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Role of Meteorological Parameters in COVID-19 Pandemic Waves in Delhi, India

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Abstract

In this study, the levels of meteorological parameters like maximum temperature (˚F), relative temperature (˚F), minimum temperature (˚F), humidity (%), dew point (˚F), wind speed (mph), rainfall (in), and air pressure (in) were analyzed for all three COVID-19 pandemic waves in the NCT of Delhi, India. After doing statistical analysis, the results showed that only a few parameters, like temperature (maximum, minimum, and relative), dew point, humidity, and air pressure, were linked to the start of COVID-19 pandemic waves, and rainfall had nothing to do with COVID-19 during any of the three waves. So, according to the results of this study, the Indian government should take strict steps to stop the spread of the fourth wave of COVID-19 and any other diseases that can spread in urban areas based on the meteorological conditions.

Keywords

COVID-19, Meteorological Parameters, SARS-CoV-2, Correlation

1. Introduction

COVID-19 has caused a global health crisis. In December 2019, Wuhan, China, reported the outbreak, which the WHO declared a pandemic in March 2020. As of November 21, 2022, this illness had 688,320,211 cases globally, including 40,720,516 in India [1]. According to the WHO website, most nations had COVID-19 [1]. However, many areas of the world have been hit significantly worse than others, both in terms of the number of infections and the fatality rates. According to the data provided by the WHO, India placed second in the world in terms of the number of cases of COVID-19 and third in terms of mortality. So far, 2,006,883 cases have been reported in Delhi alone, with 26,516 people losing their lives as a result. The majority of cases and fatalities related to the COVID-19 epidemic were reported in Delhi during all three waves [2] [3]. COVID-19 infection symptoms observed globally included high-grade fever, cold, pneumonia, shortness of breath, and body ache, all of which caused kidney failure and even death in the short course, and its incubation time period ranged from 6 to 14 days [3]. Some of the best ways to stop a pandemic are to keep your distance from other people, wash your hands often, and try not to touch your face, especially your mouth, nose, and eyes [5]. Surprisingly, the vast majority of the world's population has been rendered helpless and is in danger as a direct result of the exponential rise in the number of deaths and infections [6]. The epidemic has had a considerable impact not only on the availability of goods and services but also on the methods in which people live their lives, the health and education systems, the environment, their daily routines, as well as commercial, sporting, religious, political, and cultural activities. Globally, the annualized rate of economic expansion is expected to fall by 3% in 2020 [7].

On January 30, 2020, India confirmed the first case of COVID-19. To raise public awareness, India announced a curfew for the general public on March 22, 2020, and on March 24, 2020, the country went into a 21-day lockdown. After that, the lockdown was gradually extended due to rising infection rates. Despite the fact that India has a far larger population than nations like the United States, China, France, and Italy, its death rate is thought to be lower because of the lockdown [8].

Infectious disease and mortality rates vary widely not only between nations but also within them [9]. Researchers from a variety of disciplines are urged to conduct exploratory experiments to better understand the role that COVID-19 may play in the spread of the virus and the resulting illnesses and deaths. Many studies from all over the world point to the possibility that air pollution and weather conditions play a role in how diseases affect different places [10]. Italy, like other pandemic-stricken nations, needed to know instantly how air pollution and meteorological aspects influenced disease transmission [11]. In Italy, COVID-19 transmission was linked to particulate matter pollution, temperature, and humidity [12] [13] [14] [15]. In a French city research study, $PM_{2.5}$ and PM_{10} were associated with COVID-19 mortality [16]. Researchers from China also concluded that air pollutants, meteorological parameters are responsible for COVID-19 spread [17]. They found that temperature differences within a day were responsible for deaths due to COVID-19 in Wuhan. In a study of three countries *i.e.*, China, the United States, and Italy done by [18], $PM_{2.5}$, CO, and NO_2 were found to be linked to COVID-19 deaths [19] [20]. In Wuhan, China, where the COVID-19 pandemic's outbreak, researchers looked at how weather affects the number of new COVID-19-related deaths each day. They found a strong link between the air quality index, humidity, and deaths [21]. In a similar way, [22] looked at how COVID-19 spread in China when temperature and air quality were taken into account as a whole. They found that when the temperature went up, the air quality didn't get worse, which made it take more time for diseases to spread. [23] expressed similar things and highlighted the link between temperature and Germany's significant COVID-19 spread. They also said that the country's "controlled" pollution was to thank for the slow spread of the pandemic in the country. As the pandemic got worse, the Chinese government put restrictions on how vehicles could move in the worst-affected cities. This was done to reduce air pollution, and the policy to limit private transport could cut $PM_{2.5}$ pollution by 32% [24].

The impact of COVID-19 has been found more in countries where temperatures range from 0˚C to 15˚C as compared to warm-weather and very low-temperature countries [25]. According to Shaobo Shi [26], there is a direct correlation between daily temperature and the number of confirmed COVID-19 pandemic cases in some regions of China, and Shi also stated that if daily temperatures rose above 10˚C, the number of confirmed cases would decrease. In the same way, if the temperature went up by 1˚C, Brazil's daily cases of COVID-19 infection would decrease [27]. Whereas, there haven't been any consistent relationships between the number of COVID-19 pandemic cases [26] and higher average, minimum, and maximum temperatures [28] [29]. Many studies have also found that the number of COVID-19 cases and deaths goes down when the temperature and humidity around the world go up [17] [30] [31]. Overall, scientists and people believe that the number of COVID-19 infection transmissions depends upon the environmental conditions.

Based on geography and environment, we can figure out how likely a COVID-19 pandemic is in a certain climate zone. Numerous studies have demonstrated that environmental elements like temperature, rainfall, humidity, wind speed, pressure, evaporation, and sunlight affect the start and transmission of infectious diseases like pneumonia and influenza [32]. Similarly, a number of research studies have looked at the link between different environmental conditions and the spread of the COVID-19 pandemic and found strong positive correlations, just like they did with the spread of other communicable diseases [17] [28] [33] [34] [35] [36] [37].

In India, no thorough academic study has been published to inform researchers and policymakers on how climate affects the spread of COVID-19 in megacities. Apart from this, the past studies in India only considered a short span of time and studied only two or three meteorological parameters; however, in Delhi, India, there were three waves of COVID-19, and most of the cases and deaths occurred in this time period; during these waves, there were seasonal differences, which meant the levels of meteorological parameters were different. This study was done to fill a gap in the research. The main purpose of this study is to investigate, compare, and discuss the eight meteorological parameters of Delhi: maximum temperature, relative temperature, minimum temperature, dew point, humidity, wind speed, rainfall, and air pressure. For three study periods, *i.e.*, the 1st wave of COVID-19 (September 1, 2020-December 11, 2020), the 2nd wave of COVID-19 (April 1, 2021-May 22, 2021), and the 3rd wave of COVID-19 (January 1, 2022-January 30, 2022). This is the first study to look at the COVID-19 pandemic as well as various meteorological parameters in India's most densely populated and rapidly growing metropolis in all of its waves. Researchers, academics, and health policymakers will get a comprehensive understanding of COVID-19 and numerous climatic factors from the study. These data will also suggest new studies on climate and COVID-19 infection spreadibility in tropical and subtropical Indian megacities.

2. Data and Methods

2.1. Study Area

The study was done in the NCT of Delhi, which is the capital of India. It is between longitudes 76˚50'E and 77˚20'E and latitudes 28˚24'N and 28˚05'N (**Figure 1**). It is about 1483 km^2 in size. Delhi is one of the top 20 cities with the most people in the world. Air pollution in the city is mostly caused by the burning of fuels (petrol, kerosene, diesel, etc.), industrial factory emissions, construction work, electricity generator plants, the burning of agricultural biomass waste by surrounding states, and many vehicles moving around because it is one of the most important places in north India for business, industry, and trade. It is also called the country's second economic and political center. It has about 16.8 million people, making it the largest urban area in the country. Delhi has harsh weather. Summer is hot (April-July) while winter is frigid (December-January).

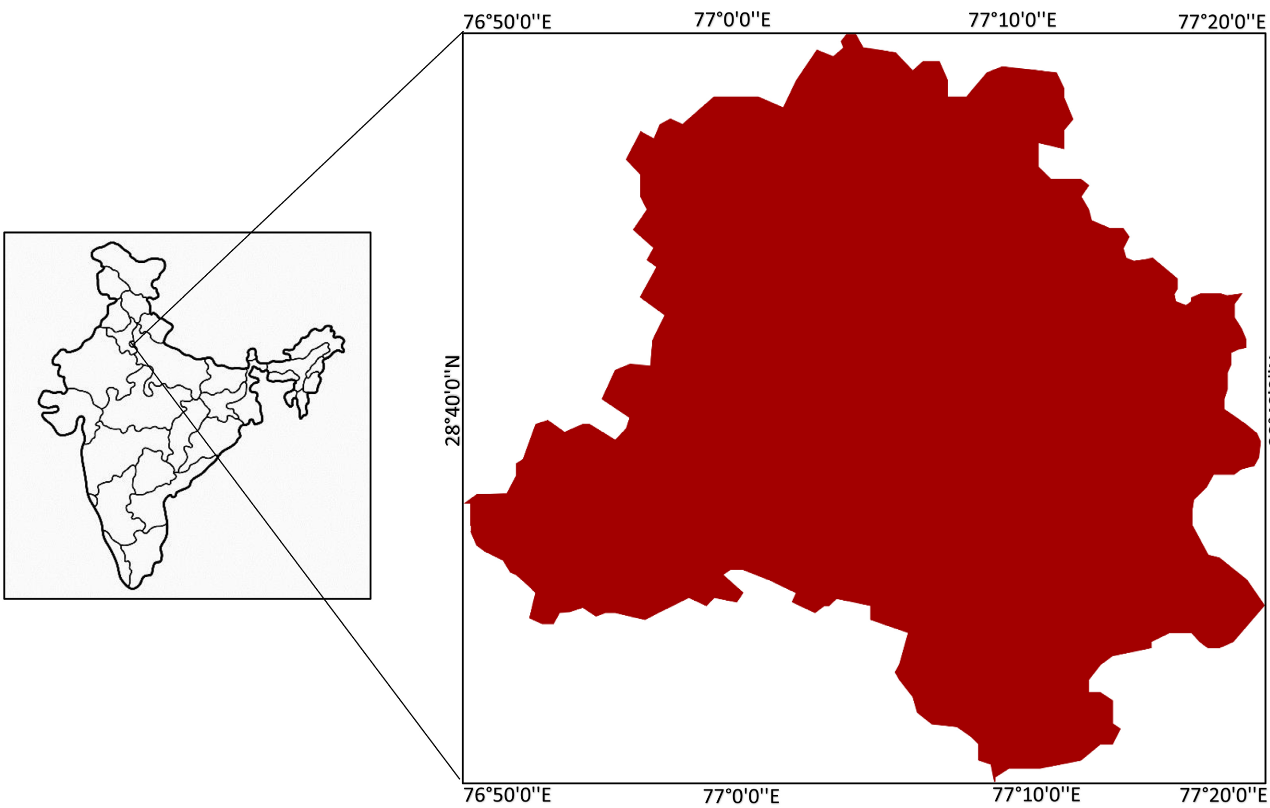

Figure 1. The study area NCT of Delhi, India.

In summer, the average temperature is 30˚C - 48˚C, while in winter it is 22˚C - 1˚C. Spring is from February to March, while the monsoon season is from July to September.

2.2. Data Description

To study, daily data for three study periods, *i.e.*, the 1st wave of COVID-19 (September 1, 2020-December 11, 2020) **Figure 2(a)**, 2nd wave of COVID-19 (April 1, 2021-May 22, 2021) **Figure 2(b)**, and the 3rd wave of COVID-19 (January 1, 2022-January 30, 2022) **Figure 2(c)** (190 days), was collected from [2] [3]. The daily COVID-19 pandemic wave data of new cases and deaths on the aforementioned website is managed by a group of volunteers who gathered this information from government websites and other reliable sources. The available dataset includes COVID-19 pandemic daily new confirmed cases, daily active and cumulated cases, daily deceased cases, and daily tests conducted. For this investigation, we have only included total confirmed cases and death data because these two factors have been determined to have stable values during the chosen period.

In addition the pandemic waves data of the NCT of Delhi, daily meteorological parameters data (maximum temperature (˚F), relative temperature (˚F), minimum temperature (˚F), wind speed (mph), dew point (˚F), humidity (%), air pressure (in), and rainfall (in) for the same period were collected with consistency for 190 days of all three waves from the prominent institute web portal of the Indian Agricultural Research Institute (ICAR), New Delhi, India [38] [39]. The available data is reliable and has been used by many researchers. The total and average of the dataset have been calculated for analysis and overview (**Table 1**).

2.3. Data Analysis

The COVID-19 pandemic data and meteorological parameter data were analyzed at the univariate level controlling other variables at same time. The COVID-19 case and death statistics display extensive tails, ranging from near zero to extremely large positive values; thus, we took this into account before beginning the Mann-Kendall analysis, Karl Pearson's correlation, and regression calculations. Microsoft Excel and Word were used to create tables and graphs. For the COVID-19 pandemic-acquired data, Mann-Kendall and Sen's slope were used to obtain the trend, and for all the data, descriptive statistics analysis was also done to get the minimum, maximum, and mean values. Karl Pearson's correlation and linear regression analysis were performed at a 95% confidence level to obtain the values of R and p for the correlation of COVID-19 pandemic waves with meteorological parameters. The data was analyzed for a 15-day interval because of the daily fluctuations in new confirmed and deceased cases, for 30 days because of the seasonal changes during the COVID-19 pandemic waves, and for an average over all the days of each pandemic wave.

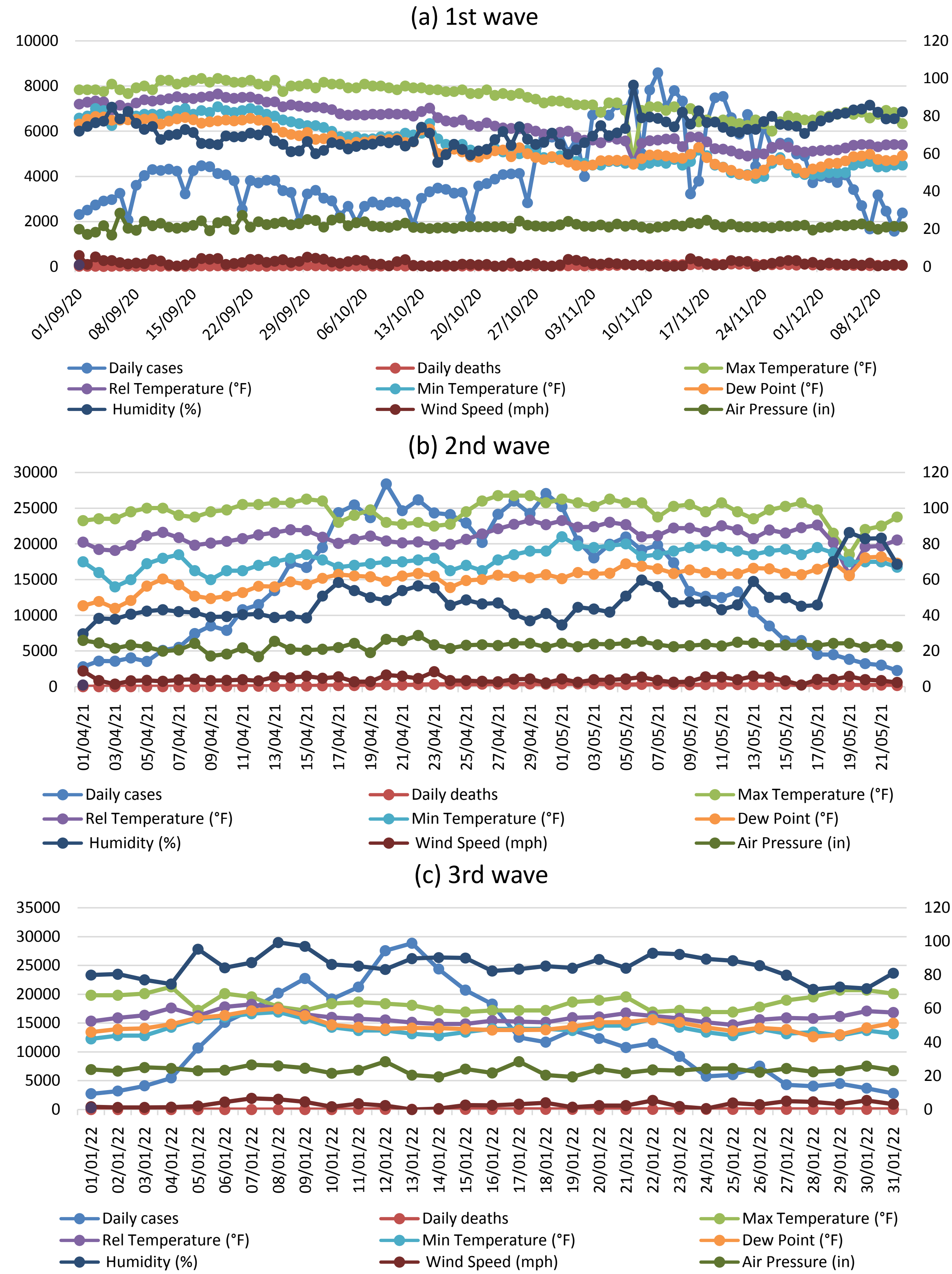

Figure 2. (a), (b), and (c) show the daily COVID-19 cases and deaths trend and the daily 24-hour concentrations of meteorological parameters for the 1st, 2nd and 3rd waves respectively.

Table 1. We used descriptive statistics to figure out the total and average values of the data we collected. Since there was no rain during the whole study period, we didn't include it in this table or in our analysis.

Variables	1st Wave	2nd Wave	3rd wave
Total cases (number of people)	428,787	752,789	382,047
Total deaths (number of people)	5428	11986	758
Average maximum temperature (˚F)	88.8	98.09	63.61
Average minimum temperature (˚F)	65.12	70.23	48.19
Average relative temperature (˚F)	75.29	84.4	55.01
Average dew point (˚F)	64.07	60.64	50.01
Average humidity (%)	71.48	48.63	85.02
Average wind speed (mph)	2.01	4.16	2.93
Average air pressure (in)	21.87	23.02	23.55

3. Result

3.1. Trends of COVID-19 and Meteorological Parameters

The trends of COVID-19 infection cases were determined through the Mann-Kendall and Sens slop tests for all three waves of the pandemic. Meteorological parameters' maximum, minimum, and average values were extracted from the collected data by using descriptive statistics analysis Table 1.

3.1.1. During the 1st Wave of COVID-19 (September 1, 2020-December 11, 2020)

Figure 2(a) shows daily COVID-19 confirmed and deceased cases from September 1 to December 11, 2020 and everyday meteorological parameter values. The total confirmed cases reported were 428,787, and 5428 deaths were reported. However, there was a sudden spike in new confirmed and deceased cases from the 3rd to the 29th of November when compared to other days, with the most of the number of cases on the 11th of November was 8593, which is around 600% more than the minimum number of cases and 120% more than the median of all confirmed cases, as well as 121 maximum deceased cases on the 22nd of November. whereas the Mann-Kendall test results for cases and deaths show a monotonic trend, the trend is increasing due to positive S and Tau values, and the Sens slope confirms this positive increasing trend with its positive value; both tests show this trend at the 95% confidence level. For the meteorological parameters, during the study period values for temperature ranged from 47 - 100˚F, for dew point ranged from 48.6 - 79.8˚F, for humidity ranged from 55.4% - 96.5%, and for wind speed 0.3 - 6 mph and air pressure 16.8 - 28.5 in and the averages (maximum temperature (˚F), relative temperature (˚F), minimum temperature (˚F), dew point (˚F), humidity (%), air pressure (in), wind speed (mph), and rainfall (in)) were observed as 88.8˚F, 75.29˚F, 65.12˚F, 64.07˚F, 71.48%, 21.87 in, 2.01 mph, and no rainfall. In the last week, humidity rose while air pressure and wind speed dropped.

3.1.2. During the 2nd Wave of COVID-19 (April 1, 2021-May 22, 2021)

Figure 2(b) shows the 53 days of new confirmed and deceased cases of disease, with a significant increase in the maximum reported newly confirmed and deceased cases, which is around 400% more as compared to cases reported in the 1st wave. As the calculated p-value for the Mann-Kendall trend test is less than the significance threshold alpha = 0.95, one must reject the null H0 hypothesis and evaluate the alternative hypothesis, Ha. The alternative hypothesis suggests a decreasing trend because of the negative s, tau, and Sen's slope value for the cases and an increasing trend for deaths at a 95% confidence level. Temperature (maximum, minimum, and average), dew point, and other parameters increased abruptly from April 26th to May 6th, 2021, while other parameters remained normal on other days. For the meteorological parameters, during the study period, values for temperature ranged from 45 - 107˚F, for dew point ranged from 43.9 - 72.8˚F, for humidity ranged from 29.6% - 86.4%, and for wind speed 1 - 8.8 mph and air pressure 16.8 - 28.8 in and the averages (maximum temperature (˚F), relative temperature (˚F), minimum temperature (˚F), dew point (˚F), humidity (%), air pressure (in), wind speed (mph), and rainfall (in)) were observed as 98.09˚F, 84.40˚F, 70.23˚F, 60.64˚F, 48.63%, 23.02 in, 4.16 mph, and no rainfall.

3.1.3. During the 3rd Wave of COVID-19 (January 1, 2022-January 30, 2022)

In the winter season, Figure 2(c) depicts the 31-day COVID-19 confirmed and deceased cases, with a minimum of 2716 new cases and 1 death and a maximum of 28,867 new cases and 45 deaths. As the calculated p-value for the Mann-Kendall trend test is smaller than alpha = 0.95, the null hypothesis, H0, must be discarded in favour of Ha. The alternative hypothesis shows a decreasing trend, and the Sens slope value also confirms the same at a 95% confidence level. And the trend for deaths is rising. In the 3rd wave, there was no abnormality seen in the values of all the parameters, during the study period values for temperature ranges from 42 - 73˚F, for dew point ranges from 43.3 - 60˚F, for humidity ranges from 71.4% - 99.4%, and for wind speed 0.3 - 6.6 mph and air pressure 19.4 - 28.5 in and the average values of all the parameters (maximum temperature (˚F), relative temperature (˚F), minimum temperature (˚F), dew point (˚F), humidity (%), air pressure (in), wind speed (mph), and rainfall (in)) were 63.61˚F, 55˚F, 48.19˚F, 50˚F, 85%, 2.94 mph, 23.55 in, and no rainfall.

3.2. Univariate Analysis

3.2.1. Karl Pearson's Correlation Coefficients Matrix

This technique is useful for identifying collinearity among potential predictors. In Tables 2(a)-(c), we can see the results of a Karl Pearson correlation analysis matrix between daily case reports and other meteorological parameters. A fairly significant positive correlation (r) is found for the first, second and third waves over Delhi, for each research period.

Table 2. (a), (b), and (c) show the Karl-Pearson correlation of the meteorological parameter coefficient matrix with COVID-19 cases for the 1st, 2nd, and 3rd waves, respectively. (a) Karl Pearson correlation matrix for 1st wave; (b) Karl Pearson correlation matrix for 2nd wave; (c) Karl Pearson correlation matrix for 3rd wave.

(a)

	Daily cases	*Max Temperature (˚F)*	*Rel Temperature (˚F)*	*Min Temperature (˚F)*	*Dew Point (˚F)*	*Humidity (%)*	*Wind Speed (mph)*	*Air Pressure (in)*
Daily cases	1							
Max Temperature (˚F)	0.518	1						
Rel Temperature (˚F)	0.51	0.925	1					
Min Temperature (˚F)	0.467	0.839	0.979	1				
Dew Point (˚F)	0.474	0.798	0.945	0.972	1			
Humidity (%)	0.235	0.622	−0.461	−0.329	−0.149	1		
Wind Speed (mph)	−0.215	0.264	0.364	0.395	0.339	−0.222	1	
Air Pressure (in)	0.02155	0.119411	0.127754	0.119062	0.07633	−0.178	0.210875	1

(b)

	Daily cases	*Max Temperature (˚F)*	*Rel Temperature (˚F)*	*Min Temperature (˚F)*	*Dew Point (˚F)*	*Humidity (%)*	*Wind Speed (mph)*	*Air Pressure (in)*
Daily cases	1							
Max Temperature (˚F)	0.308	1						
Rel Temperature (˚F)	0.37	0.859	1					
Min Temperature (˚F)	0.259	0.324	0.667	1				
Dew Point (˚F)	0.196	−0.046	0.275	0.636	1			
Humidity (%)	−0.161	−0.665	−0.515	0.009	0.668	1		
Wind Speed (mph)	0.123	−0.284	−0.187	0.155	−0.031	0.055	1	
Air Pressure (in)	0.21715	−0.20196	−0.01591	0.280938	0.241068	0.184324	0.349005	1

(c)

	Daily cases	*Max Temperature (˚F)*	*Rel Temperature (˚F)*	*Min Temperature (˚F)*	*Dew Point (˚F)*	*Humidity (%)*	*Wind Speed (mph)*	*Air Pressure (in)*
Daily cases	1							
Max Temperature (˚F)	0.452	1						
Rel Temperature (˚F)	0.113	0.588	1					
Min Temperature (˚F)	0.328	−0.165	0.662	1				
Dew Point (˚F)	0.311	−0.075	0.712	0.896	1			
Humidity (%)	0.558	−0.755	−0.093	0.549	0.628	1		
Wind Speed (mph)	0.055	0.056	0.499	0.562	0.412	0.0378	1	
Air Pressure (in)	−0.056	0.108	0.293	0.241	0.211	−0.046	0.418	1

1) Maximum temperature and COVID-19 cases

The first wave maximum temperature is moderately positive, the second wave maximum temperature is weakly positive, and the third wave maximum temperature is moderately positive in relation to the number of daily new COVID-19 cases in Delhi.

2) Relative temperature and COVID-19 cases

The first wave relative temperature is moderately positive, the second wave relative temperature is weakly positive, and the third wave relative temperature is very weakly positive in relation to the number of daily new COVID-19 cases in Delhi.

3) Minimum temperature and COVID-19 cases

The first wave minimum temperature is moderately positive, the second wave minimum temperature is weakly positive, and the third wave minimum temperature is weakly positive in relation to the number of daily new COVID-19 cases in Delhi.

4) Dew point and COVID-19 cases

The first wave dew point is moderately positive, the second wave dew point is weakly positive, and the third wave dew point is weakly positive in relation to the number of daily new COVID-19 cases in Delhi.

5) Humidity and COVID-19 cases

The first wave humidity is weakly positive, the second wave humidity is weakly negative, and the third wave humidity is moderately positive in relation to the number of daily new COVID-19 cases in Delhi.

6) Wind speed and COVID-19 cases

The first wave wind speed is weakly negative, the second wave wind speed is very weakly positive, and the third wave wind speed is very weakly positive in relation to the number of daily new COVID-19 cases in Delhi.

7) Air pressure and COVID-19 cases

The first wave air pressure is very weakly positive, the second wave air pressure is very weakly positive, and the third wave air pressure is weakly negative in relation to the number of daily new COVID-19 cases in Delhi.

In this univariate analysis, we found that the meteorological parameters temperature (maximum, relative, and minimum), dew point, humidity, air pressure, and wind speed showed positive associations with the COVID-19 daily cases in all three waves in the NCT of Delhi. And also, as can be seen in the tables, all the chosen parameters except rainfall were correlated with each other. Which is the sign of collinearity, and get stronger results, we further did linear regression analysis for every parameter with cases to get r values and also to control other variables at one time.

3.2.2. Correlation of Meteorological Parameters with COVID-19 Pandemic Waves

The below **Table 3** and **Figure 3** show the linear regression r values for each selected variable. To get these values of r for every parameter, linear regression was

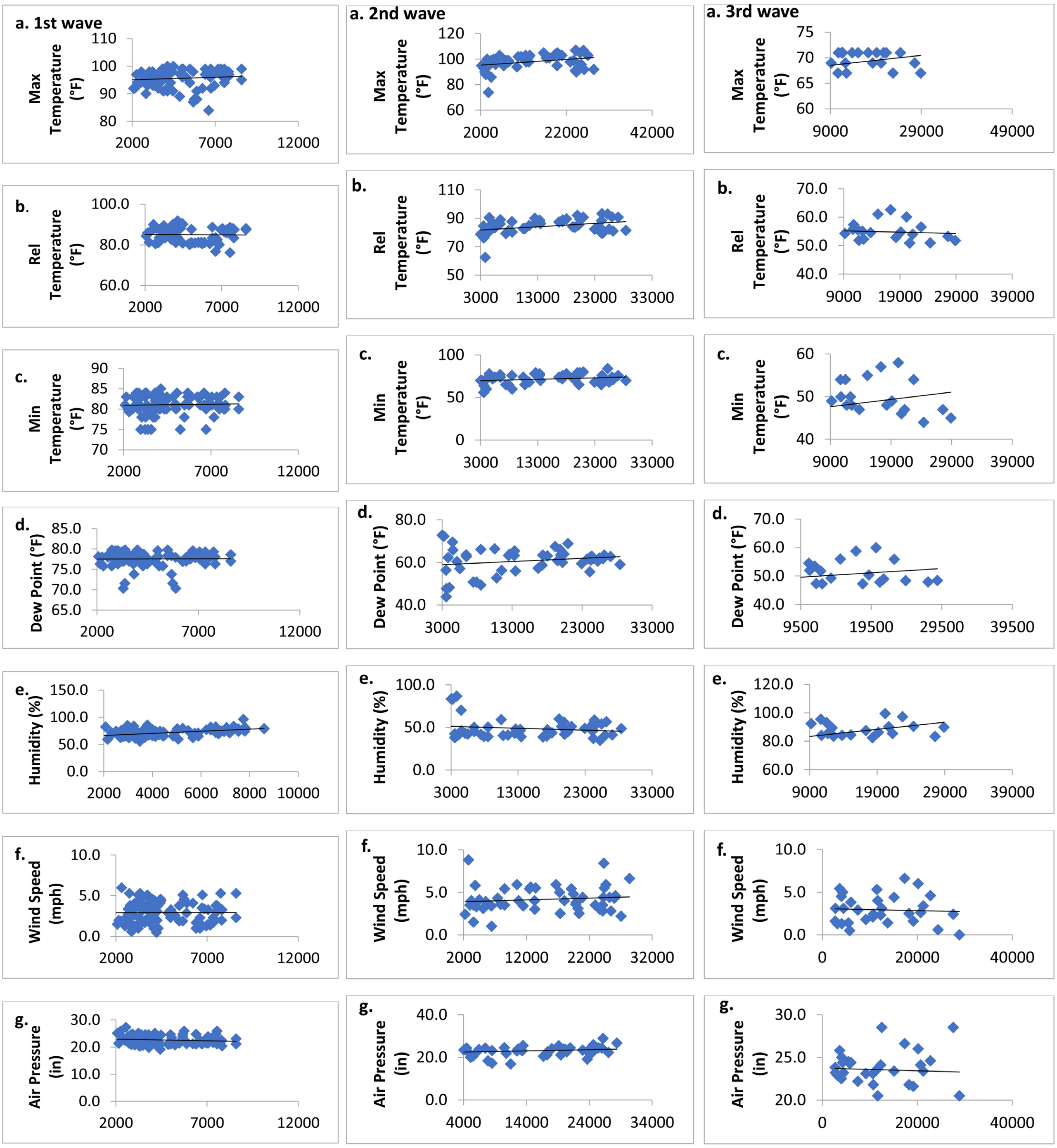

Figure 3. Correlation of all the parameters with the cases for the 1st, 2nd, and 3rd waves of COVID-19.

done between every variable and case one by one to control other parameters, and the value signifies that the temperature (maximum, minimum, and relative) shows a strong positive association with the newly confirmed cases in all three waves. In which for the three waves, r values of 0.51, 0.3, and 0.45 show strong dependability of COVID-19 cases with the maximum temperature, it means that with increasing temperature, cases will increase. This relationship can be seen in Figure 3.

Table 3. Linear regression r values for all the parameters with cases of the waves, performed at a 95% significance level.

	1st wave of COVID-19	2nd wave of COVID-19	3rd wave of COVID-19
Meteorological parameters	r value for cases	r value for cases	r value for cases
Maximum temperature (˚F)	0.51	0.3	0.45
Minimum temperature (˚F)	0.46	0.36	0.11
Relative temperature (˚F)	0.5	0.27	0.32
Dew point (˚F)	0.47	0.19	0.31
Humidity (%)	0.23	0.16	0.55
Wind speed (mph)	0.21	0.12	0.05
Air pressure (in)	0.02	0.21	0.05

As depicted in **Table 3**, dew point shows the positive correlation with new daily cases of COVID-19 pandemic of all the three waves; r value (0.47, 0.19, 0.31) shows strong correlation with the 1st and 3rd waves, for the 2nd wave, dew point shows weak association with the new daily COVID-19 cases **Figure 3**.

According to the analysis shown in **Table 3** and **Figure 3**, humidity was also positively related with COVID-19 new cases, with r-values for the first and second waves of 0.23, 0.16 indicating a weak positive association and r value 0.55 indicating a strong positive correlation with COVID-19 daily cases.

Wind speed was positively associated with the daily new COVID-19 cases, but for the 1st, 2nd waves it showed a weak association and a very weak association in the 3rd wave with the COVID-19 new cases. And air pressure also shows the very weak positive correlation in 1st and 3rd wave and weak (0.21) in 2nd wave with the new daily COVID-19 cases **Table 3** and **Figure 3**.

4. Discussion

The linear regression analysis yields the values shown in (**Table 2**), which describe the positive correlation of temperature (maximum, minimum, and average) with all three waves of the pandemic for cases at a 95% confidence level. We also observed cases increasing with increases in temperature during all the waves. These results agree with what [40] found, which is that the number of cases of COVID-19 is likely to increase as the air temperature in India rises. However, it is not clear what role humidity plays. [41] looked at the climate records of temperature, sun light, humidity, population density, rainfall, and wind speed. They found that COVID-19 is more likely to spread in areas of India that are hot and dry and at a lower altitude. In Japan, though, the correlation was found to be positive (r = 0.416, P = 0.001). Many cities, including Shanghai (China), Hong Kong (China), Seoul (South Korea), Kuala Lumpur (Malaysia) and Tokyo (Japan), had a positive association with the number of new daily confirmed cases, deceased cases and the average temperature and relative humidity.

This was especially true when using lagged 3D modelling, which showed that temperature was responsible for confirmed cases of disease in the locations (exceptions: Beijing, Malaysia, and Korea) [42]. COVID-19 pandemic cases are statistically associated with minimum, maximum temperatures (˚C), and humidity (%) (r values = 0.93, 0.94, 0.83, and 0.30, respectively, at the 99% confidence significance level). Cold temperatures increase COVID-19 cases ($r = 0.447$, $p = 0.01$, and $r = 0.362$, $p = 0.05$, respectively) [43].

The r value in **Table 3** reflects the strong association of dew point with the spreadibility of COVID-19 cases in all three waves, which are significant at a 95% confidence level. The fact that the dew point is going up suggests that there will be more cases. Temperatures, dew point, wind, and humidity were all found to be related to the emergence of new cases of COVID-19 in studies of correlation and regression (P 0.05). In high population densities, humidity does not show any association with COVID-19 cases; in low population densities, the opposite was observed [44]. [45] demonstrated that high temperatures and high relative humidity had a detrimental impact on the survival and transmission of COVID-19, whereas low temperatures, rainfall, dew point, wind speed, and surface pressure all helped to prolong the life and spreadibility of the virus for a longer length of time.

The regression analysis witnessed the link of the humidity with the COVID-19 disease cases; it witnessed a strong association with the rise in new cases. All these were significant at a 95% confidence level. These results match up with what [34] found, to the fact that states with moist and very wet weather have taken on the majority of the COVID-19 pandemic's confirmed cases. But [46] found that higher temperatures contributed to the rapid spread of COVID-19. On the other hand, in China, researchers found no relationship between COVID-19 infection spreadibility and humidity. The spreadibility of this disease is affected by a number of things, such as the number of people in a location, the number of people moving in and out of that area, the host's immunity, the quality of medical care, and, most likely, the weather (temperature and humidity) [32] [47]. Also, [37] has proven that humidity does not usually cause COVID-19 pandemics in Türkiye. [36] has demonstrated that there is a slightly negative significant association between the level of humidity and the number of confirmed cases of the COVID-19 pandemic in New York City.

Wind speed shows the correlation values are very low as compared to other parameters at the 95% confidence level. The Karl-Pearson test was applied to get to know by which level COVID-19 cases are related to factors such as the speed of the wind, the temperature, the amount of daylight hours, the amount of rainfall, and the level of humidity. Low wind speed increased COVID-19 instances ($r = 0.314$; $p = 0.05$) [43]. $PM_{2.5}$ pollution increased COVID-19 instances. In conclusion, the maximum wind speed, rain, $PM_{2.5}$ pollution, and temperature may increase COVID-19 spreadability [48]. Transmission was higher when wind speeds were less than 5.5 mph. Scientists believe higher wind speeds disperse

SARS-CoV-2 particles and minimize infection risk. Since cooler outside temperatures discourage socializing, they may have indirectly boosted infection rates by encouraging people to stay indoors. Airflow and quality will also reduce infection risk because transmission rates are higher inside [49]. After accounting for a variety of potential confounding factors, the results demonstrate that high temperatures and high winds have a strong inhibitory influence on virus propagation [50]. What has been seen with SARS-CoV and MERS-CoV-2 is also true for COVID-19. They also found an inverse association with wind speed, suggesting COVID-19 stays in the air for a shorter duration, and a higher UV index (but just for the 14 days before the pandemic), which makes sense because viruses die at higher temperatures [49].

Air pressure also showed a correlation with COVID-19 spreadibility in the NCT of Delhi, but the strength of the correlation was lower at a 95% significant level. We tried those meteorological variables (air temperature, average humidity, rainfall, wind speed, and air pressure) are not linked to COVID-19's ability to spread when the basic reproduction rate is used to measure it (R0). We used data that was available to the public about the number of COVID-19 cases each day (n = 108,308), the weather every three hours, and how people moved around their communities over the course of three months [51]. Weather conditions and air pollution factors spread COVID-19 to 3739 locations of the world. The predicted reproduction number was considerably negative with temperatures over 25˚C and weakly positive with air pressure, wind speed, rainfall, SO_2, and O_3. The findings indicated that, whereas higher air pressure was associated with a lower incidence rate, higher wind speeds had the opposite impact. Crucial meteorological parameters had a comparable effect on the incidence rate and the total number of reported cases [52].

There was no rainfall during the chosen time period of the COVID-19 pandemic waves, so there was no correlation between the three waves of the COVID-19 pandemic [53]. Wind speed and rainfall appear unrelated, but they may influence behaviour to limit exposure and infection risk. One study examined how weather affects COVID-19 outcomes in all Chinese regions. Rain was associated with Fujian COVID-19 fatalities and cases in Shanghai [54]. The average rainfall in the chosen cities is between 20 and 40 mm, which makes COVID cases drop by 18% and 26% over the next three days [55]. COVID-19 is often effective at 27˚C - 32˚C and 250 - 350 mm of monthly average rainfall. This study reveals that both temperature and rainfall aren't the main factors that cause COVID-19; however, both variables appear to play substantial roles in the spread of it in India, particularly during the summer time of 2020 and 2021, when the rainy season was heavier in some states. This was especially true during the summer time of 2020 and 2021 [56]. In one study RH and rainfall were found to be negatively related to new daily cases and mortality [57].

5. Conclusion

In this study, we selected the following meteorological parameters: maximum temperature (˚F), relative temperature (˚F), minimum temperature (˚F), dew point (˚F), humidity (%), air pressure (in), wind speed (mph), and rainfall (in). The Mann-Kendall test and Sens slope were used to obtain the trend in the COVID-19 data, and the Karl-Pearson analysis was used to determine the role of meteorological parameters in the COVID-19 pandemic waves. From the overall analysis, it can be concluded that the meteorological parameters such as maximum temperature (˚F), relative temperature (˚F), minimum temperature (˚F), wind speed (mph), dew point (˚F), humidity (%), and air pressure (in) were positively associated with the spreadibility of COVID-19 pandemic waves. However, some of the parameters of this study show a very weak association. The whole analysis was done at a 95% significant level. The findings of this study have the potential to provide information on how changes in the environment impact urban areas with high population densities that are located in hotter, more tropical regions. This study will also serve as a new base for more research on climatic factors and the potential for the COVID-19 pandemic to spread to other megacities located in the subtropical region of India. Researchers and those who are responsible for making choices on health policy might make use of these results.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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