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Seasonal and annual emission trends of $PM_{2.5}$ and PM_{10} over the national capital Delhi from 2015 to 2020

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ABSTRACT

Introduction: Many urban cities in India, including National Capital Territory (NCT) of Delhi, have been adversely affected by air pollution since 2010s. Factors like atmospheric circulation, topography, local weather patterns, vehicular emission, industrial activities, waste burning etc. lead to extreme air pollution which is a growing threat to public health.

Materials and methods: The study was conducted to examine severity of air quality in Delhi from 2015 to 2020. For this purpose, Particulate Matters ($PM_{2.5}$ and PM_{10}) measurements were done at ITO, Mandir Marg, Punjabi Bagh, Anand Vihar, and R K Puram for a period of 2015 to 2020. Everyday data was collected to interpret and analyze the trend of air pollution both seasonally and annually.

Results: There was a significant increase in particulate matter levels at ITO, Mandir Marg, and RK Puram in the year 2016 while in the case of Anand Vihar the highest levels were measured in 2017. Also, Punjabi Bagh showed the highest PM_{10} levels in 2017. The annual average data for all five sites indicates that $PM_{2.5}$ and PM_{10} levels were above the air quality standard throughout the study period. Anand Vihar showed the highest level of particulate matter among all five locations during the study period of 2015 to 2020. The change in seasons is also one of the important factors affecting air quality. Overall, $PM_{2.5}$ and PM_{10} concentration were recorded maximum during winters i.e. 218.07 µg/m^3 and 358.80 µg/m^3 respectively.

Conclusion: The results conclude that air quality deteriorated more during winters>autumn>summers>monsoon. Also, the air quality index (AQI) recorded for Delhi during the study period was highest in 2016, respectively. Though AQI decreased over the years, it lied in poor quality only.

Introduction

The deterioration of urban air quality has been happening for a long time due to the rise in industrial, transportation, as well as construction activities. Dust storms, open burning of waste, forest fires, etc. also contribute to air pollution. All such activities increase the level of air pollutants including CO_2, Particulate Matters (PM), SOx, NOx, and other harmful gases. Increased levels of air pollutants, further lead to many diseases, such as acute and chronic bronchitis, asthma attacks, diseases associated with the heart and

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lungs, pulmonary diseases and a reduction in life expectancy [1, 8].

The National Capital of India, Delhi, and the National Capital Region (NCR) are the regions that are highly populated, have the highest number of vehicles, and are surrounded by high pollution-causing industrial clusters [5, 9, 10]. This is one of the reasons that people in Delhi and the NCR are experiencing the problem of deteriorating air quality. In the past few years, the level of Particulate Matter (PM) has increased drastically. PM may directly emit from the source or could be formed by a chemical reaction of gases in the atmosphere. Sulphate, nitrates, mineral dust, ammonia, black carbon, sodium chloride, and water are the major components of particulate matter [3, 4]. Transportation is the main source of $PM_{2.5}$ emissions in Delhi and NCR. The total number of registered motor vehicles in the National Capital Territory of Delhi in 2018 was 109.86 lakhs and reached 11.89 million in 2020 [11]. Further, industrial activities, landfills, waste burning, dust from construction activities, pollen, and fragments of bacteria are major sources of PM_{10} emissions. Long-term exposure to $PM_{2.5}$ and PM_{10} is leading to cardiovascular diseases, respiratory mortalities, and premature deaths among people who have chronic heart and lung diseases. The international Agency for Research on Cancer also concluded in their study that PM in outdoor air leads to lung cancer [12]. The World Health Organization has updated the air quality guidelines, which provide an assessment of the health effects of air pollution and thresholds for harmful pollutants [2]. The guideline values for $PM_{2.5}$ are 5 $\mu g/m^3$ (annual mean) and15 $\mu g/m^3$ (24-h mean), while in the case of PM_{10} it is 15 $\mu g/m^3$ (annual mean) and 45 $\mu g/m^3$ (24-h mean).

Air pollution has been of great concern to the environment and human health, and the air quality index (AQI) is an important index to understand the air pollution level to enhance public awareness about health. The important air pollutants, including PM, SO_2, NO_2, CO, O_3, NH_3, and Pb, are taken into consideration for estimating AQI. Low AQI is an indicator of a good environment and health, whereas high AQI leads to poor air quality and bad health [4, 6].

The current study was carried out to estimate the concentrations of $PM_{2.5}$ and PM_{10} in the National Capital of Delhi over a period of 2015 to 2020. For the study, a total of five sites were selected within Delhi to measure both seasonal and annual concentrations of $PM_{2.5}$ and PM_{10}.

Materials and methods

Study Area

The study was conducted in the National Capital Territory (NCT) of Delhi to analyse the air quality from 2015 to 2020. Selected study locations are shown in the map (Fig. 1).

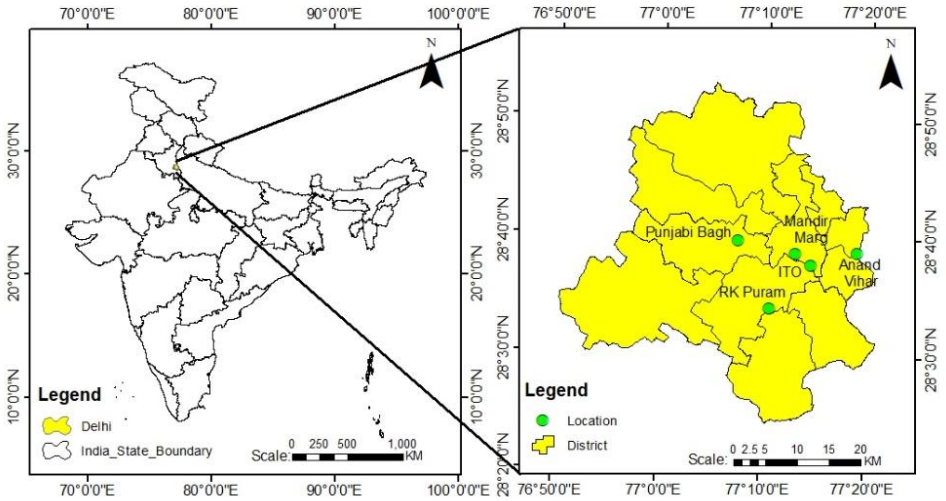


Fig. 1. Map showing study locations

Air quality data for Delhi

Delhi is located in North India at 28o24′17″ and 28o53′00″ N Lat., 77o45′30″ and 77o21′30″ E long, and approximately 216 m amsl. Located in the subtropical belt, Delhi has intensely hot summers and cold winters. The population of Delhi increased from 25,866,000 in 2015 to 30,291,000 in 2020. A significant change in air quality all over Delhi has been observed in the past few years due to the growth in population and their demands. Therefore, the Central Pollution Control Board installed an air quality monitoring station in different parts of Delhi under the National Ambient Air Quality Monitoring Programme. In the present study, a total of five monitoring sites were identified in the Delhi region to measure the air pollution levels, which include Anand Vihar, Punjabi Bagh, ITO, R K Puram, and Mandi Marg. The annual data on air pollutants for $PM_{2.5}$ and PM_{10} was obtained from the Central Pollution Control Board website at an interval of every 24 hours for the period of 2015 to 2020. The data collected was analysed statistically to observe the air quality over NCT Delhi. For studying the seasonal variations, 5 years of data were taken, including the winter season from December to January, the autumn season from the end of September to November, the monsoon season from July to mid-September and the summer season from April to June.

Air quality index (AQI) for Delhi

The air quality index is an important index that tells us about the quality of the air we breathe. It also focuses on health effects related to air pollutants. AQI ranges from 0 to 500. AQI lying between 0 to 50 is good, 51-100 is satisfactory, 101-200 is moderate, 201 to 300 is poor, 301-400 is very poor, and above 401 is severe [4]. Higher AQI values pose serious health hazards to people who are very weak and sensitive to air pollution. The AQI of Delhi for the study period of 2015 to 2020 was analysed to depict the number of healthy/ moderate /poor or severe years. Following Eq. 1 is to calculate AQI as per the Central Pollution Control Board:

$$Ip = [IHi - ILo/BPHi - BPLo] (Cp - BPLo)+ILo \quad (1)$$

Where,

Ip = index of pollutant p

Cp = truncated concentration of pollutant p

BPHi = concentration breakpoint i.e. greater than or equal to Cp

BPLo = concentration breakpoint i.e. less than or equal to Cp

IHi = AQI value corresponding to BPHi

ILo = AQI value corresponding to BPLo

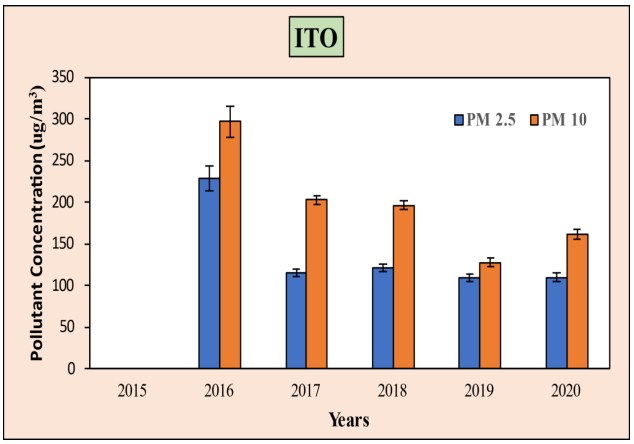
Results and discussion

The everyday data collected from 2015 to 2020 was interpreted, and annual variations were recorded for all the sites. The results are shown in Fig. 2 (a, b, c, d, e).

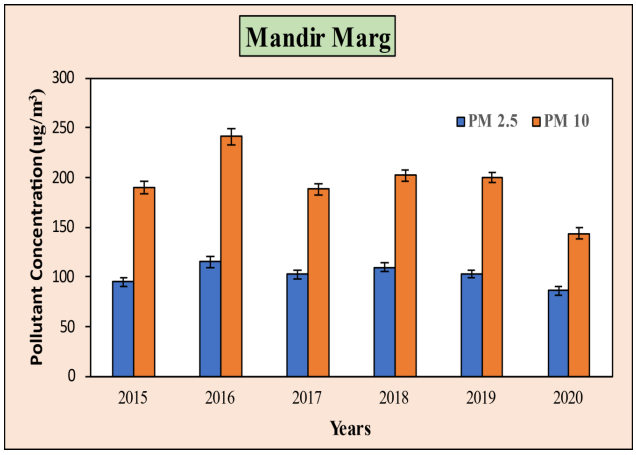
Annual variations

Fig. 2a shows the average annual variations obtained for ITO. The average PM_{10} and $PM_{2.5}$ concentrations of 296.60 µg/m^3 and 228.08 µg/m^3 were recorded in 2016, and the minimum PM_{10} and $PM_{2.5}$ concentrations of 127.76 µg/m^3 and 109.08 µg/m^3 were recorded in 2019. In the case of Mandir Marg (Fig. 2b), the average annual concentration of PM_{10} was recorded 241.22 µg/m^3 and $PM_{2.5}$ was 115.61 µg/m^3 in the year 2016. Despite the PM concentration being reduced to certain levels at Mandir Marg in the year 2020, the air quality was not favourable. Data collected for R K Puram also shows the highest levels of PM_{10} and $PM_{2.5}$ during the year 2016 (Fig. 2c). The average annual concentration of PM_{10} was

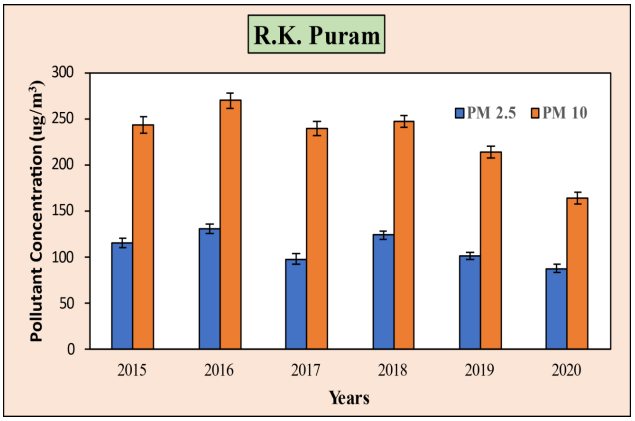
found to be 269 µg/m^3, and for $PM_{2.5}$ was 130 µg/m^3 in 2016. The average annual variation of PM_{10} and $PM_{2.5}$ recorded for Punjabi Bagh is shown in Fig. 2d. PM_{10} average annual concentration was recorded a maximum of 299 µg/m^3 in the year 2017, and a minimum concentration of 183 µg/m^3 was recorded in 2020. A maximum $PM_{2.5}$ average annual concentration of 131 µg/m^3 was recorded in 2018, and a minimum of 91 µg/m^3 was recorded in 2016. The data analysed for Anand Vihar shows that PM_{10} and $PM_{2.5}$ levels were very high as compared to the other four sites. PM_{10} average annual concentration varied from 462 µg/m^3 in 2017 to 206 µg/m^3 in 2020, and $PM_{2.5}$ concentration was found to be 192 µg/m^3 in 2017 to 114 µg/m^3 in 2020 (Fig. 2e).



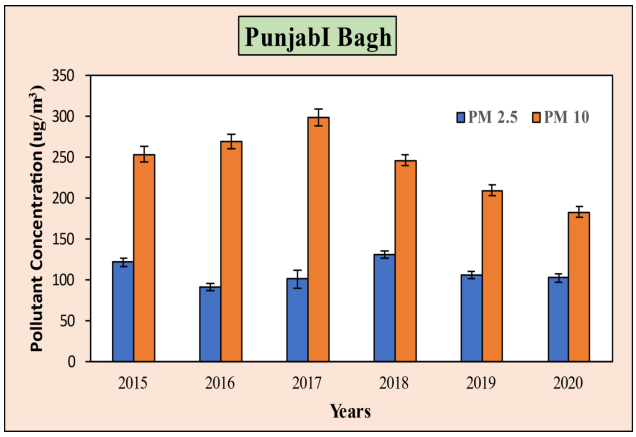
(a)



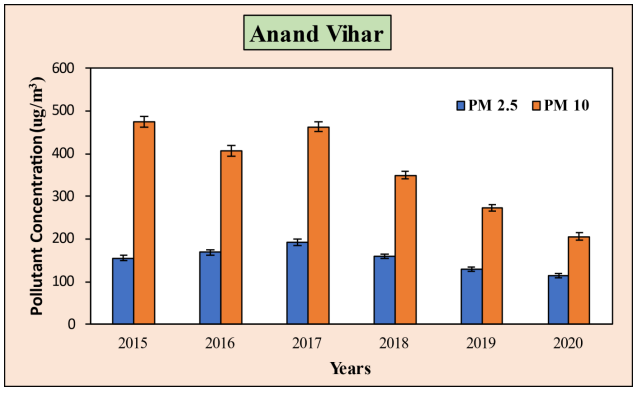
(b)



(c)



(d)



(e)

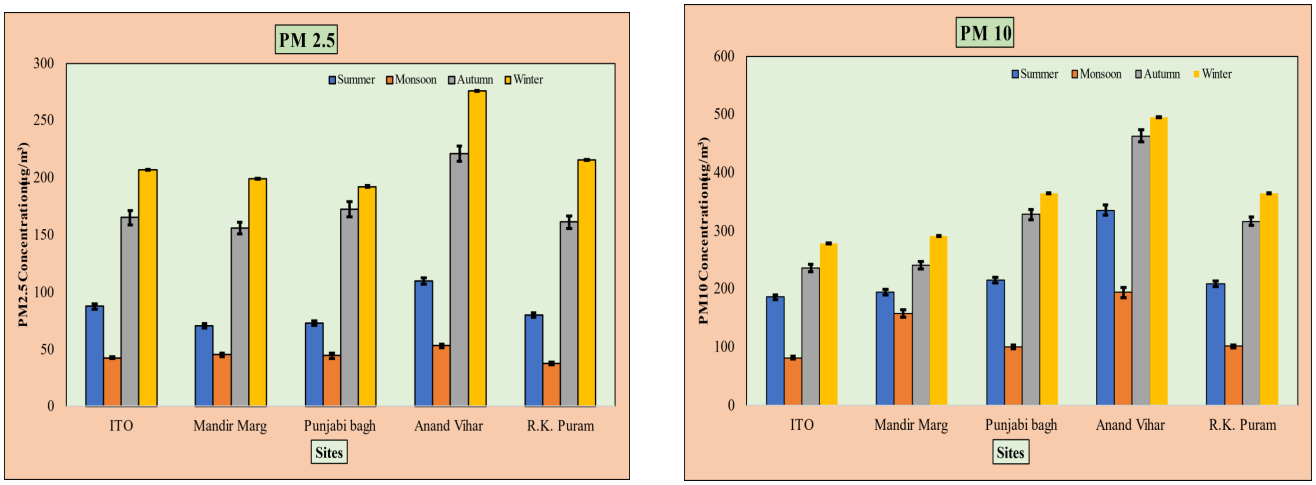
Fig. 2. The average annual concentrations of PM_{10} and $PM_{2.5}$ from 2015 to 2020 over Delhi (a: ITO; b: Mandir Marg; c: R K Puram; d: Punjabi Bagh; e: Anand Vihar)

Seasonal variations

Fig. 3 (a and b) shows the seasonal trend for four seasons, including winter, autumn, monsoon, and summer, in Delhi from 2015 to 2020. The trend for both $PM_{2.5}$ and PM_{10} was observed and analysed. Anand Vihar showed the maximum $PM_{2.5}$ levels (275.99 µg/m^3) among all five sites, while Punjabi Bagh and Mandir Marg showed the minimum pollution levels in the case of $PM_{2.5}$. PM_{10} levels (495.10 µg/m^3) were observed on the higher side in the case of Anand Vihar, while ITO showed minimum PM_{10} levels among all five sites. Overall, the air quality seems to be deteriorating more during the winter than during the autumn, summer, and monsoon seasons, respectively.

Air quality index of Delhi from 2015 to 2020

The AQI of Delhi was interpreted from the data available on the CPCB website. The results are shown in Fig. 4. Data available for Delhi in the year 2015 showed that AQI was moderate for four months, poor for six months, and very poor for two months. There was no period of low AQI or satisfactory air quality. During the year 2016, Delhi had nearly one month of satisfactory AQI, 2.5 months of moderate AQI, and 4 months of poor AQI, whereas AQI was very poor for 3.5 months and severe for almost one month. In the year 2017, the AQI of Delhi was satisfactory for almost 1.5 months. Moderate for 3.5 months, poor for 4 months, and very poor for 3 months. In between the periods, AQI reached severe for a couple of days. The AQI of Delhi in the year 2018 was satisfactory within 2 months, moderate for 3.5 months, poor for 3.5 months, very poor for 2.5 months, and severe for almost 15-20 days. AQI in 2019 was in the categories of satisfactory for 2 months, moderate for 4 months, poor for 3.25 months, very poor for 2 months, and severe for 24 days (less than a month). The AQI improved a little during 2020, which was a lockdown period due to the COVID-19 pandemic. The AQI was satisfactory for a period of 2 months, moderate for 5 months, poor for 4 months and very poor for one month only. All industrial, construction, and vehicular activities were restricted during the COVID-19 pandemic, which led to an improvement in air quality to a large extent.



(a) (b)

Fig. 3. Seasonal variations in the concentration of $PM_{2.5}$ and PM_{10} over the period of 2015 to 2020

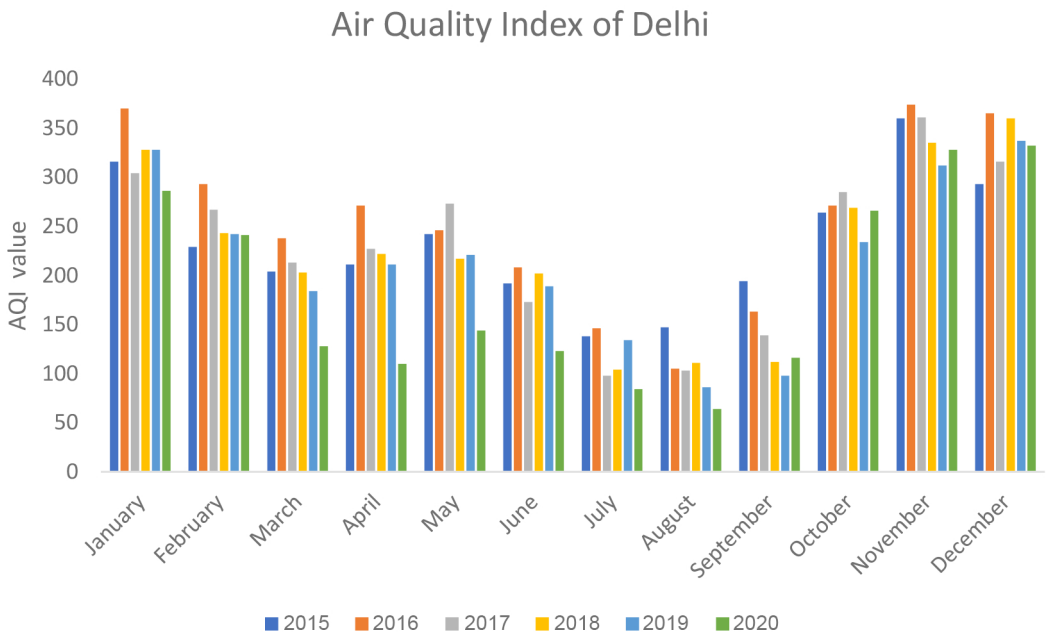


Fig. 4. Average air quality index of Delhi in different months over the period of 2015 to 2020

The average AQI of Delhi in the year 2015 was 232, 254 in 2016, 229 in 2017, 225 in 2018, 215 in 2019, and 185 in 2020. The air quality index of Delhi indicates that the year 2016 had a maximum AQI. AQI decreased from 2017 onwards and was recorded as moderate in the year 2020. AQI was reported on the lower side in the months of July and August and on the higher side in the months of November, December, and January every year. An increase in AQI is a result of mixed activities such as the construction of flyovers, transport, and industrial activities, etc.

Conclusion

Based on the annual and seasonal variations, it can be concluded that the air quality in Delhi is deteriorating very much. The data analysed for all five busiest stations in Delhi indicate that Anand Vihar is the most highly polluted site among all in terms of PM_{10} as well as $PM_{2.5}$. The seasonal trend for four seasons, including winter, autumn, monsoon, and summer, in Delhi from 2015 to 2020 demonstrated that air quality deteriorated more during winter than during autumn, summer, and monsoon seasons, respectively. The air quality index of Delhi indicated that the year 2016 had a maximum AQI, resulting in poor air quality. Though AQI has decreased over the years, it lies in the poor category only.

Delhi is a highly populated state, and the number of vehicles is increasing day by day on the roads. With almost 3182 industries in Delhi and NCR, particulate matter levels are increasing, which tends to increase air pollution. Also, a lot of construction activities keep on going in Delhi on a regular basis. Therefore, major factors responsible for an increase in air pollution in

Delhi seem to be vehicular emissions, biomass/ waste burning, road dust, and industrial activities, etc.

Financial supports

No financial support was received for the study.

Competing interests

Not Applicable. The study was conducted to analyze the level of air pollution in busiest places of Delhi over a period of 2015 to 2020.

Authors' contributions

The study was conducted by Bhupender Singh under the supervision of Dr. Vishant Gahlaut.

Bhupender Singh: Data compilation, Interpretation, writing of research paper.

Dr. Neetu Rani: Data compilation and preparation of manuscript.

Dr. Vishant Gahlaut: Assessment and guidance.

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Ethical considerations

"Ethical issues (Including plagiarism, Informed consent, misconduct, data fabrication and/ or falsification, double publication and/ or submission, redundancy, etc) have been completely ob-served by the authors."

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