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Observation of atmospheric pollutants in Dhaka, Bangladesh

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***Abstract*— Simultaneous ground-based measurement of trace gaseous pollutants were conducted at Continuous Air Monitoring Station in the metropolitan area of Dhaka, Bangladesh during April 2002 - December 2005 in order to investigate the ozone precursor characteristics and their distribution. Seasonal and diurnal variations of the O_3, CO, NOx and SO_2 concentration are studied and their possible causes are identified. It is shown that all measured trace gases have peak in winter and base in monsoon period. Two major emission sources motorized transport vehicles and brick kilns are attributed to high peak of trace gases in winter. The diurnal variation of O_3, with high concentration is the result of strong local photochemical O_3 production as well as transportation of O_3 and precursors from nearby brick kiln area to the site. The diurnal variations of CO, NOx and SO_2 in all seasons show higher in the early morning and evening peak hours of traffic.**

INTRODUCTION

Air pollution in urban area has become one of the important factors in many developed and undeveloped countries all over the world which poses adverse effects to human health and the environment. The environmental impacts are increasing concern in developing regions of south Asia with rapid growth of cities, intense industrial activity, huge populations and increased motor vehicle usage. Sulphur dioxide (SO_2) is produced from the combustion of any sulphur-bearing material, such as coal and fuel oils. Nitrogen oxides (NOx = NO + NO_2) is generated from fuel burning at high temperatures. The major sources of NOx are from motor vehicle emissions and NOx is contributing to photochemical smog and particulate matter formation through chemical reactions in the atmosphere. Both NOx and SO_2 are the main precursors of acid rain which is health hazards and harmful to plants and animals. Ground level O_3 is produced from the photochemical reactions with precursors like NOx, CO and VOCs. CO, the most important O_3 precursors – produce from any type of combustion during industrial processes, transportation of vehicles and biomass burning. In urban atmosphere, CO shows high concentration.

Generally, there are four distinct seasons in Bangladesh namely; winter (December-February), Pre-monsoon (March-May), monsoon (June-Aug) and post-monsoon (September-November). Studies have found significant increase of air pollution over Bangladesh during dry season (November-March) [1], [2]. However, very few works have been done concerning the emission of O_3 precursors and pollution problems for urban areas of the country. The purpose of this study is to characterize the seasonal and diurnal variation of O_3 precursors and their source and influential factors.

EXPERIMENT

Measurements of trace gases were done in Continuous Air Monitoring Station (CAMS), near parliamentary area (latitude, 23.77º N; longitude, 90.37º E) of Dhaka. The location is known as one of the most traffic congestion area of Dhaka. A number of commercial instruments were used for continuous measurement of trace gases. O_3 was observed with a UV photometric analyzer (Teledyne Monitor Labs (TML), Inc., model 9810B). CO was measured using non-dispersive infrared spectrometer (TML, model 9830B). NO, NO_2 and NOx were measured using chemiluminescence analyzer (TML, model 9841B) and SO_2 were measured using a pulsed UV fluorescence analyzer (TML, model 9850B). All instruments were housed in an air-conditioned room. Times to time calibration were performed. All calibration processes were traceable to National Institute of Standards and Technology (NIST) standard. The concentrations of trace gases are mentioned here as 1-hr averages and data in this work are mentioned in Bangladesh Standard Time.

RESULTS AND DISCUSSIONS

Seasonal variations

The monthly average concentrations of O_3, CO, NOx and SO_2 in Dhaka are shown in Fig. 1. The data cover the period from April 2002 to December 2005. The O_3 concentration shows higher values in winter and lower values in monsoon. The maximal monthly O_3concentrations in 2002, 2003, 2004 and 2005 were 41 ppb (December), 60 ppb (November), 60 ppb (February), and 59 ppb (February), respectively. O_3 (variation between O_3concentrations of daytime and 24-hr monthly averaged) of each season have found higher values than 24-hr monthly averaged O_3 concentration. For example, the averaged O_3 concentrations (2002-2005) in winter are obtained highest values (38 ppb), followed by post-monsoon (20 ppb), pre-monsoon (18 ppb) and monsoon (4 ppb), respectively. Higher O_3 indicate photochemical O_3 production is significant in Dhaka almost all seasons. Like O_3, the seasonal cycle of CO, NOx and SO_2 also have found peak in winter and base in summer season. The major emission sources in Dhaka are motor vehicles and brick fields. Brickfields have large contribution to the air pollution in Dhaka which operates only in dry season (November-March) due to meteorological conditions and use coal as main fuel. As a result of this seasonal operation, emissions from brick kilns spread over the surrounding atmosphere.

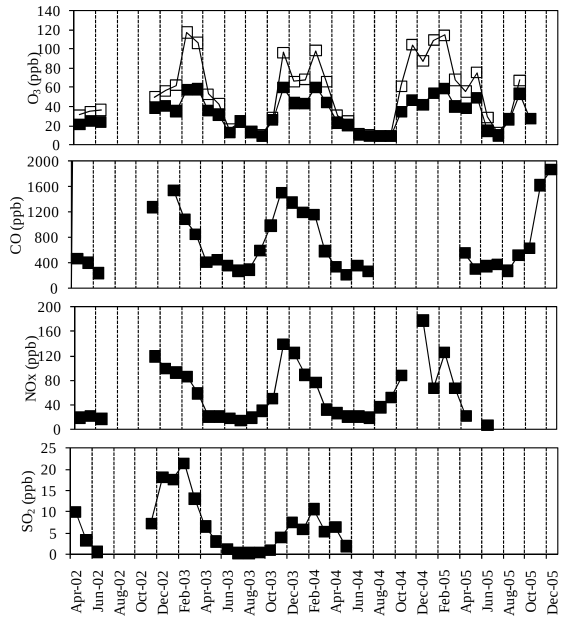


Fig.1. Monthly average concentrations of trace gases in Dhaka during 2002-2005. The open squares represents the daytime (10:00-17:00) averaged O_3 concentration.

Diurnal variations

The average diurnal variations of O_3, CO, NOx and SO_2 in Dhaka in different seasons are shown in Fig.2. Diurnal variation of O_3 depicts an apparent feature of O_3 status in Dhaka. In general, O_3 concentration gradually increases after sunrise, attains maximum value during noontime and then decreases. O_3 concentrations in Dhaka frequently exceed national and USEPA´s (United State Environmental Protection Agency) 120 ppb hourly averaged environmental standard during winter, pre-monsoon and post-monsoon season. The largest diurnal amplitude of O_3 have found in winter (97 ppb), followed by post-monsoon (70 ppb), pre-monsoon (46 ppb) and monsoon (16 ppb), respectively. The O_3 concentration shows peak between 14:00 h - 15:00 h at Bangladesh standard time in all seasons. The similar O_3 peak is available in other countries of the world [3], [4]. High peak in day time indicate the photochemical O_3 production is significant in Dhaka with strong local pollution also. The O_3 peaks of Dhaka are higher than Tokyo, Japan [6]. Another possible reason of high peak is transport of O_3 and precursors from nearby brick kiln area to Dhaka. A majority of brick fields have been set up in the northern part of the city. During winter, northerly winds dominate over Dhaka, contributing of their emissions to the Dhaka air quality. After the peak, O_3 concentration decreases gradually due to reduction of photochemical process and the reduction is caused by higher concentrations of precursors and H_2O.

It seems that, the diurnal cycles of CO and NOx follows daily social activities. CO and NOx concentration increases in the early morning due to rush hours of traffic, show valleys around noon and also have higher values in evening peak hours of traffic. The diurnal amplitude of NOx in pre-monsoon (35 ppb) and monsoon (18 ppb) are much smaller than those in post-monsoon (150 ppb) and winter (172 ppb). These trends of CO and NOx may be attributed from emissions of different industrial sources as well as huge number of vehicles circulating in Dhaka metropolitan area. Besides these, some meteorological factors like stable nocturnal boundary layer, lower height of the mixing layer and weaker wind speed are associated with peak of CO and NO_X in night. The diurnal variations of SO_2 in almost all seasons are consistent with those of CO and NOx excepting monsoon. In monsoon, no significant day-night differences available due to clean air from the Bay of Bengal and winter peak is attributed by mainly high emissions of sulphur from brick kilns.

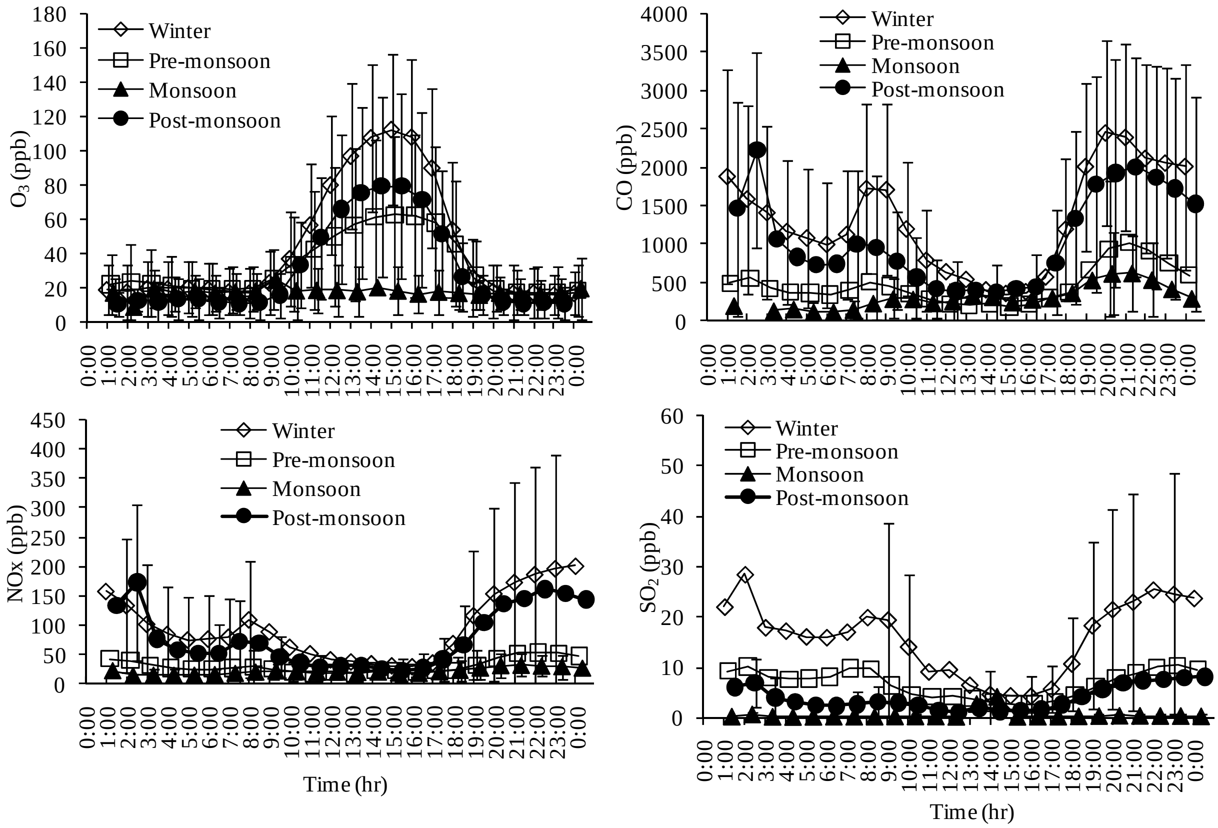
Statistical analysis

A scatter plot was used to provide a better overview and interpretation of the correlations between O_3-CO and O_3-NOx. Table 1 shows the 4-year monthly average slopes (O_3/ CO); (O_3/ NOx) and correlation coefficients (R^2) for the entire data set. Slope and R^2 values were calculated from simple linear regression plots of O_3-CO and O_3-NOx, where CO as x axis and O_3 as y axis; and x is O_3 and y is NOx, respectively (figures are not shown). From the overall data set (O_3-CO and O_3-NOx), negative correlations observed in winter and post-monsoon. No correlation observe in pre-monsoon, while slight positive correlation is found in monsoon, with some exceptional. For example, summer of O_3- NOx has found good positive correlation. Both NOx and CO are emitted from combustion, vehicles and can react to produce O_3. Therefore, negative correlation between O_3-CO and O_3-NOx are reasonable. It seems that negative correlation between trace gases is the typical characteristics of urban area as this behaviour has been observed in other countries of the world [3], [5]. Fig.3 shows one-day average relationship between O_3 – CO and O_3 – NOx as an example of negative correlation (2nd February, 2003). The R^2 values of these two relationships are near to each other (R^2= 0.54 and 0.43, respectively). The behaviour of chemical species in urban atmosphere show complexity and it is difficult to understand their characteristics in the atmosphere.

From our results, highest R^2 values of winter come from February (O_3/ CO = 0.34 and O_3/ NOx = 0.14) associated with high concentration of trace gases. These indicate depression of O_3 by precursors. As O_3 show peak in noon and CO, NOx peak in early morning and late evening, this incidence can occur. A much polluted area like Dhaka, ozone concentrations are depressed through the process of NOx titration (removal of O_3 through reaction with NO). The same explanation can be applicable for post-monsoon O_3 formation and destruction processes.

Some other meteorological factors like solar radiation, rainfall, relative humidity, wind direction and wind speed are responsible for correlations of trace gases. Previous studies [1] have found that lower temperature and rainfall, slower wind speed etc. deteriorate the pollution problem in Dhaka during dry season. The opposite effects are available in pre-monsoon and monsoon season. Much rainfall, strong wind speed and clean air from the Bay of Bengal are the results of weak and no correlation with associated with lower concentration in pre-monsoon and monsoon, respectively. O_3 – NOx in monsoon shows positive correlation with highest slope and R^2 values. However, monthly ***data*** do not afford the validity that is necessary to define monsoon correlation explanation

Fig.2. Averaged diurnal variations of trace gases for four seasons at CAMS during 2002-2005.



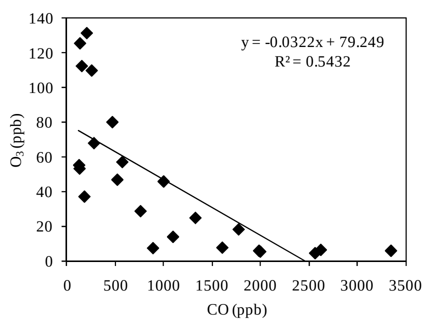


Fig.3. Scatter plot between O_3 – CO (a) and O_3 – NOx (b) at the sampling station

Table 1. Correlation between O_3, CO and NOx concentrations at CAMS, Dhaka.

Month	O_3 - CO		O_3 - NOx	
	Slope	R^2	Slope	R^2
Dec.	-0.02	0.22	-1.03	0.06
Jan.	-0.02	0.2	-0.67	0.1
Feb	-0.03	0.34	-0.81	0.14
Mar	-0.02	0.14	-0.4	0.1
Apr	0	0	-0.04	0
May	0	0	-0.05	0
Jun	0	0.02	0.49	0.12
Jul	0.01	0.17	1.44	0.59
Aug	0	0	1.31	0.4
Sep	0.1	0.54	0.64	0.1
Oct	-0.01	0.04	-0.21	0.04
Nov	-0.02	0.3	-1.6	0.24

CONCLUSION

We present measurements of O_3, CO, NOx and SO_2 at Continuous Air Monitoring Station in the metropolitan area of Dhaka, Bangladesh during April 2002-December 2005. Based on these measurements, the annual mean concentrations were in the range of 28.7-43.3 ppb for O_3, 329.3-829.8 ppb for CO, 41.0-63.2 ppb for NOx and 6.7-9.4 ppb for SO_2. Monthly averaged concentration of measured trace gases show highest in winter and lowest in monsoon. O_3 (variation between O_3concentrations of daytime and 24-hr monthly averaged) of each season have found higher values than 24-hr monthly averaged O_3 concentration. Highest O_3 values indicate strong local pollution with significant photochemical O_3 production in Dhaka. The diurnal cycles of O_3 in different seasons show peaks between 14:00 and 15:00, suggesting local O_3

production as well as transportation of pollutants from nearby brick kilns area are significant. The diurnal variation of CO, NOx and SO_2 have peak during morning and late evening hours over the study area. Scatter plot analysis has revealed negative correlations between O_3-CO and O_3-NOx in winter and post-monsoon associated with high concentration of trace gases also. On the contrary, pre-monsoon and monsoon have weak and no correlation, respectively. Motorized transport vehicles and brick kilns are attributed to high peak of trace gases in different seasons. Observation results suggest that more attention should be given to reduce contribution from emission sources as well as to improve the air quality of Dhaka.

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REFERENCES

[1] A.K. Azad and T.Kitada, Characteristics of the air pollution in the city of Dhaka, Bangladesh in winter, *Atmos. Environ*, Vol.32, No.11, May1998, pp.1991-2005.

[2] B.A. Begum., S.K. Biswas., and P.K. Hopke, Assessment of trends and present ambient concentrations of $PM_{2.2}$ and PM_{10} in Dhaka,

[3] Bangladesh, Air Qual Atmos Health, 2008, pp.125-133.

[4] E.C. Teixeira., E.R de Santana., F. Wiegand., and J. Fachel, Measurement of surface ozone and its precursors in an urban area in South Brazil, *Atmos. Environ*, 43(2009), pp. 2213-2220.

[5] G. Tang., X. Li., Y. Wang., J. Xin., and X. Ren., Surface ozone trend details and interpretations in Beijing, 2001-2006, *Atmos. Chem. Phys.*, 9, 2009, pp. 8813-8823.

[6] M.A. Barrero., J.O. Grimalt., and L. Canton, Prediction of daily ozone concentration maxima in the urban atmosphere, *Chemometrics and Intelligent Laboratory Systems*,80 (2006), pp. 67-76.

[7] Y. Kanaya., M. Fukuda., H. Akimoto., N. Takegawa., Y. Komazaki., Y. Yokouchi., M. Koike., and Y. Kondo, Urban photochemistry in central Tokyo:2. Rates and regimes of oxidant (O_3 + NO_2) production, *J. Geophys. Res.*, 113, D06301, doi: 10.1029/2007JD008671, 2008.