J Environ Sci Public Health 2022; 6 (1): 001-014 *DOI: 10.26502/jesph.96120151*

Research Article

COVID-19 and Environmental Factors. A PRISMA-Compliant Systematic Review

Chatziprodromidou I[1*], Dimitrakopoulou ME[1], Apostolou T[2], Vantarakis A[1]

[1]Department of Public Health, Medical School. University of Patras, Greece

[2]Department of Physiotherapy, School of Health Sciences, International Hellenic University, Greece

[*]**Corresponding Author:** Chatziprodromidou IP, Department of Public Health, Medical School, University of Patras, Greece

Received: 30 November 2021; **Accepted:** 07 December 2021; **Published:** 11 January 2021

Citation: Chatziprodromidou I, Dimitrakopoulou ME, Apostolou T, Vantarakis A. COVID-19 and Environmental Factors. A PRISMA-Compliant Systematic Review. Journal of Environmental Science and Public Health 6 (2022): 001-014.

Abstract

The emergence of a novel human coronavirus, SARS-CoV-2, has become a global health concern causing severe respiratory tract infections to humans. Human-to-human transmissions have been described with incubation times between 2-10 days, facilitating its airborne spread via droplets. The impact of environmental factors on the coronavirus disease 2019 (COVID-19) outbreak is under consideration. Therefore, we reviewed the literature on all available information about the impact of environmental factors on human and veterinary coronaviruses. Temperature, humidity and other environmental factors have been recorded as environmental drivers of the COVID-19 outbreak in China and in other countries. It is also reported that, higher temperatures might be positive to decrease the COVID-19 incidence. In our review, the analysis of 23 studies show evidence that high temperature and high humidity reduce the COVID-19 transmission. However, further studies concerning the role of other environmental (namely meteorological) factors should be conducted in order to prove this correlation. As no specific therapies are available for SARS-CoV-2, early containment and prevention of further spread will be crucial to stop the ongoing outbreak and to control this novel infectious threat.

Keywords: Coronaviruses; Covid-19; Environment; Risk factor; Epidemiology; Survival

1. Introduction

A novel coronavirus (SARS-CoV-2) has recently emerged from China with a total of 45171 confirmed cases of pneumonia (as of February 12, 2020). Coronaviruses (CoVs) most commonly cause mild illness; however, in recent years, they have occasionally, led to major outbreaks. Approximately ten years after SARS, in December 2019, another novel, highly pathogenic CoV, SARS-CoV-2, was identified in the City of Wuhan, Hubei Province, a major transport hub of central China.

The earliest COVID-19 cases were linked to a large seafood market in Wuhan, initially suggesting a direct food source transmission pathway [1]. Along with Severe Acute Respiratory Syndrome (SARS) coronavirus and Middle East Respiratory Syndrome (MERS) coronavirus [2, 3], this is the third highly pathogenic human coronavirus that has emerged in the last two decades. Since the identification of the initial cases, COVID-19 has spread to 180 countries and territories and there are approximately 664,564 confirmed cases and 30,890 deaths (as of 29 March 2020) worldwide.

Person-to-person transmission was confirmed as one of the main mechanisms of COVID-19 spread [4]. The modes of transmission have been identified as host-to-human and human-to-human. Increased spread of SARS-CoV-2 causing COVID-19 infections worldwide has brought increased attention and fears surrounding the prevention and control of SAR-CoV-2 from both the scientific community and the general public. While many typical precautions for halting the spread of common respiratory viruses are being implemented, other less understood transmission pathways should also be considered and addressed to reduce further spread.

Nonetheless, the role of environment and its mediated pathways for infection by other pathogens have been a concern for decades. Substantial research into the presence, abundance, diversity, function, survival and transmission of microorganisms in the environment has taken place in recent years. Thus, concerning Covid-2, there is preliminary evidence that environmentally mediated transmission may be possible; additionally, COVID-2 could be affected by environmental factors such as seasonality, temperature, humidity [5-7].

Therefore, the aim of the review is, to summarize all available data on the impact of environmental factors concerning the survival of coronaviruses including emerging SARS-CoV and MERS.

2. Methodology

The methodology of this systematic review and the inclusion criteria were indicated in advance and recorded in a priori protocol in order to determine the rationale, the objectives, the eligibility and the selection criteria, the search strategy and the study selection process of this systematic review. However, due to the gravity of the subject and due to the pandemic awareness concerning COVID-19, this systematic review was not registered with PROSPERO (International Prospective Register of Systematic Reviews).

2.1 Eligibility criteria

All study design types were considered in this systematic review. The reviews were not included but were screened for any information within the scope of this review. No language, publication status or publication year restrictions were imposed. Because of the COVID-19 emergency state, even not proofread publications were included in our study. All non-English studies, including Chinese, Japanese, and French were translated via Google translator and were included in this systematic review. Although COVID-19 concerns years 2019 and 2020, no year of publication limit was applied, in order to exploit valuable information concerning the coronavirus relationship with environmental factors, as indicated by the past SARS and MERS lessons. All studies, concerning human coronavirus strains of various types were included. This systematic review was limited to studies focusing on the impact of environmental factors on COVID-19. Searched experts' and researchers' opinions were not handed in this study. The selection criteria developed a priori are described below:

- Year of publication
- Country of epidemics
- Continent of epidemics
- Environmental factor
- Assessing method

2.2 Information sources

The search strategy and analysis process were conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement for systematic reviews [8, 9]. Titles and abstracts of the retrieved articles were screened, while full length articles were evaluated for eligibility and were further acquired via SwetsWise Online Content. The search for articles was applied in three electronic databases: Google Scholar, PubMed and Springerlink. Google Scholar was our starting point. No unpublished information was obtained. The literature search was performed from 25th to 28th March 2020.

2.3 Search

The following terms were used to search all databases, always in combination with "coronavirus" and "COVID-19": "environmental factors", "clima", "temperature", "humidity", "absolute humidity", "relative humidity", "wind speed", "wind power", "precipitation", "rainfall". The search strategy was conducted by IPC and was peer-reviewed by AV as part of the systematic review process.

2.4 Study selection

An eligibility assessment procedure was performed in a standardized and independent manner, primary by two authors (IPC and AV), to analyze and validate all relevant data. Disagreements were resolved through discussion among all authors and resulted in a final consensus. After excluding records upon the eligibility criteria set, we screened all titles and abstracts of the retrieved studies, although a full text review also proves to be necessary for further consideration.

2.5 Data collection process

A data extraction sheet was developed in order to summarize the evidence of this systematic review, based on the Cochrane Consumers and Communication Review Group' data extraction template for included studies [10]. This was pilot tested on the first ten randomly selected studies and no refinement was needed. One author (IPC) extracted all proper data from the included studies and another author (AV) checked all the extracted data. No disagreements arose. In order to ascertain duplicate publications, we used the tool "check for duplicates" of Mendeley Desktop software (Version 1.19.4).

2.6 Assessment of study quality

To ascertain the validity of the included studies, two reviewers (IPC and AV) in a blind manner and independently scored the quality of the included papers upon the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist [11]. Both reviewers independently scored the quality of each included paper and all studies received a score that ranged from 0 to 22 points by each reviewer. Based on a criterion included in the initial protocol of the study, the scores between the reviewers should not differ by more than 2 points. In order to generate a final score, both scores of the reviewers were averaged.

2.7 Planned methods of analysis

In order to handle data and combine the results of all the included studies, we used SPSS (Statistical Package for the Social Sciences) [12] or R software [13].

3. Results

3.1 Study selection and characteristics

The search through Google Scholar, Springerlink and PubMed provided a total of 14640, 51 and 28 articles, respectively. From the initially obtained 14719 articles, 8499 were excluded as duplicated by the "Check for duplicates" tool of Mendeley Desktop. The remaining 6220 articles were assessed for eligibility and a total of 6007 articles were discarded because based on a detailed evaluation of abstracts, they did not meet the eligibility criteria set and concerned:

a) 2457 discussed the clinical and epidemiological considerations of COVID-19, b) 813 discussed the environmental factors associated with other diseases, c) 760 discussed the ethical considerations of COVID-19, d) 743 discussed the transmission dynamics of COVID-19, e) 655 discussed the diagnostic and management outbreak investigations of COVID-19, f) 500 discussed the prospects and the advances in designing and developing vaccines and immuno-therapeutics for COVID-19 and g) 79 discussed the socio-economic impact of COVID-19. From the remaining 213 articles, 124 were excluded because they did not meet the inclusion criteria. The full text of the rest 89 articles was evaluated in further detail. Finally, 23 were included for further analysis in this systematic review (Figure 1).

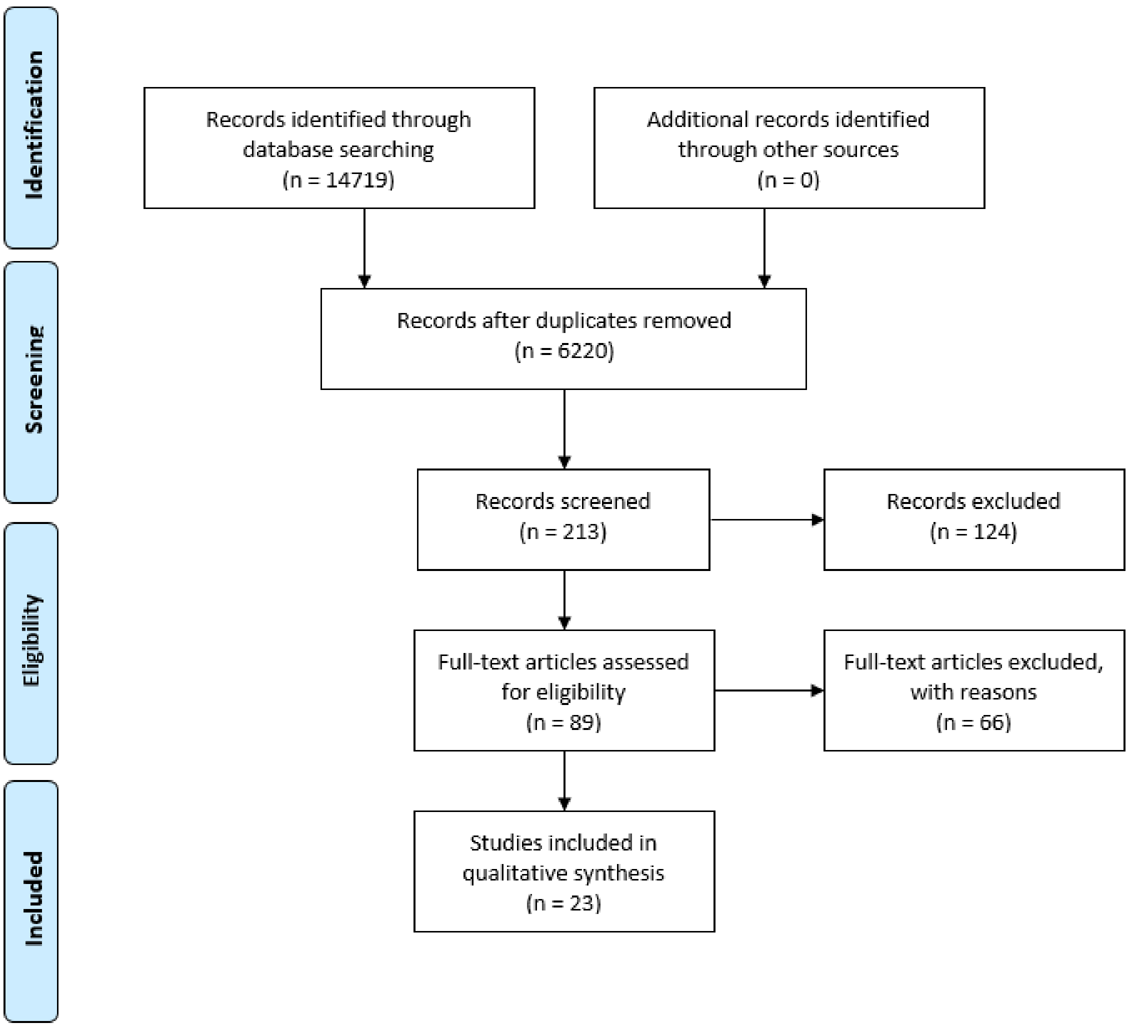

Figure 1: Flow diagram of the study selection process.

All the 23 studies which were selected for this systematic review were published in 2020 and in English. 65.2% of the included studies mentioned China, 26.1% did not mention a certain country of epidemics, 4.3% concerned the epicenter of the disease, namely Iran, Italy, South Korea, etc. and 4.3% concerned Singapore. Concerning the continent of the epidemics, Asia hold the leads with 69,6%, followed by Africa with 4.3%, whereas almost 21.7% did not mention a specific continent and 4.3% refers to mixed continents (Asia, Europe, etc.). All included studies assessed the role of various environmental factors correlating to the transmission rates of COVID-19.

In 24.1% of the studies, temperature was assessed for its impact on COVID-19, followed by humidity (11.1%), absolute humidity (5.6%), rainfall/precipitation (5.6%), relative humidity (5.6%), travel (5.6%), air travel (3.7%), wind speed/power (3.7%), latitude (3.7%), built environment (1.9%), general lockdown (1.9%), visibility (1.9%), specific humidity (1.9%), airborne dust (1.9%), air pollution (1.9%), chemical pollution (1.9%), air index (1.9%), atmospheric radiation (1.9%), cloud cover (1.9%), precipitation of the driest month (1.9%), mean temperature of the wettest quarter (1.9%), isothermality (day-to-night temperatures difference relative to the summer-to-winter annual difference) (1.9%), annual mean temperature (1.9%), mean diurnal range (1.9%), minimum temperature of the coldest month (1.9%) and precipitation of the coldest quarter (1.9%).

In order to examine the association between these environmental factors and COVID-19, most of the studies employed the review method (20.4%), followed by maximum entropy model (13%), the model (11.1%), dynamical model and ERA-5 reanalysis (9.3%), the statistical modeling Loess regression (Generalized-linear or non-linear model) (7.4%), the R proxy method (5.6%), the R reproductive number (3.7%), the One-way ANOVA followed by a post-hoc Tukey's HSD test (3.7%), the distributed lag log-linear model (3.7%), the linear regression model (3.7%), the global meta-population disease transmission model (3.7%), the Mann-Whitney U test (3.7%), the mathematical model (3.7%), the restricted cubic spline function and the generalized linear mixture model (3.7%) and the multivariate analysis (3.7%). The detailed characteristics which were included in the studies, like author, title and year of publication, country and continent of the study, method of assessing the impact of the environmental factors and the outcome variable are described in Table 1.

	Author/year	**Country of epidemics**	**Continent of epidemics**	**Assessing method**	**Environmental factor assessed**
1	Gilbert et al., [14]	Not mentioned	Africa	Multivariate analysis	Air travel
2	Wang et al., 2020	China	Asia	Restricted cubic spline function & Generalized linear mixture model	Temperature
3	Luo et al., [15]	China	Asia	Estimation of a proxy for the reproductive number	Absolute humidity
4	Bonilla-Aldana et al., [16]	Not mentioned	Not mentioned	Review	Temperature Rainfall/precipitation Humidity
5	Poirier et al., [17]	Not mentioned	Not mentioned	Estimation of a proxy for the reproductive number	Temperature Humidity
6	Dietz et al., 2020	Not mentioned	Not mentioned	Review	Built environment
7	Oliveiros et al., [18]	China	Asia	Linear regression model	Temperature Humidity
8	Shi et al., [19]	China	Asia	3 Distributed lag loglinear models	Temperature Absolute humidity
9	Lau et al., [20]	China	Asia	One-way ANOVA followed by a post-hoc Tukey's HSD test	Air travel General lockdown
10	Chen et al., [21]	China	Asia	Statistical modelling: Loess regression (Generalized-linear or non-linear model)	Temperature Visibility

					Wind speed/power Relative humidity
11	Sun et al., [22]	China	Asia	Review	Temperature Humidity Rainfall/Precipitation
12	Gostic et al., [23]	Not mentioned	Not mentioned	Model	Travel
13	Peeri et al., [3]	Epicentre (Iran, Italy, etc.)	Epicentre (Iran, Italy, etc.)	ERA-5 reanalysis	Temperature Absolute humidity Humidity Specific humidity Latitude
14	Qu et al., [24]	Not mentioned	Not mentioned	Review	Airborne dust Air pollution Chemical pollution
15	Gupta, [25]	China	Asia	Mathematical model	Temperature
16	Cai et al., [26]	China	Asia	Mann-Whitney U test	Temperature
17	Chinazzi et al., [27]	China	Asia	Global metapopulation disease transmission model	Travel
18	Lee et al., [28]	Singapore	Asia	Review	Travel
19	Wang et al., 2020	China	Asia	Estimation of a proxy for the reproductive number	Temperature Relative humidity
20	Jiwei et al., [29]	China	Asia	Dynamical model	Temperature Wind speed/power Rainfall/precipitation Relative humidity Air index
21	Poole [30]	Worldwide	Worldwide	Model	Temperature Atmospheric pollution Humidity Cloud cover Latitude
22	Bariotakis et al., 2020	Worldwide	Worldwide	Maximum entropy model	Precipitation Isothermality (day-to-night temperatures difference relative to the summer-to-winter (annual) difference) Min temperature of the coldest month Mean diurnal range Mean temperature of wettest quarter Annual mean temperature
23	Bu et al., [31]	China	Asia	Review	Temperature Humidity Rainfall/Precipitation

Table 1: Characteristics of the studies included in this systematic review.

Figure 2. displays the exact temperature range proposed by certain studies included in this systematic review, in which virus survival is facilitated.

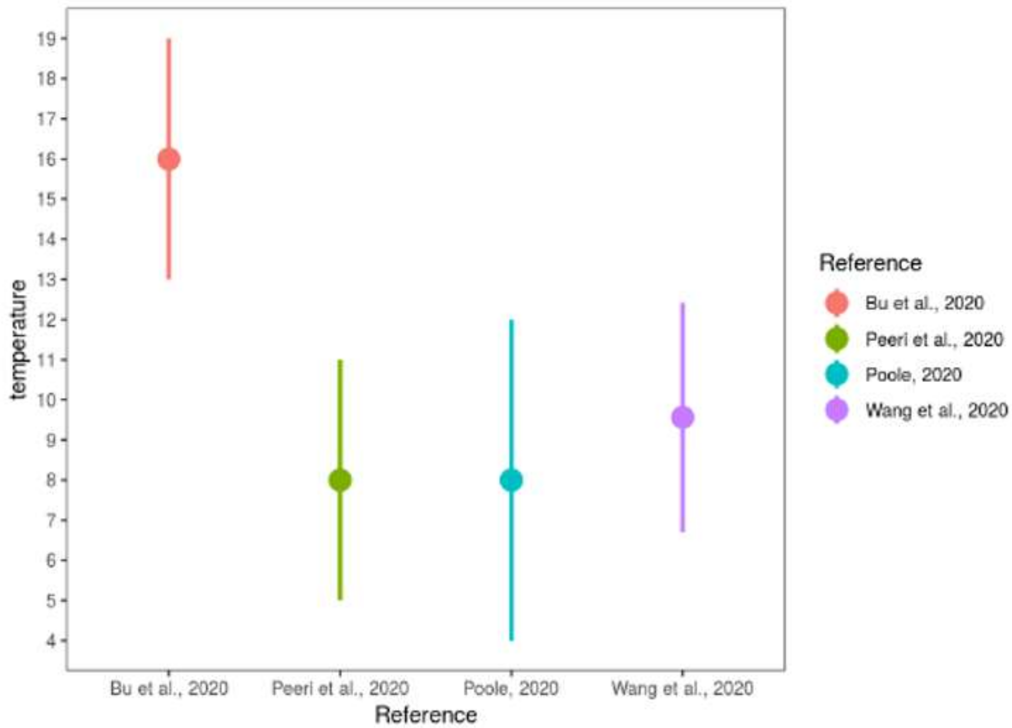

Figure 2: Environmental factors associated with the assessing methods the country of epidemics.

3.2 Results of individual studies

Gilbert et al. used the volume of air travel concerning the flights from the infected China provinces (Guangdong, Fujan and the city Beijing) to Africa and concluded that there are 2 identified clusters of African countries: a) those that have the higher importation risk of exposure to COVID-19, which have moderate to high capacity to face an outbreak, like Egypt, Algeria and South Africa and b) those that are at moderate risk and have high vulnerability and variable capacity [14]. Mao et al. concluded that temperature has a non-linear dose response relationship with COVID-19 transmission, whereas there is a specific temperature range, in which virus transmission is facilitated and this might also explain the emergence of the epidemic in Wuhan city. Wang et al. suggest that regions with lower temperature records should take even stricter measures in order to prevent future outbreaks (Wang et al. 2020). Luo et al. and Poirier et al. suggest that changes in weather conditions alone, namely the increase of humidity and temperature (which are usually met in spring and summer seasons) may not suffice to decrease the number of cases, if no proper public health interventions are adopted [15, 17]. Bonilla-Aldana et al. propose that temperature, rainfall and humidity may play a significant role in the virus transmission, as occurs with many zoonotic diseases [16]. Dietz et al. combined the current literature and the built environment and assessed its role in COVID-19 transmission, suggesting that the built environment plays a significant role in the control and mediation of the disease which may be taken into consideration in the building design market [32]. Oliveiros et al. verified the doubling time of COVID-19 cases with the aid of temperature and humidity, whereas the wind speed proved not to be significantly associated [18]. Based on Shi et al. conclusions, lower and higher temperature rates may decrease the COVID-19 incidence rates and the role of absolute humidity has not yet been established [19]. Lau et al. recorded an increase in the doubling time of COVID-cases and this was attributed to the lockdown measurements which were implemented [20] . Chen et al. found out that the optimal temperature for COVID-19 is 8.07 °C, within a humidity range of 60-90% [21]. Sun et al. concluded that cold and dry winter are considered as a common environmental condition conductive for COVID-19 [22]. Peeri et al. attributed the increased and rapid COVID-19 perforation to air travel frequency and circumstances (i.e. connection flights) [3]. Gostic et al. estimated that screening during travelling may miss more than half of the infected cases, as they may not have developed the symptoms at the time of the screening [23]. Sajadi et al. reached the conclusion that temperature range of 5-11°C, combined with low specific range of 3-6g/kg and absolute humidity range of 4-7 g/kg are the optimal environmental factors for COVID-19 transmission [33]. Qu et al. linked the COVID-19 transmission with airborne dust [24]. Gupta showed that for every 1°C increase above 5 °C, the temperature, as a factor, may decrease the COVID-19 transmission rate by 10% [25]. Cai et al. found no correlation between the daily mean temperature and the epidemic growth rate in the cases of Hunan or Wuhan, but insist that there is a weak correlation between the daily mean temperature and the mortality rates in both provinces [26]. Chinazzi et al. assessed the travel limitation practices applied both in China and on an international scale and verified that travelling quarantine delayed the epidemic progression 3 to 5 days in China or more on a worldwide basis [27]. Lee et al. reviewed Singapore's approach to COVID-19 epidemic concerning travel restrictions applied at all ports of entry [28]. Wang et al. propose that high temperature and high relative humidity significantly affect the COVID-19 transmission rates [34]. Poole suggests that a climatological range of 4-12°C within an area of 25-55° latitude may enhance the COVID-19 spread [30]. Bu et al. conclude that the temperature rate of 13-19°C and humidity rate of 50-80% are conducive to the virus survival [31].

3.3 Study quality

The studies included in this systematic review were scored from 17 to 19.8, upon the predefined criteria. The criteria on which the studies were assessed with the minimum score were those which failed to clearly address the following items: report of the study design and assessing method in the title and abstract; clearly define the participants, the interventions and the outcomes; clearly state the handling of the missing data and the accuracy of the data; the generalization of the findings.

4. Discussion

To the best of our knowledge, the present systematic review is the first to summarize the available evidence on the association of COVID-19 with environmental factors. Taking into consideration that the new coronavirus is a new human pathogen, which due to its outbreak in China and its rapid worldwide spread, it is important to understand the reliable epidemiological information for its survival in the environment [21]. Therefore, it is necessary to find prognostic predictors to distinguish high-risk areas or countries in order to improve the new challenging situation.

The origins and the spread of any infectious disease occurs only when it is affected by certain natural and social factors that act as the source of infection, the mode of transmission and the susceptibility of the population. Besides the social factors, the environmental factors, such as meteorological factors, namely temperature and humidity proved to play a part in the outbreak of coronavirus [29]. In our systematic review, the overall evidence is sufficiently robust to determine the impact of temperature in the survival of the virus via different methods, like the effect of each 1°C increase which lowers the virus' R by 0.225 [34] and the doubling time of the confirmed cases which is positively correlated with temperature [18]. Four studies included in this systematic review determine the exact temperature range, within which temperature is conducive to the virus spread and survival. The pooled results of these 4 studies indicated that temperature range different from 4-24°C is not conducive to the survival of the coronavirus [35, 36, 30, 31]. Concerning humidity, although the results in this review did not reveal robust associations between humidity and coronavirus survival and are always validated in combination with temperature, they need to be interpreted carefully given the monotonic functional relationship between humidity and temperature. In other words, if temperature was associated to COVID-19 transmission, it is very likely that absolute humidity could also play a role. The pooled results of the studies which were included in this systematic review show that combined with high temperature, absolute humidity range of 4-7 g/m3 [36] or specific humidity range of 3-6 g/kg [36] or humidity of 50-80% [36] may reduce the transmission of COVID-19. Other factors, such as air index, rainfall/precipitation, wind speed, do not show to have significant impact to the virus stability and survival and need to be further assessed. Although not all environmental factors are clearly and in depth described by authors of the included studies, important associations are observed and need further investigation. Variability in the results among the studies included in our review may be attributed to i) the utilization of different types of assessing methods of each environmental factor, ii) the different qualitative characteristics of the populations used, iii)sample size, iv) duration of the study and others.

Environmental factors, characterized by lag effects and threshold effects, can target both objects, the host and the virus, during infectious disease outbreaks. On the one hand, human activity patterns and immunity can be influenced by environmental factors. But the effect caused by environmental conditions was limited during the COVID-19 outbreak, due to the absence of extreme weather conditions and specific immunity for a newly emerging virus. On the other hand, environmental impacts on the SARS-CoV-2 are more significant than the host population because the transmission and virulence of the virus varies in different conditions. Finally, the environmental impacts on the transmission of the virus should be characterized by the dynamic model because infectiousness estimated in the traditional dynamic model is actually a confounding effect relating to the environmental effect. It is necessary to take into account the environmental issues on the basis of the dynamic transmission model so that the impacts could be isolated and qualified.

5. Limitations

Due to the limited available data, other meteorological factors such as air pressure, atmospheric particles, ultraviolet, and social factors such as population movement were not included for analysis. The inclusion of such factors will provide more accurate and reliable results.

In addition, the relatively short time length of the current outbreak, combined with the imperfect daily reporting practices, make our results vulnerable to changes as more data becomes available. We have assumed that travelling limitations and other containment interventions have consistently been implemented across provinces and have had similar impacts (thus population mixing and contact rates are assumed to be comparable) and have ignored the fact that different places may have different reporting practices. Further improvements could incorporate data augmentation techniques that may be able to produce historical time series with likely estimates of case counts based on the onset of the disease rather than the reporting dates. This, along with more detailed estimates of the serial interval distribution, could yield more realistic estimates of R. Finally, further experimental work needs to be conducted to better understand the mechanisms of transmission of COVID-19. The mechanistic understanding of the transmission could lead to a coherent justification of our findings.

6. Conclusions

COVID-19 is globally an extremely new challenge and thus, it is an essential need, to explore the impact of the environmental factors on the virus transmission. These data could provide helpful information for policymakers or public health authorities in order to manage or prevent further threat. In summary, despite the limitations, our results provided evidence that high temperature and high humidity reduce the COVID-19 transmission. However, further studies concerning the role of other environmental (namely meteorological) factors should be conducted in order to further prove this correlation.

References

1. Thompson, Robin. Pandemic Potential of 2019-NCoV. The Lancet Infectious Diseases 20 (2020): 280.
2. de Wit, Emmie, Neeltje van Doremalen, et al. ARS and MERS: Recent Insights into Emerging Coronaviruses. Nature Reviews Microbiology 14 (2016): 523.
3. Peeri, Noah C et al. The SARS, MERS and Novel Coronavirus (COVID-19) Epidemics,

the Newest and Biggest Global Health Threats: What Lessons Have We Learned? International journal of epidemiology (2020).
4. Chan, Jasper Fuk-Woo, et al. A Familial Cluster of Pneumonia Associated with the 2019 Novel Coronavirus Indicating Person-to-Person Transmission: A Study of a Family Cluster. The Lancet 395 (2020): 514-523.
5. Tan, Jianguo, et al. An Initial Investigation of the Association between the SARS Outbreak and Weather: With the View of the Environmental Temperature and Its Variation. Journal of Epidemiology & Community Health 59 (2005): 186-192.
6. Shaman, Jeffrey, Melvin Kohn. Absolute Humidity Modulates Influenza Survival, Transmission, and Seasonality. Proceedings of the National Academy of Sciences 106 (2009): 3243-3248.
7. Geller, Chloé, Mihayl Varbanov, et al. Human Coronaviruses: Insights into Environmental Resistance and Its Influence on the Development of New Antiseptic Strategies. Viruses 4 (2012): 3044-3068.
8. Liberati, Alessandro et al. The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration. PLoS Medicine 6 (2009).
9. Page, Matthew K. et al. Updating the PRISMA Reporting Guideline for Systematic Reviews and Meta-Analyses: Study Protocol (20+18): 1-21.
10. Cochrane Consumers and Communication. Data Extraction Template for Included Studies (2016).
11. Von Elm, Erik et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational Studies. International journal of surgery 12 (2014): 1495-1499.
12. IBM SPSS Statistics for Macintosh, Version 25.0.
13. R Development Core Team. R: A Language and Environment for Statistical Computing (2013).
14. Gilbert, Marius et al. Preparedness and Vulnerability of African Countries against Importations of COVID-19: A Modelling Study. The Lancet 395 (2020): 871-877.
15. Luo, Wei et al. The Role of Absolute Humidity on Transmission Rates of the COVID-19 Outbreak (2020).
16. Bonilla-Aldana DK, Dhama K, Rodriguez-Morales AJ. Revisiting the One Health Approach in the Context of COVID-19: A Look into the Ecology of This Emerging Disease. Adv Anim Vet Sci 8 (2020): 234-237.
17. Poirier, Canelle et al. The Role of Environmental Factors on Transmission Rates of the COVID-19 Outbreak: An Initial Assessment in Two Spatial Scales (2020).
18. Oliveiros, Barbara, Liliana Caramelo, et al. Role of Temperature and Humidity in the Modulation of the Doubling Time of COVID-19 Cases (2020).

19. Shi, Peng et al. The Impact of Temperature and Absolute Humidity on the Coronavirus Disease 2019 (COVID-19) Outbreak - Evidence from China (2020).
20. Lau, Hien et al. The Positive Impact of Lockdown in Wuhan on Containing the COVID-19 Outbreak in China. Journal of travel medicine 001 (2020).
21. Chen, Biqing et al. Roles of Meteorological Conditions in COVID-19 Transmission on a Worldwide Scale (2020).
22. Sun, Zhong et al. Potential Factors Influencing Repeated SARS Outbreaks in China. International Journal of Environmental Research and Public Health 17 (2020): 1-11.
23. Gostic, Katelyn M. et al. Estimated Effectiveness of Symptom and Risk Screening to Prevent the Spread of COVID-19. eLife 9 (2020): 1-18.
24. Qu, Guangbo, Xiangdong Li, et al. An Imperative Need for Research on the Role of Environmental Factors in Transmission of Novel Coronavirus (COVID-19). Environmental science and technology (2020): 0-2.
25. Gupta, Dhruv. Effect of Ambient Temperature on COVID-19 Infection Rate (2020).
26. Cai, Yuwen, Tianlun Huang, et al. The Effects of 'Fangcang, Huoshenshan, and Leishenshan' Makeshift Hospitals and Temperature on the Mortality of COVID-19 (2020).
27. Chinazzi, Matteo et al. The Effect of Travel Restrictions on the Spread of the 2019 Novel Coronavirus (COVID-19) Outbreak. Science (2020).
28. Lee, Vernon J, Calvin J Chiew, et al. Interrupting Transmission of COVID-19: Lessons from Containment Efforts in Singapore. Journal of Travel Medicine (2020).
29. Jia, Jiwei et al. Modeling the Control of COVID-19: Impact of Policy Interventions and Meteorological Factors (2020): 1-21.
30. Poole, Logan. Seasonal Influences On The Spread Of SARS-CoV-2 (COVID19), Causality, and Forecastabililty (3-15-2020). Causality, and Forecastabililty (2020).
31. Bu, Jin et al. Analysis of Meteorological Conditions and Prediction of Epidemic Trend of 2019-NCoV Infection in 2020 (2020).
32. Conraths FJ, et al. Highly Pathogenic Avian Influenza H5N8 in Germany: Outbreak Investigations. Transboundary and emerging diseases 63 (2015): 10-13.
33. Sajadi, Mohammad M, Parham Habibzadeh, Augustin Vintzileos, et al. Temperature and Latitude Analysis to Predict Potential Spread and Seasonality for COVID-19 (2020).
34. Wang, Jingyuan, Ke Tang, et al. High Temperature and High Humidity Reduce the Transmission of COVID-19 (2020).
35. Wang, Mao et al. Temperature Significant Change COVID-19 Transmission in 429 Cities (2020).

36. Sajadi, Mohammad M, Parham Habibzadeh, et al. Temperature, Humidity, and Latitude Analysis to Predict Potential Spread and Seasonality for COVID-19 (2020): 6-7.