Poll Res. 39 (3) : 632-635 (2020)

ISSN 0257–8050

ANALYSIS OF FINE PARTICULATE MATTER PM_{10} AND $PM_{2.5}$ IN THE CITY OF VISAKHAPATNAM, INDIA

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(Received 11 October, 2019; accepted 7 February, 2020)

ABSTRACT

Mass concentrations of $PM_{2.5}$ and PM_{10} over different time scales during each season of the year were measured from March 1, 2018 to February 28, 2019 in port city of Visakhapatnam (17.6868° N, 83.2185° E) located on the east coast of India. The city is studded with 14 major industries and surrounded on the three sides by the mountains and the Bay of Bengal on the fourth side. It is effectively shielded from many winds, with only marine air moving into the basin. Highest and lowest values of PM concentrations occurred in winter and summer respectively. The diurnal changes of $PM_{2.5}/PM_{10}$ mass concentrations were calculated for different seasons to identify dominant particulate matter pollution. The results indicate the fine particles arise from anthropogenic sources. The R-squared value of linear regression between $PM_{2.5}$ and PM_{10} is high with highest being 0.95 during winter season indicating coherence between them.

KEY WORDS : Coastal city, Atmospheric air pollutants, $PM_{2.5}$, PM_{10}, Seasonal variations

INTRODUCTION

Visakhapatnam (17°422N; 83°202E) is a major industrial city in the northeastern coastal Andhra Pradesh, India. The city with an area of about 680 km^2 is surrounded on three sides by mountains and the Bay of Bengal on the fourth. It is effectively shielded from many winds, with only marine air moving into the basin. The major industries along with the Port are located within a distance of 13 km from the coast. The city is studded with major industries such as Hindustan Zinc Limited (HZL), Coromandel Fertilizers Limited (CFL), Visakhapatnam Port Trust (VPT), Hindustan Petroleum Corporation Limited (HPCL), Bharat Heavy Plates and Vessels (BHPV), Hindustan Polymers Limited (HPL), Visakhapatnam Steel Plant (SP), Coastal Chemicals (CC), Andhra Cement Company (ACC) and Simhadri Thermal Power Corporation (STPC). About 200 ancillary industries were also established to supplement the main industries, which turned the central basin of Visakhapatnam into an "air-polluting chimney". The emissions from these industries and port activities along with vehicular exhaust contribute significantly to air pollution in this city. This situation is further exacerbated by atmospheric aerosol content which is the highest during the "dry" periods, resulting in a high ionic content due to precipitation scavenging. Marine aerosols also add to the industrial "contribution". The emissions and aerosols are shielded from the wind by mountains on three sides, only allowing coastal spray (marine aerosols) from the east. Visakhapatnam, thus, is subject to heavy air pollution (Srinivas *et al*., 2013).

Urbanization, population growth, industrialization and increased vehicular emissions affect the environment. Several studies reported the contamination of atmospheric Particulate Matter PM (Singh *et al.* 2014; Das *et al*., 2015; and Sarath Guttikunda *et al*., 2015) and its adverse effect on climate and health (Correia *et al*., 2013; Lakshmana Rao and Sai Lakshmi, 2014).

Atmospheric aerosols particles are important air pollutants and level of aerosol particles is represented by mean concentrations of fine particulate matter PM_{10} and $PM_{2.5}$. The ratio $PM_{2.5}$ /

PM_{10} is a useful tool to identify dominant aerosol types.

Against this backdrop, this paper attempts to analyse diurnal variations of fine Particulate Matter $PM_{2.5}$ and PM_{10}andcoherence between them in Visakhapatnam city of Andhra Pradesh in India.

MEASUREMENT METHODS

The real time hourly mass concentrations of $PM_{2.5}$ and PM_{10} were recorded by National air quality index of Central Pollution Control Board compiled for each city under the Ministry of Environment, Forests and Climate Change, India. The instruments measuring the mass concentrations are located in the central point of the city. The mass concentrations of $PM_{2.5}$ and PM_{10} are measured using beta attenuation method. The data are publicly accessible and data used in this paper were obtained from the website (https://app.cpcbccr.com/AQI_India/). The hourly mean variations of $PM_{2.5}$, PM_{10} in each season (Summer: March, April and May, Rainy: June, July, August and September, Autumn: October and November, Winter: December, January and February) during March 2018 - February 2019 at the present location were measured.

RESULTS AND DISCUSSION

Figures 1 and 2 illustrate Seasonal mass concentrations of $PM_{2.5}$ and PM_{10}. Regardless of size of particle, winter has highest PM concentration while summer has lowest PM concentrations. The winter recorded highest value probably due to prevailing inverse conditions trapping the pollutants.

The higher concentrations of $PM_{2.5}$ and PM_{10} are observed during winter (178.5, 150.7μg/m^3 respectively) and autumn (111.05, 115.6 μg/m^3 respectively) than summer and rainy seasons (Table 1). During winter the maximum values recorded for $PM_{2.5}$ and PM_{10} are 247.1 and 215.2 respectively while minimum values recorded are 118.6 for $PM_{2.5}$ and 105.6 for PM_{10} during the same season. The standard deviation of PM_{10} and $PM_{2.5}$ are lower in rainy season when compared to other seasons. The higher standard deviation values of PM_{10} (σ = 37.8) and $PM_{2.5}$ (σ = 41.8) in winter indicates complex PM dispersion phenomena because of inversion conditions.

The PM concentrations are high during daytime than night time. The peak value is observed after

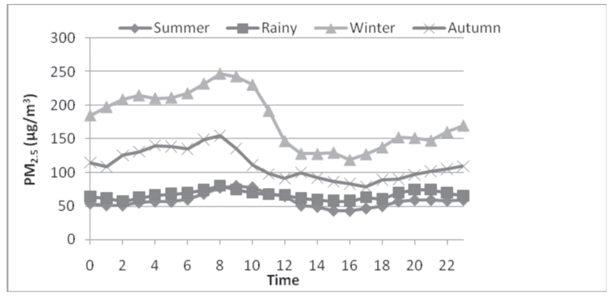

Fig. 1. Diurnal variations of hourly $PM_{2.5}$ concentrations

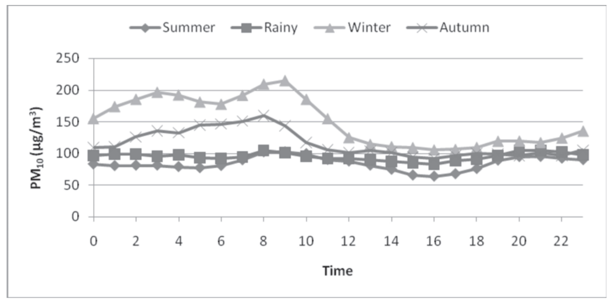

Fig. 2. Diurnal variations of hourly PM_{10} concentrations

08:00AM and falls to lowest in afternoon hours after 1:00PM. It is evident from observations, the increase in PM after 4:00PM and before 11:00AM is because of vehicle emissions as a result of transportation in rush hours. The heavy duty vehicle traffic is more during morning and night hours. As traffic related emissions are less from 12:00PM to 3:00PM there is significant decrease in PM concentrations in all seasons. The decreasing boundary layer heights also contribute to increase in PM concentrations after 4:00PM. In all seasons during night time the increase in PM levels are due to accumulation of emissions from automobiles and secondary PM formation.

The ratio $PM_{2.5}/PM_{10}$ is a useful tool that assists in spatial and seasonal identification of dominant aerosol types. Low and high ratios indicate dominance of dust aerosols and anthropogenic aerosols respectively. The diurnal changes of $PM_{2.5}/PM_{10}$ over four seasons were calculated to identify the dominant particulate matter pollution at the present location. The ratio is highest in winter (1.18) and autumn (0.95) and lowest in summer (0.68) indicating the particulate matter arise predominantly from anthropogenic sources such as heavy traffic and industrialization and also confirms the prevalence of $PM_{2.5}$ in proximity to industrial area.It also reflects that the high value is due to effect of winter inversion layer on the atmosphere.

The correlation between PMs is also measured.

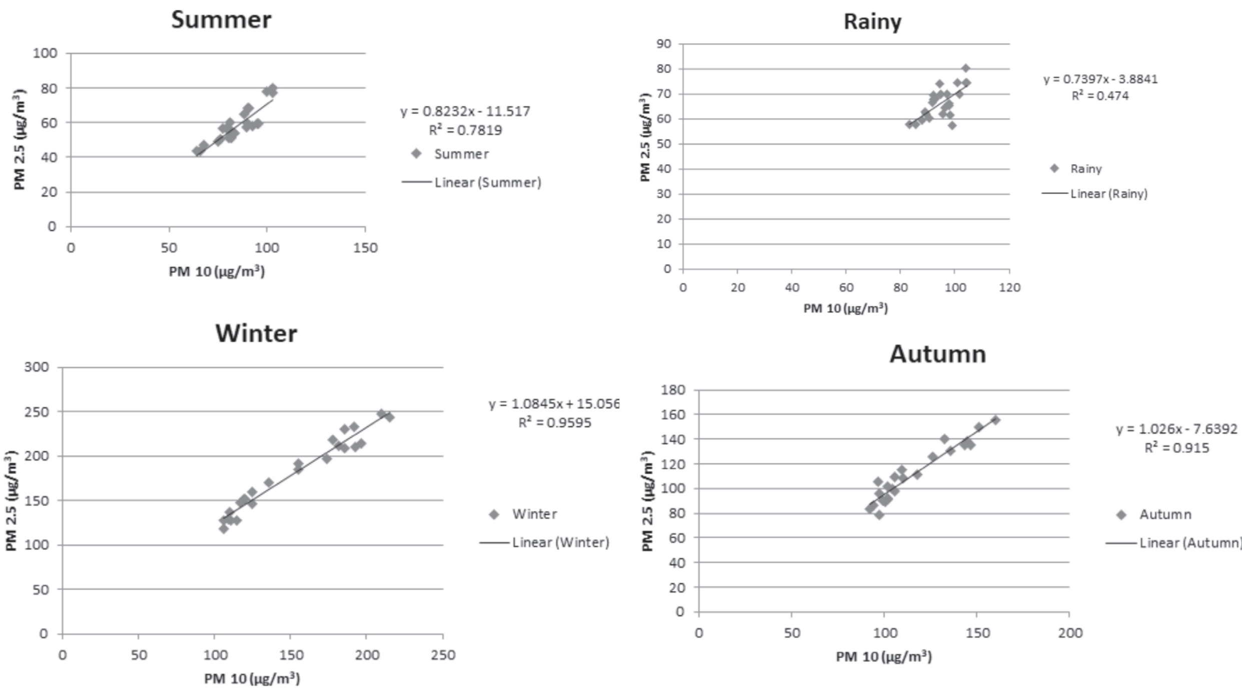

Fig. 3. Correlation of $PM_{2.5}$ and PM_{10} concentration in four seasons

Table 1. Mean and standard deviation of PM_{10} and $PM_{2.5}$ during different seasons

Season	Mean SD (µg/m³)		Maximum (µg/m³)		Minimum (µg/m³)		$PM_{2.5}/PM_{10}$
	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	
Summer	84.74 ± 10.8	58.24 ± 10	102.8	79.5	63.9	43.3	0.687295
Rainy	95.10 ± 5.8	66.46 ± 6.2	104.4	80.3	83.2	57.2	0.698855
Winter	150.77 ± 37.8	178.57 ± 41.8	215.2	247.1	105.6	118.6	1.184338
Autumn	115.68 ± 20.9	111.05 ± 22.5	159.7	155.1	92.2	78.2	0.959953

The Pearson correlation coefficient between PMs is high in all seasons (Summer: r =0.88; Rainy: r = 0.68; Winter: r = 0.97; Autumn: r= 0.95). Figure 3 shows correlation between $PM_{2.5}$ and PM_{10}. The correlation coefficients and R squared of linear regression between $PM_{2.5}$ and PM_{10} are high. The R squared of linear regression model between $PM_{2.5}$ and PM_{10} is 0.95 in winter representing remarkable coherence between two of them. The remarkable coherence indicates the proportion of $PM_{2.5}$ contained in PM_{10} is high and stable. This indicates that fine particulate matter with diameter less than 2.5 µm may be the main component of PM_{10} at this location.

CONCLUSION

The PM concentrations showed a remarkable seasonal variability - highest during winter and lowest during the summer. The winter maximum is due to temperature inversion and stagnant weather. The seasonal variations of $PM_{2.5}/PM_{10}$ ratios were in between 0.68 and 1.18 which shows the dominance of anthropogenic aerosols because of industrialization and heavy traffic at the present location. Further the PM concentrations exhibited high correlation in all seasons except rainy season. The R- squared value of 0.78 in summer, and in winter the variations were correlated with R - Squared value of 0.95. It is observed that the annual averaged PM exceeded the WHO standards (10 µg/m³) in all seasons in Visakhapatnam city.

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