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MONITORING AND TREND ANALYSIS OF AIR-BORNE PARTICULATE MATTER (PM_{10} AND $PM_{2.5}$) AT MAJOR HOT-SPOT AREAS: MOHAKHALI AND FARMGATE IN DHAKA CITY

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Abstract
The objectives of this work were to monitor and quantify the airborne particles (PM_{10} and $PM_{2.5}$) and to predict the influence of human and natural activities on their ambient concentrations. Samples of Air-borne Particulate Matter (APM) in the size range 0-2.5 µm ($PM_{2.5}$) and 0-10 µm (PM_{10}) were collected simultaneously using two MiniVol portable air samplers at Mohakhali and Farmgate area in Dhaka city. At Mohakhali effective sampling duration was from May 16 to May 23, 2004 and at Farmgate from June 6 to June 13, 2004. Continuous seven day monitoring was carried out to find the effect of meteorology, traffic load and other anthropogenic activities on ambient Particulate Matter (PM) pollution level. Weekday and weekend average traffic number was evaluated by field technicians at both sampling sites. These sites are regarded heavily polluted because of the proximity of major roadways. Daily and weekly average concentrations of PM_{10} and $PM_{2.5}$ at Mohakhali were found higher than USEPA and Bangladesh 24-hrs average guideline values but at Farmgate the concentrations were within the guideline values. Average proportions of $PM_{2.5}$ in PM_{10} were found higher at Farmgate than that at Mohakhali.

1. Introduction

The particulate matters are classified into two groups: fine micro particles (≤ 2.5 µm) $PM_{2.5}$ and large micro particles (≤ 10 µm) PM_{10}. Through respiration fine micro particles get into blood stream and dissolve into it [Biswas et al., 2003].

The number of motor vehicles in Dhaka up to the registration year 2003 was 3,29,644 among which 26,429 were two stroke three-wheeler auto rickshaws and auto tempos [BRTA, 2004]. The total number of vehicles in the city is not large relative to the population. However, high traffic congestion due to poor traffic management and poor vehicle maintenance (using impure fuel, high-sulfur diesel) has resulted in the transport sector being a major contributor to air pollution in Dhaka [ICTP, 2001]. Particulate Emissions calculated for different vehicles in 1998 by World Bank revealed that two-stroke three-wheeler was the main polluter vehicles with respect to particulate pollution in Dhaka city [WB, 1998].

Follow the observation and pressure from social and environmental organizations the government banned two-stroke three wheelers for Dhaka by December 31, 2002. In January 2003, after the complete phase-out of two-stroke three-wheelers, a step decrease in ambient levels of particulate matter was observed [Fabian, 2004].

Before banning two-stroke three wheeler (during 2001-2002), the average concentrations of $PM_{2.5}$ and PM_{10} were 67.2 and 147 µg/m^3 respectively in Dhaka city. In the following year (2003) these concentrations were 47.4 and 125 µg/m^3 respectively [Begum et al., 2006]. Even after this significant reduction, the average concentrations of PM_{10} and $PM_{2.5}$ in 2003 were much higher than the US EPA standards as well as the yearly average standards of PM_{10} (50 µg/m^3) and $PM_{2.5}$ (15 µg/m^3) for Bangladesh. Currently it is believed that along with vehicular emission, building and road construction, soil dust, biomass burning and other industrial sources also contribute to particulate emission levels [Begum et al., 2005].

It has already been understood from the ambient air quality measurements by different initiatives that the main air quality related health problem in Dhaka city is associated with the airborne particulate matters (PM_{10} and $PM_{2.5}$) [Akhtar, 2004]. The impact of airborne particles on human health has been observed [Dockery et al., 1993]. Severity of damage on human health is related with the size, composition and concentration of the particulate matter [Seinfeld, 1975]. Estimation of economic loss due to health impact of PM_{10} in Dhaka city has revealed a huge loss of about 124,184 million taka per year, an equivalent of 3-4% of GDP [Azad et al., 2003].

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2. Materials and Methods

2.1. PM Sampling Set-up and Sampling Preparation

Two MiniVol Portable Air Samplers (Model no. Ver. 4.2, AirMetrics, U.S.A) were used to collect particulate matters (PM10 and PM2.5) from ambient air. Prior to sampling, the filters were conditioned (for 24 hrs at a constant room temperature and relative humidity of 25oC and 55% respectively) in conditioning room at Atomic Energy Centre (AEC), Dhaka. After conditioning, the filters were weighed in a microbalance. Filters were charged neutralized before each weighing by an electrostatic charge eliminator (Po-210; alpha emitter electrostatic charge eliminator, STATICMASTER). Airflow through the sampler was calibrated prior to each sampling. “O”-ring supported Teflon filter (Pall Corp., Gelman Lab., Zelfluor, 2 µm pore size, 47 mm diameter) was used for sampling ambient PM [AirMetrics, 1998].

2.2. Site Selection and Sampling Protocol

The objective of the project was to understand the air quality of Dhaka city, in particular the most densely polluted areas. Apparently it seems that the vehicles in Dhaka are the major polluters. This is why the samplers were placed near the busiest traffic intersections.

At Mohaklhali, the sampler was kept in a box but the air inlet line was kept outside. With the support and cooperation of the police department, the sampler was setup within the police station compound, which was guarded by the police round the clock. At Farmgate, the samplers were placed over the flat roof of the guardhouse of Bangladesh Agricultural Research Council (BARC). The sampling location and the intersections of major roadways are shown in Figures 2.1 and 2.2.

The sampler was positioned with the intake upward and located at an unobstructed area (at least 30 cm from any obstacle to air flow) and the sampler inlet was placed at a height of 3.5 m above ground level for Farmgate area and 2.5 m for Mohakhali area following US guideline (40 CFR, part 58, Appendix-6). The intake nozzle of the sampler at Farmgate location was about 5 m away from roadside whereas at Mohakhali it was about 3 m. Particulate fractions (PM_{10} and $PM_{2.5}$) were collected simultaneously for 24 hours at every sampling station by two samplers. The sampling was continued for seven consecutive days at each site (for Mohakhali it was from midday of May 16 to midday of May 23, 2004 and for Farmgate it was from midday of June 6 to midday of June 13, 2004).

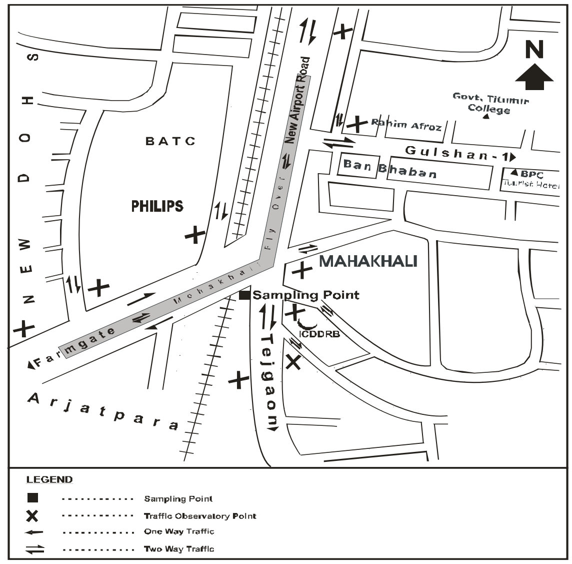

Fig. 2.1. Sampling site at Mohakhali

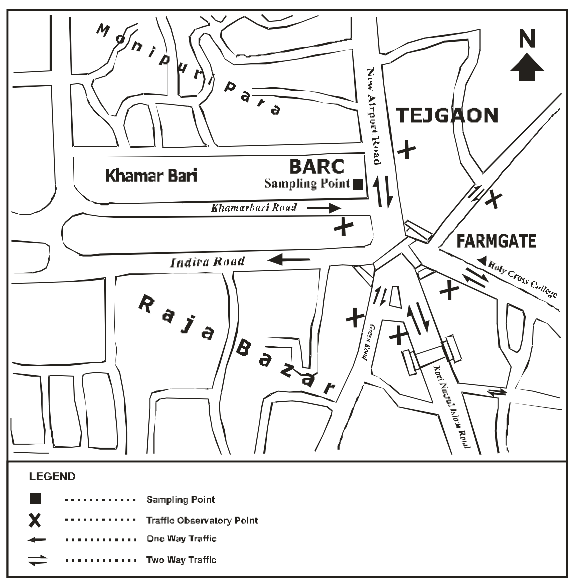

Fig. 2.2. Sampling site at Farmgate

Preconditioned filters were placed to respective filter holder assembly of the sampler at the laboratory of AEC, Dhaka and were carried to sampling station in separate clean polyethylene bags at each sampling day. After sampling, filter holder assemblies (keeping the exposed filters inside) were brought back to the laboratory of AEC, Dhaka in separate clean polyethylene bags for conditioning prior to weigh and PM retrieval. A field blank was also used to make necessary correction in PM weight.

2.3. Meteorological Condition

The meteorological data (Temperature: Max and Min, Percentage of Relative Humidity (%RH), Rainfall, Wind speed and Direction shown in Table 2.1 and Figures 2.3 and 2.4) in this study were obtained from meteorological station which is about 3 km at north-north-west of Farmgate sampling station and at west of Mohakhali sampling station.

Table 2.1: Temperature, rainfall and relative humidity data collected from local meteorological center for the period- May 16 to 23 and June 06 to 13, 2004

Date	Max. and Min. temperature (oC)		Relative Humidity	Rainfall
	Max. (ºC)	Min. (ºC)	(%)	(mm)
For Mohakhali				
May 16	35.5	29	66.55	00
May 17	36	29	68.00	00
May 18	35.6	27.6	64.33	00
May 19	36.2	27.8	62.67	00
May 20	35.2	27.6	66.55	00
May 21	31.5	21.2	72.33	39
May 22	32.3	22.9	77.22	16
May 23	25.9	20.2	66.55	48
For Farmgate				
June 06	32.9	27.5	83.80	00
June 07	33.3	23.2	71.50	29
June 08	35.2	26.7	69.22	00
June 09	33.7	27.6	71.90	00
June 10	34.4	27.4	78.00	00
June 11	31.6	23	77.00	01
June 12	33.4	23.7	77.60	29
June 13	30.3	25.3	83.80	06

Source: Local Meteorological Centre, Agargaon, Dhaka

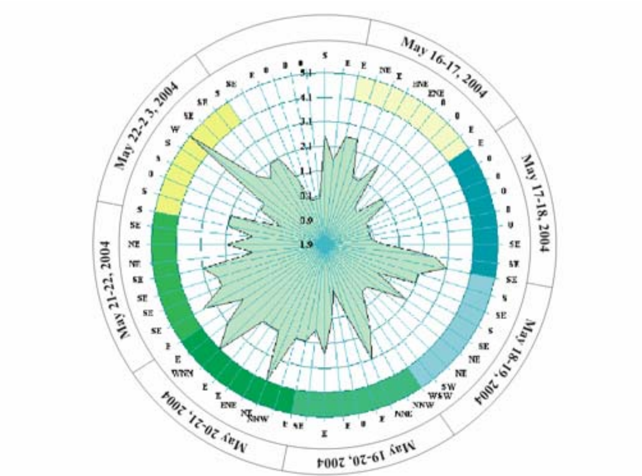

Fig. 2.3. Wind velocity from May 16 to May 23, 2004 during sampling at Mohakhali

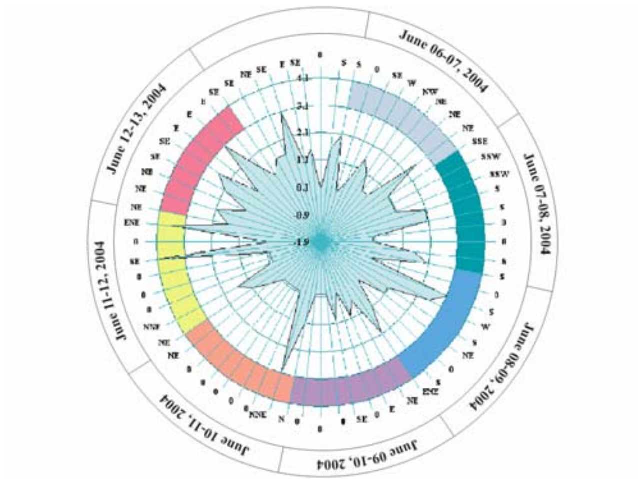

Fig. 2.4. Wind velocity from June 06 to June 13, 2004 during sampling at Farmgate

2.4. Traffic Volume Measurement

Traffic volume (Figure 2.5) was determined during weekdays and weekends at Mohakhali and Farmgate by manual counter round the clock to study the effect of vehicular emission on ambient air pollution. Suitable observatory points were selected by the incoming traffic route toward the sampling stations which are shown in Figures 2.1 and 2.2.

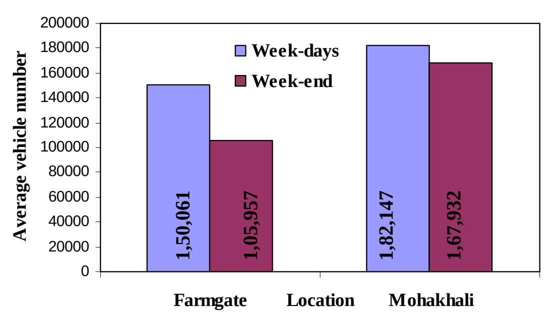

Fig 2.5 Average traffic volume at Mohakhali and Farmgate during weekdays and weekends

2.5. Particulate Mass Measurements

The masses of blank conditioned filters along with the collected particulate samples ($PM_{2.5}$ and PM_{10}) and filters (conditioned) were weighed at AEC as described in section 2.2. From the weight differences the PM masses were obtained.

3. Results and Discussions

Particulate Matters (PM_{10} and $PM_{2.5}$) at Mokhali and Farmgate were collected over a week (seven consecutive days including weekends, at Mohakhali samples were collected from May 16-23 and at Farmgate from June 06-13, 2004) which picks up the impact of traffic on the ambient air quality of the city. Sampling started at midday and terminated at the same time next day (24 hours of sampling).

Weekly average concentrations of PM_{10} and $PM_{2.5}$ at Mohakhali were recorded much higher than amended Bangladesh national ambient air quality standards and USEPA standards (24-h average) for PM_{10} and $PM_{2.5}$, which were set as 150 and 65µg/m^3 respectively. However, the PM concentrations at Farmgate were recorded below the standard values. Results show that weekly average concentrations of PM_{10} at Mohakhali and Farmgate were 312.52 and 102.84 µg/std.m^3 and concentrations of $PM_{2.5}$ at Mohakhali and Farmgate were 87.45 µg/std.m^3 and 54.66 µg/std.m^3 respectively (Figure 3.1). It was found that average weekly proportion of $PM_{2.5}$ in PM_{10} mass was 28% at Mohakhali, which was 53% at Farmgate (Figure 3.2).

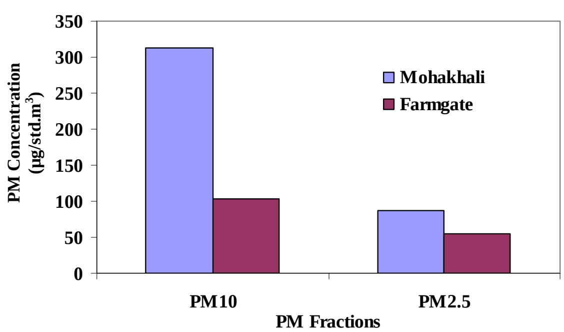

Fig 3.1. Weekly average concentrations of PM_{10} and $PM_{2.5}$ at Mohakhali and Farmgate

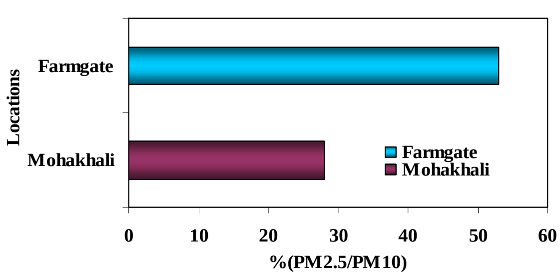

Fig 3.2. Weekly average percent ratio of $PM_{2.5}$ and PM_{10} at Mohakhali and Farmgate

Higher PM concentrations at Mohakhali were due to the fact that the number of motor vehicles was higher at Mohakhali than that at Farmgate. Even the weekend average number of the vehicles at Mohakhali was higher than the weekday average vehicles number at Farmgate (Figure 2.5). Particulates emit into atmosphere due to incomplete combustion and soil dusts are resuspended as vehicles run on the street. During sampling at Mohakhali massive construction work of Mohakhali flyover was going on. At Mohakhali, sampling was performed at the end of pre-monsoon period whereas sampling at Farmgate was performed at the beginning of the monsoon period. Several brik kilns were in operation at the periphery of Dhaka city up to the end of pre-monsoon period. These might be the possible reasons behind higher PM concentrations at Mohakhali. Lower proportion of $PM_{2.5}$ in PM_{10} at Mohakhali compared to Farmgate might be due to presence of higher amount of coarse particles ($PM_{2.5\text{-}10}$) in ambient PM_{10} at Mohakhali.

It is believed that ambient PM concentration decreases as the horizontal wind speed increases. But this correlation was not observed completely during sampling at Mohakhali (Figure 3.3). This correlation held good from mid of sampling day Mon-Tue to mid of Tue-Wed (i.e., Tuesday), from mid of Wed-Thu to mid of Thu-Fri (i.e., Thursday) and mid of Fri-Sat to mid of Sat-Sun (i.e., Saturday). In the weekend, on Friday (from mid of Thu-Fri to mid of Fri-Sat) PM_{10} and $PM_{2.5}$ concentration profiles reached the minimum. This relates to the lower volume of vehicular emission and other anthropogenic activities, which were lower during weekends. In the weekend the traffic volume was 92.2% of weekdays at Mohakhali (Figure 2.5). There was about 39 mm rainfall on that day (Table 2.1). Combined effect of these effects offset the effect of decreasing wind speed that might otherwise increase ambient PM levels. Tendency of increasing PM was observed during Fri-Sat to Sat-Sun.

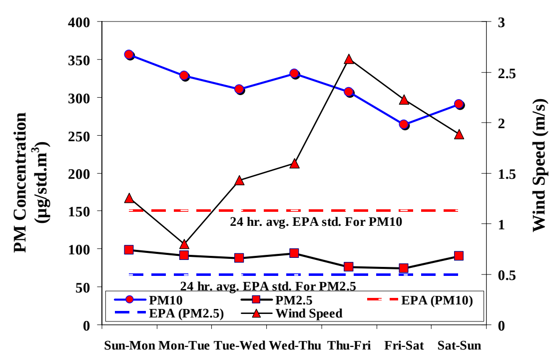

Fig 3.3. Average concentrations (daily) of respirable particulate matter (PM_{10}) and fine particulate matter ($PM_{2.5}$) and the impact of wind speed on PM concentration at Mohakhali (samples collected between May 16 and May 23, 2004)

This is because; each sampling was started at midday and was terminated at about the same time next day. Thus, during sampling through Thursday (12.25 PM)-Friday (12.25 PM), samples were collected during heavy traffic load in the afternoon and evening of Thursday. Low traffic volume was recorded during morning through noon of Friday. Higher traffic volume was recorded during Friday afternoon through evening. During this time city dwellers usually go out for recreation, shopping, visiting relatives and friends. From the evening of Friday and by the morning of Saturday (beginning of working week) people return to work from distant places by various types of vehicles. As a result, greater traffic load within Friday evening is observed. The traffic load during Saturday morning becomes heavier than that of on Friday evening because of weekly routine activities. Thus, an increasing tendency of PM concentrations in the air was marked from Fri-Sat through Sat-Sun instead of occasional rain on Saturday and Sunday (May 22 and 23, 2004).

Figure 3.3 shows that during Monday (from mid of Sun-Mon to mid of Mon-Tue), PM concentrations decreased though the average wind speed was low. Figure 2.3 shows that during May 17, 2004 (Monday), air was stagnant (zero wind speed) for about 15 hours. Maximum and minimum temperatures were recorded as 36-29°C during May 17 of 2004 (Table 2.1). And the day was recorded sunny. During this sampling period the average (24 hours) relative humidity was approximately 68% (Table 2.1). These conditions were favorable for the city atmosphere to become unstable. In this situation, vertical ventilation (dilution) of the pollutant predominates. The earth surface rapidly absorbs heat and transfers that to the surface air layer. So, this hot air parcel rises vertically and the cooler air falls to replace it. In this way vertical movements in both directions might be enhanced [Core, J., 2004]. On Wednesday (mid of sampling day Tue-Wed to Wed-Thu) PM concentration increased in spite of increasing wind speed. During this time wind blew predominantly from east, north-east and north-northeast (Figure 2.3). In these directions there are major traffic corridors where huge traffic congestion is a usual phenomenon (Figure 2.1). Wind also occasionally blew from north-northwest (Figure 2.3) part of the sampling point where massive civil construction of Mohakhali flyover was going on (Figure 2.1).

Daily average concentrations of PM_{10} and $PM_{2.5}$ at Farmgate were much lower than that at Mohakhali (Figure 3.1). Normally during weekdays PM levels show higher value than that of weekends due to higher traffic volume and other anthropogenic activities. However, during this sampling session meteorological effects offset traffic load effect and contribution from other anthropogenic activities. Synoptic southerly wind from Bay of Bengal was predominant during this sampling session (Figure 2.4), which had to travel a shorter distance over the land compared to easterly or westerly wind. Average relative humidity was higher but ambient temperature (29.3°C) was lower (Table 2.1).

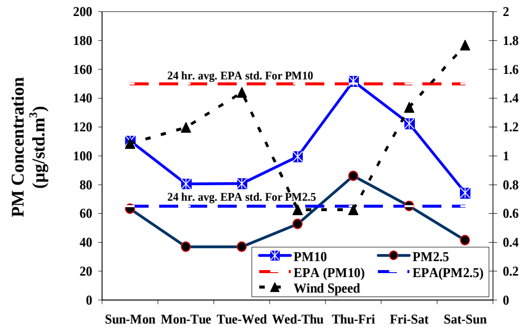

Fig 3.4. Average concentrations (daily) of respirable particulate matter (PM_{10}) and fine particulate matter ($PM_{2.5}$) and the impact of wind speed on PM concentration at Farmgate (samples collected between June 06 and June 13, 2004)

As the wind speed goes high pollutant concentration level in air decreases. This phenomenon was well correlated during the sampling session at Farmgate (Figure 3.4). During second and third sampling day PM concentrations were observed minimum. But normally these concentrations should be higher than the weekends due to traffic load since average traffic volume during weekdays was about 30% higher than that of weekends (Figure 2.5). Rain induced washout effects (Table 2.1) offset the traffic effect and contribution from other anthropogenic activities during these sampling days. During second sampling day wind directions were predominantly from south and south-west having high speed accompanying with occasional rainfall. In third sampling day PM concentrations were observed almost unaffected although there was no rainfall. This was probably due to clean air resulted from rains in the previous day that might prolong concentration build up of pollutants in air. During this sampling day wind directions were predominantly from south and north-east. Wind from north-east and east-northeast directions might contribute to PM load at Farmgate since in these directions heavy traffic congested area of Mohakhali and Tejgaon industrial area are located. Moreover, at Mohakhali massive construction work of Mohakhali flyover was continuing. At South of the sampling station there are several traffic intersections within 200 m of the sampling station (Figure 2.2). This might contribute to PM level at this station. The fourth sampling day was also rainless and sunny (Table 2.1) and the average wind speed was low (Figure 3.4). So an increasing trend in PM concentrations was observed due to gradual pollutant build-up in the air. Highest level of PM concentrations was observed on Thursday (from Wed-Thu through Thu-Fri sampling day). This was due to stagnant atmosphere (zero wind speed) for most of the time (Figure 2.4) and rainless and sunny weather conditions (Table 2.1). Moreover this was also the day before weekend when heavy traffic is observed. Again a decreasing PM trend concentration was observed during Friday (from Thu-Fri through Fri-Sat sampling day). This was due to high wind, rain washout and lower traffic volume on the weekend. During these sampling days predominant wind directions were from north-northeast, north and north-east (Figure 2.4). Low wind from Mohakhali and Tejgaon industrial area might contribute to the PM concentrations at Farmgate. Stagnant atmosphere (zero wind speed) for most of the time (Figure 2.4) might also help to build up PM levels in the air. This was why average PM levels during Thu-Fri through Fri-Sat sampling days were higher than that during Mon-Tue through Tue-Wed sampling days. Further decreasing trend in PM concentrations was observed during Saturday (from Fri-Sat through Sat-Sun sampling days). This was due to maximum average wind speed during this sampling session, rain induced washout effect irrespective of weekday heavy traffic volume and predominant wind from Tejgaon industrial area, heavy traffic congested Mohakhali area and major traffic intersections at Farmgate.

4. Conclusion

Air quality of Dhaka city is poor in terms of particulate matter (PM_{10} and $PM_{2.5}$) as measured at Mohakhali, the PM fractions were measured lower at Farmgate compared to that at Mohakhali which was due to lower traffic volume, termination of brick kiln activity and monsoon period when synoptic southerly prevailed from Bay of Bengal that carries less pollutant. Weekly average PM concentrations (both fine and respirable particulate matters) at Mohakhali were much higher than USEPA 24-hrs average standard values of150 $\mu g/m^3$ for PM_{10} and 65 $\mu g/m^3$ for $PM_{2.5}$. It has been found that the contribution of fine particles with aerodynamic diameter less than 2.5 µm to PM_{10} at Mohakhali was about 28% and at Farmgate it was about 53%, which are mainly of anthropogenic origin and predominately from incomplete combustion sources.

Vehicular and brick kiln emission has significant effect on particulate pollution. Positive correlation between vehicular and brick kiln emission and ambient particulate concentrations was identified. Particulate concentration shows decreasing trend as the number of vehicles goes down during weekends and with termination of brick kiln operation.

It was observed that the particulate concentration reduces as the wind speed increases. However, some discrepancy was observed at Mohakhali due to wind directions. High-speed wind even increases particulate concentrations if it is directed towards sampling location from polluting sources and vice versa.

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