 hour until the evaporation of the acid solution. The procedure was

(a)



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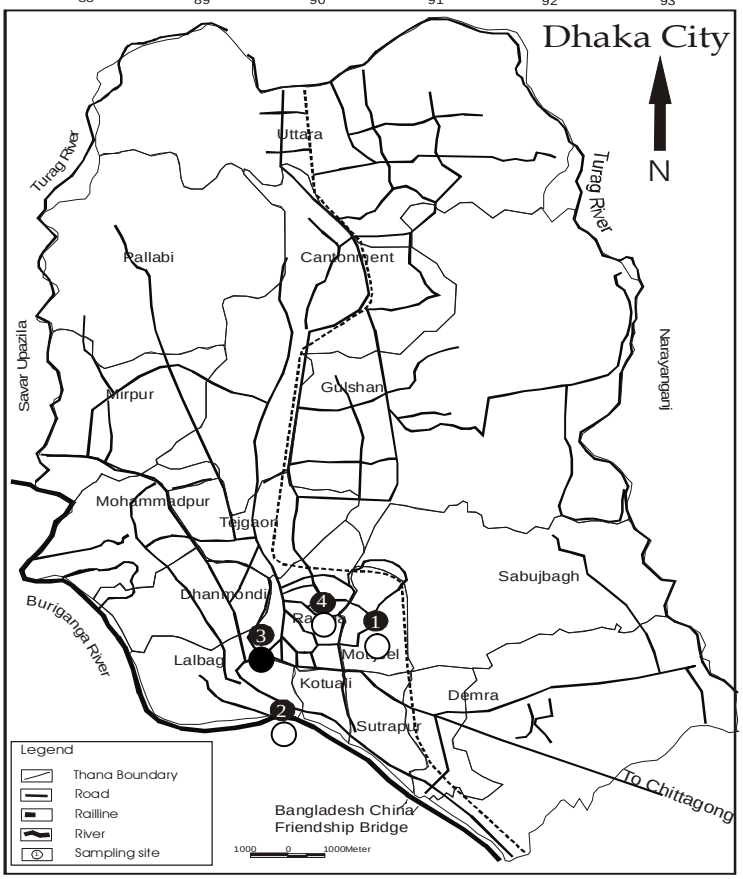

Figure 1. **Map of Bangladesh (1a) and Map of Dhaka city 1(b) indicating the sampling site with solid black circle [●]**

repeated twice and was continued to heat until the residue was barely dry. Upon cooling, 60 mL water was added and agitated carefully. The solution was filtered to a 100 mL volumetric flask and diluted to the mark with de-ionized water and used for the trace metal analysis with AAS. One unexposed filter was prepared as a blank by the same procedure followed for the air-exposed filter.

Results and Discussion

Particulate Matter (PM) Concentration

Aerosol particulate matters for the size fractions of TSP, PM_{10}, and $PM_{2.5}$ were determined between the period of August and September, 2005 in a Southeast Asian mega city (Dhaka - Bangladesh). The time series of the TSP, PM_{10}, and $PM_{2.5}$ masses are given in Figure 2. The TSP concentrations were varying from 94 µg m^{-3} on August 29, 2005 to 59 µg m^{-3} on September 15, 2005 (Figure 2). The maximum concentration of PM_{10} was 68 µg m^{-3} on August 30, 2005 and minimum was 29 µg m^{-3} on September 14, 2005 (Figure 2). In the case of $PM_{2.5}$, particulate mass concentrations were ranging from 62 µg m^{-3} (on August 30, 2005) to 25 µg m^{-3} (on September 15, 2005) in Figure 2. The average mass of total suspended particulate (TSP) matter for the period of August and September, 2005 was 68 µg m^{-3} (Figure 3), which is about three times lower than the Standard Value (200 µg m^{-3} for 8 hours average) in Bangladesh The average concentrations for PM_{10} and $PM_{2.5}$ were about 43 µg m^{-3} and 36 µg m^{-3}, respectively. The widespread problem of suspended particulate matter is due to the synergistic effects of both anthropogenic and natural sources. Some of the sources are extensive urbanization, industrialization, construction activities, increased vehicular pollution and also biomass burning.

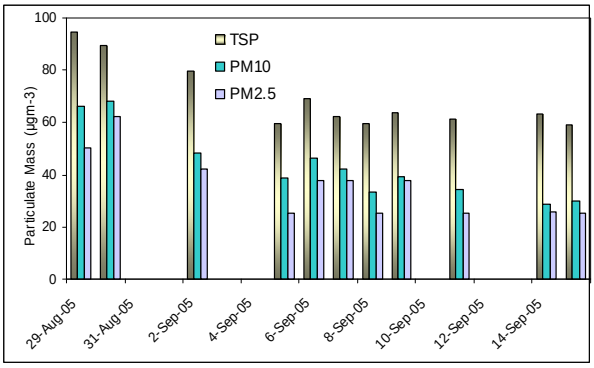

Figure 2. **Time series of the measured particulate matters concentrations of TSP (total suspended particulate matter), PM_{10} (particles ≤ 10 µm in aerodynamic diameter) and $PM_{2.5}$ (particles ≤ 2.5 µm in aerodynamic diameter) in Dhaka, Bangladesh**

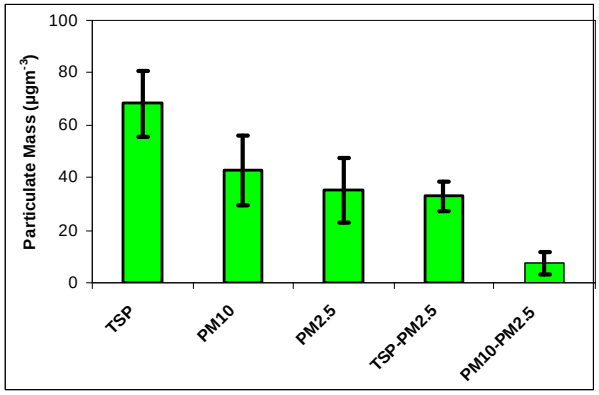

Figure 3. **The average concentrations of TSP, PM_{10}, $PM_{2.5}$, $PM_{TSP-2.5}$ and $PM_{10-2.5}$ particle mass in Dhaka, Bangladesh. The vertical bars are the error bars equal to the standard deviation of the measurements conducted at each size fractions.**

PM_{10} is about 62% of TSP, where as $PM_{2.5}$ is about 52% of the TSP mass. $PM_{2.5}$ mass is about 82% of the PM_{10}, which means most of the particles are form the fine fractions, which indicates the major source of particulate matter pollutions in Dhaka city air are due to fossil fuel burning or from mechanical processes. Begum et al[15] also reported that vehicles normally produce more fine particles ($PM_{2.2}$ particles) than coarse ones ($PM_{10-2.2}$ particles) which mostly originates from mechanical processes.

The comparison between fine ($PM_{2.5}$) and coarse ($PM_{TSP-2.5}$) particles were given in Figure 4. The coarse particles ($PM_{TSP-2.5}$) concentrations are varying from 44 to 24 µg m^{-3}. The average concentration of the coarse particles ($PM_{TSP-2.5}$) is 33 µg m^{-3}, which is about 48% of the average TSP mass.

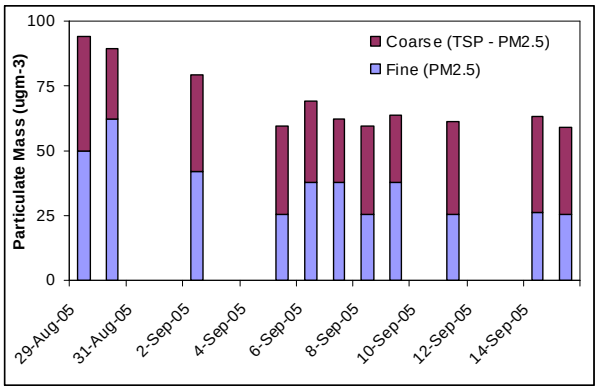

Figure 4. **Comparison between fine ($PM_{2.5}$) and course ($PM_{TSP-2.5}$) particulate matters mass in Dhaka, Bangladesh.**

Heavy Metals Concentration

The heavy metal (lead, copper, zinc and iron) concentrations were determined with Atomic Absorption Spectrophotometer (AAS), Shimadzu (Model AA-680), Japan for PM_{10} in Dhaka, Bangladesh during the period of August and September, 2005. The average concentrations of the trace metals obtained in this study are given in Table 1 with other international measurements. The some of the literatures (Table 1) for the metal concentrations were found in the coarse fraction (TSP) of the particles for the comparison, which is also a reasonable effort to compare between TSP and PM_{10}. The overall concentrations of the trace metals in Dhaka city under the current study conditions are lower than other Southeast Asian cities and also from the previous measurements in Dhaka, but still much higher than European cities (Table 1).

Table 1: **Comparison of the trace metal concentrations of Dhaka, Bangladesh with other international measurements. All units are in ng m^{-3}.**

Trace Elements	Dhaka, Bangladesh		[19]Athens, Greece, PM_{10}	[21]Islamabad, Pakistan, TSP	[22]Mumbai India, TSP
	PM_{10} (Current study)	*[14]TSP (Previous study)*			
Pb	96	279	47	146	550
Cu	28	54	52	-	-
Zn	911	801	-	1033	210
Fe	2360	24800	-	2467	2950

Lead: The average lead concentration in Dhaka city is 96 ng m^{-3} in PM_{10}, which is much lower than previous values reported by Salam et al [14]. (279 ng m^{-3}) and Khaliquzzaman et al. [18] (465 ng m^{-3}) for TSP. This is a clear indication of decreasing lead concentrations in Dhaka city. However, the lead concentration in Dhaka city is still higher than the European values [19], but considerable lower than other Southeast Asian cities (Table 1). The major source of Pb in the atmosphere is combustion of petrol containing Pb additives and from smelting. The decreasing of lead concentration in Dhaka city is probably due to the ban of the leaded gasoline and two strokes engine (locally called baby taxi) by the Government of Bangladesh.

Copper: The average Cu concentration in Dhaka is 28.3 ng m^{-3}. It is lower than the value (54 ng m^{-3}) reported by Salam et al. [14] for Dhaka city; but also much lower than the concentration (54 ng m^{-3}) reported for Athens [19].

Zinc: The average Zn concentration in Dhaka is 911 ng m^{-3}, which is comparable with the previous measurement (801 ng m^{-3}) in Dhaka city[14]. The value is about four times higher than Mumbai (Table 1), but slightly lower than Islamabad (Table 1).

Iron: The average Fe concentration in Dhaka city is 2360 ng m^{-3}, which is similar to the Islamabad, Pakistan and slightly lower than Mumbai, India, but about 10 times lower than the previous measurement in Dhaka city (Table 1). The major sources of Fe are both anthropogenic and crustal origin, they include iron and steel manufacturing units and weathering of exposed iron in urban areas, although the overwhelming source of Fe particles in the atmosphere is from the crustal weathering [20]. Chronic exposure to Fe can cause benign Pneumonia-conuisis and can enhance harmful effects of SO_2 and various carcinogens. Ingestion of Fe in excessive quantity inhibits the activity of many vital enzymes.

Conclusions

Aerosol particulate matters were collected with Envirotech samplers during the period of August and September 2005 for different size fractions (TSP, PM_{10}, and $PM_{2.5}$) in Dhaka, Bangladesh. The average concentrations were 68.2 μg m^{-3} for TSP, 42.6μg m^{-3} for PM_{10} and 35.3μg m^{-3} for $PM_{2.5}$ in Dhaka, Bangladesh. About 82% of the PM_{10} mass in Dhaka city air was from fine particle ($PM_{2.5}$) fraction, which indicated that the origin of particulate matters in Dhaka might be from anthropogenic sources. The concentrations of lead, copper, and iron are considerably lower than the previous measurements in Dhaka, Bangladesh.

The result of this paper (2005) have been compared with the previous measurement (2002-03) in Dhaka city was carried out under Air Quality Management Project coordinating by Department of Environment, Government of the People's of the Republic of Bangladesh. The average results of air pollutants were very much higher in the year 2002-2003 than the result of 2005. This is due to the two stroke three wheeler engine have been withdrawn by a notification of the Government of Bangladesh.

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