The study of variation of PM$_{10}$ concentrations with meteorological conditions in ambient air

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Abstract

A review of the annual PM$_{10}$ concentrations over 3 years showed the study area was subjected to severe particulate pollution. Meteorological data of Hyderabad city obtained from Central Pollution Control board (CPCB) at ICRSAT monitoring station. Investigations of daily PM$_{10}$ concentration variation with the meteorological records were done it was identified that a unique aspect of the monsoon climate, changes in wind direction, and wind speed mainly governs the general trend of concentration of PM$_{10}$ within each year. The results in this study are obtained by graphical representation of the collected data.

Keywords: Particulate matter; relative humidity; wind speed, wind direction; meteorological conditions

1. Introduction

Particulate matters are complex air contaminants that come in a variety of sizes, forms, and sources. PM$_{10}$ is the collective term for particles with an aerodynamic diameter of less than 10µm. The effect on human health of short and long-term exposures to particulate matter(PM) in the air has been well established. [1][2] World Health Organisation(WHO) has recognized the prolonged exposure to PM$_{10}$ as a cause of premature deaths worldwide[3]. The average daily permissible limits of PM$_{10}$ in ambient air set by the Pollution control board in India is 60 µg/m$^3$. [4] In general, the levels of PM$_{10}$ are usually high in cities due to the increased population and the use of carbon-based fuels. [5][6]

Environmental patterns have a significant influence on air pollution levels in urban areas. [6][7]. According to the Telangana state pollution control board, dust emissions from road re-suspension and building activities, residential emissions from cooking, heating, and lighting activities, and transportation emissions contributed 68.2, 12.1, and 9.2 percent of total PM$_{10}$ emissions in the city of Hyderabad, respectively, in 2018. [8]. However, severe events of urban pollution are not generally triggered by sudden rises in pollutant emission, but by environmental factors that limit the air's capacity to disperse pollutants. [9][7]. This paper aims to investigate the qualitative effects of metrological factors on particulate matter concentrations, such as relative humidity, wind speed, and wind direction.

2. Study area and data

Hyderabad is the capital of Telangana, a state in southern India. It is a major industrial hub in south-east India, with several heavy industries and research institutes. It is one of the fastest-growing cities in the world, with a population density of about 17,000 people per square kilometre, owing to its importance as a major high-tech hub. The density of the city is depicted in Figure 1. Rapid urbanization has encouraged migration to the city, increasing personal, public, and para-transit vehicles (3 and 6 seat autos), industrial production, and a rising strain on city infrastructure. The climate of Hyderabad features an arid climate. The days are hot and dry, with temperatures regularly reaching 35°C, while the nights are cool and breezy. The most important aspect of the climate in Hyderabad is the monsoon climate while lasts from July to September. [10]

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The metrological data and particulate matter concentrations for this study were obtained for a period of three years (2018 to 2020) from the Central pollution control board (CPCB) - Hyderabad. The three variables considered in this study are relative humidity (%), wind speed (km/hr), and wind direction. Table 1 summarizes the daily mean wind speed, wind direction, and relative humidity extracted from the above data. Winds prominently blow from the southern region with wind speeds ranging from 0.8 to 1.6 km/hr. The monthly mean relative humidity varies from 49 percent to 78 percent throughout the year. Particularly during the monsoon months (June to October) relatively high humidity levels are observed. Since monsoon-related meteorological conditions are persistent due to their seasonal scales, they are expected to have a significant impact on ambient air quality, especially PM$_{10}$ concentrations.

3. Results and discussions

3.1. Variation of PM$_{10}$ with relative humidity

Figure 2 depicts the three-year trend in monthly mean PM$_{10}$ concentrations. The maximum average and minimum average levels of PM$_{10}$ concentration are 126.01 and 31.40 µg/m$^3$. The monthly mean concentration of PM$_{10}$ shows a regular seasonal variation with a decrease in the concentration during the monsoon months. The highest monthly mean concentration of PM$_{10}$ (126.01 µg/m$^3$) appears in January. Figure 2 clearly shows that with the increase in atmospheric humidity and the corresponding decrease in the levels of PM$_{10}$. Notable fluctuations in PM$_{10}$ are seen when the humidity is greater than 55% as humidity affects the dry deposition rate of particulate matter[7][11]. Figure 3 illustrates this change in the concentration of PM$_{10}$ with respect to Relative humidity

3.2. Variation of PM$_{10}$ with wind speed and direction

Concentrations of PM$_{10}$ over the three-year period from January 2018 to October 2020 and wind speed on the corresponding days are shown in figure 5. The wind speed was 0.82 m/s on average. Three distinct peaks were seen when a moving average filter was added that displayed above-average wind speeds. The reduction of PM$_{10}$ concentrations in the ambient air corresponded to these peaks. Between July and October, these changes were particularly observed. The wind direction distribution over the three-year period is shown in figure 4. The speeds of wind were recorded in radians. The winds blow from the southern region. Winds from the south-western regions are dominant during the monsoon months (July to October). It is during this period the PM$_{10}$ concentrations are the least.
Figure 1. Population density map of Hyderabad city.

Table 1. Monthly means of meteorological data from 2018 to 2020

| Month     | Atmospheric temperature (°C) | Relative humidity (%) | Wind speed (km/hr) | Wind Direction |
|-----------|------------------------------|-----------------------|-------------------|----------------|
|           | Mean max | Mean min | Mean |                   |               |                   |                   |                 |
| January   | 26.17     | 22.28    | 23.85 | 63.05             | 0.76          | SE                |
| February  | 27.55     | 23.50    | 25.74 | 56.71             | 0.83          | SE                |
| March     | 30.32     | 26.23    | 26.21 | 55.77             | 0.83          | SE                |
| April     | 30.05     | 26.15    | 28.39 | 51.59             | 0.81          | SE                |
| May       | 36.13     | 27.39    | 30.39 | 49.42             | 0.85          | SE                |
| June      | 33.38     | 26.93    | 29.87 | 66.26             | 1.36          | SW                |
| July      | 31.76     | 24.89    | 30.27 | 74.70             | 1.52          | SW                |
| August    | 31.24     | 27.85    | 29.62 | 78.36             | 1.52          | SW                |
| September | 31.32     | 28.26    | 29.92 | 78.36             | 0.94          | SW                |
| October   | 31.16     | 28.19    | 29.75 | 73.68             | 0.73          | SE                |
| November  | 30.95     | 27.47    | 29.43 | 66.48             | 0.69          | SE                |
| December  | 29.61     | 22.51    | 25.90 | 69.40             | 0.73          | SE                |
Figure 2. Monthly mean PM$_{10}$ concentrations from 2018 to 2020.
Figure 3. PM10 vs relative humidity

Figure 4. Daily wind direction vs PM10

Figure 5. PM10 vs Daily wind speed
4. Conclusions

PM₁₀ concentrations show fluctuations concerning meteorological factors. An increase in relative humidity results in a corresponding decrease in PM₁₀ concentrations. For the majority of the year, the winds blow from the south. The south-western winds which bring the monsoon greatly disperse the PM₁₀ concentrations in the ambient air. Higher wind speeds also result in significantly reducing PM₁₀ concentrations.

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