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

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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$_{10}$ (81.52 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 & Wielgosi ski 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 & Wielgosi ski 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 & Wielgosi ski 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 2.5µm and 10µm (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

| 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 |

Table 1: Continuous ambient air quality monitoring stations.

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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:

$$\text{ROC} \% = \frac{[X - Y]/Y} \times 100 \quad \cdots(1)$$

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

$$\text{CV} = \text{STD/ } \bar{X} \quad \cdots(2)$$

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 possible reasons for high negative ROC and low PM concentrations at Central University may 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

| 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.

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Diurnal and Seasonal Variation of PM Concentrations:

To study diurnal variation of particulate matter concentration, hourly values of PM for two years were averaged over Hyderabad. The CV is observed to be in the same order for all the stations, which indicates that there is not much spatial 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 emission 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).
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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).

### 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                  |

### 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).
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**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
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.

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