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Trend of ambient air quality in Chittagong City

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Abstract

The ambient air quality data for particulate matter as well as criteria of gaseous pollutants were collected during December 2006 to December 2008 at the Continuous Air Quality Monitoring Station (CAMS) located at TV center, Pahartoli, Chittagong. It was observed that during April- October, 24 hour average concentration of PM_{10} and $PM_{2.5}$ were within the National Ambient Air Quality Standard (NAAQS) level but it increased occasionally by more than two and a half times during the whole non-monsoon period (November-March). The highest values found of $PM_{2.5}$ were 327 µg/m^3 and 254.9 µg/m^3 24 hour average concentration in January 2007 and December 2008 respectively. Whether, the highest alarming concentration of PM_{10} was reported as 545 µg/m^3 in January 2007. The other gaseous pollutants such as SO_2, NO_2, O_3, CO and hydrocarbons remain well within the permissible limit except dry winter.

Keywords: Gaseous pollutant, $PM_{2.5}$, PM_{10} , Air quality

Introduction

Chittagong is a port city situated in the southern region of Bangladesh. The city is surrounded by hills to the east and the Bay of Bengal in the southwest. One of the beautiful rivers in Bangladesh, the Karnaphuli River flows into the Bay of Bengal through the city. The city has complete tropical monsoon climate with hot, wet summer and dry, cool winter seasons. The maximum temperature are between 29 °C and 35 °C in monsoon and minimum temperature are between 12 °C and 17 °C in winter. The total annual rainfall throughout the city varies between 2159 mm (85 inches) and 3048 mm (120 inches) rising sometimes to 3810 mm (150 inches). On average approximately 80% of the rainfall occurs during the May to September monsoon. During summer season, winds are generally from the southeast. Easterly and northeasterly winds prevail during the winter periods.

The 2001 National census determined that the Chittagong statistical metropolitan area had a population of approximately 3.56 million in approximately 430,000 households.

It is one of the most densely populated cities in the country and facing a high level of air pollution. High influx of people from rural areas, emissions from various kinds of diesel vehicles and badly maintained automobiles, biomass/coal burning for cooking and in the brick kilns, huge number of construction works, re-suspended road dust etc. is making Chittagong as one of the most polluted cities in the country. Not much research has been done on air quality of Chittagong, but the air quality of the city is comparable to capital city Dhaka, where according to a recent World Bank Report, it has been estimated that every year around 10,800 premature deaths along with several million cases of illness are being caused by the air pollution. The economic cost of this sickness and deaths is estimated to be $132 - $583 million per year for Dhaka (Brandon, 1997). Similar scenario is also present for the second largest city of Bangladesh. Impact of banning of two-stroke engine of airborne particulate matter concentrations in Dhaka has been studied (Begum *et al.,* 2006).

Atmospheric pollution in urban areas is a major issue in many developing countries around the world. Sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) are important primary pollutants in the ambient air because of their adverse effects on human health and vegetation, their contributions to the acidification of the environment (Legge and Krupa, 1990) and the role of oxides of nitrogen (NO_2) in the formation of photochemical oxidants. NO_2 contributes to the buildup of tro-

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pospheric ozone (O_3) and to the lifetime of greenhouse gases (Houghton *et al.,* 1990) and thus be also a key species for global warming. Particulate air pollution can be generated by natural and anthropogenic activities. Anthropogenic sources can be stationary and mobile. It has been estimated in many countries that, traffic-related emissions constitute more than 50% of the total particulate air pollution (Protection, 1996). Diesel engines power land and sea transports, provides electrical power, and are used for many farming, construction, and industrial activities. However, diesel engines pollute the environment, and concern is growing over how much diesel pollution affects human health and well-being. Chittagong (latitude 22.22N, longitude 91.47E) has the largest port in Bangladesh, and is heavily trafficked, especially the central city area covering about 10 km^2. The main road network in the city goes toward the port area and northward toward the industrial areas. These roads are also heavily trafficked, with persistent traffic jams most of the day. Trucks transporting goods between the port and the industrial areas constitute a significant part of the traffic, and the combination of the hilly nature of the area, the stop and start mode of the congested traffic, and the age and heavy loading of most of the trucks causes large emissions of black diesel smoke. Brick kilns are important source of building materials and pollution. Prior work in Dhaka has suggested a major role for brick kilns in producing air pollution there (Begum *et al*., 2004). Vehicular emissions, as well as biomass/coal burning for cooking and in the brick kilns around the city, are the main contributor to these emissions (Chaloulakou *et al.,* 1999; Kassomenos *et al*., 1995).

Impact on human health of both the particulate matter ($PM_{2.5}$ and PM_{10}) has been studied (Dockery *et al.,* 1993, Dockery *et al.,* 1989). The monitoring activities and results of these harmful particulate matter along with other gaseous pollutant should be disseminate to the general public as well as policy makers to identify the areas where the ambient air quality standards are being violated and plans are needed to reduce pollutant concentration levels to be in attainment with the standards. Motorized transports are suspected to be the single largest contributor of air pollution in Chittagong City. Smoke opacity of different type of diesel vehicle in Dhaka City has been studied (Rouf *et al.,* 2008). Diesel engine emissions are now the major source of air pollution and therefore significant improvements in air quality will only be realized through diesel engine emission control. Trend of particulate matter $PM_{2.5}$ and PM_{10} in Dhaka City has been studied (Rouf *et al.*, 2011). Assessment of particulate air pollution at Kalbagan and Shisumela area along the Mirpur Road has been done (Begum *et al.,* 2011). Investigation of sources of atmospheric aerosol at urban and semi-urban areas in Bangladesh has been studied (Begum *et al.,* 2004). A high concentration of air pollutants such as black carbon in Dhaka City has been reported (Salam *et al.,* 2003). Sources identification for air pollution has been done by (Begum *et al.,* 2009). Begum *et al.,* 2012 has also been studied on Ground level concentration of ozone in ambient air of Chittagong City for the period of December 2006 to December 2007. Ambient air quality standard for Bangladesh is shown in Table I.

Table I: Ambient air quality standards for Bangladesh

Pollutant	Objective (Bangladesh Standard), $\mu g/m^3$	Averaging Time
CO	10 000, (9 ppm) [a]	8 hour
	40 000, (35 ppm) [a]	1 hour
Lead	0.5	Annual
NO_2	100, (0.053 ppm)	Annual
PM_{10}	50	Annual [b]
	150	24 hour [c]
$PM_{2.5}$	15	Annual
	65	24 hour
O_3	235 , (0.12 ppm)	1 hour [d]
	157, (0.08 ppm)	8 hour
SO_2	80, (0.03 ppm)	Annual
	365, (0.14 ppm)	24 hour [a]
SPM	200	8 hour

[a] Not to be exceeded more than once per year.
[b] The objective is attained when the annual arithmetic mean is less than or equal to 50 $\mu g/m^3$.
[c] The objective is attained when the expected number of days per calendar year with a 24 hour average of 150 $\mu g/m^3$ is qual to or less than one.
[d] The objective is attained when the expected number of days per calendar year with the maximum hourly average of 0.12 ppm is equal to or less than one.

The following are the objectives of this research work:

To find out seasonal variation of concentration of gaseous pollutants in Chittagong City in order to understand its health impact.

To identify main air pollutant in order to develop Air Quality Index (AQI).

Methodology

A continuous air monitoring station (CAMS) was operated in Chittagong to measure criteria pollutants. The location of the CAMS is in the Chittagong Television Station Camps at Khulshi, which is on the hilltop about 2.5 km northwest of the downtown and about 100 meters above the surrounding area. Because of the topography of the city (hilly area) and no significant source of air pollution close to this site, this location is relatively unaffected by nearby air pollution sources. It is representative of the air pollution concentrations at that height in the area, within a radius of some 500 meters. This will be radius of the station to avoid nearby pollution of the monitoring station.

Multiple gaseous / PM analyzers as shown in Figure 1 are used for Continuous gaseous monitoring. Gaseous PM analyzers were made by Environment S.A., France. UV Fluorescence was used as SO_2 analyzer; chemiluminescence was used as NO_2 analyzer, while NDIR principle was employed to analyze CO. CH_4 and non CH_4 were measured by Flame Ionization Detector. Particulate matter was analyzed by Beta Gauge analyzer and O_3 was measured by UV Fluorescence. All instruments were certified by USEPA.

Fig. 1: Multiple Gas analyzers inside of CAMS

The on line air monitoring has been designed by Environment S. A., French for monitoring SO_2, NO_2, CO, O_3 and Hydrocarbon & Non-methane hydrocarbon. Air sampling was done continuously and the data were recorded in Data logger as 15 minute average. Different data reporting system were carried out by CAMS personnel.

Results and Discussion

Based on 24 hour average data for gaseous pollutants, it has been found that the trend of the levels increased during the time 6 PM to 10 AM time in the Chittagong City. Normally, in the range of 10 AM to 6 PM concentration of gaseous pollutants were remained below the level. In the day time, the level of concentration remains below at certain time. This phenomenon was happened mainly for SO_2 and NO_2 gaseous pollutants. But the levels of concentration of these pollutants were not alarming against their standard. Other gaseous pollutants did not show this type of order. This situation was happened for the falling of temperature at night time and for the increasing of flying of diesel vehicles. It has clearly been shown in the daily report (Table II). It may be noted that normally gaseous pollutants level concentration are related to temperature, vehicle emission and seasonal variation. At night time concentration level become higher because gaseous pollutants come down the ground level with the decreasing of temperature and mainly gross polluting diesel vehicles were increasingly run in city area. At that time those gross polluting vehicles emit SO_2 and NO_2. So, at night time gaseous pollutants concentration were increased significantly. At morning, it becomes again decrease due to less vehicle flow and temperature variation. In other words pollution concentration was affected by seasonal variation. Pollution concentration was found to be decreased, during monsoon period mainly April to October due to rain, moderate wind speed and highest temperature. In non-monsoon period mainly November to March (dry weather) pollution concentration was higher due to less wind speed, temperature falling as well as less rainfall.

It was found using trend analysis of gaseous pollutants (SO_2, NO_2, CO, O_3, CH_4, NMHC, THC) since January 2007 to December 2008 that the concentrations of pollutants were fluctuated during non-monsoon period (November to March) and monsoon period (April to October). All Pollutants level were maintained below against its respective average standard (Table I) during monsoon (April to October) and non-monsoon period (November to March).

Table II: Daily report format of different gaseous pollutants (Station: CAMS CTG, Report Type: Mean, Time Base: 1 Hour)

Date	Time	SO_2 (ppb)	NO (ppb)	NO_2 (ppb)	NO_X (ppb)	CO (ppm)	O_3 (ppb)	CH_4 (ppm)	NMHC (ppm)	THC (ppm)	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)	WD (Deg)	WS (m/s)	VWS (m/s)	RH (%)	AT (DegC)	Rain (mmH$_2$O)	SR (w/m^2)	BP (KPA)
15/02/2007	01:00	0.71	19.46	25.46	45	3.42	1.21	6.36	0.87	7.18	140.33	118.7	135.35	0.47	1.71	98.63	18.41	19.72	-1.41	998.76
	02:00	1	20.72	27.04	48	3.43	0	7.05	0.77	7.82	99.11	74.75	29.05	0.63	1.71	99.6	18.21	19.72	-1.14	998.92
	03:00	2.94	9.4	22.81	33	3.53	0.07	8.05	0.87	8.92	86.89	54.76	33.66	0.83	1.71	99.63	17.99	19.72	-1.25	998.98
	04:00	1.66	12.34	21.06	34	3.52	0	7.6	0.74	8.35	106.59	73.39	40.44	0.85	1.71	99.64	17.86	19.72	-1.28	999.22
	05:00	2.9	15.16	21.39	37	3.35	0	7.08	0.69	7.66	118.98	84.45	34.64	0.75	1.71	99.59	17.59	19.72	-1.33	999.47
	06:00	11.91	22.23	25.47	48	3.49	0.02	7	0.62	7.61	138.3	85.6	37.19	0.88	1.72	99.65	17.24	19.72	-1.27	999.66
	07:00	8.88	16.34	22.43	39	3.55	0.04	4.26	0.57	4.83	156.95	101.76	34.56	0.91	1.72	99.6	16.66	19.72	11.19	999.8
	08:00	14.52	26.44	30.32	57	4.72	0.55	4.93	0.87	5.8	132.99	92.69	32.07	1.04	1.72	99.65	17.47	19.72	80.28	998.65
	09:00	7.87	27.85	30.79	59	4.13	1.16	4.01	0.53	4.52	165.56	109.76	56.72	0.88	1.72	99.13	18.28	17.87	59.82	997.73
	10:00	7.36	8.75	26.32	35	3.56	6.69	3.14	0.43	3.57	151.45	105	47.54	0.73	1.72	89.08	19	1.93	205.95	997.44
	11:00	14.5	20.08	43.29	64	3.88	6.21	3.57	0.52	4.07	127	74.82	43.47	0.63	1.72	73.43	21.97	1.93	417.79	992.87
	12:00	4.19	2.69	17.52	21	2.62	18.46	2.65	0.25	2.89	130.39	67.43	65.02	1.5	1.72	67.1	23.46	1.93	672.42	990.86
	13:00	DNA	0.15	10.75	11	1.21	28.26	2.42	0.16	2.55	98.26	36.58	58.08	1.24	1.72	DNA	24.05	DNA	321.25	DNA
	14:00	1.13	0.07	9.97	11	1.1	31.43	2.19	0.12	2.3	69.65	19.51	197.29	1.14	1.71	45.72	25.46	1.93	631.55	989.26
	15:00	0	0.26	12.09	13	0.66	33.88	2.17	0.12	2.29	40.87	13.32	244.07	0.95	1.71	30.4	25.92	1.93	533.53	990.58
	16:00	0	0	8.87	9	0.88	34.26	2.16	0.09	2.26	22.02	10.54	224.74	0.53	1.71	29.32	25.94	1.93	380.8	989056
	17:00	0	0	10.24	10	0.8	35.46	2.28	0.14	2.43	17.11	8.27	205.07	1.86	1.71	32.13	25.33	1.93	202.31	990.27
	18:00	0	0	10.23	10	0.97	35.08	2.58	0.23	2.82	20.14	9.96	192.98	1.65	1.71	45.23	23.07	1.93	39.47	994.19
	19:00	0.52	3.47	25.67	29	1.59	17.35	3.17	0.51	3.68	21.06	21.16	182.5	0.61	1.71	60.19	21.16	1.93	-1.32	996.84
	20:00	2.13	117.14	79.62	197	4.47	1.86	6.05	2.13	8.17	98.28	61.69	214.34	0.18	1.71	80.07	19.17	1.93	-1.5	998.58
	21:00	2.39	117.23	71.9	190	5.59	1.74	8.37	2.31	10.39	310.33	200.01	166.82	0.17	1.71	86.08	18.35	1.93	-1.22	999.15
	22:00	2.37	136.13	69.43	206	5.16	0.75	8.41	1.86	10.17	421.64	297.84	140.99	0.16	1.71	86.18	18.17	1.93	-1.41	999.22
	23:00	1.87	34.7	41.25	76	3.16	1.01	4.94	0.72	5.54	395.19	271.64	145.15	0.17	1.71	77.97	18.22	1.93	-1.32	999.47
	24:00	1.59	63.73	46.31	111	3.68	0.85	5.9	0.93	6.72	290.03	195.1	214.96	0.12	1.71	82.65	17.62	1.94	-1.52	999.97
Min		0	0	8.87	9	0.66	0	2.16	0.09	2.26	17.11	8.27	29.05	0.12	1.71	29.32	16.66	1.93	-1.52	989.26
Time		15.00	16.00	16.00	16.00	15.00	02.00	16.00	16.00	16.00	17.00	17.00	02.00	24.00	17.00	16.00	07.00	22.00	24.00	14.00
Max		14.52	136.13	79.62	206	5.59	35.46	8.41	2.31	10.39	421.64	297.84	244.07	1.86	1.72	99.65	25.94	19.72	672.42	999.97
Time		08.00	22.00	20.00	22.00	21.00	17.00	22.00	21.00	21.00	22.00	22.00	15.00	17.00	09.00	06.00	16.00	06.00	12.00	24.00
AVG		3.93	28.1	29.59	58	3.02	10.68	4.85	0.71	5.52	139.96	91.2	115.7	0.79	1.71	77.42	20.27	8.81	147.52	996.5
Num		23	24	24	24	24	24	24	24	24	24	24	24	24	24	23	24	23	24	23
Data,%		95.8	100	100	100	100	100	100	100	100	100	100	100	100	100	95.8	100	95.8	100	95.8
STD		4.493	38.91	19.53	57.84	1.426	13.84	2.186	0.59	2.623	107.9	77.18	77.18	0.461	0.004	24.43	3.127	8.587	217.1	3.777

***DNA: Data Not Available**

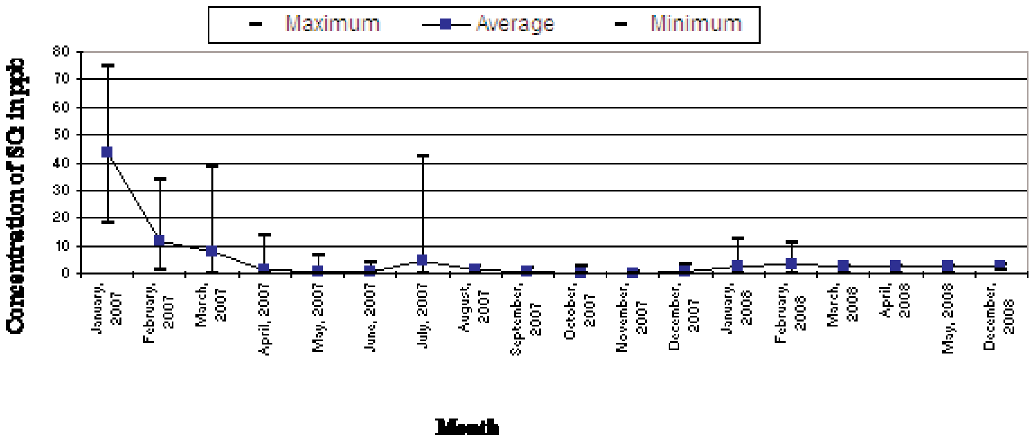

Fig. 2: 24 hour average SO_2 at CAMS, Chittagong (monthly average, maximum and minimum)

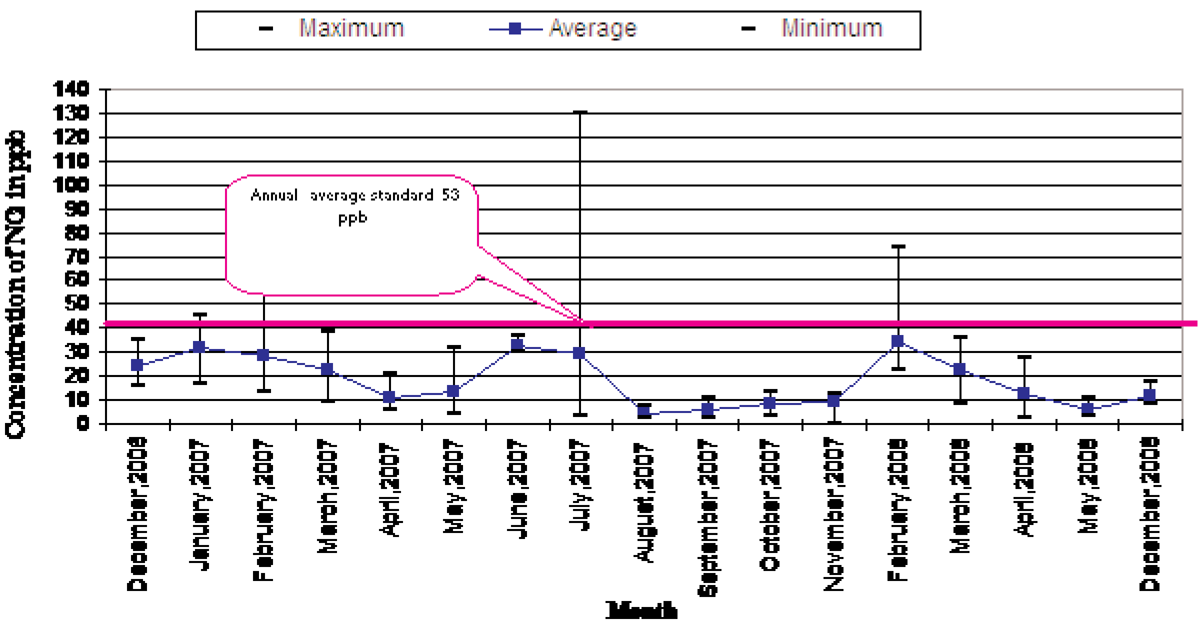

Fig. 3: 24 hour average NO_2 at CAMS, Chittagong (monthly average, maximum and minimum)

However, average concentration level of NO_2 was higher in the month of January 2007. But none were able to exceed the standard against 1 hour average and also 24 hour average. In January 2007 and December 2008, the highest monthly average (24 hour and 1 hour) concentration was found for most of the pollutants (SO_2, NO_2, CO and O_3) except CH_4 (Figure 2-6).

The highest and lowest 24 hour monthly average concentration of SO_2 was 43.64 ppb and 0.01 ppb in January and November 2007 respectively. It was unfortunate that we could not able to get 24 hour average concentration of SO_2 and NO_2 from June to November 2008 due to non-functioning of SO_2 and NO_2 analyzer. In February 2008 and August 2007 highest and lowest 24 hour monthly average concentration of NO_2 was found to be 32.98 ppb and 2.7 ppb respectively. The highest 1hour monthly average concentration of CO was found to be 3.13 ppm in January 2007 and lowest 1 hour average concentration 0.92 ppb was found in June 2007. These values were below than that of the 1 hour CO standard. 1 hour monthly average concentration O_3 was

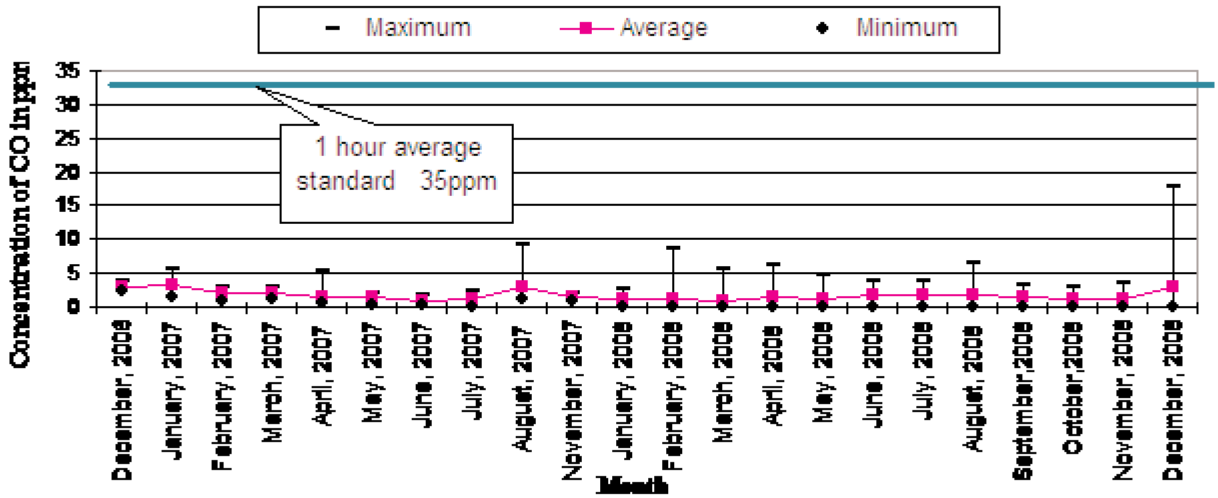

Fig. 4: 1 hour average CO at CAMS, Chittagong (monthly average, maximum and minimum)

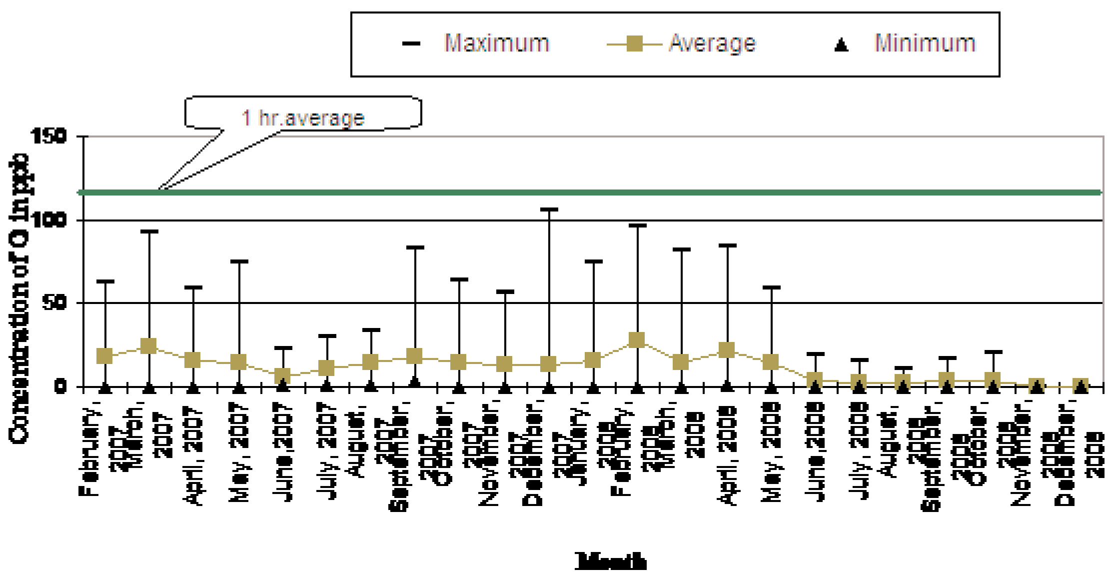

Fig. 5: 1 hour average O_3 at CAMS, Chittagong (monthly average, maximum and minimum)

found to be 28.15 ppb, in February 2008. Although in December 2007 the maximum value of O_3 was 105 ppb. This was the highest monthly 1 hour concentration of O_3 since CAMS instillation. However the lowest concentration 2.53 ppb was found in July 2008.

The highest 15 minute average monitoring results of CH_4 was found 5.83 ppb in September 2008 and lowest average concentration 0.09 ppb was in March 2008. Unfortunately, continuous two years monitoring could not be accomplished due to equipment disruption. Last nineteen months sampling results revealed that CH_4 were not much concerning pollutants in terms of air pollution. However, lots of CNG vehicles were running into the city area. It was envisaged from the present number of CNG vehicles that the concentration of CH_4 may be raised in near future. O_3 and NO_2 have been denoted much concerning pollutant among the gaseous pollutants at Chittagong CAMS. Although monthly average value of O_3 is remained always lower than its 1 hour average value. So far, monthly 24 hour average CAMS data indicates that all gaseous pollutants were remained within the permissible limit except dry winter.

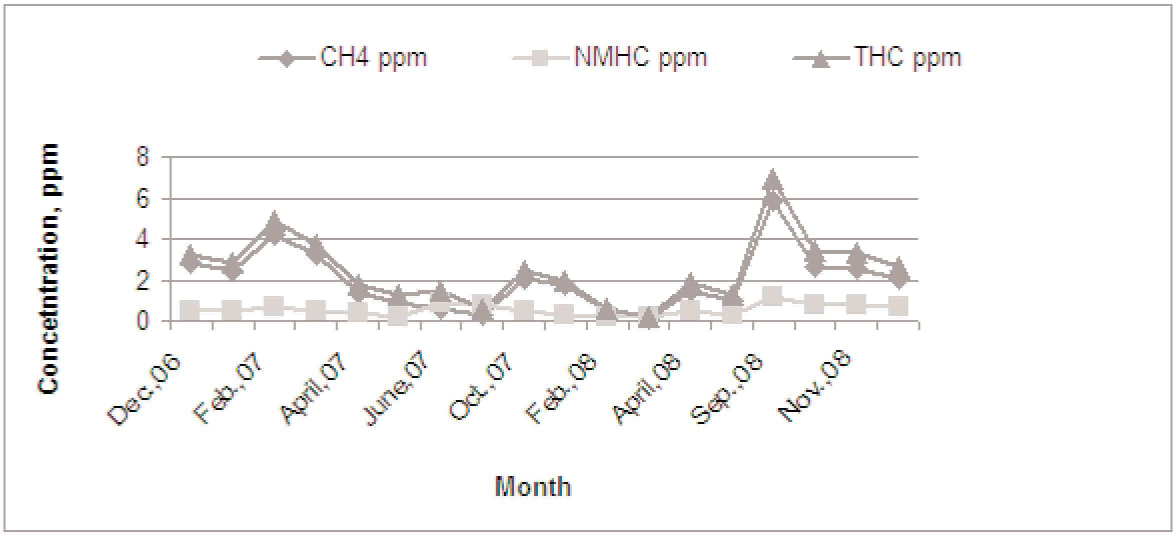

Fig. 6: Monthly 15 minute average hydrocarbon at CAMS, Chittagong

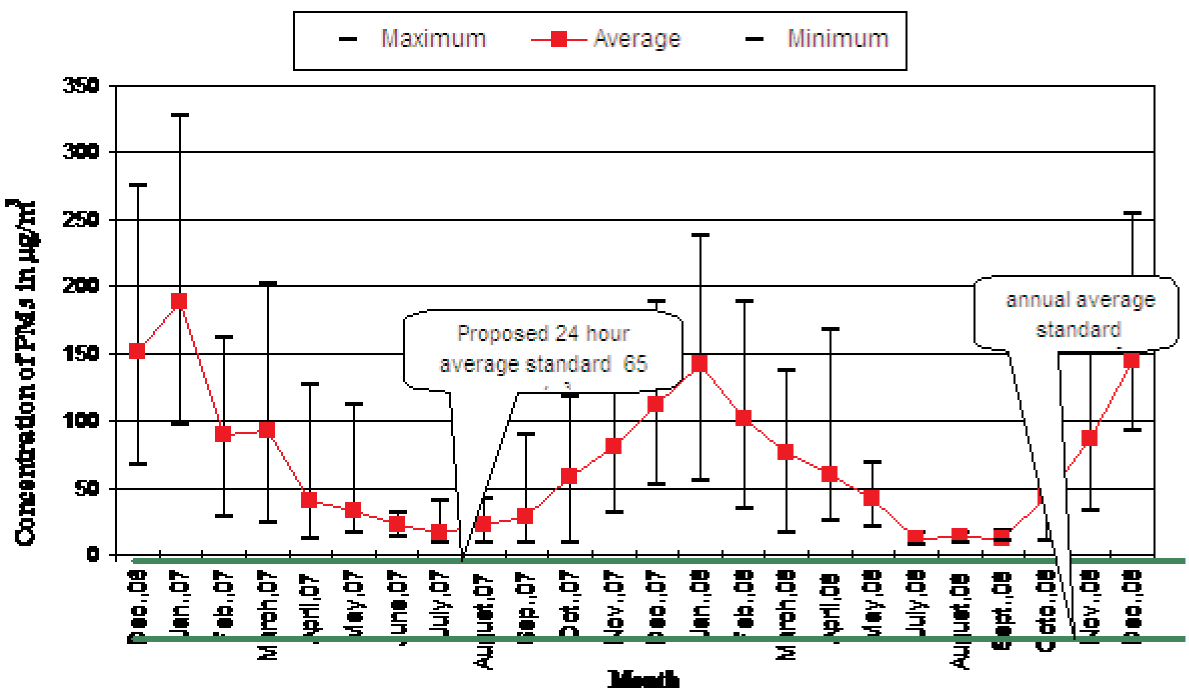

Fig. 7: 24 hour average $PM_{2.5}$ at CAMS, Chittagong (monthly average, maximum and minimum)

$PM_{2.5}$

The National Ambient Air Quality Standard for $PM_{2.5}$ is 65μg/m^3 for 24 hour on average (Table I) and for annual arithmetic mean the standard is 15 μg/m^3. Figure 7 presented the individual $PM_{2.5}$ data measured at CAMS in 2007-2008. It revealed clearly the seasonal variation of $PM_{2.5}$ concentration in monsoon (April to October) and non-monsoon (November to March) period against the 24 hour average standard since December 2006. Moreover, from November to March $PM_{2.5}$ exceeds 24 hour average standard. The concentration starts to decrease from February and it continues till July and again it starts to increase from August and continues till January. In the period of April to October, the concentration of $PM_{2.5}$ remains below the 24 hours standard. In fact, 24 hour average $PM_{2.5}$ concentration starts to increase in

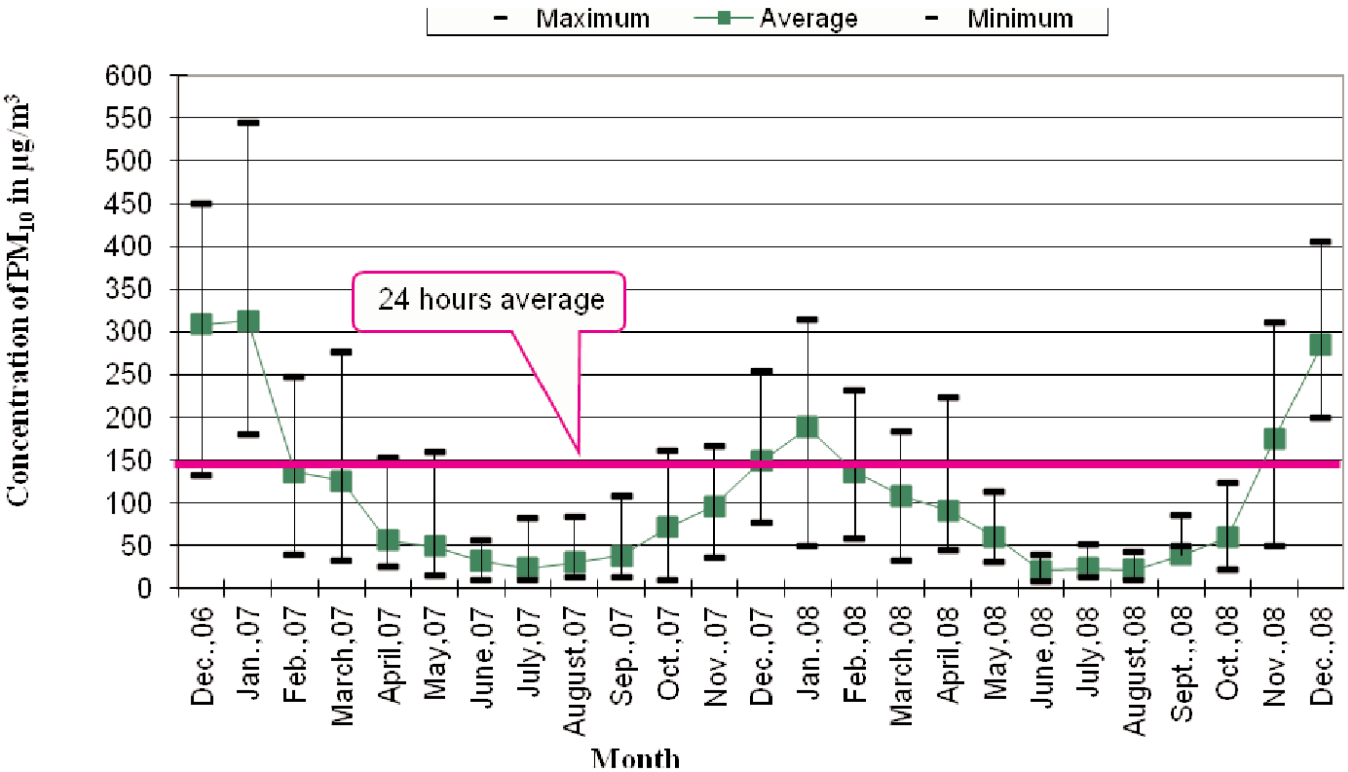

Fig. 8: 24 hour average PM_{10} at CAMS, Chittagong (monthly average, maximum and minimum)

October. The maximum concentration of $PM_{2.5}$ has been observed in January. It has behaved like other gaseous pollutants. The maximum and minimum value of $PM_{2.5}$, 24 hour average concentration was found to be 327µg/m^3 in January 2007 and 9µg/m^3 in July-October 2007 respectively. However, the maximum average concentration was existing 187.79 in the month of January 2007.

But the highest concentration was found 254.9 µg/m^3 and lowest concentration was 07 µg/m^3 in December and July 2008 respectively. During this time the average concentration remained 144.68 µg/m^3. It is noted that lowest rainfall was recorded in the month of January 2008 resulting $PM_{2.5}$ concentration found less than that of 2007. In addition, CNG vehicles increased significantly than that of previous year. Most cases, monthly percentage of $PM_{2.5}$ were exceeded by almost 42%.

PM_{10}

The National Ambient Air Quality Standard for PM_{10} is 150µg/m^3 for 24 hour average and for annual arithmetic mean the standard is 50 µg/m^3 (Table I). Fig. 8 presents the individual PM_{10} data measured at CAMS in 2007-2008. 24 hour average monthly concentration of PM_{10} has been found distinctly differed from that of monsoon (April to October) and non-monsoon (November to March) period against the 24 hour average standard. It has also indicated that January was the worst polluted month in terms of PM_{10}. The highest values found of $PM_{2.5}$ were 327 µg/m^3 and 254.9 µg/m^3 24 hour average concentration in January 2007 and December 2008 respectively. Whether, the highest alarming concentration of PM_{10} was reported as 545µg/m^3 in January 2007. So, it is clear that the highest as well as the average 24 hour concentration superseded its standard in 2007 and 2008. Almost all pollutants have been shown its highest concentration in January. It is noted that the decreasing and increasing trend of pollution for PM_{10} followed almost like $PM_{2.5}$.

However, percentages of PM_{10} were exceeded by almost 17% against the 24 hour monthly average that was much below than $PM_{2.5}$. In the monitoring period of December 2006-December 2008 (Fig. 8) indicated that the highest and lowest 24 hour average monthly value was observed 312.57 $\mu g/m^3$ and 23.36 $\mu g/m^3$ in January and July 2007 respectively. In January 2008, little rainfall was occurred declining concentration of PM in comparison to January 2007. During January to March, average 24 hour concentration of PM_{10} value was reported higher than same period of previous year. The level of concentration found in 2008 was lesser than that of 2007. Moreover, CNG vehicles gradually increasing in the city area since 2007 might be responsible for the improving situation.

Conclusion

Chittagong City is affected with severe air pollution where particulate matter is being identified as the main pollutant of concern. Data from the monitoring station reveals that the pollution from particulate matters greatly varies with climatic conditions. While the level comes down the limit value in the monsoon period (April-October), it goes beyond the limit during non-monsoon time and sometimes even crosses two and a half times during the non-monsoon period (November-March). The extent of pollution level during non monsoon period was found to be much higher than the standard level indicating alarming threat to the human heath. The highest values of 24 hour average concentration of $PM_{2.5}$ are 327 $\mu g/m^3$ and 254.9 $\mu g/m^3$ in January 2007 and December 2008 respectively, while other gaseous pollutants remain within the permissible limit except dry winter. Emission from vehicles, domestic cooking, brick fields, industries, and building construction material and road dust are the main sources of pollution. It is also necessary to remove all old vehicles from the city for improving the air quality. Government should take proper initiative to control air pollution in order to improve health quality of the people of the city.

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