PARTICULATE MATTER CONCENTRATION EMITTED FROM HETEROGENOUS TRAFFIC NEAR URBAN ROADWAYS IN KHULNA CITY

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ABSTRACT

Particulate matter is the major contaminants of air pollution especially in the urban roadway and industrial air which can cause adverse effects both to human health and environment. A significant seasonal variation was noticed in the study areas and it was found that at Fulbarigate $PM_{2.5}$ concentration was 136±14 µg/m^3 in winter and 60±7 µg/m^3 in summer. The concentration of $PM_{10.0}$ was 199±19 µg/m^3 during winter and 113±21 µg/m^3 in summer. PM concentration concentrations was highest at Fulbarigate than other sites as the maximum Heavy Commercial Vehicle (HCV) 7% was found at Fulbarigate. The Air Quality Index (AQI) was 340 for $PM_{2.5}$ and 249 for $PM_{10.0}$ indicating a poor air quality. The particulate matter concentration at every location exceeds 40 µg/m^3 for $PM_{2.5}$ and 80 µg/m^3 for $PM_{10.0}$ based on Environmental Protection Agency (EPA) at 1-hour average PM standard level. Moreover, at Fulbarigate $PM_{2.5}$ exceeds 125 µg/m^3 and $PM_{10.0}$ exceeds 141 µg/m^3 which implies the polluted air. As air related study is rare in Khulna city, this study would be very effective to maintain the air quality especially the urban roadways and industries.

Keywords: *Particulate Matter (PM), Urban roadway, Seasonal variation, Air Quality Index (AQI).*

1. INTRODUCTION

Air quality degradation is occurring around the world and it becomes a global problem recently due to rapid urbanization, industrialization, high growth rate of population and increasing amount of traffic movement. Around 4.2 million deaths occur every year throughout the world as a result of exposure to ambient (outdoor) air pollution (WHO,2016). According to WHO (2016), around the world 20 cities, 14 cities in India are more polluted due to $PM_{2.5}$. Srimuruganandam, *et al*. (2010) conducted a study at Chennai City in India states that about 50% of particulate matter emits due to vehicular emissions in this city keeping more than 600 million people in a dangerous situation and 30% of respiratory diseases are directly related to particulate matter. A study by Adeniran, *et al.* (2017) states that particulate matter attracts the human respiratory track, respiratory and cardiovascular diseases such as asthma. Bangladesh is a densely populated country, is known to all and air pollution is one of the major problems declared very recent World Air Quality Report (2018). Except Dhaka City, Khulna is the third largest city in Bangladesh and is facing the air pollution problems greatly in the urban roadways due to the increase of particulate matter concentration. According to the Department of Environment the Air Quality Index (AQI) in Khulna City is 402, which indicates extremely unhealthy condition. Vehicular emissions are one of the main sources of particulate matter (PM) and various gases are also emitted from the emissions. A study in Europe City by Visin, *et al.* (2016) states that air quality is the main burden of human health and long-term concern in this city. Fine particles are more harmful than coarse particles and the long-term PM exposure cause the premature death evident by the same study by Srimuruganandam, *et al*. (2011). Particulate matter is also generated by friction between, brakes, tires, road surface. Road dust flying due the movement of vehicles is one of the sources of PM due to meteorological condition. Jain, (2017) reported that PM concentration depends on several factors such as wind speed, relative humidity, temperature, driving lane, roadway type, congestion level, seasonal changes, vehicles type, vehicles emissions rate etc. Singh, *et al.* (2017) reported that airborne particulates are the mixture of various component and suspension of liquid and solid particles which impose a negative impact on human health, climate change, food security and reduction of visibility. A research by Mahapatra, et al. (2018) conducted in Eastern India, Bhubaneswar found the seasonal and meteorological variation of PM concentration and it was higher in winter than summer. Pant, *et al.* (2013) states that exhaust emissions and non-exhaust emissions are the two main sources of emissions. Qiu, *et al*. (2018) conducted a case study in China states that the coarse particles ($PM_{10.0-2.5}$) and fine particles ($PM_{2.5-1.0}$) are emitted respectively from non-exhaust and full engine combustion. The concentration of particulate matter (PM) is a key air quality indicator since it is the most common air pollutant that affects short term and long-term to health. Particulate matter (PM) is the major risk to public health in urban areas as well as environment. Around 91% of the world′s population lives in places where air quality levels exceed WHO limits. Sreekanth, *et al.* (2018) reported that ambient air pollution is the main contributor of the Global Burden Diseases (GBD) and their harmfulness is increasing more than the previous 25 years.

Another study conducted by Pant, *et al.* (2017) in Birmingham (UK) states that road traffic emissions are considered to be the major source of particulate matter emission. Pant, *et al.* (2015) conducted his research in Birmingham (UK) and New Delhi (India) found that PM concentration was higher in New Delhi than Birmingham. Desai, (2018) reported that vehicular emissions are becoming major source of air pollution during recent years. During 2011, India reported 141.8 million registered vehicles. Motorization rate in India is 26 vehicles per 1000 people. Particulate matter concentration is increasing due to the increases of motorized vehicles and high combustion of low-quality fuel. According to Khulna Districts Statistics 2011, the total number of registered Easy bike and Auto-rickshaw is 683, Tempo is 568 and non-registered Easy bike and Auto-rickshaw is 159, Tempo is 38 in Khulna City Corporation areas. The large number of buses and trucks is also moving through this city as Mongla Port, Jute Mills, and Cement Factories and other different factories are situated here. This indicates Khulna is one of the congested cities in Bangladesh and vehicular emission is the major pollutants in the roadway air pollution. Among the three roadways study areas, Fulbarigate is the major traffic congested points as most of the heavy buses and trucks are passing through it and a railway crossing also situated here. Various short- and long-term diseases are caused due to large exposure of fine particles ($PM_{2.5}$) and coarse particles ($PM_{10.0}$). Children and adults are mostly affected by these particulate matters final result of PM exposure is premature death. Guttikunda, *et al.* (2013) reported that limited studies have been conducted about air pollution in Dhaka and among them most of the studies were focused on the air pollution from brick kiln and motor vehicles in Dhaka city. Recently, a few studies are conducting in Khulna City about air pollution due to traffic emitted particulate matter and this study would be very effective to realize this type of pollution and introduce the harmful effects.

2. METHODS AND DATA ARCHIVING

There are several methods for sampling the airborne particulate matter. Most of them are needed the continuous data collection. The method used this study is very simple and collecting data continuously in a short duration. The digital PM counter Handheld 3016 model is used for PM data collection.

2.1 Selection of Study area

Monitoring sites are established for different reasons based on the monitoring objectives. Improperly located sites will provide unsuitable results for the intended purpose of monitoring and will in turn lead to incorrect decisions. The study location also has CC camera, suitable power supply, setting equipment facilities and other facilities. The equipment is set up at the place which don′t interference the vehicles and pedestrian movement. The heavy dusty areas, construction sites, external fuel combustion areas etc. are avoided for selecting the study location.

2.2 Location and site description

The selected location for this study are Fulbarigate (Lattitude-22º53′47.8″N and 89º30′36.0″E), Sonadanga Bus Terminal (Lattitude-22º49′01.8″N and Longitude-89º32′32.7″E), New Market (Lattitude-22º49′29.7″N and 89º33′04.9″E) and a Cement Factory at Labanchara (Lattitude-22º47′05.7″N and Longitude-89º34′42.8″E) in Khulna City as shown in Figure 1. The air quality in KUET campus is considered as controlled ambient air having the bearable PM concentration. Fulbarigate is one of the busiest places and traffic congested as the Khulna-Jashore -Dhaka highway (N7) passing through it and one of the renowned public university KUET situated adjacent to it. It also has a school, mosque, a railway crossing, two banks and bazar place. Sonadanga Bus Terminal is main bus terminal in Khulna City. One can travel any places from here within Bangladesh such as Khulna to Dhaka, Bagerhat, Satkhera, Chittagong, Jashore, etc. There are several waiting rooms for passengers and rest rooms. New Market is one of the old and prestigious shopping destinations at Khulna City for middle- and upper-class people. People enjoy shopping in a big wide and open area. Sharee, Gold & silver jewelry, cosmetics, carpets, mobile handsets readymade garments, gift shops and fast food shops are available there. That′s why it is all time in dense population and traffic. A big factory of Seven Rings Cement was established in 2014 in Labanchara, KDA Industrial Area, Khulna under the name Shun Shing Cement Mills Ltd (SSCML) on the bank of Rupsha River which is only 7 KM away from Khulna City Center with production capacity of 1.6 Million M/tons per annum to cover the demand of southwest zone and northern districts of the country. A considerable amount of road dusts and the bag filters dusts are generated from CMF at Labanchara during the manufacturing and marketing process.

Figure 1: Study Location Map (Source: Google Map)

2.3 Particulate Matter (PM) Monitoring

The equipment, laser particle counter named as Handheld 3016 set up on each monitoring location with the help of tripod stand or small table as shown in Figure 2. The equipment was calibrated and then start by pressing ON button. The data was taken at different dates for 1-hour continuously from April to December, 2018 on the four selected locations in Khulna City. It takes the particulate matter concentration data per min with various particle sizes such as 0.3μm, 0.5μm, 1.0μm, 2.5μm, 5.0μm and 10μm.

2.4 Traffic Monitoring

Traffic concentration was collected simultaneously within the period of PM monitoring at all considered locations. Traffic data was collected by recording the video of moving vehicles while the PM concentration was taken with the selected location. At Fulbarigate CC camera was used for recording the movement of vehicles and where CC camera was not available mobile camera was used. The videos were transferred to computer and vehicles were counted manually. For counting the traffic, digital counter was used and vehicles were counted at a constant 5 minutes interval. The types of vehicles moving in Khulna city are heterogenous in character. Motorized and non-motorized both types vehicle moving the same road and caused a heavy congestion. For simplicity, only motorized vehicles were considered. Buses, trucks, motorcycles and private cars are found this study areas. Taxi and Tuk-tuk are considered as 3-Wheeler (3W), Small buses and private car, large buses and trucks, motorcycle are considered as 4-Wheeler (4W), Heavy Commercial Vehicle (HCV) and 2-Wheeler (2W) respectively.

Figure 2: Particulate Matter and traffic monitoring

3. RESULTS AND DISCUSSIONS

3.1 PM mass concentration

According to National Ambient Air Quality Standard in Bangladesh (BAAQS, 2005) the PM standard for $PM_{2.5}$ for 24-hour average is 65 (µg/m^3) and annual average is 15 (µg/m^3). The PM standard for $PM_{10.0}$ for 24-hour average is 150 (µg/m^3) and annual average is 50 (µg/m^3). National Ambient Air Quality Standard in Bangladesh does not recognize yet for 1-hour average PM standard level for PM monitoring. Environmental Protection Agency (EPA) follows some PM ranges for evaluating air quality for 1-hour and 24-hour average PM data.

1-hour average $PM_{1.0}$, $PM_{2.5}$ and $PM_{10.0}$ concentration at KUET campus as 62±1.0 µg/m^3, 125±1.50 µg/m^3 and 141±3.0 µg/m^3 respectively. These concentrations are little higher than other monitoring locations. This scenario may be evident due the effect of monitoring period. Monitoring campaign at KUET campus was conducted in the month November of 2018 presenting post-monsoon season. As presented in Table 1, Fulbarigate location depicts highest concentration of $PM_{2.5}$ and $PM_{10.0}$ as 135.97 µg/m^3 and 198.91 µg/m^3 respectively. Due to the higher vehicular movement at Fulbarigate could be responsible for these higher concentrations. Highest concentration of $PM_{1.0}$ found at Sonadanga location as 72.62 µg/m^3 among all the observed locations, which indicates the presence of higher amount fine particle at this location during the mentoring period.

Table 1: PM monitoring data for 1-hour average during study period

Description Months	Item	Fulbarigate (December)	Sonadanga (October)	New Market (December)	Labanchara (September)
PM Mass in (concentration ±SD)	$PM_{1.0}$	31.71±2.92	72.62±6.33	45.05±18.36	62.25±4.55
	$PM_{2.5}$	135.97±13.84	119.11±9.01	93.17±51.97	93.17±7.42
	$PM_{10.0}$	198.91±19.06	187.87±11.89	139.61±55.70	133.23±8.02
PM Mass ratio	$PM_{1.0}/PM_{10.0}$	0.16±0.001	0.39±0.01	0.32±0.01	0.47±0.003
	$PM_{2.5}/PM_{10.0}$	0.68±0.01	0.64±0.001	0.67±0.10	0.70±0.01
	$PM_{1.0}/PM_{2.5}$	0.23±0.002	0.61±0.01	0.48±0.05	0.67±0.004
Pearson Corre.	$PM_{1.0}$ vs $PM_{10.0}$	0.91	0.27	0.98	0.69
Coefficient (R^2)	$PM_{2.5}$ vs $PM_{10.0}$	1.00	0.45	0.98	0.73
	$PM_{1.0}$ vs $PM_{2.5}$	0.92	0.97	0.90	1.0

Environmental protection agency (EPA) follows the following PM ranges for evaluating air quality based on 24 hour and 1-hour average PM data with dividing air various air quality category as shown in Table 2.

Every sampling location, $PM_{2.5}$ exceeds the 60 (μg/m^3) and $PM_{10.0}$ exceeds 120 (μg/m^3) for 1-hour average data and indicates that air quality category is very poor at the sampling sites as shown in Table 2. The highest 1-hour average PM mass concentration for $PM_{2.5}$ is 135.97±13.84 (μg/m^3) and $PM_{10.0}$ is 198.91±19.06 (μg/m^3) are obtained at Fulbarigate due to larger quantity of HCV and 4W vehicles moving here as shown in Table 3.

Table 2: Air Quality Category based on $PM_{2.5}$ and $PM_{10.0}$

Air Quality Category	24-hour average (μg/m^3)		1-hour average (μg/m^3)	
	$PM_{2.5}$	$PM_{10.0}$	$PM_{2.5}$	$PM_{10.0}$
Very Good	0-8.2	0-16.4	0-13.1	0-26.3
Good	8.3-16.4	16.5-32.9	13.2-26.3	26.4-52.7
Fair	16.5-25.0	33.0-49.9	26.4-39.9	52.8-79.9
Poor	25.1-37.4	50.0-74.9	40.0-59.9	80.0-119.9
Very Poor	37.5 or greater	75.0 or greater	60.0or greater	120 or greater

The good relationship is obtained for $PM_{2.5}$ vs $PM_{10.0}$ and $PM_{1.0}$ vs $PM_{2.5}$ where R^2 is 1.0 for both as shown in Table 1.

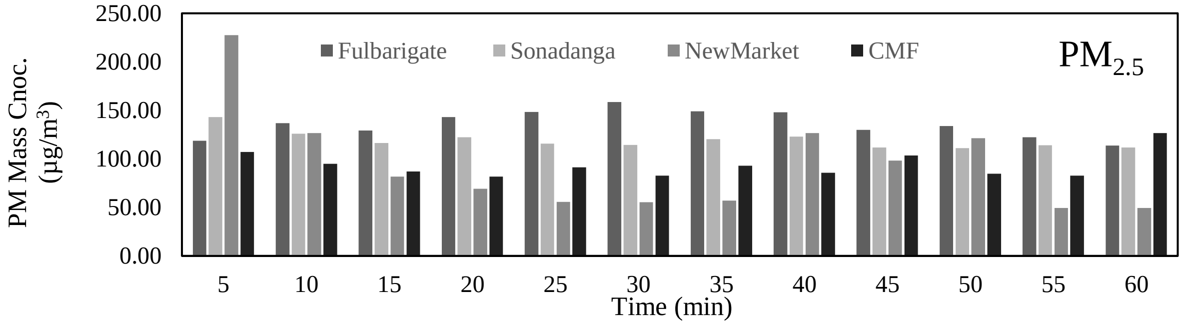

Figure 3: $PM_{2.5}$ mass concentration with 5 minutes time interval at the sampling locations.

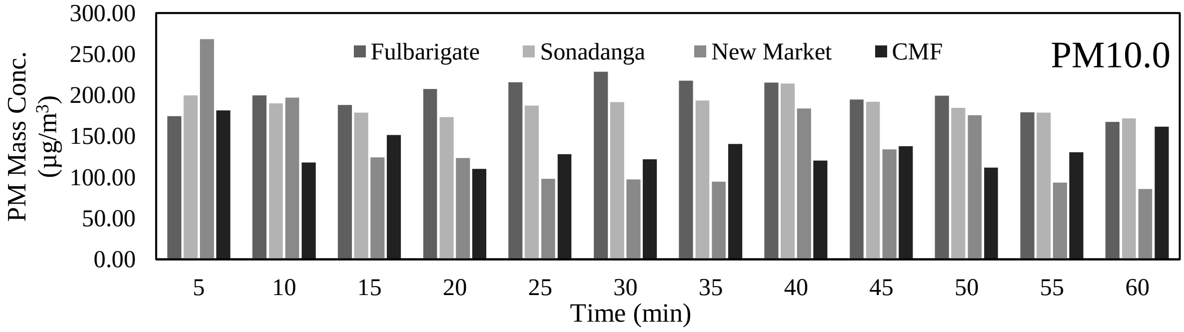

Figure 4: $PM_{10.0}$ mass concentration with 5 minutes time interval at the sampling locations.

Bar diagrams represent that $PM_{1.0}$ is all time higher in Fulbarigate than the other three locations. $PM_{2.5}$ and $PM_{10.0}$ at first 5 minutes is high at New Market but other three locations these values are low as shown in Figure 3 and Figure 4 as at New Market the vehicles volume is high and movement is so speedy due to less congestion. After that, PM mass concentration is high at Fulbarigate. At Labanchara CMF has the lowest PM concentration because of less vehicular emissions here. Raw materials, chimney′s emission and whole manufacturing process of cement are mainly contributing these particles at CMF.

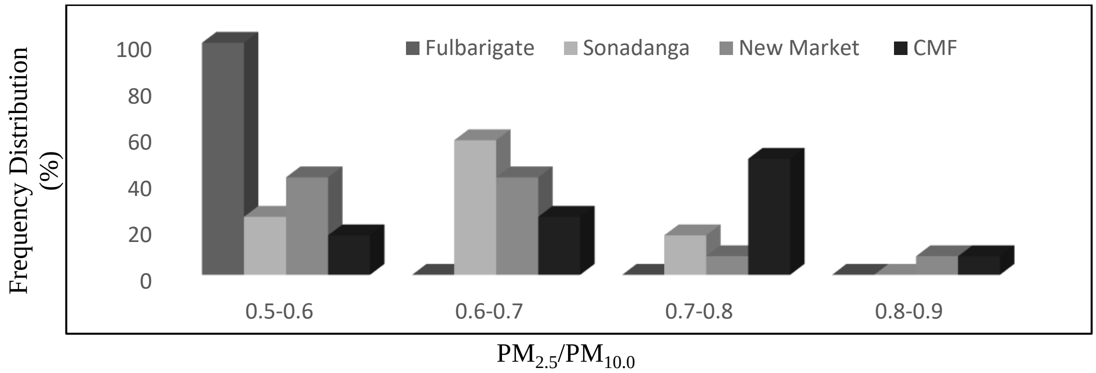

Figure 5: Frequency Distribution of $PM_{2.5}/PM_{10.0}$ ratio

The peak is found for $PM_{2.5}/PM_{10}$ ratio at 0.5-0.6 at Fulbarigate which shows a symmetric pattern as shown in Figure 5. High ratio indicates that significant portion of particulate matter responsible fall under the size distribution of PM for air pollution.

3.2 Traffic concentration

The average traffic moving per five minutes at Fulbarigate, Sonadanga and New Market are 101, 116 and 156 respectively. Average traffic was obtained by counting the vehicles manually at 1-hour duration and five minutes interval in the study locations. Among these three locations, at Fulbarigate has the maximum amount of HCV (7%) which is the major contributors for PM highway emissions. The 4Wheeler (4W) vehicles volume also high at Fulbarigate. The national Khulna -Jashore-Dhaka road goes through the Fulbarigate and a large number of buses and trucks moving here. The highest concentration of PM at Fulbarigate can be supported by the rising concentration of vehicle. Although average moving vehicles at New Market is maximum, the PM concentration is low. The reasons behind this condition are huge number of auto rickshaw moving here but large buses and trucks are rarely found. The meteorological conditions also a major factor for this condition. At Sonadanga the HCV is less than the Fulbarigate because the sampling site is few distance far from the main Sonadanga Bus Terminal. The following Table 3 and Figure 6 represent the 1-hour average traffic concentration precisely.

Table 3: Categories of vehicles in the sampling locations

	Fulbarigate	**Sonadanga**	**New Market**
2W	28%	22%	28%
3W	55%	65%	59%
4W	10%	9%	11%
HCV	7%	4%	2%

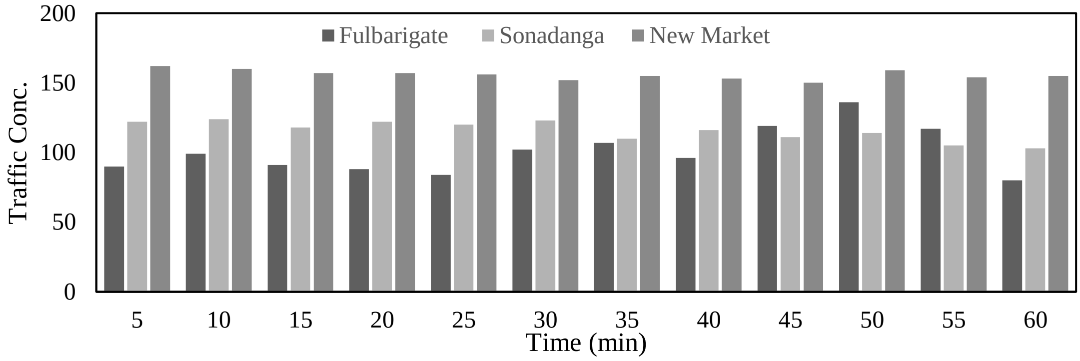

Figure 6: Traffic Conc. Vs Time at sampling location

3.3 Variation of PM Mass Concentration and traffic concentration

Particulate matter concentration is increasing with the increases of traffic concentration. The following figures represent that at first PM concentration in these three locations are increasing gradually with traffic volume. Sometimes, it was seen that PM concentration increases although the traffic decreases specially in Fulbarigate as shown in Figure 7. As at Fulbarigate heavy congestion is noticed when train is crossing the Khulna -Jashore-Dhaka Highway. When the congestion occurs the vehicles still standing at the same place no movement is possible. The vehicular emissions increase due to their fuel combustion although vehicles number is not increased. The shops near the sampling locations sweeps their yard and it affects the exact PM concentration. For these reasons, some unexpected points are obtained in graphical representation.

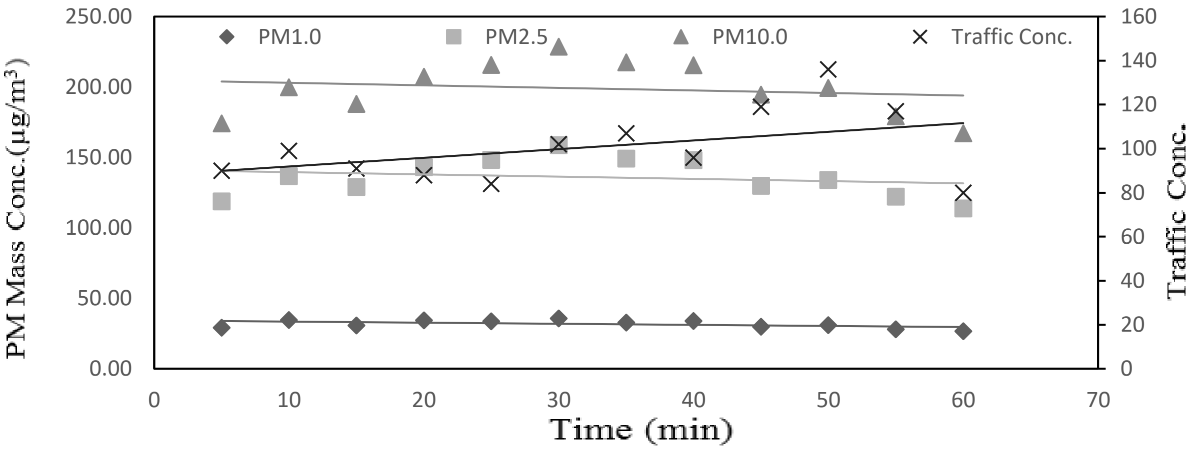

Figure 7: PM Mass Conc. vs Traffic Conc. at Fulbarigate

At Sonadanga the variations are comparatively less than New Market as shown in Figure 8 and Figure 9. There were no congestions noticed at New Market because the road was wider than other locations and vehicles moving so fast.

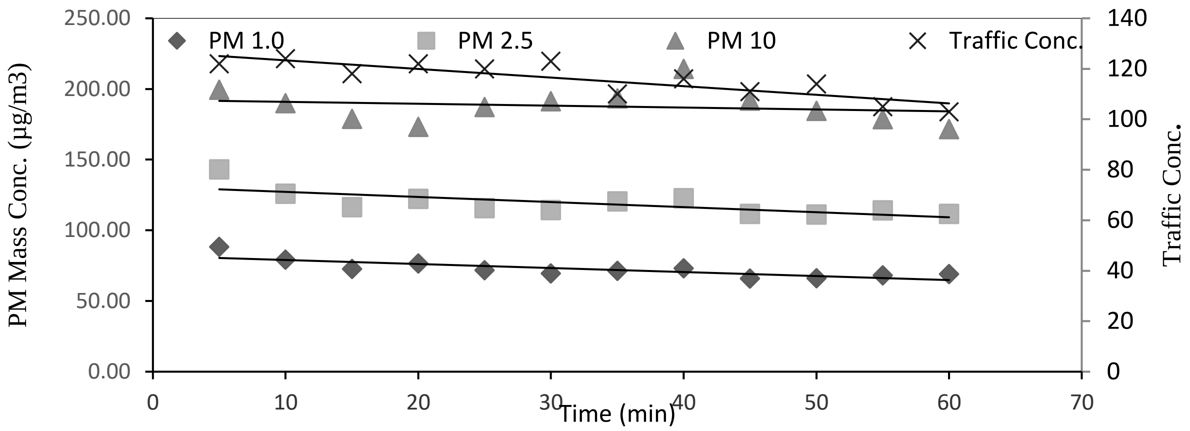

Figure 8: PM Mass Conc. vs Traffic Conc. at Sonadanga

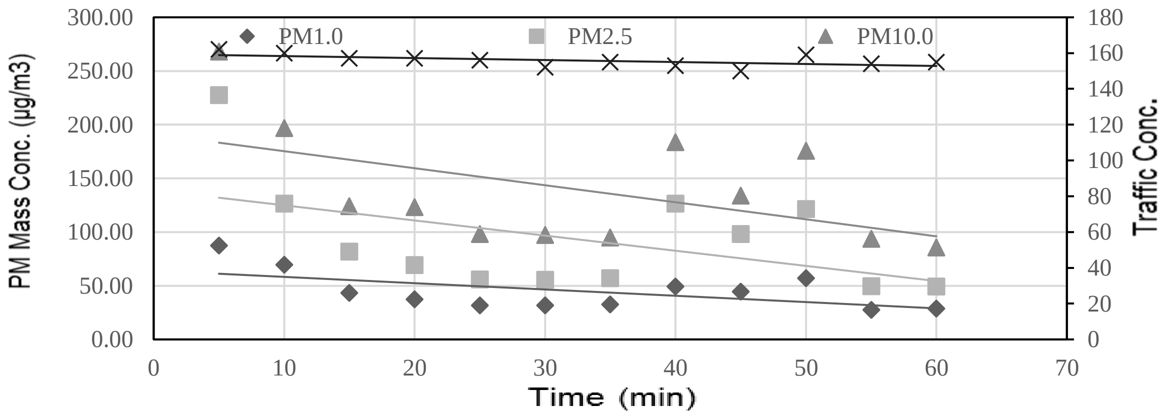

Figure 9: PM Mass Conc. vs Traffic Conc. at New Market

3.4 Determination of Air Quality Index (AQI)

Air Quality Index is tools for reporting the daily air quality and tells how clean or polluted the ambient air and whether it is suitable to breathe in. It focuses on the human health effects that one might experience within a few hours or days after breathing polluted air. According to the National Air Quality Standard for the pollutants the AQI value generally corresponds to 100 which is the level that set by the mandated Environment Protection Agency (e.g., for the Bangladesh Department of Environment) to protect public health. The acceptable value of AQI is 100 which represents the healthy air but exceeding this value the air becomes unhealthy.

To determine the Air Quality Index (AQI) the following formula is usually used

$$\text{Air Quality Index (AQI)} = \frac{\text{Pollutant concentration}}{\text{Pollutant standard level}} \times 100 \tag{1}$$

Table 4: Air Quality Index at sampling locations based on EPA standard

Location		1-hr average $PM_{2.5}$(µg/m3)	AQI for $PM_{2.5}$	1-hr average $PM_{10.0}$(µg/m3)	AQI for $PM_{10.0}$
Fulbarigate	Dec.	136	340	199	249
	April	60	150	113	142
Sonadanga BS		119	298	188	235
New Market		93	233	140	175
CMF(Labanchara)		93	233	135	169
KUET campus		125	192	141	94

There is currently no national standard for the 1-hr $PM_{2.5}$ and $PM_{10.0}$ average but EPA uses the value 40

(µg/m3) and 80 (µg/m3) as the level that triggers a poor or unhealthy for all air quality category.
Example: AQI = 136* 100/40 =340

Every location the AQI exceed 100 which indicates that recently, the air quality in the sampling sites is in worse conditions. The DoE of Bangladesh has set national ambient air quality standards for air pollutants as follows in Table 5.

At Fulbarigate the air quality lies in extremely unhealthy and very unhealthy category due to the AQI of $PM_{2.5}$ and $PM_{10.0}$ are 340 and 249 respectively in the month of winter season as December as shown in Table 4. In summer season the air quality at Fulbarigate is comparatively better than other locations. Only this location was monitored twice during the study period. At Sonadanga, New Market and CMF (Labanchara) the ambient air quality also lies in unhealthy and very unhealthy category.

Table 5: Approved Air Quality Index for Bangladesh

AQI Range	**Category**	**Color**
0-50	Good	Green
51-100	Moderate	Yellow Green
101-150	Caution	Yellow
151-200	Unhealthy	Orange
201-300	Very Unhealthy	Red
301-500	Extremely Unhealthy	Purple

This study implies that the air quality in the sampling goes to deteriorate conditions due to vehicular emissions. Immediate steps must be taken to proper monitoring the ambient air quality otherwise the roadway atmospheric air becomes unsuitable to breathe in.

4. CONCLUSIONS

The maximum $PM_{1.0}$ was 73±6.5 (µg/m3) found at Sonadanga, and $PM_{2.5}$ as 136±14 (µg/m3) and $PM_{10.0}$ as 199±19 (µg/m3) were found at Fulbarigate for 1-hour average PM monitoring. The PM concentration at Labanchara Cement Factory for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10.0}$ were found 62±5 (µg/m3), 93±7 (µg/m3) and 133±8 (µg/m3) respectively. Significant correlation coefficient found for $PM_{2.5}$ and $PM_{10.0}$ at Fulbarigate, for $PM_{1.0}$ and $PM_{2.5}$ at CMF where Pearson Correlation Coefficient (R^2) was 1. 0. The AQI value at Fulbarigate indicates extremely unhealthy air quality among all the observed locations.

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