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Assessment of Air Quality for Selected Locations in Chittagong City Corporation Area, Bangladesh

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ABSTRACT
Air quality is one of the important environmental components that must be assessed. This paper provides an overview of air quality in Chittagong city as well as an evaluation of air contaminant emissions, air quality trends. The ambient air quality data for particulate matter as well as criteria of gaseous pollutants were congregated for 2013 to 2015. Analysis manifested that during April to October, 24 hour average concentration of PM_{10} and $PM_{2.5}$ were within the National Ambient Air Quality Standard (NAAQS) level, while it accelerated about three times of NAAQS during the whole non-monsoon period (November to March). The other gaseous pollutants such as SO_2, NO_2, O_3 and CO remain decent within the permissible limit except dry non-monsoon period. The gradual increase of yearly average Air Quality Index (AQI) value indicates the air pollution turns up over the years in Chittagong city. The main responsible pollutant for pollution is found as $PM_{2.5}$. In this study, emission inventory model has been also developed for five pollutants, namely PM_{10}, $PM_{2.5}$, SO_x, NO_x and CO, considering vehicular emission in Chittagong city. It is found that diesel driven vehicles (i.e. buses, trucks) release significant percent of emission which is about 77 percent of total emission (5264.08 tons/year). The amount of emission about 300 (tons/km/year) for the road aligned from Dewanhat to GEC circle is appeared to be the most polluted road sites than the other roads considered illustrating higher ADT and confined nature of road sites.

Keywords
Air quality; emissions; pollutants; emission inventory

1. INTRODUCTION
Chittagong, the commercial capital of Bangladesh stands on the right bank of the river Karnaphuly. There are several sources of air pollution in Chittagong city, among these road traffic sectors, manufacturing industries, on-going construction activities are seen prominent [1]. In Bangladesh, the number of reconditioned vehicles has increased every year while one third of these vehicles merely have any fitness certificate [2]. Apart from road presence of port facilities this city is an attractive option for the investors to build up industries. A number of Export Processing Zones (EPZ) has been established by the local and foreign investors (BBS, 2010) [3]. While industrial development is key for economic prosperity, nevertheless, maintaining the environmental rules and regulations is also key for sustainable development. Along with this, it is also seen that many shopping and recreational facilities are placed alongside the roads within the boundary of the study area considered, where human exposure to air pollution caused by vehicular induced turbulence is found to occur. Though green landscape around Chittagong city and heavy rainfall during monsoon helps to reduce the intensity of air pollution, a significant change in land uses and human intervention since last decade aggravate the degradation of air quality. The major steps taken so far to protect the city dwellers from the hazards of air pollution primarily involve reducing vehicular emission using compressed natural gas as fuel. However, the emissions from non-vehicular sources have been neglected [4]. The prevalent issues and conditions of the country urge considerable studies on air quality and its probable hazard assessment towards improved air quality and environment of Chittagong city. A study is therefore planned to assess air quality in selected locations in Chittagong city corporation area for identifying the pollution level. It is also aimed to develop emission factor for improved monitoring and better management of air quality. It is hoped that the study will help to develop a tool for concerned authority as well as others to evaluate the potential option for improved air quality.

2. LITERATURE REVIEW
Air pollution is one of a variety of manmade environmental disasters that are currently taking place all over the world [5], [6]. Air quality has deteriorated both due to human activities, and natural phenomenon such as windblown dust particles etc. Recently, air pollution has received priority among environmental issues in Asia, as well as in other parts of the world. Exposure to air pollution is the main environmental threat to human health in many towns and cities. Particulate emission derived from road traffic sector is primarily responsible for increased death rate and respiratory problems for the urban population. This problem is acute in Dhaka being the capital of the country and also in Chittagong the commercial city of Bangladesh [7], [8]. Hence, estimation and understanding of the present status and the level of air pollution at different sites is deemed necessary. A comprehensive study on air pollution and its impact need to be undertaken to find out the degree of air pollution. The effect of air pollution can be estimated only when the quality of air of the region is available. In order to understand the air quality of an area, measurements of air quality parameters are required. In order to assess quality of air for the designated locations it is always essential to evaluate and compare the measured data with already established standard. Table 1 lists the air quality standards of Bangladesh and the World Health Organization (WHO) [9] that are used in this study. It is seen from the Table 1 that these WHO guideline is bit more stringent than Bangladesh standard. It is generally understandable that in Bangladesh air pollution got only a recent attention to the policy makers and environmental professionals. The standard used for Bangladesh is explained in general, and in some cases results are also compared with WHO guideline for better representation from global context.
Air Emission Inventories (AEIs) can be considered as a structured collection of both information about emissions and technological,

economical and territorial data. By organizing data, inventories permit the individuation of pollution sources and their localization. The quantitative emissions estimates provided by an inventory promote a better understanding of the actual emissions and help to raise the awareness of both policy makers and the general public. Through this process, the major emission sources can be identified, priorities for emission reduction defined and any data gaps requiring further work are revealed.

An emission factor is a representative value that relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e. g., kilograms of particulate emitted per mega gram of coal burned). To calculate emission rates for different types of vehicles, various emission factor models are used throughout the world. Density, flow, vehicle composition, v/c ratio, the number of traffic lights per mile, signal coordination, and the number of stops per mile are traffic-related variables. Congested traffic conditions increase emissions and reduce speed compared to free flow conditions [10],[11].

Table1. Ambient air quality standards for Bangladesh and WHO (2006) Guideline

Pollutant	Bangladesh standard	WHO Guideline	Averaging time
Carbon Monoxide (CO) (mg/m^3)	10 mg/m^3 (9 ppm)	10	8 hour(a)
	40 mg/m^3 (35 ppm)	30	1 hour(a)
Oxides of Nitrogen (NOx) ($\mu g/m^3$)	100 $\mu g/m^3$ (0.053 ppm)	-	Annual
Suspended Particulate Matter (SPM)	200 $\mu g/m^3$	-	8 hours
Coarse	50 $\mu g/m^3$	20	Annual
Particulates (PM_{10}) ($\mu g/m^3$)	50 $\mu g/m^3$	15	Annual(b)
	150 $\mu g/m^3$	50	24 hours(c)
Fine Particulates ($PM_{2.5}$) ($\mu g/m^3$)	15 $\mu g/m^3$	10	Annual
	65 $\mu g/m^3$	25	24 hours
Ozone (O_3) ($\mu g/m^3$)	235 $\mu g/m^3$ (0.12 ppm)	-	1 hour(d)
	157 μg/m3 (0.08 ppm)	100	8 hours
Sulfur dioxide (SO_2) ($\mu g/m^3$)	80 $\mu g/m^3$ (0.03 ppm)	-	Annual
	365 $\mu g/m^3$ (0.14 ppm)	20	24 hours(a)

Notes:

(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 ug/m3.

(c) The objective is attained when the expected number of days per calendar year with a 24- hour average of 15 μg/m3 is equal to or less than 1.

(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 1.

3. METHODOLOGY

The methodology followed in the present study in field investigation, comparison and evaluation trend of air quality for different time period, total vehicular emission inventory for Chittagong city considering the major roads and establishing emission factor for local context.

3.1. Selection of Base year

For the development of the vehicular emission inventory, the year 2015 has been selected as the base year, considering the time-frame of the available data and for comparing and evaluating the trend of air quality the years 2013-2015 has been selected as the base year.

3.2. Field Investigation

For assessing the air quality, suspended particulate matter weew measured in some selected locations in Chittagong city as below.

- A.K. Khan Gate
- City Gate
- GEC Moor
- Sholashar Gate-2
- Agrabad Moor
- New Market Moor

In Figure 1, the selected locations are showed.

Figure 1. Selected locations of field investigation

3.3. Selection of Pollutants

In this study only one pollutant e.g. suspended particulate matter has been selected for field investigation. For developing emission inventory 4 criteria pollutants have been selected. These are particulate matter (PM_{10} and $PM_{2.5}$), Carbon Monoxide (CO), Oxides of Nitrogen (NOx) and Oxides of Sulfur (SOx).

3.4. Trend of Air Quality

The ambient air quality data for particulate matter as well as criteria of gaseous pollutants were collected during December 2013 to December 2015 from the Continuous Air Quality Monitoring Station (CAMS) located at Agrabad, Chittagong.

There are eleven (11) fixed Continuous Air Monitoring Stations

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(CAMS) in Bangladesh. Two of them located in Chittagong one at TV station, Khulshi and another at Agrabad.
Since Chittagong TV stations data are not reliable and available for the whole period, only data from Agrabad CAMS station are used for preparing trend of air quality in Chittagong city.

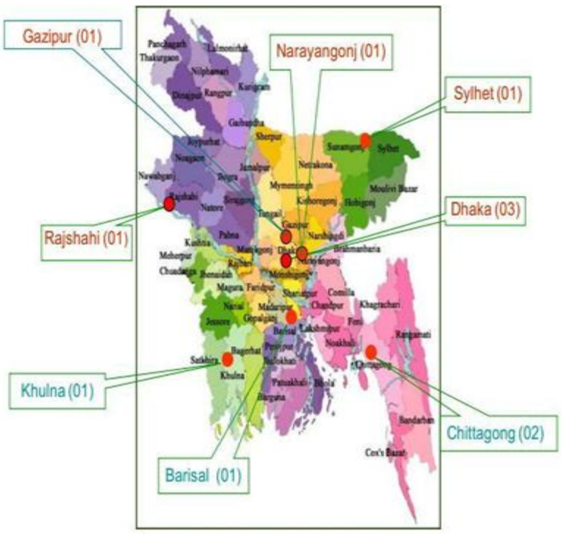

Figure 2. CAMS location in Bangladesh

An air quality index (AQI) is a number used by government agencies to present the limit of air pollution to the public how polluted the air currently is or how polluted it is forecast to become. As the AQI increases, an increasingly large percentage of the population is likely to experience increasingly severe adverse health effects [12].Based on AQI, air quality is categorized by USEPA which is presented in Table 2.
Air Quality Index (AQI) is calculated according to the formula given by USEPA for the year 2013 to 2015. The mathematical expression is given below:

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}}(C_p - BP_{Lo}) + I_{Lo}$$

Where, I_p = the index value for pollutant P;

C_p = the truncated concentration of pollutant P;

BP_{Hi} = the breakpoint that is $\geq C_p$;

BP_{Lo} = the breakpoint that is $\leq C_p$;

I_{Hi} = the AQI value corresponding to BP_{Hi} ;

I_{Lo} = the AQI value corresponding to BP_{Lo} ;

Table 2. AQI Categories (USEPA) [13]

AQI Value	Descriptor
0-50	Good
51-100	Moderate
101-150	Unhealthy for Sensitive group/Caution
151-200	Unhealthy
201-300	Very Unhealthy
>300	Extremely Unhealthy

3.5. Development of Emission Inventory

Like other busy city, the major sources of air pollutants in Chittagong city are motor vehicles, road dust and industries i.e. brick kilns, cement factories. In the present study, only the emissions from the motor vehicles/ traffic have been considered; efforts are underway to include other industrial emissions in the emission inventory.
Based on the road length in a particular area and the reported ADT, the activity level for each pollutant source (i.e. vehicle type) for each road was then calculated as follows:
A or VKT = L*ADT

Where,

A = Activity level for each pollutant source for each road (km/day)
VKT = Vehicle Kilometers Traveled (km/day)
L = Road length (km)
ADT = Average Daily Traffic (traffic volume/day)

For vehicular emission inventory, the relevant emission factors (in gm./km units) for pollutants such as PM_{10}, $PM_{2.5}$, NOx, and SOx have been collected from available literature which shows in Table 3. Vehicular emission inventory requires estimation of the number of vehicles and/or traffic activity. Based on the length of road in a particular area and the reported ADT, the activity level for each pollutant source (i.e., vehicle type) for each road the total emission from different vehicle modes has been estimated for each road separately [14]. The formula used for emission estimation is given below,

Σ Emission Ei = Σ jΣ k [EFijk * Ajk]
Where, i = Type of Pollutant like $PM_{2.5}$
j = Fuel Uses like CNG, Disel
k = Vehicle type like Car
EF = Emission Factor for each pollutant
A = Activity level for each pollutant source

Table 3. Emission Factor (gm/km) [14]

Vehicle Type	Fuel Type	Emission Factor (gm/km)				
		PM_{10}	$PM_{2.5}$	SO_x	NO_x	CO
Taxis	CNG	0.03	0.05	0	1.5	5
Car/Jeep/Micro bus/St.Wagon	CNG	0.03	0.2	0	0	0
Autorickshaw/ 3Wheeler	CNG	0.03	0.05	0	1.5	5
Bus/Minibus	Diesel	1.6	0.8	0.8	17	10
Trucks	Diesel	1.6	0	0	17	10
Motorcycle/2w	Gasoline	0.1	0.05	0.02	0.3	5

4. RESULT AND DISCUSSION

4.1. Field Investigation Result

From the field Investigation it is found that the Concentration of SPM increases from the month July to November, 2016. The maximum value found from field investigation is 398µg/m3 at GEC Moor. Most of the time, the maximum values of SPM were found in GEC Moor and Sholashar Gate- No. 2, the very busy area of Chittagong City. Roadway environmental characteristics along and sides of the road can have a significant influence on pollution. The type of land use (e.g., whether the landuse is residential or commercial) is especially influential. Due to the side confinement and surrounding environment from GEC Moor to

Sholashar Gate- No. 2 the concentration of particulate matter is high.

Table 3. SPM data at different locations of Chittagong

Location	SPM concentration (July to November) (µg/m³)		
	Maximum	Minimum	Average
A.K. Khan Gate	356	176	238
City Gate	362	134	226
GEC Moor	398	178	276
Sholashar Gate-2	395	152	270
Agrabad Moor	373	156	241
New Market Moor	363	163	257

4.2. Trend of Air Quality Analysis

Trend of the concentration of NO_2, SO_2, $PM_{2.5}$ and PM_{10} from 2013 to 2015 are prescribed in Figure 3 to 6.

However, the average highest concentration of SO_2 was found in April, 2015. But the highest and lowest 24 hour monthly concentration of SO_2 was 25.75 ppb and 0.00 ppb in December, 2015 and October, 2013 respectively. The highest concentration of NO_2 found 37.74 ppb in October, 2014. In January 2013 and June 2015 highest and lowest 24 hour monthly average concentration of NO_2 was found to be 21.76 ppb and 0.09 ppb respectively.

All the value found of SO_2 and NO_2 throughout the year 2013-2015 were within the standard limit. Figure 3 and Figure 4 represent the maximum, minimum and average concentration of SO_2 and NO_2)

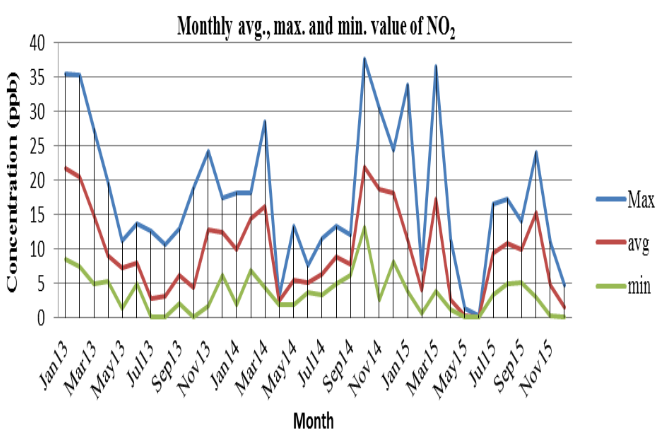

Figure 3. 24 hour average NO_2 at CAMS, Chittagong (monthly average, maximum and minimum)

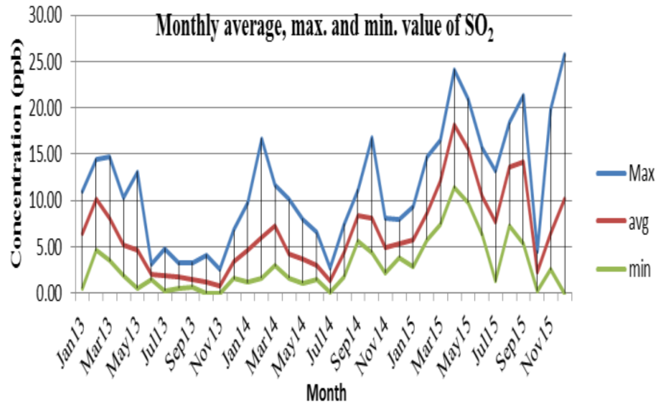

Figure 4. 24 hour average SO_2 at CAMS, Chittagong (monthly average, maximum and minimum)

The National Ambient Air Quality Standard for $PM_{2.5}$ is 65µg/m³ for 24 hour on average (Table 1) and for annual arithmetic mean the standard is 15 µg/m³. Figure 5 presented the individual $PM_{2.5}$ data measured at CAMS in 2013- 2014. 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 2013. 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 October. The maximum concentration of $PM_{2.5}$ has been observed in January, 2013 which is 321.1 µg/m³. It has behaved like other gaseous pollutants. The maximum and minimum value of $PM_{2.5}$, 24 hour average concentration was found to be 183.2µg/m³ in January 2013 and 18µg/m3 in July 2013 respectively.

The National Ambient Air Quality Standard for PM_{10} is 150µg/m³ for 24 hour average and for annual arithmetic mean the standard is 50 µg/m³ (see Table 1). Figure 6 presents the individual PM_{10} data measured at CAMS in 2013-2014. 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 $PM_{2.5}$ and PM_{10}. The highest values found of $PM_{2.5}$ were 321.1µg/m³ and PM_{10} were 474 µg/m³ in January, 2013.24 hour average concentration in January 2007 and December 2008 respectively. The maximum and minimum value of PM_{10}, 24 hour average concentration was found to be 289.9µg/m³ in January 2013 and 33.2µg/m³ in September, 2013 respectively.

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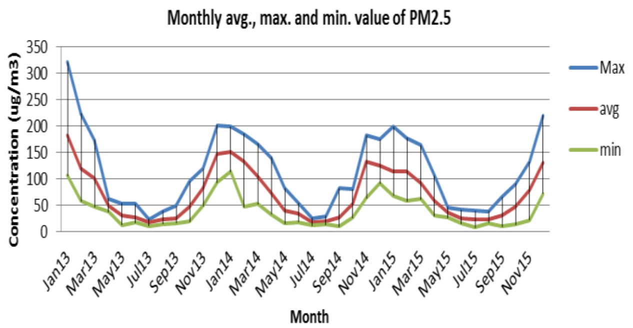

Figure 5. 24 hour average $PM_{2.5}$ at CAMS, Chittagong (monthly average, maximum and minimum)

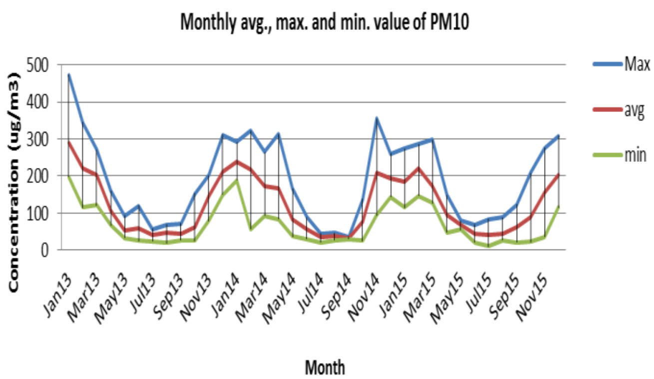

Figure 6. 24 hour average PM_{10} at CAMS, Chittagong (monthly average, maximum and minimum)

The Daily Air Quality Index (AQI) is calculated for the year 2013- 2015 considering six criteria pollutants (NO_2, SO_2, CO, O_3, $PM_{2.5}$, and PM_{10}). The maximum AQI was found 371 in 10 January 2013 which classify as hazardous environment [14]. The responsible pollutants found for air pollution in Chittagong city is $PM_{2.5}$. In almost all the cases, the concentration of $PM_{2.5}$ governed for AQI. The average AQI of the year 2013, 2014 and 2015 is 127, 132 and 133 respectively. This is the indication of increasing air pollution in Chittagong city. Figure 7 to Figure 9 represent the daily AQI trend from 2013 to 2015.

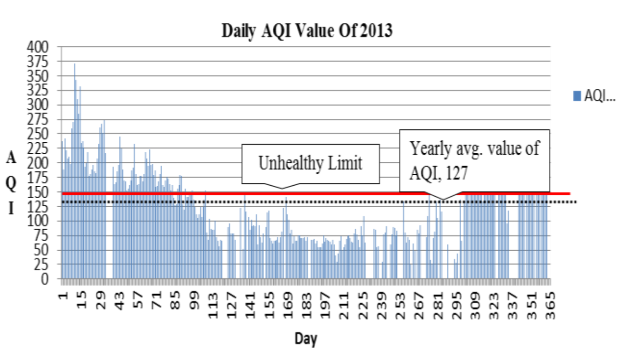

Figure 7. Daily AQI for the year 2013

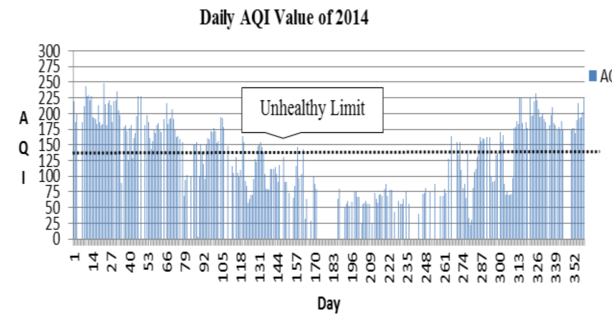

Figure 8. Daily AQI for the year 2014

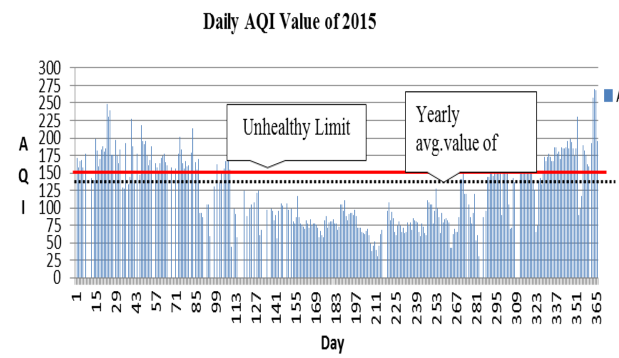

Figure 9. Daily AQI for the year 2015

The concentration of most responsible pollutants for AQI $PM_{2.5}$ considerably decrease in monsoon season, that's why the value of AQI remain below 100 which is categorized according to USEPA as moderate for health impact. The yearly average value of AQI for Chittagong city is above 100 which mean the environmental condition is unhealthy.

The pollutants concentration largely depends on meteorological parameters. When the rainfall and wind speed is high especially in monsoon period the concentration of $PM_{2.5}$ slows down. The time series plot of $PM_{2.5}$ and metrological parameter presented in Figure 10 to Figure 12, shows temporal (daily) variation of $PM_{2.5}$ concentration with the change of intensity of metrological parameter over the sampling period.

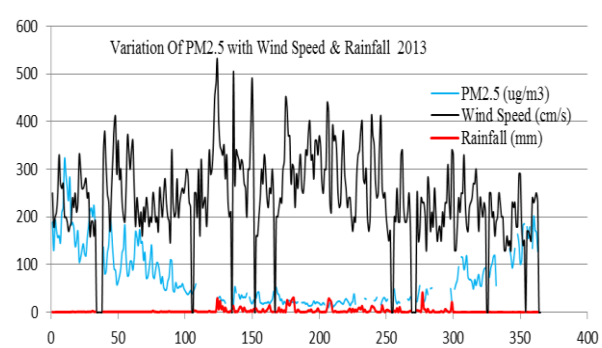

Figure 10. Temporal (daily) variation of $PM_{2.5}$ concentration with variable wind speed & rainfall in 2013

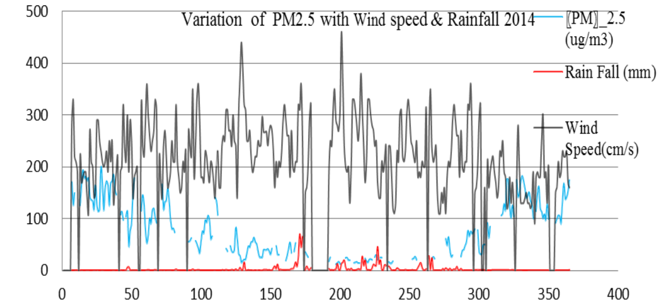

Figure 11. Temporal (daily) variation of $PM_{2.5}$ concentration with variable wind speed & rainfall in 2014

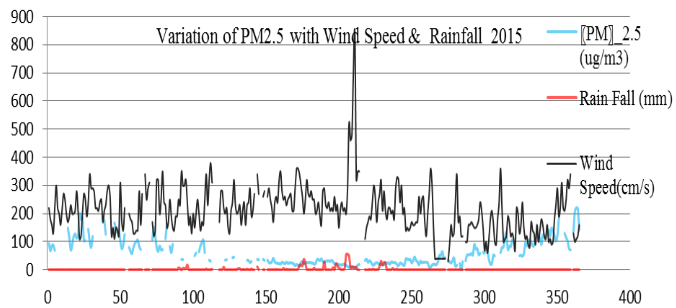

Figure 12. Temporal (daily) variation of $PM_{2.5}$ concentration with variable wind speed & rainfall in 2015

4.3. Vehicular Emission Inventory

Emissions that are released directly into the atmosphere from the tailpipes of cars, trucks etc. are the primary source of vehicular pollution. Since the rate of emission of NOx from various vehicles is high, NOx occupied half of the total emission which shows in Figure 13. Figure 13 also shows the emission from specific vehicle categories where maximum portion is covered by diesel driven vehicles. Total concentration from various vehicles in tabular format shows in Table 4.

Table 4. Annual Vehicular Emission from various vehicles

Pollutants	Annual Vehicular Emission (tons/Year)				
	PM_{10}	$PM_{2.5}$	SO_x	NO_x	CO
Concentration	160.73	105.10	62.30	2637.40	2298.60
Vehicle Categories	Taxis	Car/Jeep/ Microbus/ St.Wagon	Autorickshaw/ 3Wheeler	Bus/Minibus	Trucks & Motorcycle
Concentration	224.5	36.35	875.79	2269.6	1858

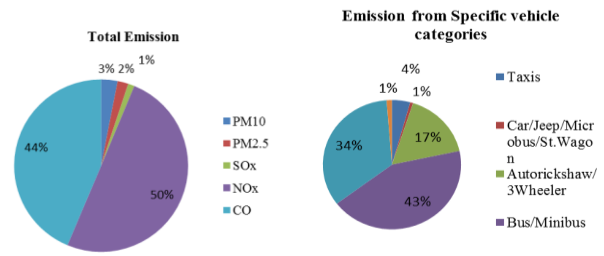

Figure 13. Total Concentration of various pollutants

Figure 14 shows the comparisons of average daily traffic (ADT) at different roads of Chittagong city and calculated emission factor with the present and previous study which is carried by Norwegian Institute of Air Research (NILU) in 2012 **[16].**

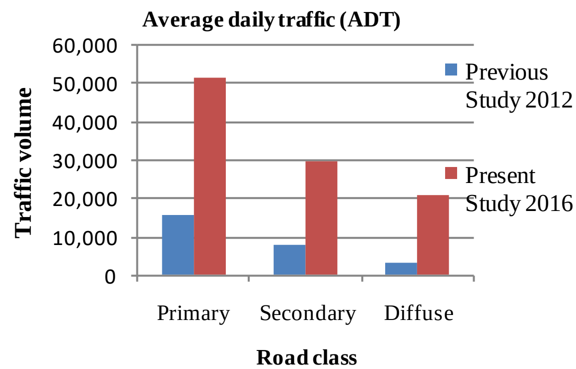

Figure 14. Comparison of average daily traffic with previous study

Figure 15 shows the amount emission (tons/km/year) at several selected roads in Chittagong. The amount of emission near about 300 (tons/km/year) for the roads Dewanhat to G. E. C. is higher than the other roads considered since the ADT in that location is higher.

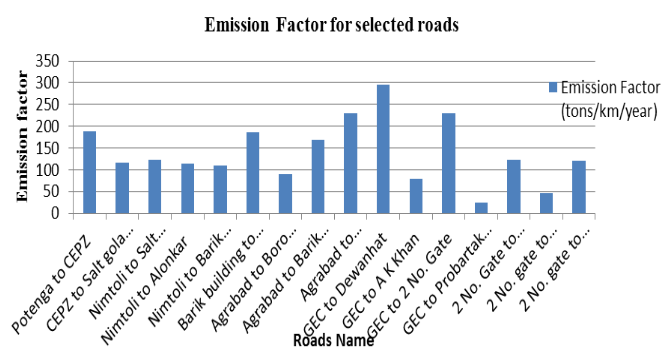

Figure 15: Amount of Emission (tons/km/year) at several selected roads in Chittagong

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5. CONCLUSION

The major objectives of the present study were to find out the major sources of air pollution, compare and evaluate the trend of air quality, evaluate total amount of pollution using secondary data information and develop emission factor for local context for better monitoring and controlling for Chittagong city considering vehicular emission. The major findings of present study summarizes below.

5.1. Field Investigation

- The maximum value of suspended particulate matter found from field investigation is 398μg/m^3 at GEC Moor in the month of November.
- Most of the time the higher concentration of SPM found in GEC Moor or Sholashar Gate-2, very important commercial zone of Chittagong City.

5.2. Trend of Air Quality

- Trend of Air Quality in Chittagong city lowered during the month April to September due to rainfall and wind speed.
- The average Air Quality Index (AQI) value of year 2013, 2014 and 2015 are 127, 132 and 133 respectively, which means the average yearly air pollution condition in Chittagong city is unhealthy for sensitive group, according to USEPA.
- Almost all the cases the responsible pollutants for AQI value is $PM_{2.5}$.
- The maximum value of $PM_{2.5}$ found in January 2013 in non-monsoon period which was 180 μg/m^3 and the minimum value of $PM_{2.5}$ found in July 2014 in monsoon period which was 21 μg/m^3.

5.3. Vehicular Emission Inventory

- The estimated yearly vehicular emission for Chittagong city (specially the roads surrounding Air Port to Bahaddarhat) is considerably higher.
- Diesel driven vehicles (i.e. buses and trucks) are responsible for majority of PM_{10}, $PM_{2.5}$, SOx, NOx and CO emissions. Together buses and trucks account for about 95 percent of vehicular PM_{10} emissions, 60 percent of vehicular $PM_{2.5}$ emissions, 99 percent of vehicular SOx emissions, 90 percent of vehicular NOx emissions and 61 percent of vehicular CO emissions.
- The ADT of different roads classified as Primary, secondary and diffuse increased remarkably. The ADT in primary roads increased around 3 percent, secondary 4 percent and diffuse 7 percent than the previous study in year 2012.
- Emissions that are released directly into the atmosphere from the tailpipes of cars, trucks etc. are the primary source of vehicular pollution. Since the rate of emission of NOx from various vehicles is high, NOx occupied half of the total emission.
- The amount of emission near about 300 (tons/km/year) for the roads Dewanhat to G. E. C. is higher than the other roads considered since the ADT in that location is higher.

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