Association of air pollution and COVID-19 in India

Rahul Tyagi,[1,2] Saurabh Mittal,[1] Karan Madan,[1] Ravindra Mohan Pandey,[3] Anjali Pandey,[3] Anant Mohan,[1] Vijay Hadda,[1] Pawan Tiwari,[1] Randeep Guleria[1]

[1]Department of Pulmonary, Critical Care, and Sleep Medicine, All India Institute of Medical Sciences, New Delhi; [2]Department of Pulmonary Medicine, Army Institute of Cardiothoracic Sciences, Pune; [3]Department of Biostatistics, All India Institute of Medical Sciences, New Delhi, India

Abstract

The COVID-19 pandemic has affected the world, leading to significant morbidity and mortality. Various meteorological parameters are considered essential for the viability and transmission of the virus. Multiple reports from various parts of the world suggest a correlation between the disease spread and air pollution severity. This study was carried out to identify the relationship between meteorological parameters, air pollution, and COVID-19 in New Delhi, one of the worst-affected states in India. We studied air pollution and meteorological parameters in New Delhi, India. We obtained data about COVID-19 occurrence, meteorological parameters, and air pollution indicators from various sources from April 1, 2020, until November 12, 2020. We performed correlational analysis and employed autoregressive distributed lag models to identify the relationship between COVID-19 cases, air pollution and meteorological parameters. We found a significant impact of particulate matter (PM) 2.5, PM10, and meteorological parameters on COVID-19. There was a significant positive correlation between daily COVID-19 cases and COVID-19-related deaths with PM2.5 and PM10 levels. Increasing temperature and wind speed were associated with a reduction in the number of cases, while increasing humidity was associated with increased cases. This study demonstrated a significant association between PM2.5 and PM10 and daily COVID-19 cases and COVID-19-related mortality. This knowledge will likely help us prepare well for the future and implement air pollution control measures for other airborne disease epidemics.

Correspondence: Saurabh Mittal, Department of Pulmonary, Critical Care and Sleep Medicine, All India Institute of Medical Sciences, Ansari Nagar, New Delhi, India 110029.
Tel.: +91-11-26546346.
E-mail: saurabh_kgmu@yahoo.co.in

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Introduction

The COVID-19 pandemic originated in Wuhan, China, in December 2019 and subsequently spread worldwide, leading to significant morbidity and mortality [1]. The pandemic has also severely affected India, and healthcare services have been overburdened and disrupted [2,3]. As of November 5, 2020, more than 8 million cases and more than 0.12 million deaths have been reported [4]. Delhi is one of the most affected states in India. More than 0.6 million cases and 6000 deaths have been reported in the metropolitan area. There are multiple factors responsible for the pandemic's spread, including host, pathogen, and environmental factors [5,6]. Various meteorological parameters are considered essential for the viability, transmission, and range of spread of the virus. Sahin studied the association between COVID-19 and meteorological parameters (temperature, humidity, wind speed, and dew point) in nine cities in Turkey [7]. The author found out that average air temperature on the day and average humidity were best related to the number of cases, and lower temperatures and humidity were associated with an increased number of cases. Another environmental factor is air pollution, which is being postulated to worsen the spread of the pandemic. Particulate matter (PM) is a heterogeneous mixture of suspended particles of varied size, shape, chemistry, and spatio-temporal variability [8]. PM may be ultrafine (PM0.1 with a diameter less than 0.1 μm), fine (PM2.5 with a diameter ≤2.5 μm), and coarse (PM10 with a diameter between 2.5 μm and 10 μm). PM10 particles deposit predominantly in the upper airways and larger conducting airways, and PM2.5 particles deposit more deeply into the lower respiratory tract. PM comprises various materials from human-made (*e.g.*, power generation, traffic sources) and natural sources (*e.g.*, dust storms) [9]. It has been postulated to worsen symptoms and increase hospitalization in patients with respiratory disorders. An epidemiological study in Scotland evaluating the effects of long-term air pollution on public health found that the risk of hospitalization for respiratory illness following long-term exposure to PM10 and NO_2 was significantly higher in two centers (relative risk 1.06 to 1.10) [10]. Multiple reports from various parts of the world suggest a correlation between COVID-19 spread and air pollution severity as measured by various parameters such as PM2.5, PM10, and sulfur dioxide [11-13]. There are similar reports from the Indian subcontinent; however, no data from New Delhi, one of the worst-affected states by COVID-19, is available [12]. This study was carried out to identify the relationship between meteorological parameters, air pollution, and COVID-19 in New Delhi, India.

Materials and Methods

We studied air pollution and meteorological parameters in New Delhi, the capital of India. This metropolitan area has a surface of 1484 km^2, a population of 16,787,941 as per the 2011 census, and a population density of 11,312/km^2; however, the current estimate of Delhi's population is around 20 million [14]. We obtained data about COVID-19 occurrence, meteorological parameters, and air pollution indicators from various sources from April 1, 2020, until November 12, 2020 (the period chosen was before the global initiation of the COVID-19 vaccination). The number of confirmed COVID-19 cases was collected from covid19india.org [15]. The testing rate (samples per day) and positivity rate were obtained from the same source. Meteorological data, including temperature, humidity, and wind speeds, were collected from timeanddate.com [16]. Data on air pollution was collected as the concentration of PM2.5 and PM10 particles. The air pollution data was collected from aqicn.org [17].

Statistical analysis

The statistical software R version 3.6.3 (R Foundation, Indianapolis, IN, USA) was used for data analysis and graphs were generated using Microsoft Excel (Redmond, WA, USA). Pearson's correlation coefficient was used to examine the relationship between meteorological parameters, air pollution, and daily COVID-19 cases. We employed autoregressive distributed lag models (ARDLM) to identify the relationship between COVID-19 cases, air pollution and meteorological parameters. ARDLM is based on the fact that some variables are affected by not only the values in the current period but also by various factors in the past and also their past values. Distributive lag models are used to study the time-delay effect of exposure and outcome in environmental health studies [18]. The ARDLMs are utilized to apply a regression analysis between a dependent series and k numbers of independent series, with the dependent series being auto-regressed. When there is only one independent series, an ARDLM of orders p and q is denoted by ARDL (p, q), consisting of p lags of independent series and q lags of dependent series. Using the lag values of the dependent series itself makes the model autoregressive. We considered the daily average temperature, humidity, wind speed, PM2.5, and PM10 for ARDLM modeling of the number of COVID-19 cases per day. The decision regarding the values of p and q was made based on Akaike information criterion values for competing models.

Results

The daily number of cases of COVID-19 in New Delhi from April 1, 2020, until November 12, 2020, was recorded. The lowest number of cases on a single day was 17, whereas the highest was 7830. The median number of COVID-19 cases per day was 1475 (interquartile range: 2350). The weather data demonstrated a mean temperature of 30.4°C, and the temperature ranged from 20 to 38.5°C. The lowest humidity observed on any day was 16%, while the highest value was 85% (mean 37.2%). The wind speed ranged from 0 km/h (lowest) to 17.25 km/h (highest), with an average of 6.078 km/h. PM2.5 ranged from a minimum of 45 to a maximum of 519, with a mean PM2.5 of 139. PM10 particles ranged from 32 to 625 with a mean PM10 of 119.4. The distribution of daily COVID-19 cases, PM2.5 and PM10, across the study period is shown in Figure 1. The correlation coefficient of various environmental parameters with the daily number of COVID-19-positive cases is given in Table 1. There was a significant positive correlation between daily COVID-19 cases and COVID-19-related deaths with PM2.5 and PM10 levels (Table 2). Figure 2 depicts the correlation between daily COVID-19 cases and PM2.5 and PM10 levels. According to the ARDLM, the significant parameters with the estimate, standard error, and p value are given in Table 3. As per this model, the average humidity on one day, two days and three days prior has a significant impact on the number of COVID-19 cases on a given day. PM2.5 on the current day, three days, and five days before has a significant impact on the number of COVID-19 cases on a given day, while PM10 level one day before has a significant impact on the number of COVID-19 cases on a given day. The model is significant at 5% and 1% significance levels, with a $p<2.2e-16$ with a moderate adjusted r^2 value of 0.7259.

Discussion

This study demonstrated a significant association of air pollution parameters, *i.e.*, PM2.5 and PM10, with COVID-19 cases in New Delhi, India. We also found a significant impact of meteorological parameters: increasing temperature and wind speed were associated with a reduction in the number of cases, while increasing humidity

Table 1. Correlation coefficient of various environmental parameters with the daily number of COVID-19 cases.

Environmental parameter	Correlation coefficient	p value
Average temperature	-0.44	<0.001
Average humidity	0.25	<0.001
Average wind speed	-0.42	<0.001
PM2.5	0.64	<0.001
PM10	0.68	<0.001

PM, particulate matter.

Table 2. Correlation coefficient of particulate matter (PM) 2.5 and PM10 with the daily number of deaths due to COVID-19.

Environmental parameter	Correlation coefficient	p value
PM2.5	0.20	0.002
PM10	0.14	0.028

PM, particulate matter.

was associated with increased cases. These findings strengthen the notion of the association of air pollution with the occurrence of COVID-19 cases. Although the correlations of air pollution parameters with COVID-19 cases are significant, correlation is not causation, and these results need prospective validation.

The emergence of COVID-19 has affected the entire world within a short period of time. It has necessitated a change in people's behavior in many forms, among which one was lockdowns being enforced in many places, especially during the initial phases of a pandemic. In addition to travel patterns and population mobility, the host and other environmental factors are also hypothesized to affect disease occurrence. Air pollution and other environmental factors such as temperature, humidity, and wind speed have been studied and may affect transmission.

Lockdown and mobility restrictions have led to reduced transportation and the closure of factories, which has improved air quality. Venter *et al*. studied the short-term effects of lockdown on the global health burden attributable to air pollution in the short term [19]. The authors studied the link between air pollution changes and

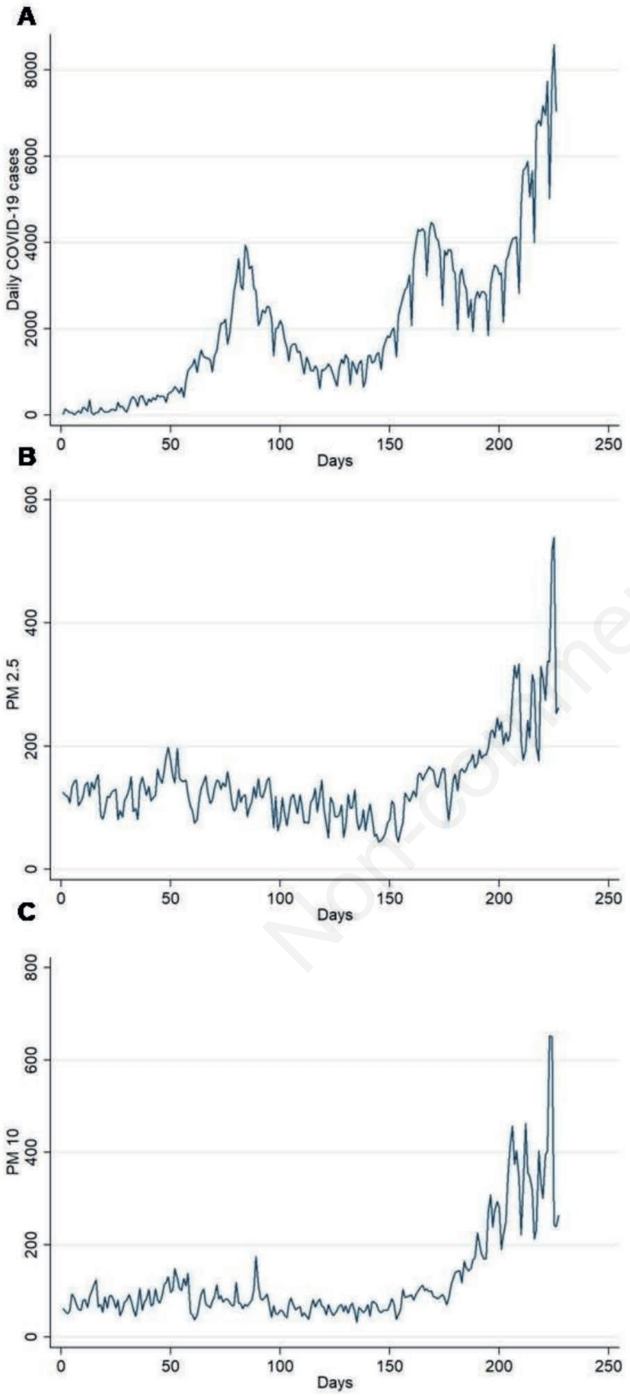

Figure 1. The time-series graph shows the distribution of daily COVID-19 cases (A), PM2.5 (B), and PM10 (C) across the study period. PM, particulate matter.

Table 3. Significant parameters with the estimate, standard error, and p value.

Weather characteristic		Estimate	Standard error	p value
Average humidity	Day-1	683.69	281.36	0.016141*
	Day-2	633.50	283.49	0.026742*
	Day-3	597.74	283.40	0.036393*
PM2.5	Series	6.81206	2.54986	0.008284**
	Day-3	7.26645	2.62991	0.006358**
	Day-5	6.13581	2.75962	0.027505*
PM10	Day-1	4.27435	1.71268	0.013524*

PM, particulate matter; * $p<0.05$; ** $p<0.01$.

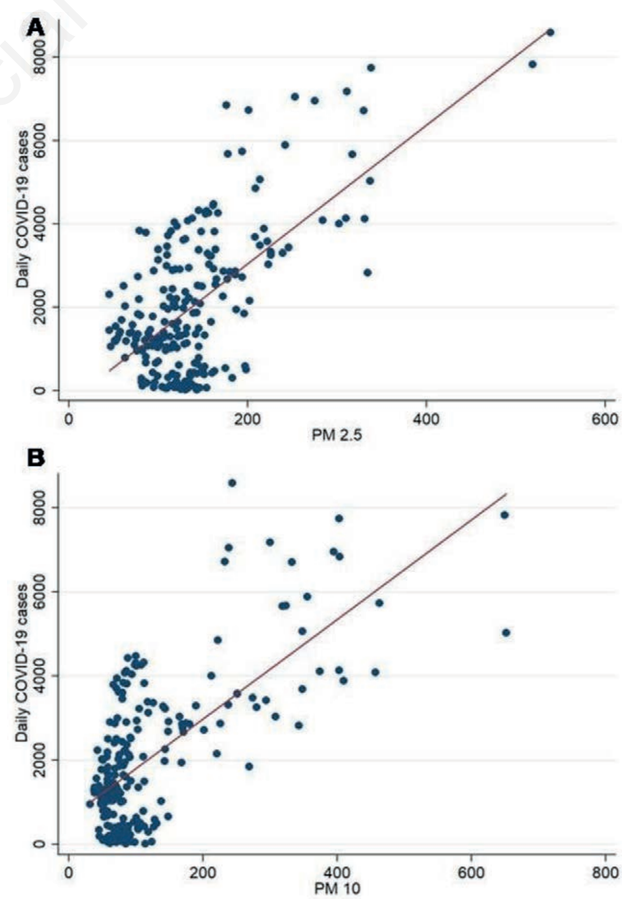

Figure 2. The scatter plot with trendline depicting the correlation of PM2.5 with daily COVID-19 cases (A) and PM10 with daily COVID-19 cases (B). PM, particulate matter.

public health burdens by assessing data from more than 10,000 air quality stations in 34 countries. The authors estimated that 49,900 deaths and 89,000 pediatric asthma emergency visits were avoided due to the lockdown. In India, metropolitan cities like Mumbai and Delhi showed a 60% and 34% reduction in PM2.5 levels during the lockdown, and it is estimated that 30,500 PM2.5-related excess deaths were avoided during the lockdown period [12,19]. However, the study of the effect of air pollution on COVID-19 transmission is essential to understand that as lockdown restrictions were lifted, there has been an increase in air pollution, which may worsen the pandemic.

One of the postulated mechanisms is that outdoor PM increases the persistence of viral particles in the environment and worsens COVID-19 transmission. In a study of 34 samples of outdoor PM10 (collected over three weeks) from an industrial site in Italy, the authors demonstrated the SARS-CoV-2 viral RNA's presence by detecting the highly specific "RtDR gene" on eight filters [20]. This might be evidence that in areas with high PM concentrations, SARS-CoV-2 may create clusters with outdoor PM, thereby enhancing its persistence in the atmosphere. The differences in infection rate among high and low PM10-level regions can be explained based on a "boost effect" of PM on viral infectivity or by the coalescence of exhaled droplet nuclei with PM, which creates a virtual "highway" for viral diffusion [11]. We found a positive association between air pollution and the daily number of COVID-19 cases. Another important aspect is the concept of lag time between exposure and the diagnosis of cases. We used the autoregressive distributed lag model to assess this lag and found that high PM2.5 levels three and five days prior were associated with more COVID-19 cases. Travaglio *et al*. studied potential links between pollution caused by fossil fuels and COVID-19 deaths in England [13]. The authors concluded that exposure to PM2.5 and PM10 increases the risk of COVID-19 and increased long-term exposure to PM2.5 is associated with increased COVID-19 infectivity. The authors' individual-level models indicated that one unit increase in PM10 was associated with an 8% increase in COVID-19 cases, while one cubic meter increase in the PM2.5 average was associated with a 12% increase in cases. The authors also suggested that air pollution levels be considered while considering the infection rate of SARS-CoV-2.

The effect of air pollution on COVID-19-related mortality is also unclear. The likely hypothesis remains that high pollution levels may be associated with worsening respiratory status and reduce the chances of recovery. We found a significant correlation between COVID-19-related deaths and air pollution parameters, *i.e.*, PM2.5 and PM10. Xiao *et al*. investigated the effect of long-term exposure to PM2.5 on COVID-19 deaths among residents of 3087 counties in the United States [21]. The authors found that a 1 mg/m^3 increase in long-term exposure to PM2.5 is associated with an 8% increase in COVID-19 mortality after adjusting for 16 possible confounders. The authors hypothesized that the increase in mortality in patients with higher long-term exposure to PM2.5 was due to inflammation and cellular damage caused by PM and various respiratory and cardiovascular comorbidities that occur due to PM2.5 exposure. Various mechanisms have been proposed by Comunion *et al.* to explain the worse outcomes in patients with higher PM exposure [22]. Exposure to PM alters the lung immune response and increases inflammatory and oxidative stress, increasing susceptibility to and severity of various viral infections. PM exposure leads to the production of pro-inflammatory interleukins (IL) like IL-6 and IL-8. This is likely to make these patients more susceptible to developing cytokine storms from exposure to COVID-19. Also, there is an overexpression of angiotensin-converting enzyme 2 (ACE2) following PM2.5 exposure. Since ACE2 is the key entry point for COVID-19, the possibility of an increase in the chances of infection exists [22].

In the ARDLM, higher humidity in the preceding three days was also associated with increased COVID-19 cases. However, this contrasts with many other studies showing that a drier environment may increase disease transmission. Higher humidity may lead to longer persistence and viability of virus-containing aerosols and droplets in the environment. Another critical environmental factor was the ambient temperature, and it has been shown from multiple previous studies that a higher ambient temperature may reduce virus viability and disease transmission.

Limitations

The study has several limitations, including the inability to measure several confounders such as lockdown measures, population mobility, masking practices, and testing strategies. Also, the analysis is limited to one state; however, Delhi is one of the most polluted states in India and may represent the correct picture of the relationship between air pollution and COVID-19. Also, the testing rate and meteorological and air pollution data were all collected from individual sources. The data being variable, a balanced weight between more sources could have been used to improve the validity; however, we preferred to use the most reliable source with the availability of all the data required for the study.

Conclusions

To conclude, this study demonstrated a significant association between PM2.5 and PM10 and daily COVID-19 cases and COVID-19-related mortality. This knowledge is likely to help us prepare well for the future and implement air pollution control measures.

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