REVIEW ARTICLE

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Meteorological factors and COVID=19 Transmission - A Review

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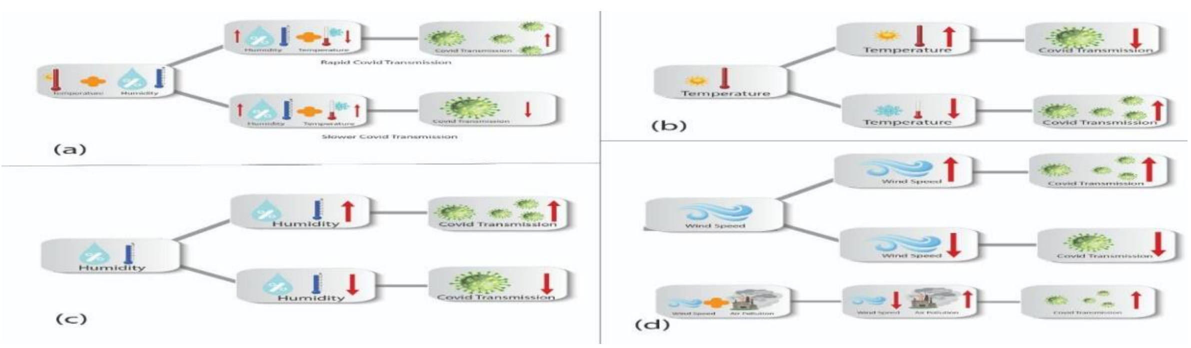
GRAPHICAL ABSTRACT

Effect of Environmental and/or Climatic Patterns (a) Temperature + Humidity (9, 12, 14, 16, 17, 31), (b) Temperature (10, 11) (c) Humidity (11), and (d) Wind Speed + Air Pollution (16, 18) on COVID-19 transmission



ABSTRACT

The coronavirus (SARS-CoV-2), emerged and identified by the end of the year 2019, has been found responsible for a series of lockdowns and a global medical emergency. Since then, several epidemiological studies have been conducted to identify and resolve the mysteries associated with the life-threatening viral strain (SARS-COV-2). The disease caused by SARS-CoV-2 is widely known as COVID-19. Researchers have well-established both the direct and indirect relationships between various climatic patterns, environmental and meteorological factors (*i.e.* air quality index (AQI), humidity, temperature, wind speed, etc.), and a surge in emergence, stability, and transmission of the COVID-19. The current review aims to dispense the relative variation in COVID-19 emergence, survival, stability, and transmission ratios due to the variant environmental, meteorological, and/or climatic factors.

Keywords: Contagiousness, Coronavirus, transmission, Air Quality Index, Pandemic

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INTRODUCTION

Corona-Virus Disease 2019 (COVID-19), has been proven widely as a fatal pulmonary pandemic, primarily emerged from Wuhan city (Hubei, Province), China. The gradual surge in the SARS-COV-2 viral infection was soon morphed into a global pandemic situation (1). The SARS-COV-2 virus exhibits distinct characteristic features like crown-spikes, positive-sense RNA, unsegmented and enveloped structural appearances, etc. (3-8).
There are different genomic structures of Coronaviruses which divides them into seven sub-groups *i.e.* alpha, beta, gamma, delta, MERS-COV, SARS-COV (beta), SARS-COV-2 (Novel coronavirus). Alpha and beta sub-groups of Coronaviruses principally affect human beings, whereas, others may primarily affect animals. The latter types of viral sub-groups may further transmit their infections from animals-to-humans *i.e.* SARS-COV (beta), MERS-COV, and SARS-COV-2 (Novel Coronavirus or COVID-19) (44).

Globally collected data on COVID-19, under WHO auspices, , entails more than 2,265,354 mortalities and 5, 2021, 104,165,066 cases of COVID-19 infection, worldwide (2). Since the pandemic hit the countries hard, across the globe, an average of four thousand cases of SARS-COV-2 infection emerged on a daily basis in Pakistan. There is no perfect statistical tool to compare the variation in COVID-19 emergence, stability, and human-to-human dispersal cases among countries around the globe. A Look at the peak percentages provides an insight into the SARS-COV-2 toll of each country, which compares it in its region and the world overall. In the Asia region, Bangladesh is reported with a high peak percentage (73%) followed by Pakistan (64%), Iran (55%), and India (51%), respectively, as given in fig.1. (45).

The current article illuminates the interconnectedness between the COVID-19 emergence, variability, dispersion in the atmosphere, human-to-human transmission, and any aid or abate in its contagiousness level for various environmental indicators, abiotic factors, and meteorological parameters. The influences of abiotic and/or environmental factors such as temperature, humidity, climate patterns, weather conditions, wind speed (WS), air pollution level, and/or air quality index (AQI).

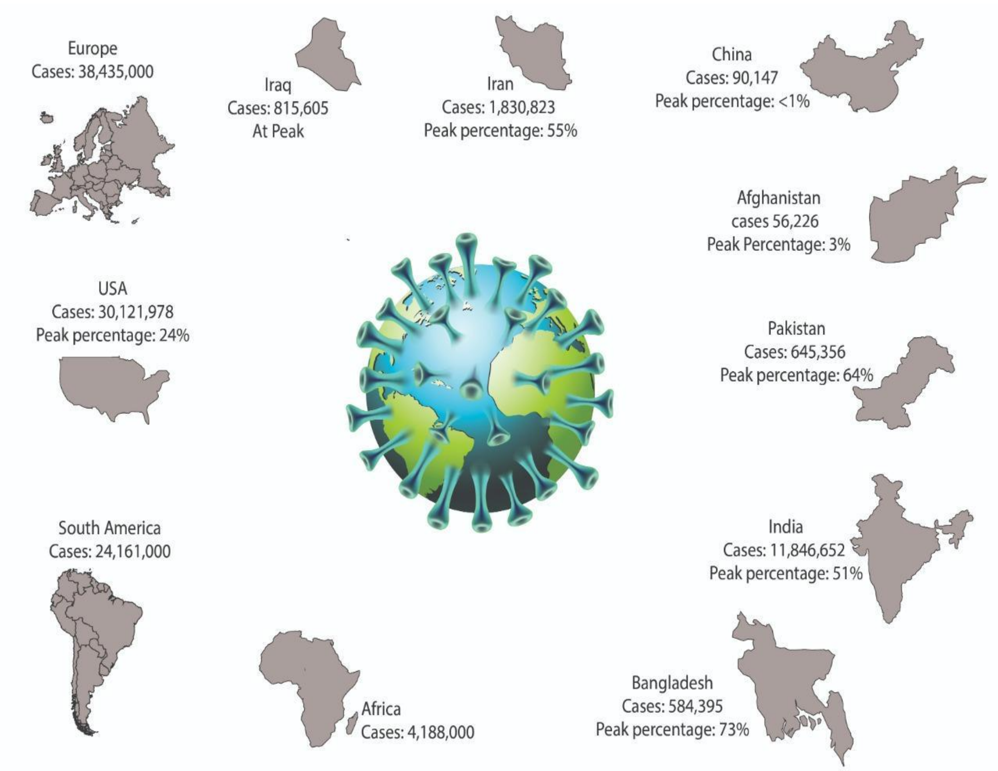

Fig. 1. A comparative Insight of The Peak Percentages (%) and COVID-19 Infection Cases around the Globe (45)

Table- 1. Impact of various Environmental, meteorological, and climatic patterns on the COVID-19 emergence, stability, and transmission rates

Sr. No.	Environmental/ Meteorological and climatic factors	Countries/ Regions	Key Findings	Reference/s
1.	Weather and/or Climatic patterns (particularly Temperature)	Spain, Switzerland, the US, Turkey, Germany, UK, France, Italy, Iran, Chile, Saudi Arabia, Brazil, Malaysia, Philippines, South Africa, Pakistan, Thailand, Indonesia, India	● Low temperature promotes the COVID-19 transmission. ● High temperature reduces transmission.	(10)
2.	Meteorological factors like Temperature	China	● A negative correlation has been found between temperature and COVID-19 transmission. ● The surge in COVID-19 transmission becomes unavoidable and uncontrollable in high populous and cold regions.	(9)
3.	Relative humidity (RH) and Temperature (Temp.)	China (Mainland), Hong Kong, and Singapore	● High RH and low temperature promote COVID-19 transmission. ● High RH and high temperature reduce transmission.	(11)

4.	Average relative humidity (ARH) & Average temperature (AT)	China (mainland)	● Average level of temperature (AT) and relative humidity (ARH) are negatively associated with COVID-19. ● The associations are not consistent throughout Mainland China.	(31)
5.	Relative humidity (RH) and Temperature (Temp.)	India (Delhi)	● A positive correlation of temperature with COVID-19 cases. ● A negative correlation of RH with COVID-19 cases.	(18)
6.	Humidity and Temperature	United States (New Jersey)	● A negative correlation b/w temperature and emerging COVID-19 cases. ● A positive and direct association b/w humidity and emerging COVID-19 cases.	(13)
7.	Relative humidity (RH) and Temperature (Temp.)	Italy, USA, France, UK, Spain, Germany, China, Brazil, Turkey, Canada, Russia, Belgium, Iran, Netherlands, Portugal, India, Ecuador, Peru, Switzerland, and Saudi Arabia	● High temperature and high RH reduce the COVID-19 transmission. ● Social distancing and precautionary measures have been proved vital and effective in containing the surge in SARS-COV-2.	(16)
8.	Ambient temperature (AT), air quality, and Relative Humidity (RH)	Malaysia (Kuala Lumpur)	● Emerging COVID-19 cases has confirmed a weak positive association with relative humidity (RH). ● A weak negative correlation exists between ambient temperature (AT) and new COVID-19 cases.	(12)
9.	Mean temperature and relative humidity (Spatio-temporal analysis)	Africa	● An inverse relationship b/w temperature, RH & surge in COVID-19.	(14)
10.	Humidity & Temperature	Bangladesh	● High humidity with high temperature may help in reducing the COVID-19 outbreak. ● Social distancing in addition to other precautionary measures may aid in abating the global pandemic.	(15)
11.	Climatic Patterns	Italy, France, Spain, Germany, Canada, USA, the UK, Russia, Scandinavian countries, Africa (sub-Saharan), Latin America.	● Cold and temperate warm climatic patterns were found favorable home grounds for the rapid COVID-19 spread. ● Arid and tropical environments are less favorable for SARS-COV-2 transmission and/or COVID-19 emergence/ outbreak..	(21)
12.	Weather and/or Climatic patterns	China	● The unaccompanied weather parameters cannot contain the spread of COVID-19.	(5)
13.	Climate and/or weather patterns	Spain, Switzerland, the US, Turkey, Germany, UK, France, Italy, Iran, Chile, Saudi Arabia, Brazil, Malaysia, Philippines, South Africa, Pakistan, Thailand, Indonesia, India	● Warm and humid states/ countries experienced fewer COVID-19 incidences as compared to the cold and dry countries.	(10)

14.	Air pollution, climatic patterns, and economic conditions	Latin America and the Caribbean region	• Warm and humid countries experience fewer COVID-19 incidences as compared to cold and dry countries. • Data varies with region.	(17)
15.	Air Quality Index (AQI), Relative Humidity (RH), and Temperature	China	• A significant association has been developed b/w AQI and COVID-19 emergence/ transmission. • The delayed effect of the Air Quality Index (AQI) on confirmed cases is noteworthy on days 1-3. • Low relative humidity increases the effect of AQI on the surge of COVID-19 emergence and/or transmission.	(24)
16.	Air pollutants, Wind Speed (WS)	Italy	• High levels of air contamination/ pollution and low (WS) wind speed are responsible for the surge in COVID-19.	(26)
17.	Climatic patterns, air pollutants, Particulate Matters (PM) & economic conditions	LAC cities, Mexico City (Mexico), Santo Domingo, San Juan, Lima (Peru), Bogota (Colombia), Manaus (Brazil), Guayaquil (Ecuador), Santiago (Chile), Sao Paulo (Brazil), Buenos-Aires (Argentina)	• A significant association has been found b/w COVID-19 surge and Prevalence of Particulate matter (PM_{10}, $PM_{2.5}$) and NO_2.	(17)
18.	Air pollutants & Ozone (O_3)	India (Delhi)	• Weak association of air pollutants with daily COVID-19 cases. • Significant positive association of O_3 with daily COVID-19 cases.	(18)
19.	Particulate Matters (PM)	The United States (New Jersey)	• Delayed effect (0-2 days) of particulate matter ($PM_{2.5}$) and air quality index on SARS-CoV-2 surge and dispersal.	(13)
20.	Air Quality Index (AQI)	China	• A decrease in coronavirus infections due to the mobility restrictions imposed at global and national level/s during the lockdown, aided in improving air quality.	(27)
21.	Wind speed	India (Delhi)	• A significant positive correlation between wind speed and COVID-19 cases.	(18)
22.	Wind Speed	The USA, Italy, Spain, France, Germany, The UK, Turkey, Iran, Russia, China, Canada, Brazil, Belgium, India, Netherlands, Switzerland, Portugal, Ecuador, Peru and Saudi Arabia	• Wind speed facilitates the emergence, survival and dispersal rates of COVID-19.	(16)
23.	Atmospheric stability, wind speed and air pollutants	Italy	• Low wind speed in polluted regions accelerated the transmission dynamics of COVID-19.	(26)
24.	Wind speed	Africa	• An inverse relation has been found b/w wind speed and COVID-19 surge and dispersal ratio.	(14)

25.	Climatic Patterns, Air pollutants, wind speed and economic conditions	Caribbean region and Latin America	• An inverse correlation has been confirmed b/w wind speed and rapidly surging COVID-19 cases.	(17)

RESULTS

Since the pandemic outbreak, the global researcher's community raced to identify and reveal the untold mysteries regarding the life-threatening viral strain (SARS-COV-2), which may aid in containing the emergence, viability, and worldwide dispersion of COVID-19. The scientific community has confirmed the high stability, sensitivity, and viability of SARS-COV-2 toward heat. With an increase in temperature up to 70°c, the viral inactivation span was reduced up to merely five minutes. Even at 4°c, the reduction in viral infectious titre was observed on the fourteenth day. SARS-COV-2 was found extremely stable at wide pH ranges, 3-to-10 (30).

Researchers have established the fact that diminished viability of SARS-COV-2 in high-temperature ranges is responsible for the low emergence, stability, viability, transmission, and/or dispersal rates of COVID-19 in hot climatic zones. A negative correlation between the COVID-19 transmission and temperature, however, was found by the scientists indicating that regions with high-temperature ranges were less prone to viral transmission (10, 11, 29, 31). According to the recent research, it has been verified that propagation of SARS-COV-2 was relatively more difficult to contain the viral transmission in cold and populous zones as given in Table 1 (9, 28).

The scientific community has confirmed a correlation between the humidity, temperature, and COVID-19 outbreaks in Bangladesh. It was found that high humidity along with high-temperature temperature ranges may help in reducing the COVID-19 outbreaks (15). Similarly, an inverse relationship between the relative humidity, temperature, and COVID-19 surge in Africa has been found through the Spatio-temporal analytic method (14). A cumulative effect of relative humidity and temperature indicated an increase in COVID-19 dispersal and/or transmission rate in the regions with high humidity and low-temperature levels. However, high temperature along with high humidity levels has been found to decrease the transmission rate. A negative effect of temperature coupled with the direct influence of humidity on the SARS-CoV-2 transmission has been detected with a similar correlation in the South-east Asian region, Africa, Bangladesh, Latin America, and Caribbean (LAC) cities and global hotspots of viral load as shown in Table-1 (11- 17). On the contrary, a plausible positive correlation between the temperature and the rapid surge in the emergence of COVID- 19 cases in India (Delhi) has been recorded (18). Human respiratory defenses against the infection are decreased in winters mainly due to the temperature dependency of SARS-COV-2 and cold nasal passageways during the cold seasons (19). However, a positive and direct correlation between humidity and a surge in COVID-19 emergence, survival, transmission, and dispersal rates, has been explained on the basis that high humidity accelerates the viral deposition on moist surfaces (20). Conversely, Average humidity (relative) and temperature (AT) ranges have also been observed to be indirectly related to the COVID-19 dispersion amongst human beings. However, this relationship was not found consistent all over China (28).

Weather conditions and climatic patterns have been found amongst the important indicators for the emergence, viability, stability, dispersion, and/or transmission rates of SARS-COV-2. A group of researchers found out, through a survey conducted in America, China, and some European, African, and Scandinavian countries, that cold and temperate-warm climate states were found as favorable breeding grounds for the rapid surge in transmission, emergence, and viability of SARS-COV-2 (21). On the contrary, arid and tropical climatic patterns having countries and/or states were found abating the feasibility and contagiousness of COVID-19 (10, 5, and 21). A Malaysian group of scientists surveyed to develop a possible association between the emerging COVID-19 cases and air quality parameters. The emerging cases of COVID-19 in Kaula Lumpur were found in weak respective negative and positive associations with the humidity (RH) and temperature (AT) parameters (12).

Studies have identified and developed a strong and positive correlation between the emergence, viability, transmission, and dispersal rate of COVID-19 with the varying abiotic factors like wind speed, atmospheric temperature, relative humidity, dew/frost, and precipitation rates. Researchers have demonstrated from the evidence collected from COVID-19 outbreak/cases of twenty countries that the reduction in viability, emergence, stability, survival, and dispersion rates of COVID-19 is caused by high temperature and highly humid atmospheric conditions (16).

It was reported that high temperature mitigates the COVID-19 dispersal and/or transmission ratio. On the contrary, cold weather (Temp. ↓) conditions promote the SARS-COV-2 survival and/or dispersal ratio (16).

Wind speed intensity coupled with the surface pressure aids the fast-track dispersal and accelerates COVID-19 transmission to far-flung destinations (32, 33). COVID-19 transmission cycle powered by the high intensity of wind speed along-with surface pressure can be explained without the human-to-human exposure (16, 32, 33). Wind speed (WS) directly aids and/or promotes the COVID-19 incidences on a global scale (16, 18). On the Contrary, Wind speed was found inversely and/or indirectly correlated to SARS-CoV-2 infections in Africa and Latin America, and Caribbean (LAC) cities (14, 17).

Global scientists raced together to unveil the possible impacts of air pollution and air quality parameters on the COVID-19 survival, emergence, viability, transmission, and/or dispersal rate of COVID-19, but still they are knowledge deficient in this regard. In general, good air quality facilitates healthy living and prevents respiratory disorders in people of all ages (26, 34-40). Human exposure to various air pollutants/ contaminants *i.e.* ozone (O_{3}), Particulate matters (i.e. PM_{10}, $PM_{2.5}$), PAH (Poly-aromatic Hydrocarbons) and Carbon Monoxide (CO) makes them susceptible to various respiratory and pulmonary distresses (17, 1, 8, 22, 23, 29).

In addition to this, human exposure to air pollutants induces and enhances oxidative stress and reduces their immunity and ability to resist viral infection (41-43). In a nutshell, the above-mentioned plausible impacts of air pollutants may directly impede the healthy quality of life and curtail the human ability to fight against the challenges imposed by SARS-COV-2 against human survival (43). The emerging COVID-19 cases were overall reduced, according to research evidence from China, due to the reduced human activity during the lockdown period (27).

Compromised air quality index (AQI) has a significantly delayed effect on COVID-19 emergence, survival, and viability ratios which are heavily affected by the temperature and humidity levels. Low temperature (10-20°C) and humidity (RH) ranges were found to increase the influence of AQI on transmission and/or dispersion ratios of COVID-19 cases (24, 25).

CONCLUSION

The global scientific community raced together to reveal the interconnectedness between the various climatic factors, ecological parameters, and meteorological indicators which either aid or abate the COVID-19 emergence, viability, stability, dispersal, and/or transmission rates, which in turn puts a direct or indirect impact on the contagiousness of SARS-COV-2. The current review depicts that the majority of studies have put forward a plausible direct correlation of wind speed, humidity, and air pollution with COVID-19 viability, stability, and transmission rates. Climatic patterns of a country/state were also established by numerous studies as significant indicators for the COVID-19 dispersion. Cold and temperate regions were found as heavens on the earth for the viability and stability of COVID-19 and vice versa. Several studies have confirmed high casualties in the countries with the bad air quality index (AQI) parameters along with the low wind speed. Putting in a nutshell, irrespective of the emergence of the COVID-19 (how did it come into being? How did it first transfer to human beings?), the deteriorated climatic factors *i.e.* temperature, air pollution, and air quality index (AQI) speak volumes about the undue anthropogenic interruptions in the environment. Hence, to control the current life-threatening viral pandemic, it has become mandatory to improve the quality of life by reversing the necessary climatic and meteorological parameters as they were originally, before the industrial revolution and globalization.

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