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Studies on Selected Metals and other Pollutants in Urban Atmosphere in Dhaka Bangladesh

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Abstract

The concentration of lead, iron and potassium were determined in suspended particulates matters (SPM) in the atmosphere Dhaka, Bangladesh between January and June, 2008. The sampling areas are Khandakar Mukarram Hossain Biggan Bhaban, University of Dhaka, Tejgaon, Hazaribagh, Uttara and Agargaon new colony. The average concentrations of TSP, PM10 and PM2.5 were 68, 43 and 35 µg m-3, respectively. About 82% particles were from fine fraction (PM2.5) and 18% were from coarse fraction (PM10-2.5), which indicates mechanical processes are one of the main sources for the particulate matters in air of Dhaka. The concentration of lead, iron and potassium were determined by using atomic absorption spectrophotometer (AAS) for the size fraction of PM10 with highest concentrations recorded for iron (10.8 µg/m3) and lowest for lead (0.10 µg/m3). The average concentration of NOx, O3 and SOx with eight hours sampling were 82.8, 22.5 and 25.5 µg/m3 respectively. This study revealed that the concentrations of Pb, K, Fe, CO, NOx, O3 and SOx in Dhaka City were higher than the WHO (World Health Organization) guideline values.

Key words: Trace Metals; Suspended Particulates Matter; PM10; PM2.5; Gaseous pollutants

I. Introduction

During recent years, air pollution has emerged as a serious environmental issue, mainly due to the presence of toxic metals in the atmosphere as a consequence of rapid industrialization and increased transportation [1-3]. The resulting quality of the atmosphere has been the subject of various publications [4-6], especially with reference to the health impacts of different toxic metals [7-11]. Several studies have also incorporated the role of size and composition of atmospheric particulate matter towards overall heavy metal toxicity [12-15]. It is understood that aerosol particulate matter has a correlation with toxic trace metals and affects human health in urban and rural environments [16-17].

Particles from macroscopic to sub-microscopic size find their origin in fuel combustion, industrial processes, automobile exhausts, mining and quarrying [18]. Generally, fine particulate matter carries more burdens of heavy toxic metals than the coarse fractions [19], the average concentration of airborne metallic elements being time dependent [20]. Accordingly, human exposure to the respirable fraction of particulate matter (PM 2.5) in the atmosphere of industrially developed and urbanized areas has gained serious concern in relation to the ill-effects caused by toxic trace metals in its presence [21].

Like most other developing countries, the industrial development and urbanization in Bangladesh have not gone in pace with environmental safety, resulting in numerous problems arising from atmospheric pollution. Over the years, in the capital city, Dhaka, the vehicular bulk has gone up tremendously as a result of increased industrial activity geared to producing the commodities of various kinds required by the large population. Consequently, the local urban population is now facing the menace of a variety of air pollutants emanating from the industrial emissions and increased vehicular traffic.

Keeping in view the environmental significance of the potential influence of toxic trace metals in air, and their continued high levels in the local atmosphere, the present investigation was undertaken to assess, in the first place, the current status of the atmospheric trace metal burden in the local urban and rural atmosphere, and then to examine its relationship with the size of airborne particulate matter. The metals lead, copper, zinc, and iron along with particle fractions 2.5, 2.5–10 mm was included in the study. It was anticipated that this study would provide baseline data to help determine the health related pollution status of the local atmosphere. The data obtained would be useful towards air pollution abatement programmes and could motivate some realistic futuristic studies on predicting the trends of spatial metal distribution, source identification, mass loading and enhancement relative to the clean background.

II. Experimental

All reagents and chemicals used were of analar grades. Distilled de-ionized water was used for the preparation of standard solutions and reagents. Standard techniques were followed for the preparation of all reagents and standard solutions.

A four decimal OHAUS analytical balance, model AR1140 was used. A fine particulate sampler (Envirotech APM 550) was used for the measurement of $PM_{2.5}$ concentration in air. A respirable dust sampler (Envirotech 460 NL) was used for the measurement of PM_{10}. It was also used for the measurement of non-respirable total particulate matter concentration (SPM) in air. An organic vapor sampler (Envirotech APM 850) was used for the measurement of CO in air. A Shimadzu UV visible model UV-160A was used for the measurement of SO_2, NO_2, O_3, SO_4^{2-} and PO_4^{3-} in air. The analytical procedure adopted for trace metal analysis consisted of cutting each filter containing particulate matter was into pieces and digested on a hot plate in HNO_3 (1:1, v/v) for Atomic Absorption Spectrophotometric (AAS) based quantification [20] of the selected trace metals. Millipore filters were used for the analysis of $PM_{2.5}$ and Whatmann Glass Micro fiber filters (20.3cm×25.4cm) were used for the analysis of PM_{10}. A BINDER heating oven was used for heating purpose in the digestion of filter paper. Parr digestion bomb was used for the digestion of filter paper.

Regular calibration was necessary to ensure that the sample collection with all the instruments were reliable for PM_{10}, $PM_{2.5}$ and CO. A factory calibration was carried out before setting up the instruments for the field measurement. It is absolutely necessary to calibrate the instruments once every 6 months if the instruments are operating 2-3 days per week. The calibrations were done directly by the manufacturer (Envirotech Instruments, New Delhi, India).

Sites description

Bangladesh situated in the eastern part of south Asia is surrounded by India on the west, the north and the northeast, Myanmar on the southeast, and the Bay of Bengal on the south. Dhaka (23_760N, 90_380E, 8ma.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 (Fig. 5). The four sampling sites are (1) Khandakar Mukarram Hossain Biggan Bhavan (KMHV), University of Dhaka-residential area with medium traffic (2) Tejgaon-industrial area with heavy traffic (3) Hazaribagh-tannery area with less traffic (4) Uttara - model town with heavy traffic.

Sampling

Sampling was performed at the sites described above using fine particulate sampler, respirable dust sampler and an organic vapor sampler. A fine particulate sampler capable of collecting air particulate samples in $PM_{2.5}$ size fractions using Millipore filter was used. A respirable dust sampler was equipped with Whatmann Glass Micro fiber filters for collecting of air particulate samples in PM_{10} size fractions, a dust cup vail for collecting of air particulate samples >PM_{10} size fractions. It was also equipped with an impinger for the collecting of gaseous pollutants (SO_2, NO_2 and O_3). An organic vapor sampler was used for the analysis of CO by using a CO detector tube. At all the sites the sampling instruments were set up on the road side. The height of the sampling instruments was about 6 fit from the surface. The sampling was carried out one day for each site between January and June, 2008. The sampling time was 8:00 AM to 4:00 PM for $PM_{2.5}$, PM_{10}, gaseous pollutant (SO_2, NO_2, O_3). For CO the sampling time was from 8:00 AM to 9:00 AM.

III. Results and Discussion

The average concentration of total suspended particulate matter (SPM) in Dhaka city ambient air is 385.3 μg/m^3 (Table 1), which is higher than the daily average given by WHO. PM_{10} is about 62 % and $PM_{2.5}$ is about 21 % of SPM concentrations. The SPM concentrations are varying from

Table. 1. Particulate Matter Concentration of Different Size Fractions in Four Different Locations in Dhaka City (All units are in μg/m^3)

Location of Sampling		Suspended Particulate Matter (SPM)	Particulate Matter (PM_{10})	Particulate Matter ($PM_{2.5}$)	$PM_{2.5-10}$	$PM_{10}/PM_{2.5}$
KMHV, DU Campus		206.1(±15)	385.5(±22)	138.4(±12)	247.2(±20)	2.8
Tejgaon		470.9(±18)	170.1(± 9)	72.1(±8)	98.0(±6)	2.4
BCLT, Hazaribagh		227.7(±20)	111.2(±18)	70.79(±11)	40.4(±4)	1.6
Uttara Model town		636.4(±26)	299.2(±20)	43.1(±5)	256.1(±22)	6.9
Average (all values for 8 hrs)		385.3(±21)	241.5(±15)	81.1(±8)	160.4(±8)	3.4
WHO Standard	8 hrs	-	-	-	-	-
	24 hrs	150-230	-	-		
	Annual	60-90	-	-		
US Standard	8 hrs	-	-	-	-	-
	24 hrs	150	-	-		
	Annual	50	-	-		
Bangladesh Standard[8]	8 hrs	200	-	-	-	-
	24 hrs	-	150	65		
	Annual	-	50	15		

Table. 2. Ambient Air Quality Parameters at Different Locations in Dhaka City. (All units are in μg/m^3)

Sampling Location	Average Time	Carbon Monoxide (CO)	Nitrogen Oxide (NO_x)	Ozone (O_3)	Sulfur Dioxide (SO_x)
KMHV, DU Campus	1 hour	448.5(±24)	-	-	-
	8 hrs	-	35.5(±4)	38.1(±2)	20.5(±4)
Tejgaon Industrial Area, Tejgaon	1 hour	584.1(±21)	-	-	-
	8 hrs	-	63.5(±10)	16.3(±2)	31.2(±7)
BCLT, Hazaribagh	1 hour	607.7(±25)	-	-	-
	8 hrs	-	16.2(±3)	7.4(±3)	12.0(±2)
Uttara Model town	1 hour	560.5(±20)	-	-	-
	8 hrs	-	56.2(±5)	28.2(±6)	38.1(±4)
Average	1 hour	550.2	-	-	-
	8 hrs	-	42.8	22.5	25.4
Bangladesh Standard[8]	1 hour	40	-	235	-
	8 hour	10	-	157	-
	Annual	-	100	-	80
	1 hour	30	-	180	-
	8 hrs	10	-	-	-
WHO Standards	24 hrs	-	150	-	100-150
	Annual	-	-	-	40-60

Table. 3. Trace Metals and Ions Concentration Analyzed with AAS and UV-Visible Spectrophotometer and Flame Photometer in PM_{10} (All units are in μg/m^3)

Location	Pb	Fe	K	PO_4^{3-}	SO_4^{2-}
KMHV, DU Campus	0.2(±0.2)	10.0(±0.2)	10.4(±1.0)	13.4(±3.0)	3.1(±0.4)
Tejgaon	1.0(±0.4)	10.8(±0.4)	10.3(±2.0)	20.5(±4.0)	2.7(±0.2)
Hazaribagh	0.1(±0.04)	9.0(±2.0)	12.3(±1.5)	11.2(±2.0)	1.5(±0.1)
Uttara model town	0.6(±0.1)	5.0(±1.0)	9.1(±2.0)	19.6(±4.0)	4.1(±0.4)
Average (Dhaka)	0.47	8.69	10.52	16.19	2.84

Table. 4. Trace Elements and ions Concentration in PM_{10} of Several Urban Areas (μg/m^3)

Element	[22]Los Angels, USA (PM_{10})	[21] Islamabad, Pakistan(PM_{10})	[25]Beijing, China(PM_{10})	[23]Delhi, India (PM_{10})	[24]Dhaka, Bangladesh in 2006	Dhaka, Bangladesh (Current study)
Pb	0.01	0.2	0.05	0.4	0.3	0.5
Fe	0.4	0.7	51.0	5.2	24.8	8.7
K	0.2	1.0	28.0	3.4	1.5	10.5
SO_4^{2-}	-	-	-	-	-	16.2
PO_4^{3-}	-		-	-		2.8

146.6 μg/m^3 at KMHV, DU Campus, Dhaka to 636.4 μg/m^3 at Road-27, Sector-7, Uttara Model Town, Dhaka. The cause of higher value of SPM in the air of Dhaka city are incomplete combustion of fossil fuel used by vehicles included car, jeep, bus, truck, minibus, mini-truck, human holler, microbus, four stroke engine driven vehicles (auto-rickshaw, CNG etc) and motorbikes. Railway engines, industrial plants, power plant, brick fields, open burning incineration, solid waste disposal sites, road side dust particles, road diggings, constructions and other development activities are also contributing to the higher value of SPM in Dhaka. The average concentrations of for PM_{10} and $PM_{2.5}$ are 241.5 and 81.1 $\mu g/m^3$ respectively. These values are also higher than the daily average of WHO standard values. $PM_{2.5}$ mass is about 34 % of PM_{10}, which indicates the source of particulate matters is not only from fossil fuel. Begum et al[9] reported that vehicles normally produce more fine particles ($PM_{2.5}$ particles) than coarse ones ($PM_{2.5-10}$ particles) which mostly originates from mechanical processes. The concentrations of PM_{10} and $PM_{2.5}$ at different places in Dhaka city is tabulated in Table 1. The concentrations of coarse particles ($PM_{2.5-10}$) are varying from 256.1 $\mu g/m^3$ to 40.4 $\mu g/m^3$ and the average concentration for the coarse fraction is 160.43 $\mu g/m^3$.

The air quality standard for Bangladesh is higher than the standards of WHO and USA. Alarmingly, the air quality of Dhaka is even higher than those levels. Only the concentration of NO_x , SO_x and O_3 is within the limited value (Table 2).

Carbon monoxide may be produced by the incomplete combustion of CNG, octane, petrol and diesel used as fuel in the vehicles. Degradation of chlorophyll during the autumns releases CO, amounting perhaps as much 20% of the total annual release. Anthropogenic sources account for about 6% of CO emissions. The decay of plant materials and the rest of CO released by industrial and automobile man made sources is the combustion of fossil fuel. Higher concentration (63.5 $\mu g/m^3$) of NO_x was found in Industrial area (Tejgaon) and the lowest concentration (16.2 $\mu g/m^3$) was found in tannery area (Hazaribagh) for eight hours sampling. It is to be noted that the concentrations of NO_x found in different locations are much lower than the guideline values of WHO and US standard.

Ozone is one of the most ubiquitous and toxic pollutants found in ambient air. Ciliated cells in respiratory airways as well as squamous cells in alveoli are injured or killed by ozone. Ozone may injure tissue membrane by oxidizing the amino acid, sulfhydryl (SH) groups of enzyme and other proteins and polyunsaturated fatty acids (lipids). Higher concentration (38.0 $\mu g/m^3$) of O_3 was found in selected area (KMHV, DU) and the lowest concentration (7.4$\mu g/m^3$) was found in tannery area (Hazaribagh) for eight hours sampling.

Higher concentration (38.1 $\mu g/m^3$) of SO_x was found in heavy traffic area (Uttara) and the lowest concentration (12.0 $\mu g/m^3$) was found in tannery area (Hazaribagh) for eight hours sampling. The reason for the higher concentration of SO_x in air is because of the higher sulfur containing oil burned in this area.

The concentrations of the trace metals obtained in the samples collected at KMHV (DU Campus), Tejgaon Industrial area (Tejgaon), Tannery area (Hazaribagh) and Uttara model town (Uttara) in Dhaka City are summarized in Table 3**.** The concentration of phosphate, sulphate concentrations were determined with UV-Visible spectrophotometer and lead, iron, potassium with Atomic Absorption Spectrophotometer for the size fraction of PM_{10}**.**

The average concentrations are 0.5, 8.7, 10.5, 16.2, 2.8 $\mu g/m^3$ for Pb, Fe, K, PO_4^{3-} and SO_4^{2-} respectively. The average lead concentrations were varied from 0.1 $\mu g/m^3$ to 1.0 $\mu g/m^3$, which was found at Hazaribagh and Tejgaon industrial area respectively. The relatively higher value of lead observed presumably due to different metallic emission in road dust in Tejgaon industrial area. The lower value of lead (0.1$\mu g/m^3$) at Hazaribagh tannery area is due to the less metallic emission in road dust compared to the Tejgaon industrial area. The lead compounds accumulate with particular matters (PM) in the atmosphere. After that the PM gradually settled down on the earth surface. It is reported that lead level in the rural areas in Bangladesh was beyond the detection limit.[10]

The average iron concentrations varied from 5.0 $\mu g/m^3$ to 10.81$\mu g/m^3$, which was found at Uttara model town and Tejgaon industrial area respectively. The higher value of iron at Tejgaon industrial area is due to the industrial area. The lower value of iron at Uttara model town is due to the less traffic compared to the Tejgaon industrial area. Iron exhibited relatively high level in all the areas. The average estimated value of iron was 8.7 $\mu g/m^3$. It might be due to lamp posts, billboards, all types of vehicular bodies, constructed buildings and road dust etc. based on iron compared to the other metals. Although lead level was low in all the samples compared to iron but it has significant effect on the environment as well as on human health.

The average Potassium concentrations were varied from 9.1$\mu g/m^3$ to 12.3$\mu g/m^3$, which was found at Uttara and Hazaribagh respectively. The values are higher comparing with the values of Mumbai, India; Los Angeles USA (Table 4). The average Phosphate concentrations were varied from 11.2 $\mu g/m^3$ to 20.5$\mu g/m^3$, which was found at Hazaribagh and Tejgaon respectively.

These values are higher than previous measurement. The average Sulphate concentrations were varied from 1.5 $\mu g/m^3$ to 4.07$\mu g/m^3$, which was found at Hazaribagh and Uttara respectively.

A comparison of the mean trace metal concentration levels in airborne particulate samples from various Asian sites and USA relevance to the present work is presented in Table 4. An examination of the Table shows that the levels of the metals in the urban atmosphere of Dhaka are, in general, comparable with those presented for other Asian sites. The local levels of Pb are relatively higher than those reported for the metals in the atmosphere of a typically polluted city, such as Beijing, China. This comparison also shows that the levels of K, Fe and Pb almost pertaining to the present study are higher than the corresponding metal levels for typical rural area of Delhi. In fact, the observed elevated levels of metals in the local urban atmosphere of Dhaka may be anticipated to have arisen initially from the nearby industrial units located in the heart of the city such as hazaribagh and Tejgaon. These industrial units are operating freely without any regard to regulation and control of their emissions putting at stake environmental safety and public health security.

IV. Conclusion

The following conclusions emerge from the present study. The urban atmosphere of Dhaka is currently under a continued severe pollution threat from industrial and vehicular emissions and increased urbanization. The dominant metals and anions are lead, iron, potassium, phosphate, sulfate which were found to several times as high as the corresponding concentration of the meals and ions of other big cities in the world. The coarse particle size PM2.5-10 emerges as a major contributor. Major metal sources are found to be industrial emissions, automotive exhaust, metallurgical units and soil based wind erosion. In the overall scenario of air pollution prevailing in adjoining regions of the world, the present data indicate that the air pollution situation in the capital city of Dhaka shows trends of enhanced pollution with respect to trace metals, a situation that calls for proper implementation of legislative measures to affect a regulated control on industrial and vehicular emissions.

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