Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454

Vol. 19 | No. 5 (Suppl) | pp. 1871-1878 | 2020

Original Research Paper

https://doi.org/10.46488/NEPT.2020.v19i05.011

Open Access Journal

Temporal Variations of $PM_{2.5}$ and PM_{10} Concentration Over Hyderabad

M. C. Ajay Kumar*, P. Vinay Kumar* and P. Venkateswara Rao†**
*Department of Physics, Aurora's Technological and Research Institute, Hyderabad, India
**Department of Physics, Vasavi College of Engineering, Hyderabad, India
†Corresponding author: P. Venkateswara Rao; kishansetty@gmail.com

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 31-07-2020
Revised: 31-08-2020
Accepted: 16-09-2020

Key Words:
Particulate matter
Temporal variation
Air pollution
Relative humidity

ABSTRACT

The association between urbanization and health at the global level, as well as the role of air pollution, has increased the interest in studies, aimed to improve the air quality of urban areas. Addressing the challenges of pollution caused by urbanization plays a crucial role in developing sustainable urbanization. Understanding the temporal characteristics of particulate matter mass concentrations with an aerodynamic diameter of less than 2.5 µm and 10 µm ($PM_{2.5}$ and PM_{10}) is very important to counter the effect of air pollution. We have analysed and interpreted the diurnal, monthly and seasonal variations of one-hour average PM concentrations taken from Central Pollution Control Board (CPCB) for six stations over Hyderabad, India during March 2018 to February 2020. Average concentrations of $PM_{2.5}$ (41.5 µg/m^3) and PM_{10} (91.52 µg/m^3) for two consecutive years (2018 and 2019) are found to exceed the standard values of World Health Organization (WHO) standards ($PM_{2.5}$ = 10 µg/m^3 and PM_{10} = 20 µg/m^3) and National Ambient Air Quality Standards (NAAQS) ($PM_{2.5}$ = 40 µg/m^3 and PM_{10} = 60 µg/m^3). A clear diurnal and seasonal variations are observed for all the stations. In diurnal cycle, a large PM concentration was observed between 8 AM to 10 AM and again between 6 PM to 9 PM with a minimum at 3 PM in all seasons and also for all stations which clearly shows semidiurnal variations. Data analysis shows a high concentration of particulate matter in winter compared to other seasons. The $PM_{2.5}$ (PM_{10}) concentrations in winter were found to be increased by three (two times) when compared to monsoon. The ratio of $PM_{2.5}$ to PM_{10} is very close to 0.5 during post-monsoon and winter, and 0.4 in summer and monsoon seasons, which clearly shows that $PM_{2.5}$ comprises a major portion of PM_{10}. The $PM_{2.5}$ and PM_{10} are highly correlated with correlation coefficient 0.9. Out of 6 stations, Zoo Park is contributing more particulate matter pollutant concentrations.

INTRODUCTION

Today, with rapid urbanization and industrialization, there is every possibility of increasing pollution concentrations. According to the World Health Organization (WHO), 92% of the world's population is currently living in areas where the air quality level exceeds the WHO standards (WHO 2016). In a natural environment, atmospheric air is an important element which does not have any natural protective barrier that can be isolated, and therefore the control and analysis of the impact of pollutants are essential not only on a global but also important at continental, national and local scale (Cichowicz & Wielgosiński 2015a, 2015b, Ménard et al. 2016, Vallero 2014). Both industrial smog and photochemical smog are forms of air pollution. According to the National Institutes of Health, both can create major health risks, including asthma, lung tissue damage, bronchial infections and heart problems. The main sources of air pollutants are combustion processes, various technological processes as well as vehicular emissions (Cichowicz & Wielgosiński 2015a, 2015b, Gurney et al. 2012, Lelieveld et al. 2015, Nemitz et al. 2002). It should be taken to count, that low-emission sources emit pollutants primarily during the heating season, whereas remote systems do it with varying intensity throughout the entire calendar year (Cichowicz & Wielgosiński 2015a, 2015b, Lin et al. 2011).

Hyderabad, the capital city of Telangana, is one of the fastest-growing metropolitan areas in India, located on the banks of the Musi River at an average altitude of 542 m above sea level. It covers an area of 650 sq. km and has a current population of around 10 million with an increase of **2.7%** from 2019, which makes it the 6th most populous urban agglomeration in India. It is a tropical urban city with wet and dry climatic conditions. The annual and monthly mean temperatures are 26.6°C and 21-33°C respectively. The summer months (March-May) are hot and humid with maximum temperatures often exceed 40°C and winter occur in the months (December – February) with the lowest temperature occasionally dipping below 10°C. In the last few years, a stunning growth of vehicle population was observed leading to ~60 lakhs vehicles by the end of 2020. The major sources contributing to particulate matter air pollution are from vehicular emission, road dust and industrial emission.

The air quality in Hyderabad often exceeds the NAAQ standards especially for particulate matter (PM).

In this paper, an attempt has been made to analyze and interpret the diurnal, weekly, monthly and seasonal cycles of $PM_{2.5}$ and PM_{10} concentrations measured for 6 stations over Hyderabad having high traffic density zones, industrial areas and mixed conditions. The impact of meteorological parameters such as temperature, relative humidity and wind speed on $PM_{2.5}$, PM_{10} concentrations are also discussed.

DATA DETAILS AND ANALYSIS

The Telangana State Pollution Control Board (TSPCB) is operating six Continuous Ambient Air Quality Monitoring Stations (CAAQMS) [IDA Bollaram (BLM); Hyderabad Central University (HCU); ICRISAT Patancheru (PTC); IDA Pashamylaram (PSM); Zoo Park (ZOO); Sanathnagar (SNN)] over Hyderabad. An hourly particulate matter ($PM_{2.5}$ and PM_{10}) data, downloaded from CAAQMS website (https://cpcb.nic.in/automatic-monitoring-data/) for these six stations were used in our study. It provides instant data generation, online data dissemination, meteorological parameters, etc., using sophisticated analysers for various parameters which include the particulate matter of size less than 2.5 μm and 10 μm ($PM_{2.5}$, PM_{10}). The meteorological parameters (temperature, relative humidity and wind speed) are also used to study the effect of these parameters on the PM concentrations. The details of the stations and their significance are mentioned in Table 1.

To access the air quality status about PM concentrations in Hyderabad, we analysed the recent two years of CAAQMS data for $PM_{2.5}$ and PM_{10} from all six stations. The PM_{10} concentration is not available for Sanathnagar station during the study period. Fig.1 shows the complete number of usable days of data in the form of a histogram. The total number of observational days for the period 1st March 2018 to 29th February 2020 was varying with minimum 698 and maximum 727 days across all stations, which

Table 1: Continuous ambient air quality monitoring stations.

S. No	Name of the station	Significance of station	Latitude (ºN)	Longitude (ºE)
1	Bollaram Industrial Area, Hyderabad – TSPCB	Industrial Residential Rural and Other Area	17.54	78.34
2	Central University, Hyderabad – TSPCB	Downstream of industrial area and sensitive zone	17.45	78.34
3	ICRISAT Patancheru, Hyderabad – TSPCB	Industrial Residential Rural and Other Area	17.51	78.27
4	IDA Pashamylaram, Hyderabad – TSPCB	Industrial Residential Rural and Other Area	17.53	78.18
5	Zoo Park, Hyderabad – TSPCB	Industrial Residential Rural and Other Area	17.34	78.45
6	Sanathnagar, Hyderabad – TSPCB	Centre of the city and Balanagar IDA	17.45	78.44

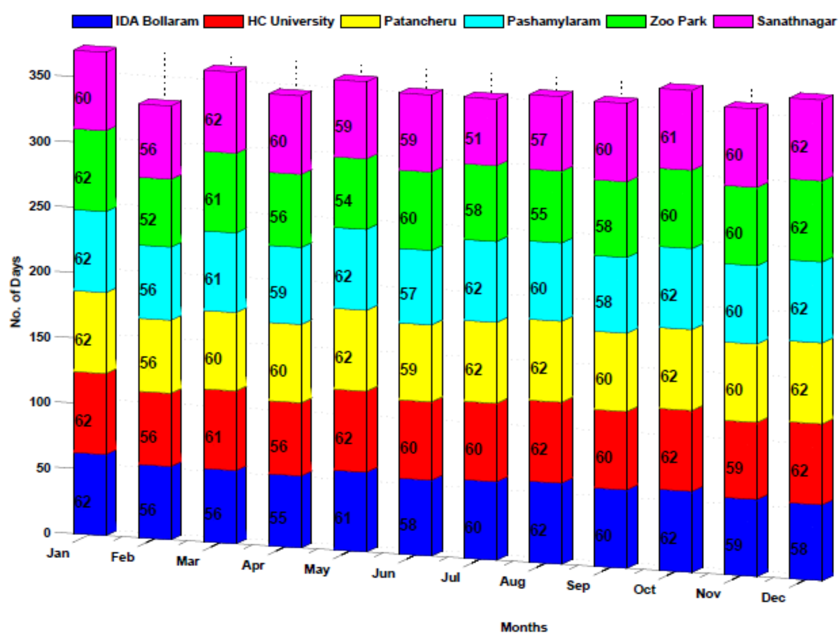

Fig. 1: Histogram of the monthly usable days for two years 2018 and 2019.

meets the valid standards for averaging, station wise (Xiao et al. 2018). Proper averaging was done to study diurnal, monthly and seasonal variations of PM concentration and effect of meteorological parameters.

RESULTS AND DISCUSSION

Temporal Variations of $PM_{2.5}$ and PM_{10} Concentrations

To evaluate the air quality status regarding the particulate matter, we attempted to analyze two years of ambient monitoring data for $PM_{2.5}$ and PM_{10} over Hyderabad. The hourly values of PM concentrations are averaged initially day-wise and subsequently averaged over a year for all six stations. The annual means are tabulated in Table 2 along with their averages. Rate of change (ROC) was used to compare the variance in $PM_{2.5}$ and PM_{10} concentrations for different stations using:

$$ROC\ (\%) = [(X - Y)/Y] \times 100 \quad \ldots(1)$$

Where, Y and X represent the average PM concentrations in 2018 and 2019 respectively, and they are tabulated in Table 2.

Coefficient of variation (CV) shown in Table 3 describes the degree of spatial variation of PM concentration in a given area and it can be expressed as

$$CV = STD/\overline{X} \quad \ldots(2)$$

We observed a significant difference in annual concentrations for six stations over Hyderabad (Table 2). The particulate matter concentrations in 2019 are found to be less than 2018 for all stations. The concentrations are much lower in Central University when compared to other stations. The percentage of days per year of particulate matter concentrations in all stations during the study period are depicted in Fig. 2.

Table 2: PM concentrations and rate of change.

Station	Parameter	2018	2019	Mean	ROC (%)
BLM	PM 2.5	45.6	40.08	43.25	-11
	PM10	100.27	95.14	97.7	-5.4
HCU	PM 2.5	38.2	29.80	34.01	-28
	PM10	90.78	78.44	84.6	-15.7
PTC	PM 2.5	40.22	35.04	37.63	-14
	PM10	93.05	81.78	87.4	-13.8
PSM	PM 2.5	42.43	37.31	39.88	-13
	PM10	93.74	89.11	91.4	-5.2
ZOO	PM 2.5	49.28	47.21	48.25	-4.4
	PM10	99.68	92.99	96.3	-7.2
SNN	PM 2.5	47.36	47.20	47.28	-0.35
	PM10	-	-	-	-

Daily concentrations of $PM_{2.5}$ (PM_{10}) ranges from 10 μg/m^3 - 75 μg/m^3 (35 μg/m^3 - 100 μg/m^3) respectively. For $PM_{2.5}$ (PM_{10}) the proportion of days with values greater than 35 μg/m^3 (70 μg/m^3) is 60%. The percentage of days with $PM_{2.5}$ concentration values of 35 - 50 μg/m^3 decrease by 10 % from 2018 to 2019 except in Zoo Park. A similar decrease in percentage was observed for PM_{10} concentration values of 75 - 100 μg/m^3.

The levels of PM concentration for different stations during the study period are shown in Fig.3. The central box comprises values of 25 and 75 percentiles, and whiskers show the range of values falling within 1.5 times the interquartile range beyond the box. The solid lines within the box represent the median values. The outliers, defined as data points beyond the inner fence are represented with '+' symbols. PM_{10} concentration data at Sanathnagar is not available and it was not shown in the figure. The average value of PM (both $PM_{2.5}$ and PM_{10}) concentration is found to be minimum at Central University. But the maximum value of $PM_{2.5}$ and PM_{10} occur at two different stations, Zoo Park and IDA Bollaram, respectively. The PM concentrations averaged for two years over Hyderabad are found to be 41.5 μg/m^3 ($PM_{2.5}$) and 91.52 μg/m^3 (PM_{10}) exceeding the values of WHO standard ($PM_{2.5}$ = 10 μg/m^3 and PM_{10} = 20 μg/m^3) and NAAQ standards ($PM_{2.5}$ = 40 μg/m^3 and PM_{10} = 60 μg/m^3) (WHO air guideline 2005, NAAQ 2009). Sarath et al. (2019) also reported similar observations from the same site.

ROC for 2019 following 2018 indicate a sharp decrease in PM concentrations at Central University when compared to other stations. The possible reasons for high negative ROC and low PM concentrations at Central University may be attributed to the improvement of roads, construction of flyovers and bypass the traffic through outer ring road. It may also due to green cover around Central University which prevent dust particles from building up in the environment. The CV is observed to be in the same order for all the stations, which indicates there is not much spatial

Table 3: Coefficient of variation (CV) of PM 2.5 and PM10 for different stations.

Station	PM 2.5			PM 10		
	2018	2019	Average	2018	2019	Average
BLM	0.39	0.42	0.41	0.31	0.37	0.34
HCU	0.51	0.62	0.57	0.44	0.5	0.47
PTC	0.54	0.55	0.55	0.45	0.52	0.49
PSM	0.51	0.53	0.52	0.45	0.48	0.47
ZOO	0.44	0.48	0.46	0.44	0.48	0.46
SNN	0.43	0.55	0.49	-	-	-

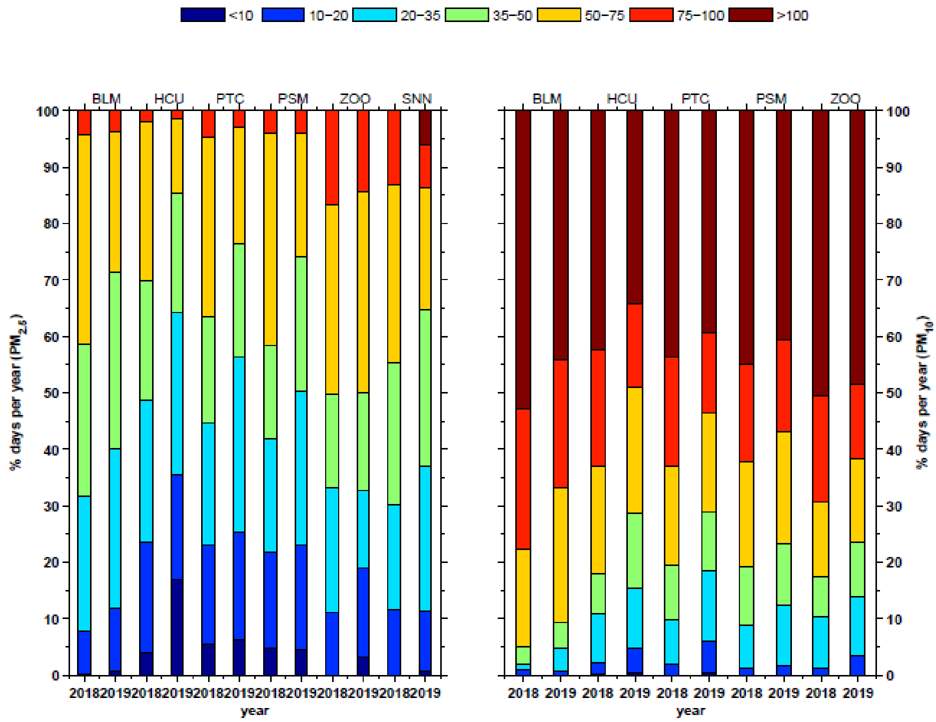

Fig. 2: The annual range of daily particulate concentrations for different stations. Left panel: $PM_{2.5}$; Right panel: PM_{10}.

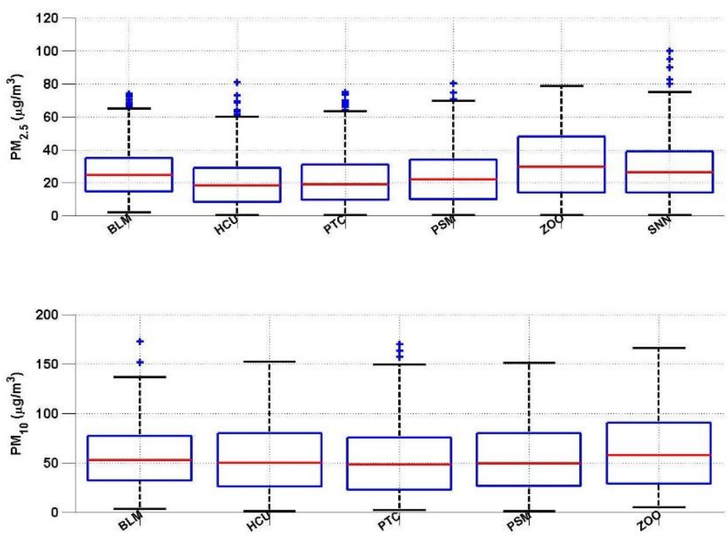

Fig. 3: The levels of PM concentration for different stations during the study period with median values (solid line within box), 25 and 75 percentiles and whiskers. The outliers are represented with '+' symbols.

variation (Yang et al. 2018). A strong correlation between $PM_{2.5}$ and PM_{10} was observed over Hyderabad with a correlation coefficient of 0.9, which could be explained by the similar sources like emissions from the combustion process, dust (due to movement of the vehicles on the road) (Tecer et al. 2008). The observed PM concentrations over six stations clearly indicate the influence of local combustion processes which includes usage of fuel in domestic heating, industrial activities, construction, transportation, and traffic.

A. Diurnal and Seasonal Variation of PM Concentrations

To study diurnal variation of particulate matter concentration, hourly values of PM for two years were averaged accordingly to get a set of 24 hour data points. Results, depicted in Fig.4, show a diurnal variation in PM concentrations which varies bimodally having two peaks between 8 AM – 10 AM and 6 PM – 9 PM, with minimum concentration observed at 3 PM. During night-time, after 9 PM the concentration was significantly decreased because of low traffic flow resulting in low emission rate (Luis et al. 2014). This behaviour mostly depends on traffic conditions in urban areas. Contributions to the annual means of PM concentrations are mainly from combustion processes and vehicle emissions. Low values of concentration are observed between 10 AM to 6 PM. One of the reasons may be the restriction of heavy-duty diesel vehicles into the city limits from 8 AM to 10 PM. The other reason is likely due to favourable dispersion conditions. Another noticeable observation is that a prominent year to year variation is observed in the case of Central University and ICRISAT Patancheru.

To study the effect of weekend and weekday on PM concentrations, mean diurnal variations of weekday (Monday - Friday), weekend (Saturday and Sunday) and their average for all stations during the study period are plotted in Fig. 5. It was observed that the difference in the trends and concentration values is marginal for weekdays and weekends. This indicates there is no noticeable weekday/weekend effect on PM concentration (Federico et al. 2015).

Further, we have analysed the averaged diurnal variations of PM concentration seasonally in all the sites during the study period for four seasons: Summer (March-May), Monsoon (June-August), Post Monsoon (September-November) and Winter (December-February). These variations are shown in Fig. 6. The variations are significantly more pronounced in winter than the other seasons. In case of $PM_{2.5}$, the post-monsoon concentration is slightly more than in summer whereas in PM_{10} it is reversed. The semi-diurnal variation was seen in all seasons except in monsoon. The seasonal variability of the PM concentrations shows a similar trend in all stations. Averaged concentrations over Hyderabad and their ratio are depicted in Table 4 for all seasons. Positive or negative correlations reflect the physical response mechanisms. A low positive and reasonable negative correlation was seen between temperature and RH with PM concentration, respectively. We also observed a better correlation between wind speed and $PM_{2.5}$ but low correlation with PM_{10}. This suggests that the dependency of $PM_{2.5}$ on wind speed was more significant than that of PM_{10} during winter (Xiao et al. 2018).

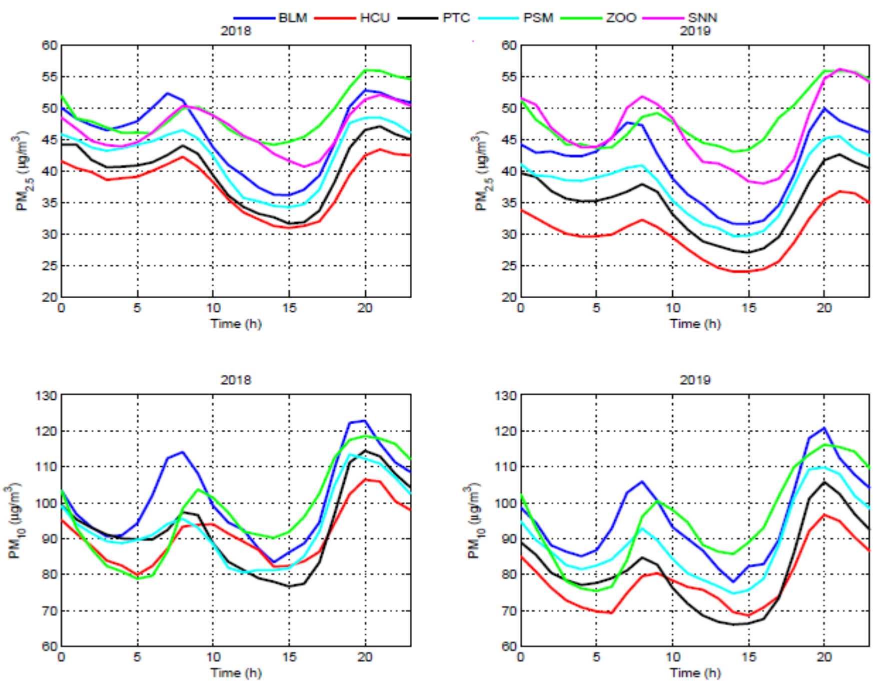

Fig. 4: Top Panel: Diurnal variations of $PM_{2.5}$ concentration of 2018 and 2019 for all stations. Bottom Panel: Diurnal variations of PM_{10} concentration.

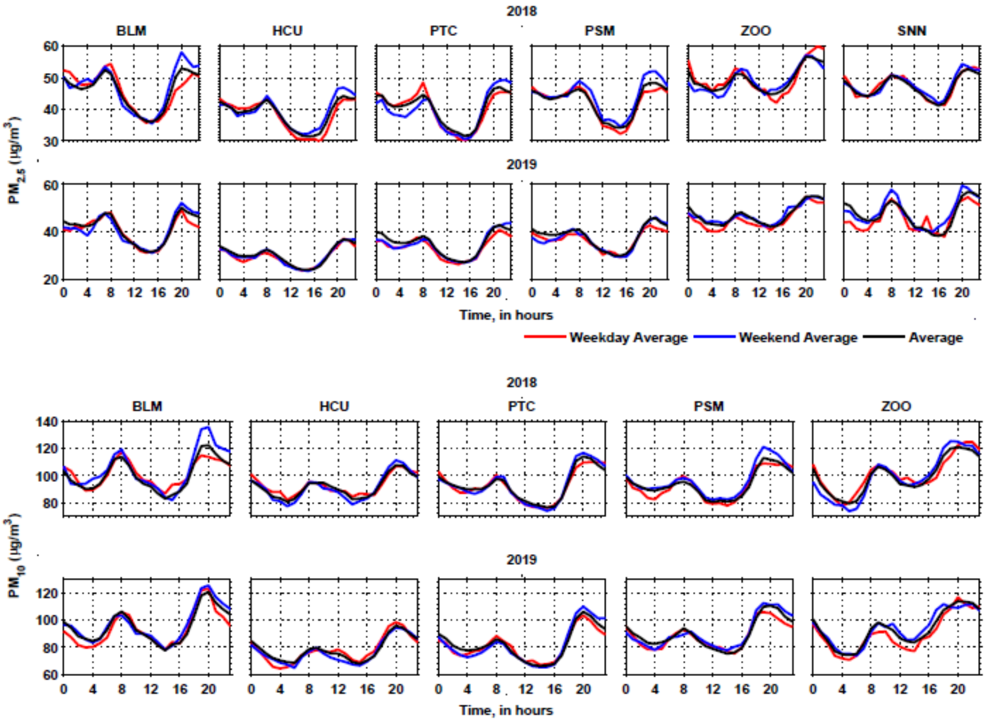

Fig. 5: Diurnal variation of PM concentrations during the weekday (Monday-Friday, Red), weekend (Saturday and Sunday, blue) and average (black) for different stations.

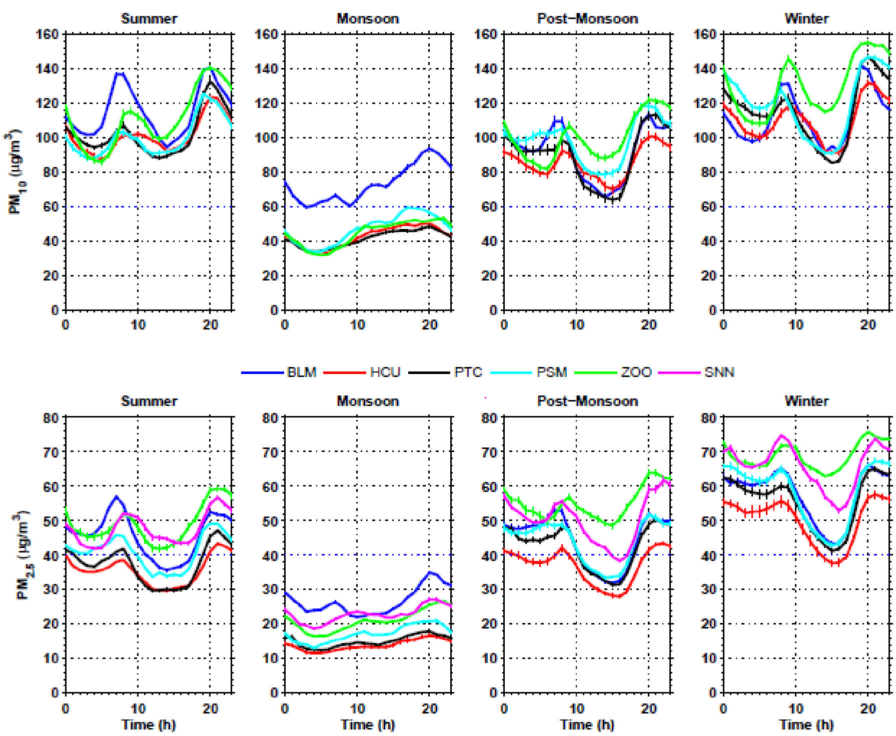

Fig. 6: Top Panel: Diurnal variations of PM_{10} concentration during summer, monsoon, post monsoon and winter seasons for different stations. Bottom Panel: Similarly, for $PM_{2.5}$ concentration.

Table 4: Seasonal variation of PM concentrations and their ratio.

Season	Mean $PM_{2.5}$	Mean PM_{10}	$PM_{2.5}$ / PM_{10}
Summer	42.7	106.1	0.4
Monsoon	19.4	49.74	0.39
Post Monsoon	45.53	93.12	0.49
Winter	59.41	117.62	0.51

High values of concentration observed in winter can be related to specific thermal inversions and domestic heating emissions. Similar observations have been examined by others (Tecer et al. 2008, Cichowicz et al. 2015). The percentage contribution of $PM_{2.5}$ in PM_{10} shows a gradual increase from summer to winter (Srimuruganandam et al. 2010). This indicates the inclusion of anthropogenic fine particles over Hyderabad. The ratio of concentrations for post-monsoon and winter is ~ 0.5 i.e., PM_{10} concentration is nearly double the $PM_{2.5}$, suggesting a large dust source in the city. A $PM_{2.5}/PM_{10}$ ratio of 0.5 is typical for developing country urban areas and is at the bottom of the range found in developed country urban areas (0.5–0.8) (WHO 2005).

B. Influence of Meteorological Parameters on Particulate Matter

To study the effect of meteorological parameters on particulate matter, daily means of $PM_{2.5}$ and PM_{10} are subsequently averaged monthly, represented by bars, and plotted in Fig. 7 along with corresponding Temperature, Relative Humidity (RH) and Wind Speed. Mean values of daily maxima of concentration in a particular month are also plotted in Fig. 7. It shows high concentrations in winter months (DJF) and low in monsoon months (JJA). Usually pollution levels in monsoon fall below the National Air Pollution standards due to precipitation, however unable to attain these standards at the other times of the year.

CONCLUSIONS

In the present study, the measurements of hourly particulate matter concentrations during March 2018 to February 2020 from six stations over Hyderabad are used to understand the temporal variations of PM concentrations and the effect of meteorological parameters. Our main conclusions are as follows: The annual mean concentrations of $PM_{2.5}$ and PM_{10} exceeded the standards of NAAQ and WHO at all stations. The concentrations are found to decrease from 2018 to 2019 and Rate of change (ROC) is declined for all station. This suggests that the measures taken by Greater Hyderabad Municipal Corporation (GHMC), as a part of the action plan (2017-2024), gave good results in controlling the particulate matter concentrations over Hyderabad. The spatial variations

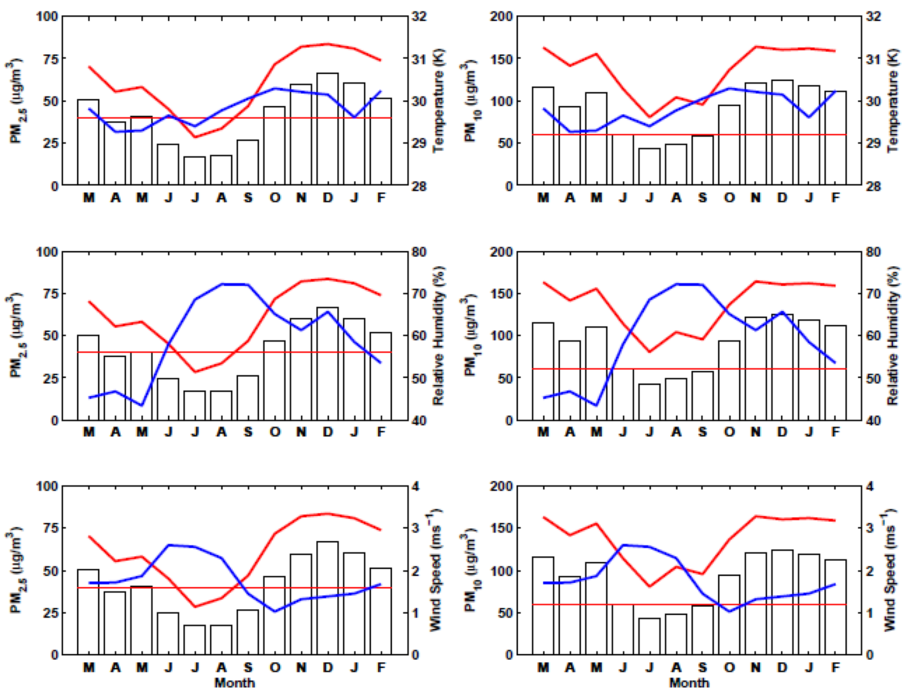

Fig. 7: Left Panel: Comparison of $PM_{2.5}$ concentration with Temperature, RH and Wind Speed. Right Panel: Similar comparison for PM_{10}. Bar graphs indicate daily means of monthly averages of PM concentration and corresponding meteorological parameters (Temperature, RH and Wind Speed, Blue); Mean values of daily maxima concentration in a particular month (Red).

in the annual average PM concentrations were observed to be in the same order for all stations. The $PM_{2.5}$ and PM_{10} concentrations are highly correlated (0.9) which indicates the sources of pollutants are mainly due to emissions from combustion sources and dust. Semidiurnal variations were seen in PM concentrations with two peaks during high traffic hours which can be attributed to vehicular emissions. A strong seasonal trend was observed in all stations, with the highest value in winter and lowest in Monsoon. The analysis showed that the meteorological parameters do not have an appreciable effect on PM concentrations. The results suggest that there is a need for a quantitative approach in evaluating the air pollutants related to the air quality over Hyderabad. To reduce further particulate matter pollutant concentrations, the developing Hyderabad city should establish and implement more joint regional air pollution control programs.

ACKNOWLEDGMENTS

The authors acknowledge Telangana State and Central Pollution Control Board for making the data available to users. The authors would like to thank the management of Vasavi College of Engineering, Hyderabad, India and Aurora's Technological and Research Institute, Hyderabad, India for their active support and encouragement.

REFERENCES

Cichowicz, R. and Wielgosiński, G. 2015a. Effect of meteorological conditions and building location on CO_2 concentration in the university campus. Ecological Chemistry and Engineering S, 22(4): 513-525.

Cichowicz, R. and Wielgosiński, G. 2015b. Effect of urban traffic on the emission of carbon dioxide in the university campus. Ecological Chemistry and Engineering S, 22(2): 189-200.

Cichowicz, R., Wielgosiński, G. and Fetter, W. 2017. Dispersion of atmospheric air pollution in summer and winter season. Environ. Monit. Assess., 189(605), doi:10.1007/s10661-017-6319-2.

Federico, M., San Martini, Christa, A. Hasenkopf and David, C. Roberts, 2015. Statistical analysis of $PM_{2.5}$ observations from diplomatic facilities in China. Atmospheric Environment, 110: 174 -185.

Gurney, K. R., Razlivanov, I., Song, Y., Zhou, Y., Benes, B. and Massih, M. A. 2012. Quantification of fossil fuel CO_2 emissions on the building/street scale for a large U.S. City. Environmental Science & Technology, 46(21): 12194-12202.

Lelieveld, J., Evans, J. S., Fnais, M., Giannadaki, D. and Pozzer, A. 2015. The contribution of outdoor air pollution sources to premature mortality on a global scale. Nature, 525: 367-371.

Lin, W., Xu, X., Ge, B. and Liu, X. 2011. Gaseous pollutants in Beijing urban area during the heating period 2007–2008: variability, sources, meteorological, and chemical impacts. Atmospheric Chemistry and Physics, 11: 8157-8170. https://doi.org/10.5194/acp-11-8157.

Luis, F., Pineda-Martínez, Noel Carbajal, Arturo Campos-Ramos, Antonio Aragón-Piña and Agustín R. García, 2014. Dispersion of atmospheric coarse particulate matter in the San Luis Potosí, Mexico, urban area. Atmósfera, 27(1): 5-19.

Ménard, R., Deshaies-Jacques, M. and Gasset, N. 2016. A comparison of correlation-length estimation methods for the objective analysis of surface pollutants at Environment and Climate Change Canada. Journal of the Air & Waste Management Association, 66: 9,874-9,895.

NAAQ 2009. https://scclmines.com/env/DOCS/NAAQS-2009.pdf

Nemitz, E., Hargreaves, K.J., McDonald, A. G., Dorsey, J. R. and Fowler, D. 2002. Micrometeorological measurements of the urban heat budget and CO2 emissions on a city scale. Environmental Science & Technology, 36(14): 3139-3146.

Sarath, Guttikunda K. and Nishadh, PujaJawahar, K. A. 2019. Air pollution knowledge assessments (APnA) for 20 Indian cities. Urban Climate, 27: 124-141.

Srimuruganandam, B. and Shiva Nagendra Saragur Madanayak, 2010. Analysis and interpretation of particulate matter PM_{10}, $PM_{2.5}$ and PM_1 emissions from the heterogeneous traffic near an urban roadway. Atmospheric Pollution Research*,* 1: 184-194.

Tecer, L.H., Pinar Süren, Omar Alagha, Ferhat Karaca and Gürdal Tuncel, 2008. Effect of meteorological parameters on fine and coarse particulate matter mass concentration in a coal-mining area in Zonguldak, Turkey. Journal of the Air & Waste Management Association, 58(4): 543-552.

Vallero, D. (5th ed.) 2014. Fundamentals of Air Pollution, London: Elsevier Inc. Academic Press.

WHO, 2005. Air Quality Guidelines, https://www.who.int/phe/health_topics/outdoorair/outdoorair_aqg/en/

WHO, 2016. Ambient Air Pollution, A Global Assessment of Exposure and Burden of Disease; Working Papers; World Health Organization: Geneva, Switzerland.

Xiao, K., Wang, Y., Wu, G., Fu, B. and Zhu, Y. 2018. Spatiotemporal characteristics of air pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, and CO) in the Inland Basin City of Chengdu, Southwest China. *Atmosphere, 9*: 74.

Yang, X., Lei Jiang, Wenji Zhao, Qiulin Xiong, Wenhui Zhao and Xing Yan, 2018. Comparison of ground-based $PM_{2.5}$ and PM_{10} concentrations in China, India, and the U.S. Int. J. Environ. Res. Public Health, 15(7): 1382.