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Temporal variation of ambient particulate matter in Chattogram City, Bangladesh

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ABSTRACT:

Introduction: Chattogram is known as the Bangladesh's commercial capital with its diversified industrial areas and seaport. This study aimed to assess the Particulate Matter ($PM_{2.5}$ and PM_{10}) in relation to meteorological characteristics in Chattogram city from 2013-2018.

Materials and methods: Monthly $PM_{2.5}$ and PM_{10} data were collected from the Continuous Air Monitoring Station (CAMS) in Chattogram City (Agrabad Point) which is operated by the Department of Environment (DoE) of Bangladesh under the Clean Air and Sustainable Environment (CASE) project.

Results: This Study found the higher concentration of both $PM_{2.5}$ and PM_{10} occurred from December to February and it decreases from July-September and begins to increase from the month of October. The PM values seasonally varied being higher during the winter seasons and decreased in rainy seasons. The $PM_{2.5}$ mass was detected 50% of that of PM_{10} which is mostly from biomass burn and vehicles activities. Meteorological parameters such as rainfall and humidity had strong inverse relation with both $PM_{2.5}$ and PM_{10} over the years.

Conclusion: The Study found the average annual concentration of $PM_{2.5}$ was 5-6 times higher and PM_{10} was 3 times higher than Bangladesh National Ambient Air Quality Standard (BNAAQS) in Chattogram city over this six year period. It can be concluded that the air pollution in Dhaka city is deteriorating rapidly and it is high time to implement the clean air act urgently to reduce such destruction.

Introduction

Ambient air pollution in urban areas is a major concern for many developing countries in the worldwide [1]. There are many sources including construction activities, brick kilns, vehicles, trash burning, open waste dumping, industrial emissions and road dust are responsible for air pollution in urban areas [2, 3]. These sources contribute various air pollutants such as Sulfur dioxide (SO_2), Nitrogen dioxide (NO_2), Ozone (O_3), Particulate Matte ($PM_{2.5}$ and PM_{10}), Carbon Monoxide (CO) and Carbon dioxide (CO_2). Among these pollutants $PM_{2.5}$ (an aerodynamic diameter of 2.5 µm or less) and PM_{10} (an aerodynamic diameter of 10 µm or less) cause an adverse effect on human health [4]. Dhaka,

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Chattogram, Narayanganj and other cities in Bangladesh have experienced some of the highest PM concentrations in the world [5-8]. Brick kilns and motor vehicles are the most common sources of fine particulate matter ($\leq PM_{2.5}$) while construction activities and road dust generates the coarse particulate matter ($\leq PM_{10}$) in urban areas of Bangladesh including Chattogram city [9]. Industrial zones are inside of this city which have potential threat to the overall air quality of Chattogram. The largely uncontrolled steel mills and some cement factories are located within commercial and residential areas, resulting in substantial PM exposure to the residents of those areas [5]. The Government of Bangladesh with the financial assistance from the World Bank has implemented the Clean Air and Sustainable Environment (CASE) project with a view to improve the air quality in the urban areas of the country. This study reviewed the monitoring of PM from 2013 to 2018 in Chattogram city.

Materials and methods

Site descriptions

Chattogram city is situated between 22°14'-22°24' N Latitude and 91°46'-91°53' E Longitude on the right bank of Karnafuli river (Fig. 1). Old and worn out commercial vehicles travel the major road network from the port area northward towards the industrial areas [9]. Some recent development projects such as flyover, road construction and industrial projects are going on in this city. The CAMS is located at the CDA residential area near the "Hatekhary" School. The sampling inlets are placed on the flat roof of the CAMS shelter, about 7 m above the ground and the intake nozzle of the sampler is located 1.8 m above the roof with good natural ventilation [10].

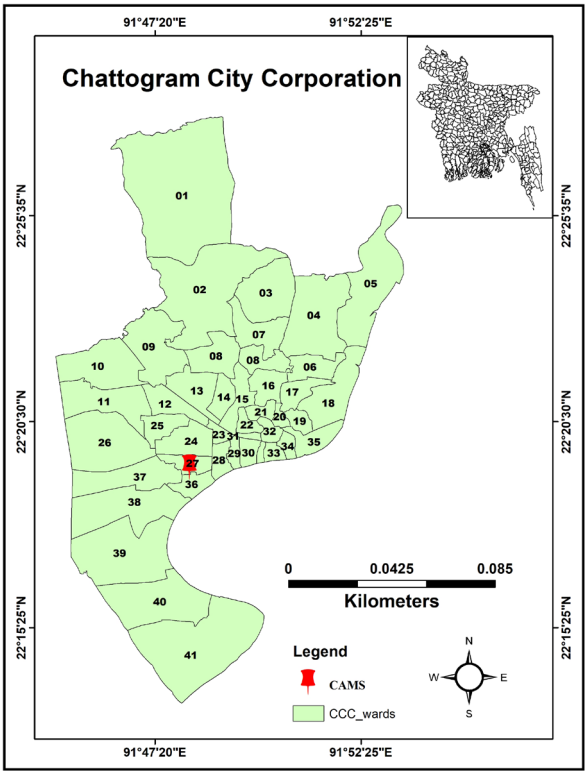

Fig. 1. Map of the study area

Data collection and analysis

Average monthly PM and meteorological data were collected from CAMS-07 (Agrabad R/A, CDA, Chittagong) operated by Department of Environment (DoE) under the project of Clean Air and Sustainable Environment (CASE). The beta gauge instrument measures the volume of air extracted through the stack/duct for each sample interval and calculates mass concentration in the specified units (e.g., µg/m^3). More information on data collection procedures are available on the CASE website: http://case.doe.gov.bd/. All collected data was analyzed using the Statistical Package for Social Science (SPSS 20). Microsoft Excel was also used for data presentation as well as for making tables and graphs.

Results and discussion

Monthly and Seasonal Concentration of Particulate Matter

The Average monthly concentration of $PM_{2.5}$ and PM_{10} in Chattogram city are shown in Figs. 2 & 3. The monthly mean concentration (January>February>December>November) of both $PM_{2.5}$ and PM_{10} exceeded the BNAAQS ($PM_{2.5}$: 65 µg/m^3, PM_{10}: 150 µg/m^3) for 24 h. This study found the higher concentration of both $PM_{2.5}$ and PM_{10} occurred from December to February. PM concentration decreases from July-September and begins to increase from the month of October. The $PM_{2.5}$ concentration decreased in 2018 compared to previous years while PM_{10} has peaked in 2018. A number of construction activities have occurred over the past 3-4 years ago in this city which attributes to high concentration of coarse particles (PM_{10}). It was shown in a study that about 40% of $PM_{2.5–10}$ mass comes from soil dust including road dust in Chattogram city [5].

Annual mean concentration of $PM_{2.5}$ found to be 71 µg/m^3, 76.5 µg/m^3, 75.4 µg/m^3, 63.9 µg/m^3, 51.1 µg/m^3 and 57.2 µg/m^3 from 2013-2018 respectively (Fig. 4) exceeding 3-4 times the NAAQS (15 µg/m^3) and 5-6 times higher than World Health Organization (WHO) (10 µg/m^3) standard. In addition, PM_{10} was 123 µg/m^3, 128 µg/m^3, 117.3 µg/m^3, 113.4 µg/m^3, 119.6 µg/m^3, 164.4 µg/m^3 from 2013-2018 respectively exceeding 2-3 times the BNAAQS and 5-6 times higher than WHO standard. It was found in a study that, yearly average PM_{10} and $PM_{2.5}$ concentrations based on 2013 and 2014 scenario in Dhaka,Gazipur and Narayanganj city of Bangladesh were about three and six times higher than the national BNAAQS respectively [11].

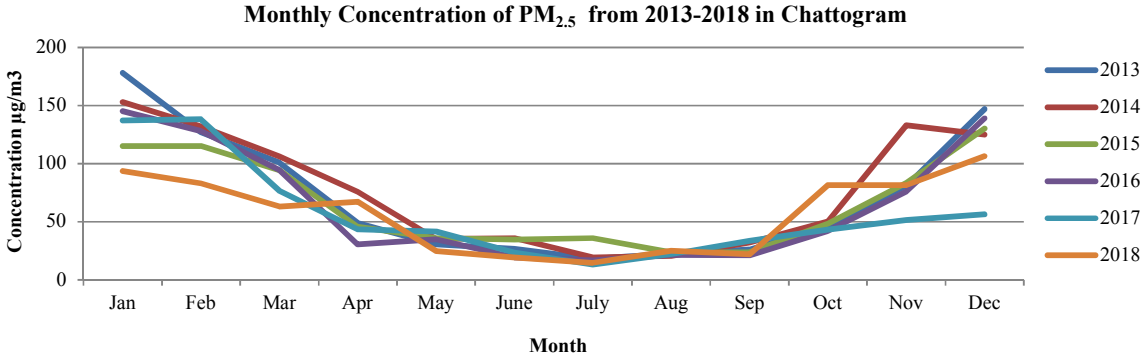

Fig. 2. Monthly Variation of $PM_{2.5}$ from 2013-2018 in Chattogram City

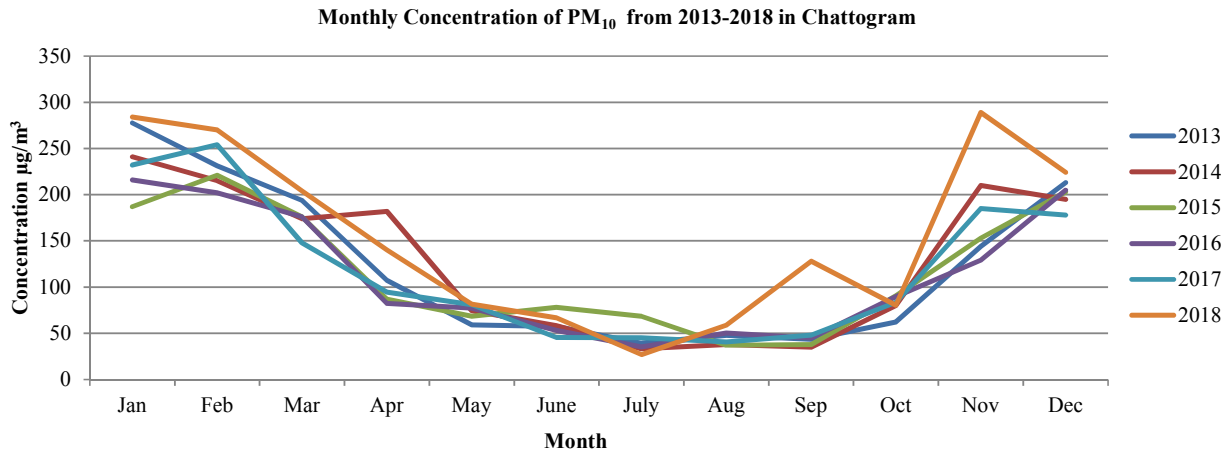

Fig. 3. Monthly variation of PM_{10} from 2013-2018 in Chattogram City

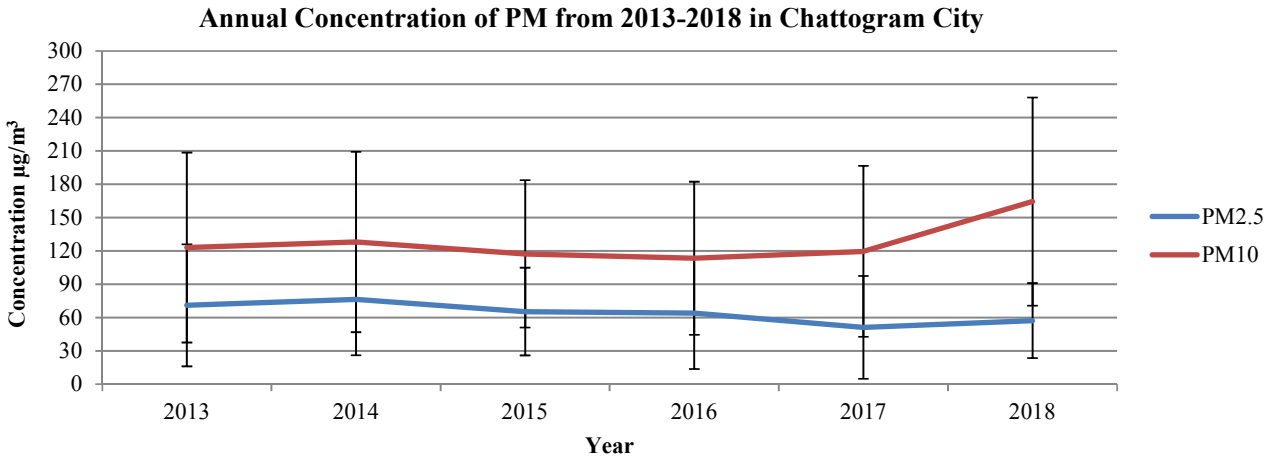

Fig. 4. Annual concentration of PM from 2013-2018 in Chattogram

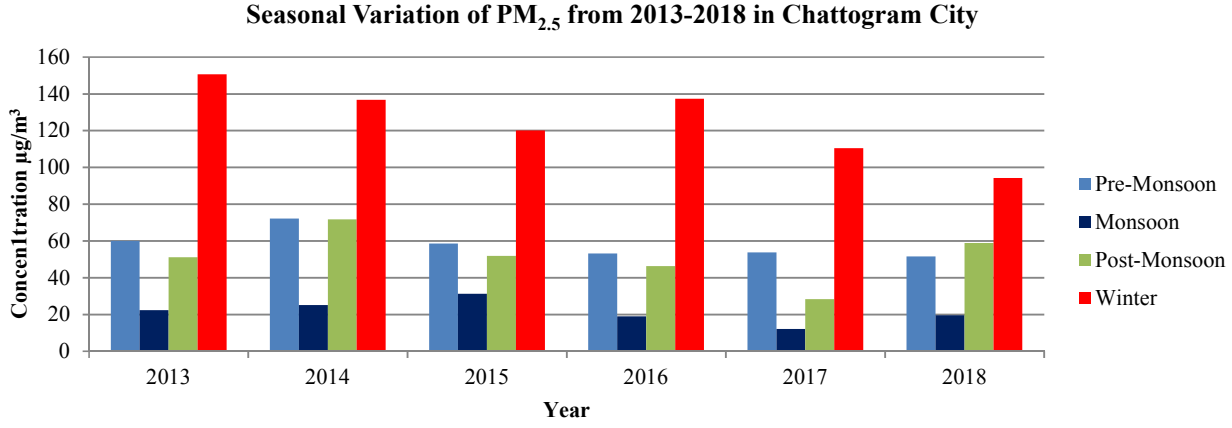

Fig. 5. Seasonal variation of $PM_{2.5}$ from 2013-2018 in Chattogram

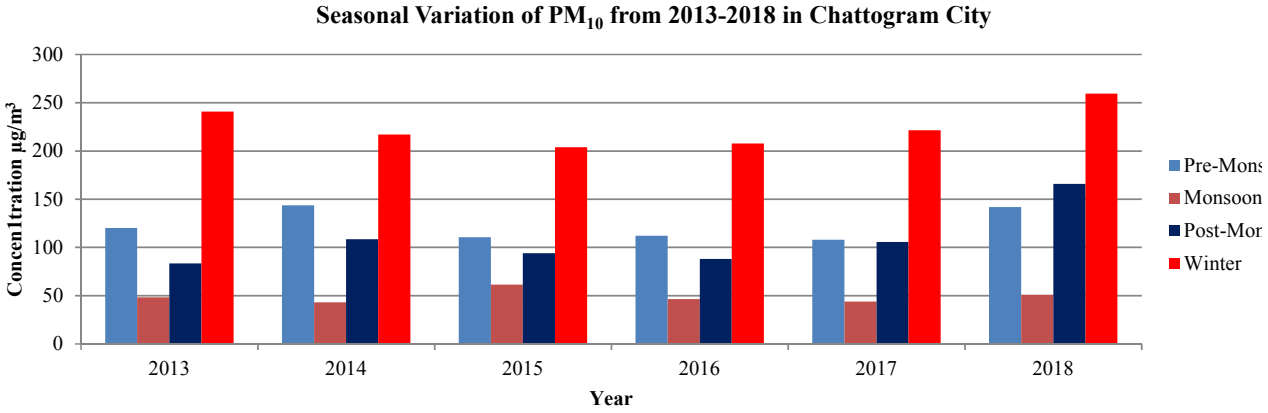

Fig. 6. Seasonal variation of PM_{10} from 2013-2018 in Chattogram

When the rainfall and wind speed is high, especially in monsoon period, the concentration of $PM_{2.5}$ and PM_{10} goes down [12]. Strong seasonal patterns were detected and the maximum concentration of PM was observed during winter time (Figs. 5 and 6). With the relatively low temperatures and low rainfall in winter and premonsoon, the mixing height becomes lower and the particulate matter is trapped nearer to ground level resulting to increase the PM concentration in the air. Besides, High emissions from brick kiln industries, vehicles emissions and road dust are thought to contribute to the increased PM concentrations especially in winter season [9]. Maximum concentration of $PM_{2.5}$ and PM_{10} was found 150.6 µg/m^3 in 2013 and 259.4 µg/m^3 in 2018 respectively during the winter season. Study found the high peaks concentration of particulate matter during the winter are caused by seasonal fluctuations of the emissions and meteorological effects including wind direction and mixed layer heights [6].

Relationship and mass ratio between $PM_{2.5}$ and PM_{10}

Fig. 7 showed the monthly PM_{10} and $PM_{2.5}$ concentration are strongly correlated (R^2=0.88) in Chattogram city over the 2013-2018. The result indicates that, fine particles and coarse particles are increased by parallel way over the year. Several studies in Bangladesh and abroad found the positive and strong relationship between the PM fractions [13-17]. Study has been found the positive relationship (R^2 = 0.82) in Dhaka city during 2002-2005 [13].

The seasonal average PM ratio calculated to be 0.50 (Table 1). The highest ratio was observed in winter season (0.56) followed by the post-monsoon season (0.52). The lowest ratio was found during monsoon season (0.45) which indicates the influence of rainfall, wind direction, humidity and temperature. Fig. 8 shows that $PM_{2.5}$ fraction decreases during rainy months especially in April to August to 50% of that of PM_{10} and increases during post monsoon and winter months. The major sources contributing to the coarse PM fraction are soil dust including suspended soil, road dust and construction activities combined account for 64% of the observed coarse mass in Chttaogram city [9]. In addition, brick kilns, old vehicles and biomass burning are found to be the major contributors for fine PM.

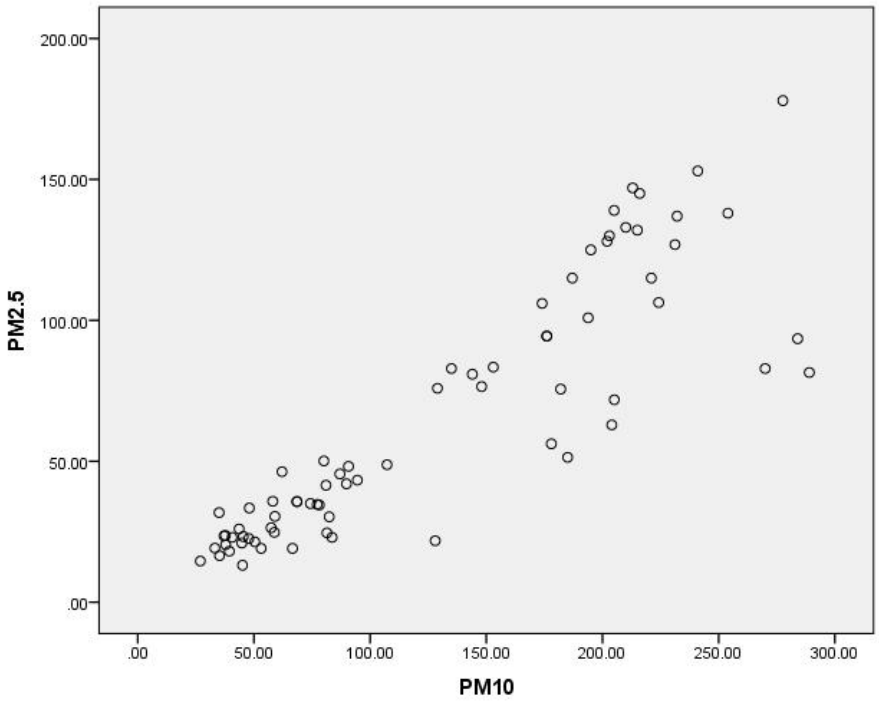

Fig. 7. Relationship between PM_{10} and $PM_{2.5}$

Table 1. Particulate matter ratio in different season since 2013-2018 in Chattogram City

Season	$PM_{2.5}/PM_{10}$	STD
Pre-Monsoon (March-May)	0.47	0.08563
Monsoon (June-September)	0.45	0.14723
Post-Monsoon (October-November)	0.52	0.21743
Winter (December-February)	0.56	0.12531
Total (2013-2018)	**0.50**	**0.15519**

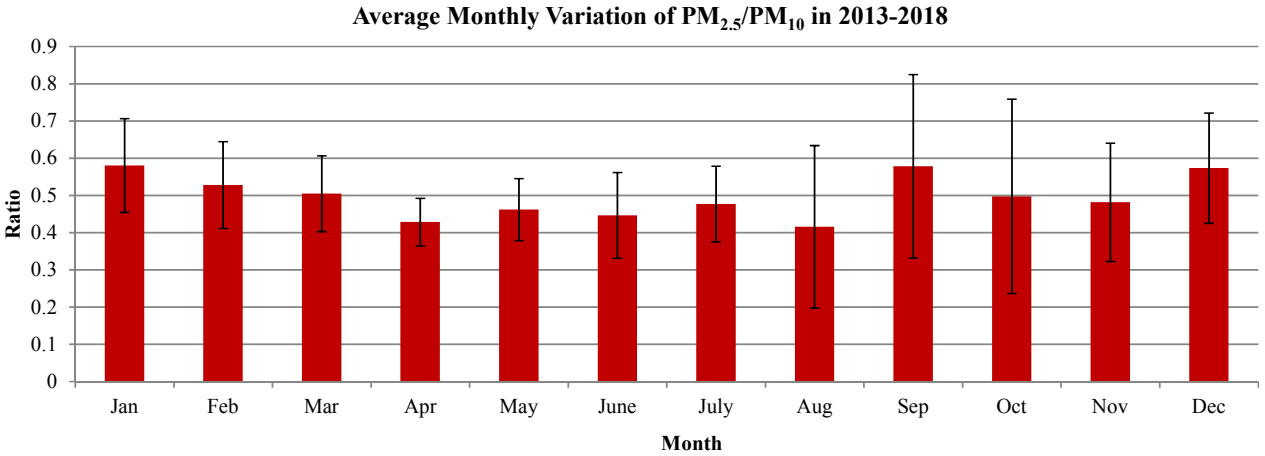

Fig. 8. Ratio between PM_{10} and $PM_{2.5}$ in Chatttogram City

Correlation between PM and meteorological parameters

Table 2 indicates the correlation between PM and meteorological parameters from 2013-2018. It was observed that, both $PM_{2.5}$ and PM_{10} had the strongly inverse relationship with humidity. That means when the annual average humidity rate increases the concentration of particles decrease. The temperature has an influence on humidity in atmosphere. This study also found the strongly negative relationship among temperature and particles. Besides, rainfall always attributes to combat the pollution level from atmosphere especially in monsoon season. This study observed the same results though in the year of 2015 the relation was not significantly strong with PM. Fig. 9 presented the seasonal relationship between PM and Meteorological parameters in Chattogram city. Humidity, temperature and rainfall have also the seasonal influence and it shows the all selected parameters had negative relation with different seasons. It indicates that, when the humidity and temperature increases especially in monsoon seasons the particles concentration decreases significantly. In addition, monsoon seasons had the highest rainfall rate which also contributes to drop the particles concentration. Eventually, winter seasons had the highest concentration of PM due to low temperature, humidity and rainfall rate.

Table 2. Correlation with PM and meteorological parameters

Year			$PM_{2.5}$	PM_{10}	Humidity	Temp.	Rainfall
2013	$PM_{2.5}$	Pearson Correlation	1	.982**	-.802**	-.947**	-.691*
		Sig. (2-tailed)		.000	.002	.000	.013
	PM_{10}	Pearson Correlation	.982**	1	-.874**	-.884**	-.723**
		Sig. (2-tailed)	.000		.000	.000	.008
2014	$PM_{2.5}$	Pearson Correlation	1	.972**	-.909**	-.850**	-.622*
		Sig. (2-tailed)		.000	.000	.000	.031
	PM_{10}	Pearson Correlation	.972**	1	-.920**	-.742**	-.646*
		Sig. (2-tailed)	.000		.000	.006	.023
2015	$PM_{2.5}$	Pearson Correlation	1	.983**	-.729**	-.928**	-.575
		Sig. (2-tailed)		.000	.007	.000	.050
	PM_{10}	Pearson Correlation	.983**	1	-.780**	-.879**	-.567
		Sig. (2-tailed)	.000		.003	.000	.055
2016	$PM_{2.5}$	Pearson Correlation	1	.988**	-.808**	-.919**	-.767**
		Sig. (2-tailed)		.000	.001	.000	.004
	PM_{10}	Pearson Correlation	.988**	1	-.879**	-.868**	-.822**
		Sig. (2-tailed)	.000		.000	.000	.001
2017	$PM_{2.5}$	Pearson Correlation	1	.904**	-.948**	-.802**	-.658*
		Sig. (2-tailed)		.000	.000	.002	.020
	PM_{10}	Pearson Correlation	.904**	1	-.929**	-.886**	-.807**
		Sig. (2-tailed)	.000		.000	.000	.002
2018	$PM_{2.5}$	Pearson Correlation	1	.866**	-.879**	-.845	-.765**
		Sig. (2-tailed)		.000	.000	.001	.004
	PM_{10}	Pearson Correlation	.866**	1	-.948**	-.824	-.882**
		Sig. (2-tailed)	.000		.000	.001	.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

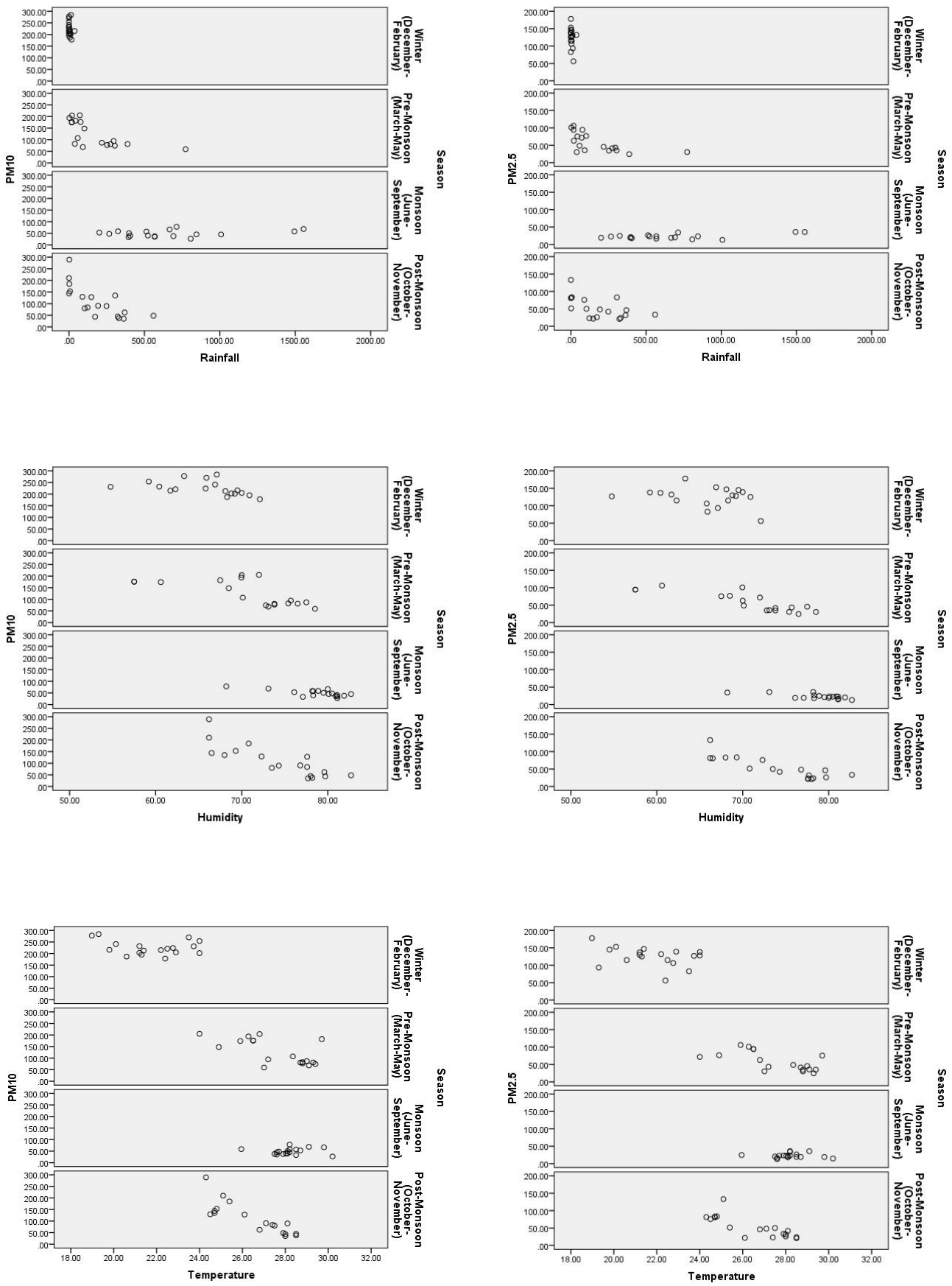

Fig. 9. Seasonal relation between PM and Meteorological parameters

Conclusion

Chattogram City is experiencing enormous problems due to worst air pollution. PM_{10} concentration gradually increased since 2013 to 2018 while the major contributing sources of this coarse particle in Chattogram city are construction activities, vehicles emission and road dust [9]. However, $PM_{2.5}$ has decreased in 2017 compared to previous year though it increases again in 2018. Both seasonal PM_{10} and $PM_{2.5}$ concentration were below or close to BNAAQS and WHO standard during the monsoon season whereas it exceeded during rest of the season in a year. The Study denotes a relationship between PM_{10} and $PM_{2.5}$ in Chattogram city for the years of 2013-2018. Average $PM_{2.5}/PM_{10}$ ratio were .50 which indicates that, $PM_{2.5}$ mass was detected 50% of that of PM_{10} in Chattogram city. Improvement of public transport system and upgradation of mass transportation may contribute to combat air pollution in Chattogram city as because a number old vehicles largely contribute to declined overall air pollution in Chattogram city. Enforcing the existing regulations and policies, such as the ban of traditional high polluting kilns or alternative use of fire brick such as sand brick could be effective steps to reducing the air pollution in Chattogram city. In addition, Government of Bangladesh should implement the clean air act as early as possible to combat this pollution.

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Competing interests

The authors declare no competing interests.

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Ethical considerations

Ethical issues have been completely observed by the authors.

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