Aerobiologia (2022) 38:277–286
https://doi.org/10.1007/s10453-022-09748-5

REVIEW PAPER

A review of the impact of environmental factors and pollutants on covid-19 transmission

Mohammad Omar Faruk · Md. Sahidur Rahman · Sumiya Nur Jannat · Yasin Arafat · Kamrul Islam · Sarmin Akhter

Received: 1 January 2022 / Accepted: 6 June 2022 / Published online: 23 June 2022
© The Author(s), under exclusive licence to Springer Nature B.V. 2022

Abstract The coronavirus disease (COVID-19) caused an unprecedented loss of life with colossal social and economic fallout over 237 countries and territories worldwide. Environmental conditions played a significant role in spreading the virus. Despite the availability of literature, the consecutive waves of COVID-19 in all geographical conditions create the necessity of reviewing the impact of environmental factors on it. This study synthesized and reviewed the findings of 110 previously published articles on meteorological factors and COVID-19 transmission. This study aimed to identify the diversified impacts of meteorological factors on the spread of infection and suggests future research. Temperature, rainfall, air quality, sunshine, wind speed, air pollution, and humidity were found as investigated frequently. Correlation and regression analysis have been widely used in previous studies. Most of the literature showed that temperature and humidity have a favorable relationship with the spread of COVID-19. On the other hand, 20 articles stated no relationship with humidity, and nine were revealed the negative effect of temperature. The daily number of COVID-19 confirmed cases increased by 4.86% for every 1 °C increase in temperature. Sunlight was also found as a significant factor in 10 studies. Moreover, increasing COVID-19 incidence appeared to be associated with increased air pollution, particularly PM10, PM2.5, and O_3 concentrations. Studies also indicated a negative relation between the air quality index and the COVID-19 cases. This review determined environmental variables' complex and contradictory effects on COVID-19 transmission. Hence it becomes essential to include environmental parameters into epidemiological models and controlled laboratory experiments to draw more precious results.

Keywords COVID-19 · Coronavirus · Environmental impact · Meteorological factors · Air pollution · Transmission

Mohammad Omar Faruk and Md. Sahidur Rahman contributed equally to this work.

M. O. Faruk · S. N. Jannat · Y. Arafat · K. Islam · S. Akhter
Department of Statistics, Noakhali Science and Technology University, Noakhali 3814, Bangladesh
e-mail: omarfaruk.faruk396@gmail.com

S. N. Jannat
e-mail: sumiyanurjannat802@yahoo.com

Y. Arafat
e-mail: yasin_arafath41@yahoo.com

K. Islam
e-mail: kamrul1514@student.nstu.edu.bd

S. Akhter
e-mail: sarmin1514@student.nstu.edu.bd

M. S. Rahman (✉)
One Health Center for Research and Action. Akbarshah, Chattogram 4207, Bangladesh
e-mail: sahid.dvm@gmail.com

1 Introduction

The coronavirus disease 2019 (COVID-19), a devastating respiratory infection, spread globally and caused the loss of nearly 6.07 million humans life (Bilal et al., 2021; "Coronavirus Graphs: Worldwide Cases and Deaths—Worldometer", 2020.). The COVID-19 is occurred by a novel Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), first identified in China's Wuhan city on December 31, 2019 (Rahman, 2020). The WHO (World Health Organization) declared it a global pandemic on March 11, 2020 (Gupta, Pradhan, et al., 2020). The irresistible spread of COVID-19 and lack of medical amenities have affected global economic growth, increased unemployment rate, and breakdown of healthcare systems even in more developed countries (Sahoo, 2021). The evidence showed that the disease spread through direct, indirect, or close contact with the infected person and also create co-infection with other viral diseases (Rahman & Rahman, 2020). The transmission occurs through the respiratory droplets during coughing and sneezing within a range of 1 m from the diseased individual (WHO, 2020; Santarpia et al., 2020). Since the outbreak, researchers have been trying to identify the substantial determinants affecting the survival and droplet transmission of SARS-CoV-2. Previous studies had recommended that the ambient environmental factors and air contaminants were acted as the hazard factors for severe respiratory disease (Sahoo et al., 2021). Recent investigations have shown that weather and climatological factors such as temperature, humidity, rainfall, wind speed, air quality, and air pollution impacted the COVID-19 pandemic (Paraskevis et al., 2021).

The effect of temperature and humidity was mostly studied in response to the COVID-19 pandemic and showed diverse outcomes from significantly positive to negative and even no relationship with viral transmission (Nakada & Urban, 2020). Moreover, a study in the USA found air pollution, particularly Nitrogen dioxide(NO_2) as a significant risk factor. The frequency of rainfall had also significantly correlated with the COVID-19 outbreak. The air quality index (AQI) has demonstrated significant positive impacts on the pandemic. Studies have confirmed more contradictory outcomes and a lack of proper evidence on current fiction between different environmental parameters and the COVID-19 pandemic. Therefore, additional investigations are required to understand the nature and extent of these factors' effect and the consequences of the air pollutants on COVID-19 infection rate and death (Ma et al., 2021). Hence, this study was undertaken to summarize the impacts of different environmental factors, including temperature, rainfall, humidity, air quality, wind speed, and air pollution, by reviewing the previous literature and providing recommendations for future interpositions. The findings will assist researchers and policymakers with better understanding an effective response to recurrent outbreaks. It will also facilitate the development of environmental policies for reducing pollution and improving air quality.

2 Methods

2.1 Bibliographical research and paper selection

An extensive literature review was conducted, including the published articles from January 1, 2020, to June 20, 2021, focusing on the effect of different environmental parameters and environmental pollutants on the spread of COVID-19. This study assessed articles from different publishers like Nature, Springer, Elsevier, MDPI, and SAGE based on the combination of keywords such as Environmental factor and COVID-19 spread, Temperature and COVID-19, Precipitation and COVID-19, Humidity and COVID-19, Air pollution and COVID-19, Weather variable and COVID-19, Wind speed, temperature, and COVID-19. The number of reports obtained from different publishers based on the searched keywords is presented in Table 1.

The initial search results showed a total of 10,553 papers from different publishers, including Nature (2031), Springer (251), Elsevier (5180), MDPI (212), and Sage (148). Then, all the articles' title and abstract (7822) were carefully screened and included only 164 documents containing specific relationships between various environmental factors and COVID-19 transmission. There are other factors like host susceptibility, immunological variation, and viral mutation could also influence the transmission of disease incorporating environmental variation. However, in this review, we only considered the contribution of environmental parameters. We also excluded internal environments like indoor temperature ventilation.

Table 1 Number of articles searched and included in the review concerning the keywords

Keywords	Nature		Springer		Elsevier		MDPI		SAGE	
	N	n	N	n	N	n	N	n	N	n
Environmental factor and COVID-19 spread	212	4	79	10	1161	14	14	0	82	1
Temperature and COVID-19	1345	3	118	6	3114	6	137	4	43	3
Precipitation and COVID-19	131	0	17	2	284	1	12	0	13	0
Temperature, humidity and COVID-19	229	2	15	8	208	8	20	0	3	1
Air pollution and COVID-19	70	2	11	5	211	4	11	0	2	1
Weather variable and COVID-19	43	0	11	5	201	17	0	0	5	1
Windspeed, temperature and COVID-19	1	0	0	0	1	2	18	0	0	0
Total	2031	11	251	36	5180	52	212	4	148	7

N: No. of articles obtained after searched by keywords, n: No. of articles included in the review

Though we tried to reach out to the highest number of literature, few journals' restricted data sharing policy limited our access. Following the first evaluation (164 papers), the number of studies was again reduced to 110 based on reading the entire text and eliminating the duplicates. The articles finally included in the review were 110. Among 110 articles, 52 were from Elsevier, 36 from Springer, 11 from Nature, 4 from MDPI, and 7 from Sage. Selected studies conducted in different countries are presented in Fig. 1. A higher number of studies were conducted in China (n = 16) and India (n = 16), followed by the USA (n = 13). The review also included 8 studies conducted in multiple countries, 6 from Italy, 10 from Spain and Brazil, and 6 from Turkey and Singapore. The category "Others" included the countries whose frequencies were two or less.

2.2 Data preparation

The data for this review article have been collected in a very organized and systematic way. All the papers obtained from the search were finally stored in a local repository in the primary stage. A simple data matrix was created after carefully reading all the documents. The data matrix focused on the methods employed in the research papers, the results, and their recommendations. In addition, the name of the journal and the country where the research was conducted were recorded. However, the methods and results of the documents remain the main sources of information and interest of the current review. Microsoft Word was used to create data matrices with nine columns: Serial Number, Authors, Year, Country, Publishers, Journal, Methodology, Results, and Recommendation (See Fig. 2).

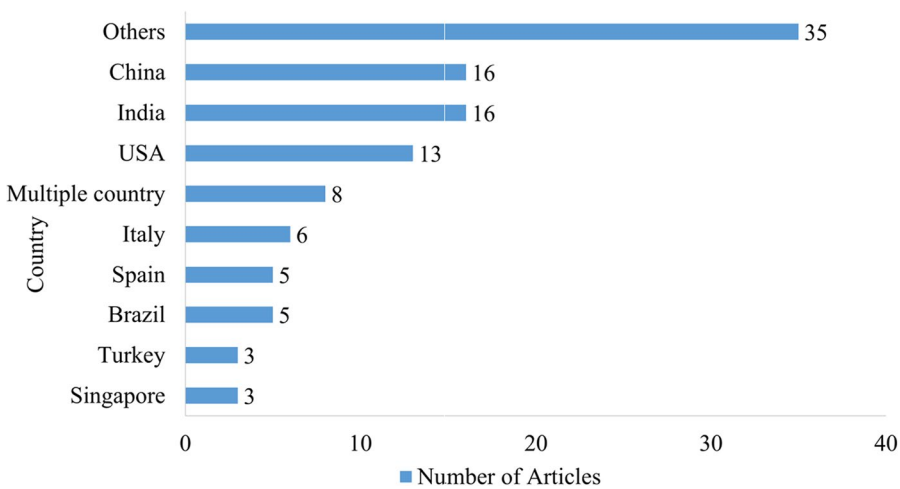

Fig. 1 The number of articles found in different countries

SN	Author	Year	Country	Publisher	Journal	Methodology	Results	Recommendations
1	Mehmet Şahin	2020	Turkey	ELSIVIER	Science of the Total Environment	(i)Spearman's Rank Correlation	(i)The correlation between the population and the COVID-19 is closely related. (ii)The wind speed of the last 14 days, including the day of the incident, represents a positive relationship with the number of COVID-19 cases. (iii)Temperature on the day of cases has the highest correlation with the COVID 19 spread. (iv)The effect of humidity is the Highest with the spread of COVID 19.	For future research, these analysis may be considered.The exact number of people, who have come from abroad and have been quarantined in cities, could enhance the accuracy of the analyses.
2	Peng Shi	2020	China	ELSIVIER	Science of the Total Environment	(i)Meta-analysis. (ii)Separate DLNMs. (iii)SEIR model, and M-SEIR model. (iv)Sensitivity analysis .	(i)Temperature was significantly associated with the daily incidence of COVID-19 based on LOESS, DLNMs, and an M-SEIR model. (ii) Temperature drove the spatial and temporal correlations of the COVID-19 outbreak in China. (iii)The transmission rate decreased as temperature increased.	Our M-SEIR model for Wuhan predicted that the COVID-19 outbreak would peak on about March 5, 2020 and end in late April.MSEIR models provide better guidance for national and international prevention and intervention measures that target COVID-19.

Fig. 2 Data matrices created based on the information of selected documents (n = 110)

2.3 Data analysis techniques applied by the selected articles

This review paper has screened 110 documents relating to the impact of weather indicators and the spread of COVID-19. Most of the countries used single country data of different cities for research. Correlations and regression analysis were the most frequently used methods to analyze the effects of environmental factors on the COVID-19. Different correlation methods such as Kendall's Rank, Pearson's, Spearman's Rank correlation were recurrently used. The Linear Regression model was frequently found in regression analysis in the studies. In addition to Linear Regression, Log-linear regression, Negative Binomial Regression, Nonlinear Regression, Poisson Regression, and Weighted Regression were also applied in previous articles. Besides correlation and regression analyses, the other methods used are: Generalized additive model, Generalized linear model, Log-linear generalized additive model, Mann–Kendall method, Sen's slope estimator, Response surface methodology, Wavelet transform coherence, etc.

3 Results

3.1 Methodologies

This study reviewed published online articles on the influence of different environmental factors on COVID-19 transmission. Different studies employed various statistical methods to find the results. Most of the papers (n = 52) employed correlation analysis as a statistical approach, 31 articles used regression analysis, and 42 studies applied other statistical techniques. Spearman and Kendall rank correlation tests were used to investigate the correlation between COVID-19 and meteorological parameters (Iqbal et al., 2021; Pani et al., 2020). This study found 24 articles that used Spearman's Rank as a method for their analysis. The spearman rank correlation is a nonparametric test that determines the strength of the relationship between two variables. A study in India investigated the relationship of daily COVID-19 cases, air pollution concentrations, and climatic variables using Spearman's correlation and the generalized additive model (GAM) (Sahoo, 2021). This review found that 21 papers used linear regression analysis, whereas two articles used nonlinear regression models. Nonlinear regression has also been proposed to represent the behavior of the growth curve of COVID-19 in big cities of Brazil. The linear and nonlinear relationship between annual mean temperature compensation and confirmed cases were explored by applying a generalized additive model (GAM) (Prata et al., 2020). The Distributed Lag Nonlinear Model was also executed to investigate the effects of climatic variables using generalized additive models (GAM) (Fawad et al., 2021; Zhu et al., 2020). Negative binomial regression was another statistical method used to find the possible meteorological impact on COVID-19 transmission (Gupta, Banerjee, et al., 2020). Some papers used other statistical techniques such as the Arimax

model, analysis of variance, and air quality index. A list of variables that influenced the COVID-19 transmission in different articles is presented in Table 2.

3.2 Relationships and impacts of meteorological factors on the spread of COVID-19

After screening, the selected literature showed that seven main variables: Temperature, Rainfall, Humidity, Sunshine, wind speed, Air pollution, and Air quality, were frequently used in the analysis of previous studies. Moreover, a few articles addressed some less significant variables, such as biodiversity, dew point, population density, climate change, and air exchange rate. A list of environmental variables that influenced the COVID-19 transmission in different articles is presented in Table 2.

Table 2 depicted that, after studying all the papers considered in this study, 55 (47.8%) research articles found a positive correlation between temperature and COVID-19 transmission. In contrast, nine research papers found a negative relationship between temperature and COVID-19 (7.8%). Temperature between 8 and 10 °C was correlated with a lower rate for COVID-19 daily confirmed cases. Moreover, a study found when the daily temperature increased in the range of 5 °C–15 °C, the number of confirmed cases decreased. In lag_{03}, each 1 °C rise in daily temperature was linked with a pooled relative risk (RR) of 0.90 (Liu et al., 2020). Following days with warmer temperatures, the global pandemic severity of COVID-19 decreased marginally with a RR of 0.96 (Shi et al., 2020). When the temperature was below 3 °C, the number of cases had a significant positive association; however, the temperature above 3 °C caused the flatten of correlation. The daily number of COVID-19 confirmed cases increased by 4.86% (95% CI: 3.209–6.513) for every 1 °C temperature increase (Xie & Zhu, 2020). Another study reveals that for every 1 °C increase in temperature below the limit of 25.8 °C, the cumulative confirmed cases fell by 5.90% ($t=4.22$, $p=0.0001$) (Prata et al., 2020). In particular, the temperature had a negative association, implying that greater temperatures resulted in decreased COVID-19 transmission (Poirier et al., 2020). In contrast, population size and average temperature do not impact COVID-19 evaluated by a negative binomial regression model (Loché Fernández-Ahúja & Fernández Martínez, 2021; Lulbadda et al., 2021). The temperature impact was not consistent throughout the South Asian countries (Hossain et al., 2021). Several studies have provided contradictory answers on this issue. However, very little research found insignificant relationships between temperature and COVID-19 transmission.

We identified nothing concerning rainfall in 95 out of the 110 research papers. Only 9 (7.8%) reports found that precipitation was associated with the

Table 2 List of meteorological variables influencing the COVID-19 transmission found in selected articles (n = 110)

Variables	Frequency	Percent	Variables	Frequency	Percent
Temperature			Wind speed		
Not included	46	44.3	Not included	86	79.1
Positive Correlation	55	47.8	No relationship found	7	6.1
Negative Correlation	9	7.8	Relationship found	17	14.8
Rainfall			Air pollution		
Not included	95	87	Not included	87	80
No relationship found	6	5.2	No relationship found	3	2.6
Relationship found	9	7.8	Relationship found	20	17.4
Humidity			Air Quality		
Not included	51	48.7	Not included	86	79.1
No relationship found	20	17.4	No relationship found	2	1.7
Relationship found	39	33.9	Relationship found	22	19.1
Sunshine			Others	4	3.47
Not included	98	89.6			
No relationship found	2	1.7			
Relationship found	10	8.7			

transmission of COVID 19, and 6 (5.2%) articles found no relationships. Precipitation showed negative impacts in a study in India, whereas the mixed-effects were found in Pakistan. Some studies claimed that excess rainfall could reduce the new coronavirus transmission, while others claim rain makes the virus more contagious. The frequency of rainfall was significantly correlated with the covid-19 outbreak (Menebo, 2020). When other environmental variables were considered, rainfall seemed to have a negative relationship with COVID-19 transmission (Hridoy et al., 2021). According to a summary from some research, precipitation does not have a purifying impact or slow down the COVID-19 virus spread. Some researchers claimed rainwater is expected to dissolve or wash the virus away from the surfaces.

From Table 2, it is observed that 39 (33.9%) of the studies found a significant relationship between humidity and COVD-19 infection, whereas 20 (17.4%) of the studies found no vital relationship. This review also identified that 9 research papers mentioned rainfall and humidity have almost the same impact. Among the selected documents, four indicated that COVID-19 spread was independent of humidity, whereas five pieces reported that rain and humidity are associated with COVID-19 outbreak. An investigation found that the precipitation and humidity were significantly associated with reduced average daily numbers of confirmed COVID-19 cases (Lorenzo et al., 2021). A study reveals that the meteorological variables influence COVID-19 transmission, and low temperatures, a mild cyclical temperature variation, and low humidity were expected to encourage the spread (Liu et al., 2020). The impact of temperature and humidity on the seasonal viability and mode of spread of COVID-19 were remarkably consistent. A comprehensive study indicated that environmental factors such as temperature and humidity might impact the spread of COVID-19. Warmer, humid climates appear to possess a lower chance of SARS-CoV-2 viral transmission. Despite the low assurance of the information based on observation configuration of the studies and the underlying risk of bias, the results suggest that high mean temperatures and average relative humidity generally supported COVID-19 transmission compared to reports from the coldest countries or periods under cold temperatures (Auler et al., 2020). Ambient temperature and specific humidity influence COVID-19 cases in USA cities were evaluated using a case-crossover design with a distributed lag nonlinear model. It exhibited a robust association within the humidity range of 5–16 g/kg (Runkle et al., 2020). Some of the studies also found opposite results. The number of COVID 19 cases was not impacted by the higher temperature and relative humidity in the south of the USA, Brazil, India, and Bangladesh (da Silva et al., 2021).

This review study found that 10 (8.7%) research articles revealed significant relationships between sunshine and COVID-19 infection. This study also observed that 17 (14.8%) of the research paper found wind speed significantly influenced the spread of the COVID-19 pandemic. Studies indicated that low wind speed is associated with a greater COVID-19 case. Low temperatures and sunlight hours are associated with more COVID-19 cases (Rendana, 2020). A study examines data from Turkey to investigate the impact of temperature, dew point, humidity, and wind speed on COVID-19 cases over one day, three days, seven days, and fourteen days. The number of COVID-19 cases positively connected with wind speed during the past 14 days, including the day of the occurrence (Şahin, 2020). Wind and population density accounted for 94% of the viral transmission variation, significantly influencing the virus dissemination or the number of cases (Coşkun et al., 2021).

Table 2 reveals that 20 (17.4%) studies found significant influences of air pollution on COVID-19 cases. Only three (2.6%) did not find relationships between these two variables. It might be stated that air pollution seems to have a hidden impact in amplifying COVID-19 consequences. This review also identified that 22 (19.1%) research found significant relationships between air quality and COVID-19 infection. Nine Asian cities have been studied PM2.5 and COVID-19 deaths and found a higher correlation than the reported COVID-19 pandemic and PM10 (Gupta et al., 2021). According to research, air pollution, particularly NO_2 in the USA, might be considered a significant risk associated with COVID-19 vulnerability and morbidity. Population density could probably play a role in the COVID-19 epidemic (Sarmadi et al., 2021). According to the previous study, there is a direct correlation between COVID19 occurrence and air quality. A study found an increasing COVID19 incidence appears to be associated with increased PM10, PM2.5, and O_3 concentrations (Stufano et al., 2021).

4 Discussion

A considerable number of research articles have validated the weather-induced COVID-19 spreading hypothesis. However, previous studies investigated the impact of air pollutants and different meteorological factors on the spread of COVID-19, concluded with wide variations and contradictory findings. Descriptive statistics, Spearman's and Kendall rank correlation, and Pearson's tests were used to explore the correlations of environmental factors, air pollutants, and air quality index (AQI) with daily identified COVID-19 cases. Though most research had identified temperature as an essential variable influencing COVID-19 transmission, many other factors could also exacerbate the rate of infection. Rainfall, humidity, air quality, wind speed, and sunlight are some of the variables included in the studies.

The majority of analyses established a positive association between temperature and COVID-19 spread. COVID-19 infection increased along with the increase in temperature, and daily new cases were positively linked with temperatures (Yuan et al., 2021). Early studies suggested the potentially decreased viral transmission in warmer regions and the summer season (Briz-Redón & Serrano-Aroca, 2020; Christophi et al., 2021). However, the continuous surging of CVID-19 cases in different countries throughout the year regrets this relationship with the temperature. Studies also found that temperature and relative humidity were negatively related to the daily new cases and new deaths of COVID-19 (Qi et al., 2020; Wu et al., 2020). In Europe, the virus was found to spread rapidly with the combination of the lower outdoor temperature and lower relative humidity indoors. However, COVID-19 may be partially suppressed by high temperature and humidity (Wu et al., 2020). Therefore, monitoring the weather conditions, such as daily minimum temperature, maximum temperature, and average temperature, is essential in minimizing the spread of infectious diseases (Lasisi & Eluwole, 2021).

Humidity is the second most influential environmental parameter of COVID-19 transmission following temperature. Temperature and humidity have a nonlinear relationship with the spread of COVID-19 (Aidoo et al., 2021). Literature stating the COVID-19 virus spreads in windy weather indicates that the virus in the air is one threatening factor for humans living in high air circulation (Coşkun et al., 2021). A study conducted in 127 countries reveals that the temperature, relative humidity, and wind speed below 20 °C, 70%, and 7 m/second were significantly associated with the daily new cases of COVID-19. Wind speed, humidity, and solar radiation have an inverse correlation with the infection rate (Ahmadi, et al., 2020). Excess rainfall could reduce transmission (Hossain et al., 2021). On the contrary, a study found humidity and wind speed did not affect the infectivity of COVID-19 (Pahuja et al., 2021). A study's results indicate that wind speed, evaporation, and pressure have a positive linear relationship with the risk of the spread of COVID-19 (Singh et al., 2021). The presence of coronavirus in the sewerage has been confirmed, but there is no evidence that it is transmitted through sewage or contaminated drinking water (Poirier et al., 2020).

Studies investigated that cities with little wind, low temperature, and frequently high levels of air pollution had higher numbers of COVID-19 cases and deaths (Islam, et al., 2021). Components, especially NO_2, could be contributing factors in the distribution of COVID-19 (Sarmadi et al., 2021). A machine-learning algorithm-based analysis investigated a direct relationship between the concentration of PM2.5 and COVID-19 deaths (Mele & Magazzino, 2020). Moreover, AQI also demonstrated significant positive impacts on COVID-19 (Pei, et al., 2021). Studies also found negative relationships of CO, NO_2, SO_2, O_3, PM10, PM2.5, and AQI with the COVID-19 cases and the number of deaths (Sangkham et al., 2021).

The diversity of the impact of meteorological factors on COVID-19 among previous studies demands further extended analysis to resolve the knowledge gaps (Qi et al., 2020). Future studies should pay more attention to experimental and observational studies, especially in the absence of public health measures (Paraskevis, et al., 2021). Several other factors like population density, public health policies, social culture, healthcare quality, and communication could play critical roles in transmitting COVID-19 infections. Therefore studies should consider the effect of these variables along with environmental parameters (Babuna, et al., 2021).

According to the information obtained so far, COVID-19 can be transmitted in different weather, climatic and seasonal conditions. Climate variables

explain some crucial aspects of COVID-19 transmission. Still, they cannot justify the disappearance of the outbreak without considering epidemiological measures like social distance (Loché Fernández-Ahúja & Fernández Martínez, 2021). This review suggests the basis for future studies and implements Spatio-temporal strategies to prevent future epidemics.

5 Conclusions

This comprehensive review scrutinized different weather and climatic variables as well as environmental pollutants influencing COVID-19 transmission. Literature investigated significant correlations among meteorological factors, air pollutants, and COVID-19- infection. The temperature has been revealed as one of the major contributing parameters for the variation in the number of COVID cases. Studies showed a positive correlation of temperature with the spread of the virus. The number of cases increases with the increase in per unit temperature below a certain threshold (25.8 °C) temperature. The humidity was another major meteorological factor that was found to have significant relationships to the pandemic followed by temperature. On the contrary, a few pieces of the literature found no correlation between temperature and COVID-19 infection. Moreover, air pollutants, especially the concentration of PM2.5 and PM10 and air quality index, significantly affect the COVID-19 infection. It is well understood that additional large-scale research is required to resolve the conflict between previous studies, including data from different seasonal and climatic conditions. This study could assist policymakers and stakeholders in formulating comprehensive action plans to establish a meteorological warning system and a prediction for timely response to the SARS-CoV-2 upsurge.

Author contributions Generate idea: MOF and Md. SR; literature search and data analysis: SN J, YA, KI, SA, MOF and Md. SR; drafted and/or critically revised the work: Md. SR and MOF.

Funding This research did not receive any specific grant from funding agencies in public, commercial, or not-for-profit sectors.

Code availability Not Applicable.

Declarations

Conflict of interest The authors declare that they do not have any conflict of interest.

Ethics approval Not Applicable.

References:

Ahmadi, M., Sharifi, A., Dorosti, S., Ghoushchi, S. J., & Ghanbari, N., (2020). Investigation of effective climatology parameters on COVID-19 outbreak in Iran. *Science of the Total Environment*. https://doi.org/10.1016/J.SCITOTENV.2020.138705

Aidoo, E. N., Adebanji, A. O., Awashie, G. E., & Appiah, S. K. (2021). The effects of weather on the spread of COVID-19: evidence from Ghana. *Bull. Natl. Res. Cent., 451*(45), 1–6.

Auler, A. C., Cássaro, F. A. M., da Silva, V. O., & Pires, L. F. (2020). Evidence that high temperatures and intermediate relative humidity might favor the spread of COVID-19 in tropical climate: A case study for the most affected Brazilian cities. *Science of the Total Environment*. https://doi.org/10.1016/j.scitotenv.2020.139090

Babuna, P., Han, C., Li, M., Gyilbag, A., Dehui, B., Awudi, D. A., Tulcan, R. X. S., Yang, S., & Yang, X. (2021). The effect of human settlement temperature and humidity on the growth rules of infected and recovered cases of COVID-19. *Environmental Research*. https://doi.org/10.1016/J.ENVRES.2021.111106

Bilal, B., & M.F., Shahzad, K., Komal, B., Bashir, M.A., Bashir, M., Tan, D., Fatima, T., Numan, U.,. (2021). Environmental quality, climate indicators, and COVID-19 pandemic: insights from top 10 most affected states of the USA. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-021-12646-x

Briz-Redón, Á., & Serrano-Aroca, Á. (2020). The effect of climate on the spread of the COVID-19 pandemic: a review of findings, and statistical and modelling techniques. *Prog. Phys. Geogr. Earth Environ., 44*, 591–604. https://doi.org/10.1177/0309133320946302

Christophi, C. A., Sotos-Prieto, M., Lan, F.-Y., Delgado-Velandia, M., Efthymiou, V., Gaviola, G. C., Hadjivasilis, A., Hsu, Y.-T., Kyprianou, A., Lidoriki, I., Wei, C.-F., Rodriguez-Artalejo, F., & Kales, S. N. (2021). Ambient temperature and subsequent COVID-19 mortality in the OECD countries and individual United States. *Science and Reports, 111*(11), 1–9. https://doi.org/10.1038/s41598-021-87803-w

Coşkun, H., Yıldırım, N., & Gündüz, S. (2021). The spread of COVID-19 virus through population density and wind in Turkey cities. *Science of the Total Environment*. https://doi.org/10.1016/j.scitotenv.2020.141663

da Silva, P. G., Nascimento, M. S. J., Soares, R. R. G., Sousa, S. I. V., & Mesquita, J. R. (2021). Airborne spread of infectious SARS-CoV-2: moving forward using lessons from SARS-CoV and MERS-CoV. *Science of the Total*

Environment. https://doi.org/10.1016/j.scitotenv.2020.142802

Fawad, M., Mubarik, S., Malik, S. S., & Ren, J. (2021). Statistical analysis of COVID-19 infection caused by environmental factors: evidence from Pakistan. *Life Sciences, 269*, 119093. https://doi.org/10.1016/j.lfs.2021.119093

Gupta, A., Banerjee, S., & Das, S. (2020). Significance of geographical factors to the COVID-19 outbreak in India. *Model. Earth Syst. Environ., 6*, 2645–2653. https://doi.org/10.1007/s40808-020-00838-2

Gupta, A., Bherwani, H., Gautam, S., Anjum, S., Musugu, K., Kumar, N., Anshul, A., & Kumar, R. (2021). Air pollution aggravating COVID-19 lethality? Exploration in Asian cities using statistical models. *Environment, Development and Sustainability, 23*, 6408–6417. https://doi.org/10.1007/s10668-020-00878-9

Gupta, A., Pradhan, B., & Maulud, K. N. A. (2020). Estimating the impact of daily weather on the temporal pattern of COVID-19 outbreak in India. *Earth Syst. Environ., 4*, 523–534. https://doi.org/10.1007/s41748-020-00179-1

Hossain, M. S., Ahmed, S., & Uddin, M. J. (2021). Impact of weather on COVID-19 transmission in south Asian countries: An application of the ARIMAX model. *Science of the Total Environment, 761*, 143315. https://doi.org/10.1016/j.scitotenv.2020.143315

Hridoy, A. E. E., Mohiman, M. A., Tusher, S. M. S. H., Nowraj, S. Z. A., & Rahman, M. A. (2021). Impact of meteorological parameters on COVID-19 transmission in Bangladesh: a spatiotemporal approach. *Theoretical and Applied Climatology, 144*, 273–285. https://doi.org/10.1007/s00704-021-03535-x

Iqbal, S., Bilal, A. R., Nurunnabi, M., Iqbal, W., Alfakhri, Y., & Iqbal, N. (2021). It is time to control the worst: Testing COVID-19 outbreak, energy consumption and CO2 emission. *Environmental Science and Pollution Research, 28*, 19008–19020. https://doi.org/10.1007/s11356-020-11462-z

Islam, A. R. M., Hasanuzzaman, M., Shammi, M., Salam, R., Bodrud-Doza, M., Rahman, M., Mannan, M., & Huq, S. (2021). Are meteorological factors enhancing COVID-19 transmission in Bangladesh? Novel findings from a compound Poisson generalized linear modeling approach. *Environmental Science and Pollution Research, 28*(9), 11245–11258. https://doi.org/10.1007/s11356-020-11273-2

Lasisi, T. T., & Eluwole, K. K. (2021). Is the weather-induced COVID-19 spread hypothesis a myth or reality? Evidence from the Russian Federation. *Environmental Science and Pollution Research International, 28*, 1. https://doi.org/10.1007/S11356-020-10808-X

Liu, J., Zhou, J., Yao, J., Zhang, X., Li, L., Xu, X., He, X., Wang, B., Fu, S., Niu, T., Yan, J., Shi, Y., Ren, X., Niu, J., Zhu, W., Li, S., Luo, B., & Zhang, K. (2020). Impact of meteorological factors on the COVID-19 transmission: A multi-city study in China. *Science of the Total Environment, 726*, 138513. https://doi.org/10.1016/j.scitotenv.2020.138513

Loché Fernández-Ahúja, J. M., & Fernández Martínez, J. L. (2021). Effects of climate variables on the COVID-19 outbreak in Spain. *International Journal of Hygiene and Environmental Health*. https://doi.org/10.1016/j.ijheh.2021.113723

Lorenzo, J. S. L., Tam, W. W. S., & Seow, W. J. (2021). Association between air quality, meteorological factors and COVID-19 infection case numbers. *Environmental Research, 197*, 111024. https://doi.org/10.1016/j.envres.2021.111024

Lulbadda, K. T., Kobbekaduwa, D., & Guruge, M. L. (2021). The impact of temperature, population size and median age on COVID-19 (SARS-CoV-2) outbreak. *Clin. Epidemiol. Glob. Heal., 9*, 231–236. https://doi.org/10.1016/j.cegh.2020.09.004

Ma, Y., Cheng, B., Shen, J., Wang, H., Feng, F., Zhang, Y., & Jiao, H. (2021). Association between environmental factors and COVID-19 in Shanghai China. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-021-13834-5

Mele, M., & Magazzino, C. (2020). Pollution, economic growth, and COVID-19 deaths in India: a machine learning evidence. *Environmental Science and Pollution Research, 28*(3), 2669–2677. https://doi.org/10.1007/s11356-020-10689-0

Menebo, M. M. (2020). Temperature and precipitation associate with Covid-19 new daily cases: a correlation study between weather and Covid-19 pandemic in Oslo. *Norway. Sci. Total Environ., 737*, 139659. https://doi.org/10.1016/j.scitotenv.2020.139659

Nakada, L. Y. K., & Urban, R. C. (2020). COVID-19 pandemic: impacts on the air quality during the partial lockdown in São Paulo state. *Brazil. Sci. Total Environ., 730*, 139087. https://doi.org/10.1016/j.scitotenv.2020.139087

Pahuja, S., Madan, M., Mittal, S., Pandey, R. M., Madan, K., Mohan, A., Hadda, V., Tiwari, P., & Guleria, R. (2021). Weather parameters and COVID-19 A correlational analysis. *Journal of Occupational and Environmental Medicine, 63*, 69–73. https://doi.org/10.1097/JOM.0000000000002082

Pani, S. K., Lin, N. H., & RavindraBabu, S. (2020). Association of COVID-19 pandemic with meteorological parameters over Singapore. *Science of the Total Environment, 740*, 140112. https://doi.org/10.1016/j.scitotenv.2020.140112

Paraskevis, D., Kostaki, E. G., Alygizakis, N., Thomaidis, N. S., Cartalis, C., Tsiodras, S., & Dimopoulos, M. A. (2021). A review of the impact of weather and climate variables to COVID-19: in the absence of public health measures high temperatures cannot probably mitigate outbreaks. *Science of the Total Environment*. https://doi.org/10.1016/j.scitotenv.2020.144578

Pei, L., Wang, X., Guo, B., Guo, H., & Yu, Y. (2021). Do air pollutants as well as meteorological factors impact Corona Virus Disease 2019 (COVID-19)? Evidence from China based on the geographical perspective. *Environmental Science and Pollution Research, 28*(27), 35584–35596. https://doi.org/10.1007/s11356-021-12934-6

Poirier, C., Luo, W., Majumder, M. S., Liu, D., Mandl, K. D., Mooring, T. A., & Santillana, M. (2020). The role of environmental factors on transmission rates of the COVID-19 outbreak: an initial assessment in two spatial scales. *Science and Reports, 10*, 1–11. https://doi.org/10.1038/s41598-020-74089-7

Prata, D. N., Rodrigues, W., & Bermejo, P. H. (2020). Temperature significantly changes COVID-19 transmission in (sub)tropical cities of Brazil. *Science of the Total Environment*. https://doi.org/10.1016/J.SCITOTENV.2020.138862

Qi, H., Xiao, S., Shi, R., Ward, M. P., Chen, Y., Tu, W., Su, Q., Wang, W., Wang, X., & Zhang, Z. (2020). COVID-19 transmission in Mainland China is associated with temperature and humidity: a time-series analysis. *Science of the Total Environment, 728*, 138778. https://doi.org/10.1016/J.SCITOTENV.2020.138778

Rahman, M. S. (2020). Origin and spillover of coronaviruses: prospects of one health action. *Hosts Virus.* https://doi.org/10.17582/journal.hv/2020/7.5.116.120

Rahman, M. S., & Rahman, T. (2020). Risks of simultaneous coinfection of dengue and COVID-19 in bangladesh: challenges and recommendations. *Dr. Sulaiman Al Habib Med. J., 2*, 137. https://doi.org/10.2991/dsahmj.k.201124.001

Rendana, M. (2020). Impact of the wind conditions on COVID-19 pandemic: a new insight for direction of the spread of the virus. *Urban Clim., 34*, 100680. https://doi.org/10.1016/j.uclim.2020.100680

Runkle, J. D., Sugg, M. M., Leeper, R. D., Rao, Y., Matthews, J. L., & Rennie, J. J. (2020). Short-term effects of specific humidity and temperature on COVID-19 morbidity in select US cities. *Science of the Total Environment, 740*, 140093. https://doi.org/10.1016/j.scitotenv.2020.140093

Şahin, M. (2020). Impact of weather on COVID-19 pandemic in Turkey. *Science of the Total Environment*. https://doi.org/10.1016/j.scitotenv.2020.138810

Sahoo, M. M. (2021). Significance between air pollutants, meteorological factors, and COVID-19 infections: Probable evidences in India. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-021-12709-z

Sahoo, P. K., Mangla, S., Pathak, A. K., Salãmao, G. N., & Sarkar, D. (2021). Pre-to-post lockdown impact on air quality and the role of environmental factors in spreading the COVID-19 cases - a study from a worst-hit state of India. *International Journal of Biometeorology, 65*, 205–222. https://doi.org/10.1007/s00484-020-02019-3

Sangkham, S., Thongtip, S., & Vongruang, P. (2021). Influence of air pollution and meteorological factors on the spread of COVID-19 in the Bangkok Metropolitan Region and air quality during the outbreak. *Environmental Research, 197*, 111104. https://doi.org/10.1016/j.envres.2021.111104

Santarpia, J., Rivera, D., Herrera, V., Morwitzer, M. J., Creager, H., Santarpia, G., Crown, K., Brett-Major, D., Schnaubelt, E., Broadhurst, M. J., Lawler, J., Reid, S., & Lowe, J. (2020). Transmission potential of sars-cov-2 in viral shedding observed at the university of nebraska medical center. *Science and Reports*. https://doi.org/10.1101/2020.03.23.20039446

Sarmadi, M., Moghanddam, V. K., Dickerson, A. S., & Martelletti, L. (2021). Association of COVID-19 distribution with air quality, sociodemographic factors, and comorbidities: An ecological study of US states. *Air Qual. Atmos. Heal., 14*, 455–465. https://doi.org/10.1007/s11869-020-00949-w

Shi, P., Dong, Y., Yan, H., Zhao, C., Li, X., Liu, W., He, M., Tang, S., & Xi, S. (2020). Impact of temperature on the dynamics of the COVID-19 outbreak in China. *Science of the Total Environment, 728*, 138890. https://doi.org/10.1016/j.scitotenv.2020.138890

Singh, O., Bhardwaj, P., & Kumar, D. (2021). Association between climatic variables and COVID-19 pandemic in National Capital Territory of Delhi. *India. Environ. Dev. Sustain.* https://doi.org/10.1007/S10668-020-01003-6

Stufano, A., Lisco, S., Bartolomeo, N., Marsico, A., Lucchese, G., Jahantigh, H., Soleo, L., Moretti, M., Trerotoli, P., De Palma, G., & Lovreglio, P. (2021). COVID19 outbreak in Lombardy, Italy: An analysis on the short-term relationship between air pollution, climatic factors and the susceptibility to SARS-CoV-2 infection. *Environmental Research, 198*, 111197. https://doi.org/10.1016/j.envres.2021.111197

WHO, (2020). Q&A: how is COVID-19 transmitted? [WWW Document]. URL https://www.who.int/vietnam/news/detail/14-07-2020-q-a-how-is-covid-19-transmitted

Worldometer, 2021. Coronavirus Graphs: Worldwide Cases and Deaths [WWW Document].

Wu, Y., Jing, W., Liu, J., Ma, Q., Yuan, J., Wang, Y., Du, M., & Liu, M. (2020). Effects of temperature and humidity on the daily new cases and new deaths of COVID-19 in 166 countries. *Science of the Total Environment, 729*, 1–7. https://doi.org/10.1016/j.scitotenv.2020.139051

Xie, J., & Zhu, Y. (2020). Association between ambient temperature and COVID-19 infection in 122 cities from China. *Science of the Total Environment, 724*, 138201. https://doi.org/10.1016/j.scitotenv.2020.138201

Yuan, J., Wu, Y., Jing, W., Liu, J., Du, M., Wang, Y., & Liu, M. (2021). Non-linear correlation between daily new cases of COVID-19 and meteorological factors in 127 countries. *Environmental Research, 193*, 1–8. https://doi.org/10.1016/j.envres.2020.110521

Zhu, L., Liu, X., Huang, H., Avellán-Llaguno, R. D., Lazo, M. M. L., Gaggero, A., Rifo, R. S., Patiño, L., Valencia-Avellan, M., Diringer, B., Huang, Q., & Zhu, Y. G. (2020). Meteorological impact on the COVID-19 pandemic: A study across eight severely affected regions in South America. *Science of the Total Environment, 744*, 140881. https://doi.org/10.1016/j.scitotenv.2020.140881