Role of pollution and weather indicators in the COVID-19 outbreak: A brief study on Delhi, India

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Abstract

The present study examines the impact of environment pollution indicators and weather indicators on the COVID-19 outbreak in the capital city of India. In this study, we hypothesize that certain weather conditions with an atmosphere having high content of air pollutants, might impact the transmission of COVID-19, in addition to the direct human to human diffusion. The Kendall and Spearman rank correlation tests were chosen as an empirical methodology to conduct the statistical analysis. In this regard, we compiled a daily dataset of COVID-19 cases (Confirmed, Recovered, Deceased), Weather indicators (Temperature and relative humidity) and pollution indicators (PM 2.5, PM 10, NO2, CO, and SO2) in Delhi state of India. The effects of each parameter within three time frames of same day, 7 days ago, and 14 days ago are evaluated. This study reveal a significant correlation between the transmission of COVID-19 outbreaks and the atmospheric pollutants with a combination of specific climatic conditions. The findings of this research will help the policymakers to identify risky geographic areas and enforce timely preventive measures.

Keywords: COVID-19; Correlation; Pollutants, Temperature; Humidity

1. Introduction

Coronavirus disease 2019 (COVID-19) is an infectious disease which initially detected in Wuhan, China, has now spread all over the world, and if not well dealt, it could even lead to the worldwide economic crisis. This virus exhibits high human-to-human transmissibility that is the reason it has spread all across the world in a very short span of time. The World Health Organization (WHO) reported 4,789,205 COVID-19 confirmed cases and 318,789 deaths worldwide until May 20, 2020 [1]. The deadly virus has affected more than 210 countries had been affected where United States (US) alone contributed approximately one-fourth of the total cases. Other major countries having a significant impact are Russia, Spain, Italy, Iran, France, Germany, UK, Turkey, China, and many more. The situation in India has started worsening day by day. The first COVID-19 case in India was reported on January 30, 2020 and as on May 20, 2020 India has 106,750 COVID-19 confirmed cases, including 3303 deaths [1]. As per WHO, India has not entered into the state of the community transmission, still it has clusters of cases.

India had enforced mandatory nationwide lockdown and enforced stricter rules to combat the COVID-19 pandemic since March 25, 2020 and further extended it till May 31, 2020. The lockdown might have helped in combating the transmission rate of the COVID-19 pandemic. Figure 1 shows the overall picture of confirmed cases of COVID-19 across the states of India.

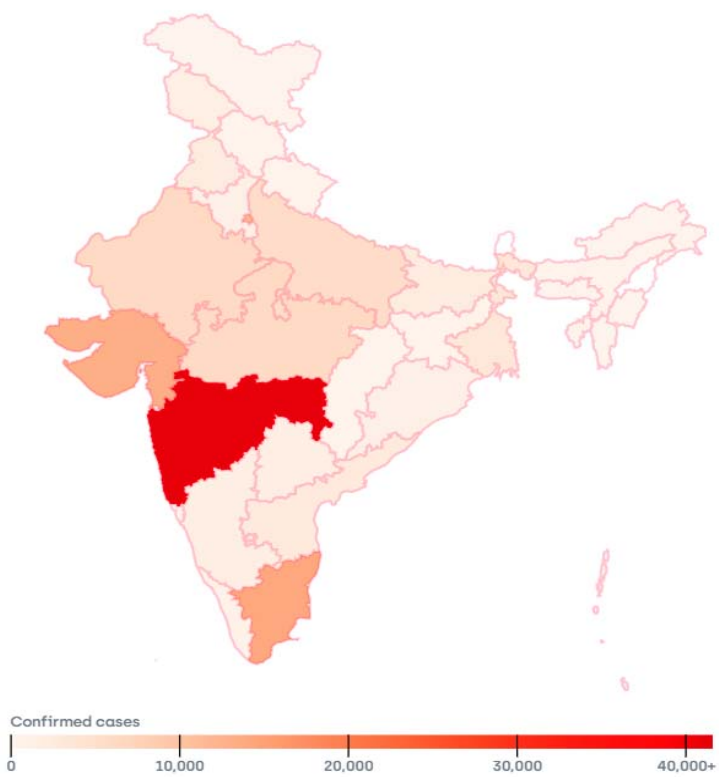

Fig. 1. Outbreak of COVID-19 in India (Source: https://www.covid19india.org/)

Many geographical, social, political, and environmental factors might influence the impact of this deadly virus. Delhi is one of the most affected states in the India, currently has fourth highest infected number of patients. As of May 20, 2020, Ministry of Health and Family Welfare, Government of India has confirmed more than 10,500 cases, including>166 deaths in Delhi state. Delhi has experienced a drastic reduction in air pollution up to 50% [2] due to the implementation of extended mandatory lockdown to prevent COVID-19 transmission. Since, Delhi is considered among the most polluted cities of the world [3], it is worth analysing the role of environment pollution indicators on COVID-19 outbreak.

The link between exposure to air pollutants such as PM2.5 and PM10, Sulfur dioxide, nitrogen dioxide, carbon monoxide and ozone and increased risk for respiratory virus infections as well as susceptibility to respiratory virus infections is well established [4] [5]. There is significant evidence that air pollution is associated with influenza [6], pneumonia and acute lower respiratory infections [7], and severe acute respiratory syndrome [8]. Although much more about COVID-19 remains to be learned, some studies have tried to examine the air quality and impact of environmental pollutants' association with COVID-19. Table 1 summarizes the findings of these studies conducted in various countries worldwide.

Table1: Recent studies on the impact of pollution indicators on COVID-19 spread

Ref.	**Country**	**Pollution Indicators**	**Statistical measure**	**Outcome of Study**	**Duration of Study**
[9]	Italy	PM10 and PM2.5		SARS-CoV-2 could find suitable transporters in air pollutant particles	Feb,2020
[10]	Italy	Air Pollution		the high level of pollution in Northern Italy should be considered an additional co-factor of the high level of lethality	Feb-Mar 2020
[11]	China	PM2.5, PM10, CO, NO2 and O3	Generative Additive Model	Positive associations of PM2.5, PM10, CO, NO2 and O3 and Negative association of SO2 with COVID-19 confirmed	Jan 23 to Feb 29, 2020

				cases	
[12]	Italy, Spain, France and Germany	NO2		long-term exposure to this pollutant may be one of the most important contributors to fatality caused by the COVID-19 virus	Feb-Mar 2020
[13]	Italy	PM10		The role of airborne PM for the virus diffusion is not evident	Feb 10 to Mar 27, 2020
[14]	United States of America	PM2.5	Negative binomial mixed model	We found that an increase of only 1 $\mu g/m^3$ in PM2.5 is associated with an 8% increase in the COVID-19 death rate	Jan 1 to Apr 22, 2020
[15]	China	PM10 and PM2.5		Higher concentration of PM10 and PM2.5 has a positive correlation with deaths caused by COVID-19	
[16]	Italy	NO2, O3, PM2.5 and PM10	Pearson Correlation	Chronic atmospheric pollution may favour coronavirus spreading	Jan 1 to Apr 27, 2020
[17]	United States of America	PM 2.5, PM 10, NO2, CO, Pb and SO2	Kendall and Spearman Correlation Coefficient	Environmental pollutants such as PM10, PM2.5, SO2, NO2, and CO have a significant correlation with the COVID-19 epidemic in California	Mar 4 to Apr 24, 2020

Earlier studies have also suggested that the meteorological parameters might be active factors in the transmission of viruses and disease emergence. Yuan et al. investigated that the peak spread of SARS occurred in a particular range of Temperature, Relative Humidity, and Wind Velocity [18]. Variations of absolute Humidity correlate with the onset and seasonal cycle of influenza viral in the US. [19]. Recently, various studies have been conducted to analyze the impact of weather conditions on the spread and effect of COVID-19. We have summarized the outcome of these studies conducted worldwide in the Table2.

Table 2: Recent studies on the impact of weather condition on COVID-19 Spread

Ref.	**Country**	**Weather Indicators**	**Statistical measure**	**Outcome of Study**	**Duration of Study**
[20]	New York, USA	Average temperature, Minimum	Kendall and Spearman rank correlation tests	Average temperature, minimum temperature, and air quality are significantly	Mar 1 to Apr 12, 2020

		temperature, Maximum temperature, Rainfall, Average Humidity, Wind speed, and Air quality		correlated with COVID-19 pandemic	
[21]	Spain	Daily temperature (mean, minimum and maximum)	Integrated Nested Laplace Approximation	No evidence of a relationship between COVID-19 cases and temperature was found	Feb 25 to Mar 28, 2020
[22]	Mainland China	Daily average temperature and Relative Humidity	Time-series analysis	Temperature and Humidity showed negative associations with COVID-19	Jan 20 to Feb 11, 2020
[23]	USA	Temperature and Absolute Humidity	Mapping of ranges with sum of new cases	COVID-19 spread in the US is significant for states with 4<AH<6 g/m3 humidity	Jan 1 to Apr 9, 2020
[24]	Wuhan, China	Daily average temperature, Diurnal temperature range, Relative Humidity, and Air pollutant data	Generalized additive model(GAM)	(i) Absolute Humidity is negatively associated with daily death counts (ii) A positive association is found between daily death counts of COVID-19 and diurnal temperature range	Jan 20 to Feb 29, 2020
[25]	China	Ambient temperature, Diurnal temperature range , and Absolute Humidity	Polynomial non-linear regression models	(i)Weather with low temperature, mild diurnal temperature range and low humidity likely favor the transmission of COVID-19. (ii) Rise in temperature may ease the Epidemic	Jan 20 to Mar 2, 2020
[26]	China	Temperature	Locally weighted regression and smoothing scatterplot (LOESS), Distributed lag nonlinear models (DLNMs), and Random-effects meta-analysis	Increase of temperature decreases the incidence of COVID-19	Jan 20 to Feb 29, 2020
[27]	Turkey	Temperature, Dew point , Humidity , and Wind speed	Spearman's correlation test	Wind speed 14 days ago and temperature on the day of the case have high impacts on COVID-19 cases	Mar 10 to Apr 5, 2020
[28]	Iran	Average temperature, Average precipitation, Humidity, Wind speed, and Average solar radiation	The Partial correlation coefficient (PCC) and Sobol'-Jansen methods	(i) Humidity has a reverse relationship within the virus outbreak speed. (ii)The outbreak at low speed of the wind is remarkable. (iii)Solar radiation threats the virus's survival.	Feb 19 to Mar 22, 2020

[29]	China	Temperature, Humidity, Precipitation and Wind speed	Linear regression models	Case doubling time correlates positively with temperature and inversely with Humidity	Jan 23 to Mar 1, 2020

The independent effect of air pollution as well as weather indicators on the transmission of COVID-19 has not been studied systemically in the Indian context. Therefore, it is reasonable to speculate that environmental and meteorological factors might affect the spread of COVID-19 in India as well. In this paper, we attempt to answer a very important research question that need prompt responses: "Is there a potential association between the transmission of the coronavirus and the levels of air pollutants as well as weather indicators?" To the best of our knowledge, this is the first study to explore the effects of air quality and weather conditions on COVID-19 outbreak in India.

The primary weather indicators i.e. temperature (°C), and Humidity (%) and pollution indicators such as PM 10, PM 2.5, Sulfur dioxide (SO2), Carbon monoxide (CO), and Nitrogen dioxide (NO2) was considered as independent variables for finding the correlation with affected cases of COVID-19. The majority of the related recent studies have considered the indicators of the same day, which could present a false picture in terms of the correlation with COVID-19 cases. Since the incubation period of the COVID-19 virus varies from 1 day to 14 days, we have evaluated the impact of pollution and weather indicators for three time frames, namely on the day, 7 days ago, and 14 days ago.

2. Materials and Method

2.1 COVID-19 Data

The data of COVID-19 cases of Delhi state of India was retrieved from a publicly available repository and accessible through this link: https://www.covid19india.org/. This is a volunteer-driven, crowd-sourced database being collected and homogenized from multiple official and private web sources. In the dataset three parameters of COVID-19 cases are collected i.e. daily confirmed, daily recovered and daily deceased cases from Apr 1 2020 to May 19 2020 as highlighted in Figure 2.

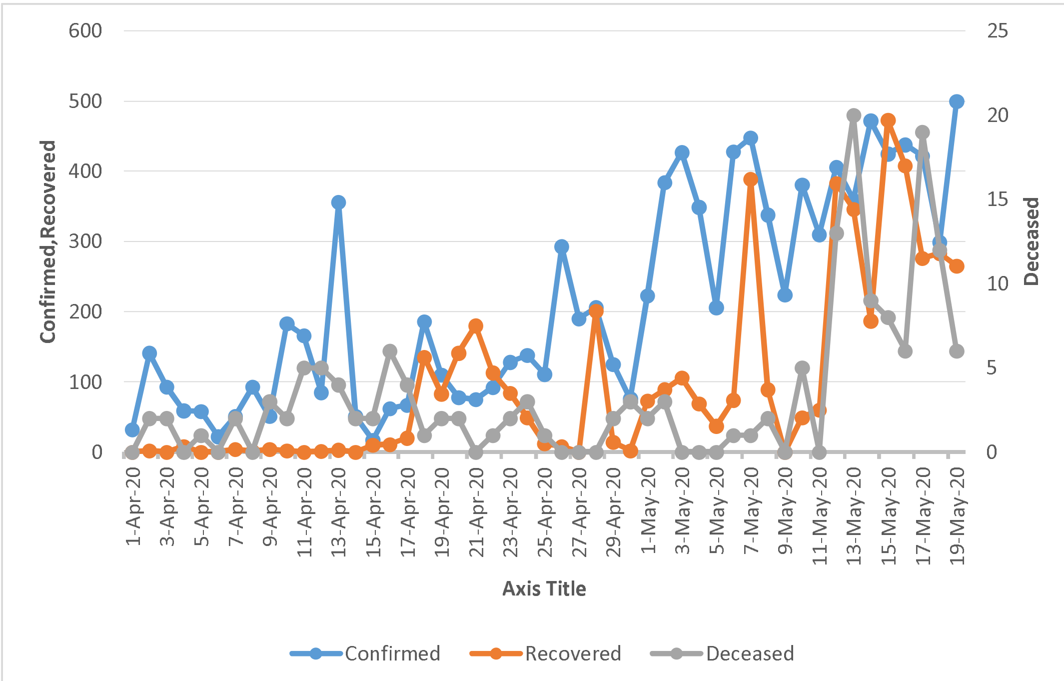

Fig. 2. COVID-19 case statistics in Delhi

2.2 Pollution Data

The dataset of environmental pollution indicators such as PM 10, PM 2.5, Sulfur dioxide (SO2), Carbon monoxide (CO), and Nitrogen dioxide (NO2) was taken from OpenAQ Platform (https://openaq.org), which includes historical archives of pollution indicators observations from local government air quality agencies i.e. Central Pollution Control Board (CPCB). The duration of data collection was Mar 15 2020 to May 19 2020 to cater the time frame of 14 days old data. Figure 3 depicts the pollution profile in Delhi during the period of this study.

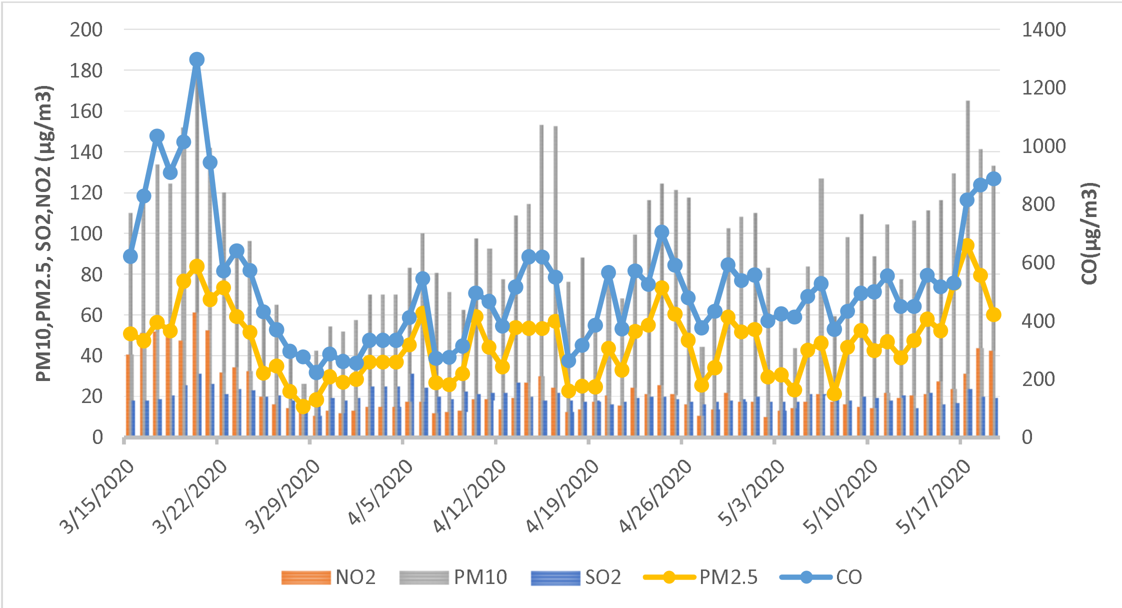

Fig. 3. Pollution indicators statistics in Delhi

2.3 Weather Data

The meteorological data used in this study including Temperature (Max, Average), Humidity (Max, Average) were retrieved from Weather Underground (https://www.wunderground.com/) from Mar 15 2020 to May 19 2020.

2.3 Statistical analysis

As the data collected are not normally distributed; therefore Kendall [30] and Spearman rank correlation [31] tests are considered in this study to investigate the association of pollution and weather indicators with COVID-19 cases. Both of these methods are accepted measures of non-parametric rank correlations. We hypothesize that certain weather conditions with an atmosphere having high content of air pollutants, might favour the transmission of COVID-19, in addition to the direct human to human diffusion. A null hypothesis corresponding to each indicator is formulated that there is no association between individual indicators and the three case statistics considered in this study.

3. Results and Discussion

The significant findings of this study show that pollution and weather indicators are significantly correlated with COVID-19 daily confirmed, recovered and deaths in Delhi. Table 3 depicts the empirical estimations of environmental pollutants' correlation with COVID-19. The study highlights that the concentration of Particulate Matter indicators PM10 and PM2.5 in two time frames i.e. same day and 7 days ago have a positive correlation with deaths caused by COVID-19. These findings are in line with the study conducted by Yao et al. [15] in China. PM10 and PM 2.5, 7 days ago are also significant for daily confirmed cases and the recovered cases. The impact of CO and NO2 same day and 7 days ago on daily recovered cases can be easily observed. SO2 values same day and 14 days ago has also shown impact on daily recovered cases and the correlation is negative similar to the findings of Zhu et al. [11] for China. Overall, the pollution indicators 14 days ago have negligible influence on the COVID-19 outbreak. Similarly, all the pollution indicators on same do not have any significant relation with daily confirmed cases. The results also indicate that the most reasonable timespan to study the impact of pollution indicators is 7 days ago.

Table 3: Correlation coefficients between pollution indicators and COVID-19 cases

Time Frame	**Pollution Indicators**	**Spearman Correlation Coefficient**			**Kendall Correlation Coefficient**		
		Confirmed Cases	Recovered Cases	Deceased	Confirmed Cases	Recovered Cases	Deceased
Same Day	CO	0.215	**0.259***	**0.328**	**0.171***	**0.177***	**0.231**
	NO2	0.186	**0.358**	**0.431***	0.126	**0.240**	**0.317***
	PM 10	0.206	0.186	**0.449***	0.142	0.125	**0.328***
	PM 2.5	0.133	0.097	**0.387***	0.089	0.077	**0.284***
	SO2	-0.226	**-0.443***	0.174	-0.155	**-0.345***	0.136
7 Days Ago	CO	**0.448***	**0.515***	0.125	**0.313***	**0.346***	0.083
	NO2	0.227	**0.378***	0.168	0.162	**0.245**	0.115
	PM 10	**0.293**	**0.517***	**0.292**	**0.191***	**0.345***	**0.196***
	PM 2.5	**0.261***	**0.399***	**0.267***	**0.171***	**0.240**	**0.196***
	SO2	-0.207	-0.004	**0.492***	-0.123	-0.003	**0.362***
14 Days Ago	CO	0.066	-0.051	-0.177	0.058	-0.018	-0.117
	NO2	-0.165	**-0.257***	**-0.311**	-0.106	**-0.172***	**-0.222**
	PM 10	-0.009	-0.045	-0.157	0.010	-0.004	-0.108
	PM 2.5	-0.107	-0.126	-0.157	-0.070	-0.079	-0.102
	SO2	**-0.495***	**-0.305**	-0.220	**-0.312***	**-0.203**	-0.172

***, **, * stands for 10%, 5% and 1% level of significance.

Table 4: Correlation coefficients between weather indicators and COVID-19 cases

Time Frame	Weather Indicators	Spearman Correlation Coefficient			Kendall Correlation Coefficient		
		Confirmed Cases	Recovered Cases	Deceased	Confirmed Cases	Recovered Cases	Deceased
Same Day	Humidity Maximum	-0.148	-0.118	**-0.484***	-0.096	-0.073	**-0.366***
	Humidity Average	0.017	-0.039	**-0.442***	0.029	-0.013	**-0.331***
	Temperature Maximum	**0.299****	**0.276*****	**0.492***	**0.198*****	**0.181*****	**0.375***
	Temperature Average	**0.403***	**0.381***	**0.473***	**0.278***	**0.243****	**0.347***
7 Days Ago	Humidity Maximum	-0.093	**-0.406***	**-0.404***	-0.062	**-0.269**	**-0.293***
	Humidity Average	0.084	**-0.288****	**-0.391***	0.059	**-0.185*****	**-0.281***
	Temperature Maximum	**0.438***	**0.672***	0.186	**0.317***	**0.511***	0.126
	Temperature Average	**0.526***	**0.698***	0.187	**0.365***	**0.531***	0.128
14 Days Ago	Humidity Maximum	-0.193	**-0.250*****	0.000	-0.131	**-0.170*****	-0.004
	Humidity Average	0.021	-0.143	0.131	0.020	-0.076	0.090
	Temperature Maximum	**0.455***	**0.456***	-0.024	**0.302***	**0.332***	-0.024
	Temperature Average	**0.536***	**0.527***	0.058	**0.360***	**0.396***	0.028

***, **, * stands for 10%, 5% and 1% level of significance.

Table 4 highlights the Kendall and Spearman's correlation coefficients corresponding to 4 weather indicators evaluated at three time frames i.e. same day, 7 days ago and 14 days ago among the daily confirmed, recovered, and deceased cases. The average and maximum temperature at all the three time frames possess strong positive correlation with both daily confirmed and the recovered cases as posited by [32]. The temperatures same day are also significant for the daily deceased cases. The study also highlights the association of average and maximum humidity at two time frames (same day and 7 days ago) with daily deceased cases. The correlation is negative, which implies that as the humidity increases, the daily mortality lowers. The average and maximum humidity at 7 days is also significant for daily recovered cases. By and large, the maximum relative Humidity on the same day doesn't exhibit a significant association with the COVID-19 daily confirmed cases in the duration of this study, which contradicts the study in Iran [28] . Both the Spearman as well as Kendall correlation coefficients supports the above findings however, the magnitude of correlation coefficients are higher in the Spearman correlation test.

This study reveal a significant correlation between the transmission of COVID-19 outbreaks and the atmospheric pollutants with a combination of specific climatic conditions. This study has shown evidence of pollution and weather indicators correlation with COVID-19 cases; however, there are various limitations under which this study has been conducted. The variables such as lockdown measures, people's individual immunity, migration index, and other climate indicators can impact the results presented in this study.

4. Conclusions

The environment pollution as well as weather indicators can play a crucial role in the fight against coronavirus. To the best of our knowledge, this is the first study to investigate the impact of environment pollution and weather indicators on COVID-19 incidences in Indian context. Unlike other studies, the present study investigates the impact of these indicators in three time frames of same day, 7 days ago and 14 days ago. We have analysed that the pollution indicators are significantly correlated with COVID-19 cases, hence limited human exposure to outdoor pollution may lead to decline in COVID-19 cases. The present study can be further enhanced by including other parameters such as demographic variations, healthcare infrastructure, and social policies like lockdowns to provide better insight into the fight against COVID-19.

Acknowledgments

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