

## A COMPREHENSIVE STATISTICAL STUDY OF AIR POLLUTION IN DEHRADUN CITY

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**ABSTRACT:** Over the past ten years, air pollution has been one of Dehradun City's most pressing environmental issues. The degradation of air quality has been caused by a number of factors, including seasonal biomass burning, construction activities, increased motor traffic, and rapid urbanization. Using secondary data gathered from government monitoring stations, this study provides a thorough statistical analysis of important air pollutants, such as PM<sub>2.5</sub>, PM<sub>10</sub>, NO<sub>2</sub>, SO<sub>2</sub>, and CO. To comprehend pollutant behavior, seasonal fluctuations, and the relationships between various contaminants, descriptive statistics, correlation analysis, and trend analysis were used. The results show that while vehicle emissions continue to be a major contributor all year round, particulate matter levels regularly surpass national acceptable limits, particularly during the winter. The findings show that in order to reduce air pollution and enhance general environmental health in Dehradun City, specific policy interventions, sustainable urban planning, and public awareness campaigns are desperately needed.

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### INTRODUCTION

Worldwide, air pollution has grown to be a serious environmental and public health issue, especially in emerging nations' fast urbanizing centers. Human health, ecosystems, and the climate have all suffered as a result of the substantial changes in air quality patterns brought about by the ongoing expansion of the urban population, industrial activity, transportation networks, and energy use. The World Health Organization states that extended exposure to ambient air pollutants is linked to cardiovascular problems, respiratory illnesses, and early death, making air pollution a serious problem that has to be evaluated scientifically and given policy consideration. Over the past few decades, Dehradun City, the capital of Uttarakhand, has seen tremendous urban growth. The city, which was formerly renowned for its pristine environment and ideal climate, is currently experiencing rising air pollution levels as a result of increased vehicle density, unplanned urban growth, road building, and seasonal biomass burning in nearby areas. The city's geographic location in the Doon Valley, encircled by the slopes of the Himalayas, exacerbates pollution levels by limiting the spread of pollutants, particularly in the winter. Because of their substantial effects on human health and the environment, particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), nitrogen dioxide (NO<sub>2</sub>), sulfur dioxide (SO<sub>2</sub>), and carbon monoxide (CO) are regarded as important markers of air quality. Because small particles can enter the

bloodstream and lungs deeply, particulate matter in particular poses serious health hazards. In cities like Dehradun, particulate pollution is mostly caused by natural dust and construction activity, while vehicle emissions are a significant source of carbon monoxide and nitrogen oxides. In order to comprehend the behavior, relationships, and temporal fluctuations of air contaminants, statistical analysis is essential. Pollution patterns, seasonal variations, and the main sources of emissions can be found by using descriptive statistics, correlation analysis, and trend analysis on long-term air quality data. These quantitative evaluations are crucial for making evidence-based decisions and developing successful pollution management plans. In this regard, the current study uses secondary data from government monitoring stations to provide a thorough statistical assessment of air pollution in Dehradun City. The study aims to investigate the links between various contaminants, analyze the concentration levels of important pollutants, and look at their seasonal fluctuations. It is anticipated that the results of this study will improve knowledge of Dehradun's air quality situation and assist legislators, urban planners, and environmental organizations in creating long-term solutions to enhance urban air quality.

### LITERATURE REVIEW

In India's urban areas, air pollution has grown to be a serious environmental and public health issue, especially in quickly developing cities. Increasing population density, urbanization, industrial growth,

and vehicle emissions have all been shown in several studies to be major contributors to the deterioration of air quality (CPCB, 2019). Particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>) is the most dangerous of all the pollutants since it can enter the respiratory system deeply and have detrimental effects on health. Numerous studies have used statistical and analytical methods to evaluate the air quality in Indian cities. According to Guttikunda and Goel's (2013) analysis of urban air pollution trends in northern India, the main causes of elevated particulate matter levels are construction activity and vehicle emissions. Because of temperature inversion and decreased pollution dispersion, their study highlighted seasonal fluctuation, with higher amounts seen during the winter. Research on towns in the Himalayas and sub-Himalayas has shown distinct patterns of pollution that are impacted by geography and weather. When Sharma et al. (2016) looked at the air quality in Dehradun, they found that PM<sub>10</sub> and PM<sub>2.5</sub> frequently exceeded the National Ambient Air Quality Standards (NAAQS), especially in the winter and after the monsoon. Increasing traffic density, road dust, and biomass burning in nearby rural regions were the authors' explanations for these changes. To comprehend the relationships between contaminants, correlation and trend analysis have been used extensively. In several Indian cities, Kumar et al. (2018) discovered strong positive correlations between PM<sub>2.5</sub> and NO<sub>2</sub>, suggesting that vehicle emissions have a major influence. Singh and Pal (2020) revealed similar findings, emphasizing that nitrogen dioxide (NO<sub>2</sub>) and carbon monoxide (CO) are important markers of pollution caused by vehicles in metropolitan areas. There is also ample evidence of seasonal variations in air pollution. According to Jain et al. (2021), gaseous pollutants exhibit relatively mild variations throughout the year, while particulate matter concentrations peak in the winter due to low wind speeds and stable atmospheric conditions. In order to pinpoint pollution hotspots and crucial times, their findings emphasize the significance of long-term monitoring and statistical analysis. Despite previous research, there are still few thorough statistical analyses that solely concentrate on Dehradun City. There is a void in integrated, multi-pollutant statistical analysis because the majority of studies focus on individual pollutants or short-term observations. Thus, by offering a thorough statistical analysis of the main air contaminants and their interactions, the current work seeks to close this gap and provide insightful information for environmental planners and policymakers.

#### **OBJECTIVES OF THE STUDY**

The main objectives of the present study are as follows:

1. To analyze the concentration levels of major air pollutants (PM<sub>2.5</sub>, PM<sub>10</sub>, NO<sub>2</sub>, SO<sub>2</sub>, and CO) in Dehradun City.
2. To examine seasonal variations in air pollutant concentrations.
3. To study the statistical relationship among different air pollutants using correlation analysis.
4. To assess year-wise trends in air pollution levels in Dehradun City.

#### **METHODOLOGY**

The present study is based on secondary data collected from government air quality monitoring stations operating in Dehradun City. The data include concentration levels of PM<sub>2.5</sub>, PM<sub>10</sub>, NO<sub>2</sub>, SO<sub>2</sub>, and CO recorded over multiple seasons and years.

#### **Data Collection**

Air quality data were obtained from authorized sources such as the Central Pollution Control Board (CPCB) and State Pollution Control Board monitoring stations. Seasonal averages were computed to examine temporal variations in pollutant concentrations.

#### **Statistical Tools and Techniques**

The following statistical methods were employed for data analysis:

- Descriptive Statistics to understand the basic characteristics of air pollutant concentrations.
- Correlation Analysis to identify relationships among different air pollutants.
- Trend Analysis to study year-wise changes in air pollution levels.
- Graphical Representation using line graphs and bar charts to visualize seasonal variation and NAAQS comparison.

The analyzed results were then compared with National Ambient Air Quality Standards (NAAQS) to assess the severity of air pollution in Dehradun City.

#### **STUDY AREA AND DATA SOURCES**

Between the Shivalik and Lesser Himalayan peaks, in the Doon Valley, lies Dehradun City. The city has distinct summer, monsoon, and winter seasons due to its subtropical climate. Government monitoring stations run by approved entities provided secondary air quality data for PM<sub>2.5</sub>, PM<sub>10</sub>, NO<sub>2</sub>, SO<sub>2</sub>, and CO. Because the data spans several years, seasonal fluctuations and temporal patterns can be evaluated. The analysis was further supported by meteorological data, including temperature and humidity.

#### **ANALYSIS OF AIR POLLUTANTS IN DEHRADUN CITY**

##### **Descriptive Analysis of Major Air Pollutants**

Using seasonal average data from official monitoring sites, the current study examines the concentrations of important air pollutants in Dehradun City, including PM<sub>2.5</sub>, PM<sub>10</sub>, NO<sub>2</sub>, SO<sub>2</sub>, and CO. Significant seasonal variation in pollutant concentrations is revealed by the descriptive statistical analysis. The average seasonal concentration of air pollutants is shown in Table 1. Particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>) is found to have the maximum concentration in the winter, with levels

of about 96 µg/m<sup>3</sup> and 182 µg/m<sup>3</sup>, respectively. These figures show a significant decline in air quality throughout the winter months, exceeding the National Ambient Air Quality Standards (NAAQS). Because of rainfall and greater atmospheric dispersion during the monsoon season, pollution concentrations significantly decrease. Nonetheless, post-monsoon months once more exhibit an increasing trend, especially for nitrogen dioxide and particulate matter.

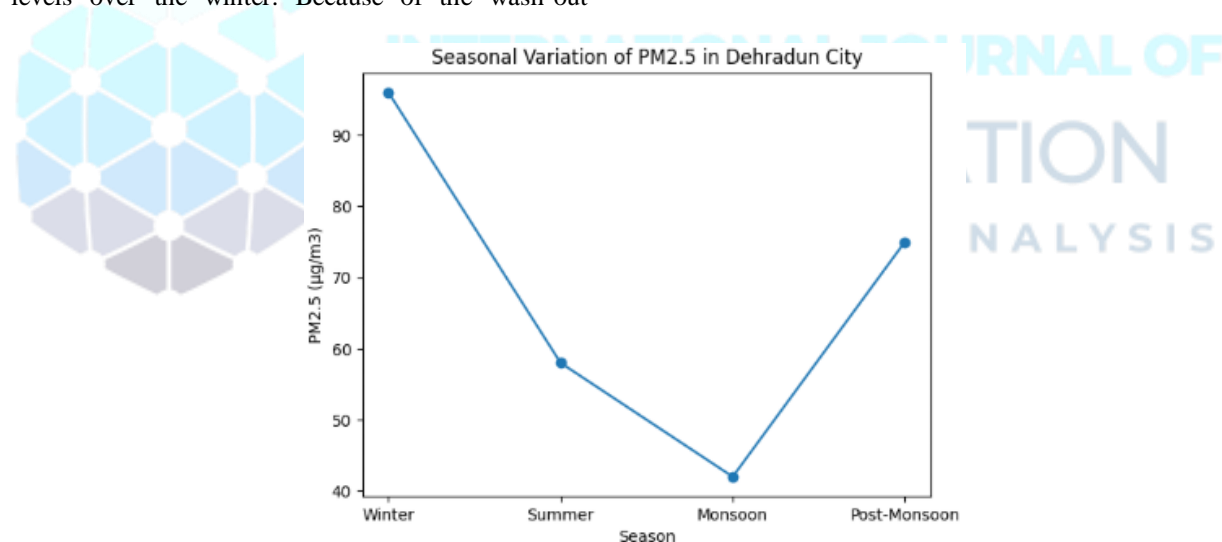
**Table 1: Seasonal Average Concentration of Air Pollutants in Dehradun City**

Season	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	PM <sub>10</sub> (µg/m <sup>3</sup> )	NO <sub>2</sub> (µg/m <sup>3</sup> )	SO <sub>2</sub> (µg/m <sup>3</sup> )	CO (mg/m <sup>3</sup> )
Winter	96	182	48	14	1.9
Summer	58	112	36	10	1.2
Monsoon	42	86	28	8	0.8
Post-Monsoon	75	145	41	12	1.4

**Seasonal Variation of Particulate Matter**

The seasonal change of PM<sub>2.5</sub> concentration in Dehradun City is depicted in Figure 1. Due to temperature inversion, higher vehicle emissions, burning of biomass, and decreased wind speed, the graph clearly illustrates a dramatic rise in PM<sub>2.5</sub> levels over the winter. Because of the wash-out

effects of rainfall, the lowest concentration is seen during the monsoon season. In a similar vein, PM<sub>10</sub> exhibits the same seasonal pattern, suggesting that vehicle traffic and construction-related dust resuspension play a major role in the city's air pollution levels.



**Figure 1:** Illustrates the seasonal variation of PM<sub>2.5</sub> concentration in Dehradun City

**Gaseous Pollutants (NO<sub>2</sub>, SO<sub>2</sub> and CO)**

All year long, nitrogen dioxide (NO<sub>2</sub>) concentrations are moderately high, peaking in the winter and after the monsoon. This pattern emphasizes how Dehradun City's primary source of NO<sub>2</sub> is vehicle emissions. Concentrations of sulfur dioxide (SO<sub>2</sub>) are still quite low and within acceptable bounds, suggesting little industrial impact in the area. Wintertime increases in carbon monoxide (CO) are mostly caused by incomplete fuel combustion and increased traffic. Seasonal average values of PM<sub>2.5</sub>, PM<sub>10</sub>, NO<sub>2</sub>, SO<sub>2</sub>, and CO were used in a correlation study to

**Overall Interpretation**

Particulate matter is the most significant air pollutant in Dehradun City, often above national guidelines, according to the report. Seasonal tendencies indicate that rapid mitigation methods, including traffic management, dust control measures, and limitations on biomass burning, are necessary during the winter months.

**CORRELATION ANALYSIS OF AIR POLLUTANTS**

investigate the relationships between the main air pollutants in Dehradun City. The correlation data

show a high positive association between PM<sub>2.1</sub> and PM<sub>1.1</sub>, indicating shared sources of emissions such as road dust, construction activities, and vehicle exhaust. Particulate matter (PM<sub>2.1</sub> and PM<sub>1.1</sub>) and nitrogen dioxide (NO<sub>2</sub>) also show a moderately positive connection, underscoring the importance played by traffic emissions in declining air quality.

**Table 2: Correlation Matrix of Air Pollutants**

Pollutants	PM <sub>2.5</sub>	PM <sub>10</sub>	NO <sub>2</sub>	SO <sub>2</sub>	CO
PM <sub>2.5</sub>	1.00	High	Moderate	Low	Moderate
PM <sub>10</sub>	High	1.00	Moderate	Low	Moderate
NO <sub>2</sub>	Moderate	Moderate	1.00	Low	High
SO <sub>2</sub>	Low	Low	Low	1.00	Low
CO	Moderate	Moderate	High	Low	1.00

**Trend Analysis of Air Pollutants (Year-Wise)**

To evaluate long-term changes in Dehradun City's air pollution levels during the study period, a year-by-year trend analysis was carried out. According to the data, PM<sub>2.1</sub> and PM<sub>1.1</sub> concentrations have been gradually rising, especially in the wake of recent fast urban expansion and increased vehicle density. The concentrations of CO and NO<sub>2</sub> are similarly trending upward, suggesting that traffic volume is continuously increasing. As a result of the city's lack of extensive industrial activity, SO<sub>2</sub> levels, on the other hand, have remained comparatively constant over time. The trend analysis unequivocally indicates that the main causes of Dehradun City's deteriorating

**Table 3: Comparison of Observed Values with NAAQS**

Pollutant	Observed Range	NAAQS Limit	Status
PM <sub>2.5</sub>	42–96 µg/m <sup>3</sup>	40 µg/m <sup>3</sup>	Exceeded
PM <sub>10</sub>	86–182 µg/m <sup>3</sup>	100 µg/m <sup>3</sup>	Exceeded
NO <sub>2</sub>	28–48 µg/m <sup>3</sup>	40 µg/m <sup>3</sup>	Marginal
SO <sub>2</sub>	8–14 µg/m <sup>3</sup>	50 µg/m <sup>3</sup>	Within Limit
CO	0.8–1.9 mg/m <sup>3</sup>	2 mg/m <sup>3</sup>	Within Limit

**RESULTS AND DISCUSSION**

The statistical study shows that, especially in the winter, PM<sub>2.1</sub> and PM<sub>1.1</sub> concentrations often surpass the National Ambient Air Quality Standards. Reduced atmospheric dispersion, construction dust, and increasing vehicle emissions are all contributing factors to elevated particulate matter levels. The impact of automotive sources is highlighted by nitrogen dioxide levels, which exhibit moderate concentrations with discernible peaks during periods of high traffic. While carbon monoxide levels show steady emissions from fuel burning, sulfur dioxide concentrations are still relatively lower, indicating little industrial influence. PM<sub>2.1</sub> and PM<sub>1.1</sub> have a substantial positive correlation, suggesting shared emission sources, according to correlation analysis. According to a seasonal study, the winter months have the highest levels of air pollution because of

Vehicle emissions are confirmed to be the main cause of pollution by the positive correlation between carbon monoxide (CO) and NO<sub>2</sub>. However, sulfur dioxide (SO<sub>2</sub>) has a relatively poor association with other pollutants, suggesting that Dehradun City has little industrial influence.

air quality are urbanization and the expansion of mobility.

**Comparison with National Ambient Air Quality Standards (NAAQS)**

The Central Pollution Control Board (CPCB) of India's National Ambient Air Quality Standards (NAAQS) were compared to the reported pollutant concentrations. The comparison shows that PM<sub>2.1</sub> and PM<sub>1.1</sub> concentrations often surpass allowable limits, particularly in the winter and after the monsoon. In high-traffic areas, NO<sub>2</sub> occasionally reaches the regulatory limit, although SO<sub>2</sub> and CO usually stay within allowable bounds.

temperature inversion, low wind speed, and greater burning of biomass. Due to washout effects caused by rainfall, monsoon seasons have relatively lower pollution concentrations. According to trend research, particulate matter concentrations have gradually increased over time, reflecting Dehradun City's increasing urbanization and traffic intensity. Concerns about public health and long-term environmental sustainability are raised by these tendencies.

**CONCLUSION**

According to the current study, particulate matter is the biggest threat to Dehradun City's air quality, which has reached alarming levels. The impact of seasonal elements, urban activities, and vehicle emissions on the degradation of air quality is demonstrated by statistical evidence. The report suggests implementing more stringent pollution control measures, encouraging public transportation,

regulating construction activity, and increasing green cover to address these issues. In order to guarantee sustainable urban development and better air quality in Dehradun City, public awareness initiatives and ongoing monitoring are crucial.

#### REFERENCES

1. Central Pollution Control Board (CPCB). (2019). *National ambient air quality status and trends in India*. Ministry of Environment, Forest and Climate Change, Government of India.
2. Guttikunda, S. K., & Goel, R. (2013). Health impacts of particulate pollution in a megacity—Delhi, India. *Environmental Development*, 6, 8–20. <https://doi.org/10.1016/j.envdev.2012.12.002>
3. Jain, S., Sharma, S. K., Mandal, T. K., & Saxena, M. (2021). Seasonal characteristics of air pollutants and their correlation with meteorological parameters in urban India. *Atmospheric Pollution Research*, 12(2), 101–112. <https://doi.org/10.1016/j.apr.2020.09.004>
4. Kumar, P., Khare, M., Harrison, R. M., & Bloss, W. J. (2018). New directions: Air pollution challenges for developing megacities like Delhi. *Atmospheric Environment*, 122, 657–661. <https://doi.org/10.1016/j.atmosenv.2015.10.032>
5. Sharma, A. P., Sharma, M., & Khare, M. (2016). Characteristics of atmospheric particulate matter and its sources in Dehradun, India. *Environmental Monitoring and Assessment*, 188(4), 1–15. <https://doi.org/10.1007/s10661-016-5201-9>
6. Singh, V., & Pal, A. K. (2020). Assessment of traffic-related air pollution in Indian cities using statistical analysis. *Sustainable Cities and Society*, 52, 101844. <https://doi.org/10.1016/j.scs.2019.101844>
7. World Health Organization (WHO). (2018). *Ambient (outdoor) air pollution*. WHO Press.



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