

## Systematic Review

# Atmospheric conditions affecting the transmission of COVID-19 virus

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## ABSTRACT

The physical environment plays an important role in the transmission of respiratory infections like COVID-19. Atmospheric conditions associated to diseases like influenza, adenovirus infections, parainfluenza, common cold viruses and so on. But we are still lacking in evidence to support the influence of meteorological conditions in spreading COVID-19. We have discussed air pollution, smoking, low air temperature, and proximity to equator, low humidity and air velocity as contributing factors in the spread of SARS-CoV-2 through this narrative synthesis. Bio-aerosol or ultra-fine particulate matter seems to be the most promising mode of transmission of COVID-19. Other methods are direct contact and droplet infection. Air pollution control can prevent priming of respiratory system which shall further protect from pulmonary infections. Air sanitization and humidifiers can be considered to modify the indoor air and prevent contracting infection at workplaces, schools and other gatherings.

**Keywords:** COVID-19, Air pollution, Smoking, Atmospheric conditions, Physical environment, Meteorological factors

## INTRODUCTION

Viral respiratory tract infections have affected the health of communities for a long time with manifestations like colds, cough, sinusitis, laryngitis, laryngo-tracheobronchitis, bronchitis, bronchiolitis, pneumonitis, pneumonia and consequent sepsis. Severe pneumonia is the most severe manifestation presenting as acute respiratory distress syndrome which has a fatal outcome. Those who recover might survive with lung fibrosis as sequelae and are more prone to re-infection and subsequent respiratory compromise.<sup>1,2</sup> Although clinically diverse, and as previous researches have opined, these infections are propagated through the atmospheric conditions of the ambient environment.<sup>3,4</sup> One such condition is air pollution that may alter the respiratory tract through inflammation resulting in diseases like COPD and Bronchial Asthma. When the primed lungs contract infections, the outcome can be fatal. There are other physical factors, humidity, air temperature that

enhance the virus transmission and should be considered when planning or strategizing control measures. With the emergence and re-emergence of respiratory viral diseases in different parts of our planet in the past decade, it becomes important to explore certain environmental causes other than mutation in the form of antigenic drift or shift, responsible for their transmission.

Countries have notified Influenza, SARS-CoV, Ebola, Zika and NIPAH virus diseases in the recent past with wide spectrum of outcomes in terms of morbidity and fatality and with different modes of transmission. The fight against them was not easy and with prompt public health efforts, followed by endemic regions, there have been established norms for the whole world in infection control methods. It is needless to emphasize that anything can happen as far as microbes are concerned. Similar to the aforementioned diseases, Covid-19 has become yet another spectacle in the world's arena that has swiped all of its human inhabitants with an economic, social, mental

health crisis other than its implication on physical health and fatality. There are limited researches on the environmental factors associated with SARS-CoV-2 pandemic. Apart from the unique phylogenetics of novel coronavirus and host factors, here we are inclined to explore some meteorological factors that have influenced the spread of Covid-19, or affected its outcome in individuals who contracted it. Research on such factors must be carried out for future containment of infectious respiratory diseases.

## METHODS

We searched Pub med central for articles based on the following key words: “Environmental pollution causing coronavirus fatality”- 73 results were obtained, with 1 relevant article downloaded, “Environmental factors affecting COVID-19”- 149 results were obtained from which 6 relevant articles were downloaded, “Impact of air pollution on COVID-19 fatality”- showed 10 results of which 3 articles were downloaded. “Environmental factors affecting respiratory viruses”- 10646 results were obtained, 4 relevant articles were downloaded. We searched Google and Google Scholar for “environmental factors affecting COVID-19 transmission” and found 11 relevant papers that were downloaded; “air temperature and humidity effects on coronavirus” and downloaded 3 articles. “COVID-19 in elderly in Italy” and downloaded 2 articles “smoking and COVID-19” and downloaded 5 articles. “particulate matter and COVID-19”-3 articles downloaded. “Environmental factors affecting respiratory viruses”-2 relevant articles downloaded.

We excluded all the duplicates in article search. Date of search was on 20<sup>th</sup> April 2020 and revised on 6<sup>th</sup> October 2020. All articles in the results were scrutinized and relevance of articles was judged based on their content, preferably full text papers that discussed meteorological and physical environment factors in the spread and severity of COVID-19 as well as other respiratory viruses. A total of 40 articles were subjected to in-depth study before writing this narrative synthesis. Most articles were perspectives theorized by eminent authors from different countries. Effect of air pollution on SARS-CoV-2 was described by correlation studies measuring AQI (Air Quality Index) and associating it with the incidence of cases during a fixed time period. We have included articles from authors comparing COVID-19 to other respiratory infections like influenza, measles and SARS-CoV-1 infection too. We found one ecological research paper describing the prevalence of COVID-19 infection in different latitudes. Few researches explained the plight and high risk among elderly population with fatal and severe outcomes associated with smoking. Effects of factors such as air temperature and humidity on respiratory virus spread were also elaborated in some literature.

## RESULTS

### *Air pollution*

Our physical environment includes air, land, water, plants and animals, buildings and infrastructure. “The immediate environment of man comprises of air on which depends all forms of life.<sup>5</sup>” High levels of nitrogen oxides in atmosphere cause air pollution. They give rise to particulate matter (PM), ozone and acid rain. They cause decreased lung function and increased rate of respiratory infections.<sup>2</sup>

There are two pronged consequences of air pollution with respect to respiratory infections. The first is priming of lungs which weaken the ability to overcome the infection and the second is the role it plays as a vehicle to its spread. There are existing postulates supporting air pollution as the reason for fatal outcomes of SARS-CoV-2 infected individuals in affected countries. But, previously there have been no reliable studies documenting the correlation between air pollution and the mortality and morbidity caused due to SARS outbreak.<sup>3</sup> Air pollution is one of the most common causes of prolonged inflammation, eventually leading to an innate immune system hyper-activation<sup>6</sup>. “The extent to which the COVID-19 virus induces respiratory stress in infected individuals may also be influenced by the extent to which an individual’s respiratory system is already compromised” and hence the role of air pollution as a co-factor in disease acquisition and severity can be emphasized.<sup>7,8</sup>

Let us begin with Italy being one of the first European countries to have handled COVID-19, with first cases detected in January 2020. In mid-February, cases of community spread were detected in the region of Lombardy, and the outbreak soon involved all of Northern Italy, eventually appearing in other parts of the country<sup>9</sup>. The reasons that have been hypothesized for Italian outbreak are a greater number of elderly patients with high risk of respiratory infections and poor reporting and quarantine system in the initial stages of the outbreak. But, a greater number of young deaths needs inquisition into other factors such as air pollution. Air particles help to diffuse and disseminate the virus for many hours and days, helping in its survival and spread in higher polluted areas.<sup>9</sup>

SARS-CoV-2 human to human transmission happens through 3 routes: direct transmission through respiratory droplets like cough, sneeze, contaminated hands of affected patients; contact transmission through skin touch on contaminated surfaces; aerosol transmission in confined spaces.<sup>10</sup>

## DISCUSSION

A study conducted by Sima has shown that air pollution has played a key role in the propagation of SARS-CoV-2,

although there is no evidence if it had rendered the community incapable to tackle the infection because of already poor health status.<sup>11</sup> According to Conticini et al, an exaggerated inflammatory status is found in airways exposed to air pollution, evidenced in an outdated paper that described, “alveolar macrophages (AM), exposed in vitro to PM10, significantly increased the levels of IL-1b, IL-6, IL-8 and TNF-a, thus underlining the prominent role of AM in cleaning particulates and activating immune response”.<sup>4</sup> Such information was elaborated by another study about the effects of air pollution in Milan city (Lombardy, Italy) during winter (PM2.5) and summer (PM10) months on human bronchial cells showing an in vitro elevated production of both IL-6 and IL-8. Another study by Coker et al, demonstrated a high positive correlation of atmospheric PM2.5 and high mortality among people living in those regions concurrently. This explains the difference in spatial variation of mortality across Northern Italy in the months of April-May 2020. They also propose that in higher polluted regions, symptoms of chronic lung damage aggravate and therefore more patients are hospitalized and registered with severe manifestations of Covid-19 disease<sup>12</sup>. Such priming of the immune system can occur even in the absence of causative microbial agents.<sup>9,13</sup> Daily concentrations of six air pollutants were measured, in 120 cities of China which included particles with diameters  $\leq 2.5 \mu\text{m}$  (PM 2.5), particles with diameters  $\leq 10 \mu\text{m}$  (PM10), sulfur dioxide (SO<sub>2</sub>), carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>), and ozone (O<sub>3</sub>). This data was correlated with average daily cases from January 23<sup>rd</sup> to Feb 29<sup>th</sup> 2020. Short-term exposure to higher concentrations of PM2.5, PM10, CO, NO<sub>2</sub> and O<sub>3</sub> was found to be associated with an increased risk of COVID-19 infection. However, a higher concentration of SO<sub>2</sub> was related to the decreased risk of COVID-19 infection in this study.<sup>7</sup> Small particles remain suspended in air for a long period of time. Therefore, PM2.5 and PM10 enable aerosol transmission.<sup>14</sup>

In a study it was mentioned that, during initial months of the pandemic, the diesel exhaust particles adsorbed more than 300 chemicals like poly aromatic hydrocarbons (PAH), aliphatic hydrocarbons, quinines, transition metals and others.<sup>15</sup> As PM2.5 fraction is also called ultra-fine particles, Bio-aerosols are such particles whose components are plants and cellular fragments of bacteria, fungi, viruses, parasites and spores. Aerosol microenvironment makes the virus embedded, suitable for its persistence. A 10 microgram/cubic meter increase in PM2.5 per day was associated with a rise in new Measles cases in China. In 2015, RSV incidence in children was also increased with rise in particulate matter. Similar to these infections, COVID-19 cases increased with 1mcm cube rise in PM2.5 concentration, according to Cole et al, who found 3.0 more hospital admissions and 2.3 more deaths in those exposed to higher pollution levels in South East Netherlands where due to livestock farming, higher levels of ammonia contributed to rise in PM2.5 levels.<sup>16</sup>

Hu et al, mentioned in their study that it is the interaction between people that is important for spread of respiratory infections and not the density of the population.<sup>17</sup> Gatherings in weddings, close proximity in family events, and other occasions are more dangerous to cause outbreaks. Tang, found in a study, that SARS-CoV-1 particles of diameters 1-2 mcm, remained suspended almost indefinitely, 10 mcm took 17 minutes to settle to floor and larger particles took minutes or seconds to settle on ground, thereby suggesting that minute dust particles have a role to play in disseminating the virus for several minutes.<sup>15,18</sup> A close contact with min 2 meters (6 feet) distance, for less than 15 minutes with a susceptible individual is considered a high risk of acquiring COVID-19 disease (CDC guidelines for social distancing).

Other studies propound that, even short-term exposure to PM 2.5, PM10, CO, NO<sub>2</sub> and O<sub>3</sub> increased the risk of infection.<sup>19,20</sup> The affinity of virus towards pollutants like particulate matter is mostly processed through adsorption. There is 30% deep penetration of 5 mcm particles.<sup>15</sup> We need to investigate the cellular mechanisms going on in lungs exposed to particulate matter and consequent increase in susceptibility to SARS-CoV-2.

### **Smoking**

Other than air pollutants, chronic exposure to irritants like cigarette smoke activates epithelial and inflammatory injury in the respiratory tract.<sup>21</sup> This makes smokers, both active and passive, more predisposed to respiratory tract damage and hence they acquire common colds (coronavirus and rhinovirus) more frequently than non-smokers. Also, their lungs are frequently affected by other viral and bacterial infections. Studies have observed that smokers are associated with more hospital admissions after contracting influenza virus, from which we can form a corollary that smoking is associated with severe pulmonary infection manifestations.<sup>22,23</sup> The inflammation in lungs leads to recurrent infections and diminished adaptive immune response. Synergism between NO<sub>2</sub> and/or Ozone and rhinovirus infection in human basal and bronchial cells have also been found.<sup>24</sup>

According to Buono et al, mortality rates of COVID-19 in Italy have been higher in men and elderly than in women.<sup>9</sup> This could be because men are more frequent smokers with more frequent cardiovascular disorders than women. A study by Diego et al surmised the initial wave of the pandemic with greater deaths among individuals aged 70 years and above, approximately more than 84%.<sup>25</sup> They attributed this finding to elderly residing in old age homes or in isolation with increased practice of smoking and alcohol abuse, and consequent higher deaths. Other confounding factors that could have been fatal are co-morbidities prevalent with age like Diabetes, Cardiovascular and Renal diseases. In South Korea, most infected by COVID-19 are young and non-smoking women who manifest as mild infections with low

lethality. Therefore, it can be hypothesized that non-smokers exhibit mild infections.<sup>9</sup>

China has a high male smoking rate at around 50% in rural areas and is estimated to be about 44.8% spread across all country.<sup>26</sup> Most of the deaths identified from the epicenter of the COVID-19 outbreak were in people from older age groups (22.8% case fatality) for 70 years and above. Those with underlying co-morbidities died from COPD (6.3% case fatality), cancer (5.6% case fatality), hypertension (6% case fatality), diabetes (7.3% case fatality), or cardiovascular disease (10.5% case fatality). People who died with no co-morbidities were only 0.9%. The initial age distribution of COVID-19 cases was skewed towards older age groups with a median age of 45 years. The patients who died were maximum at the age of 70 years and above.<sup>27,28</sup>

According to a study, out of 19% of patients who were severely affected, 17% were current smokers and 5.2% were former smokers. Therefore, smoking can be postulated as a predisposing factor for acquiring SARS-CoV-2 infection as well as being associated with fatal outcomes.<sup>29,30</sup>

Recent studies have found that the modified S protein of SARS-CoV-2 exhibits higher affinity for ACE2 receptor in human cells in comparison to the S protein of the previous SARS-CoV.<sup>27</sup> Thus the virus has a prerogative in smokers who are found more likely to up regulate ACE2 expression on type 2 pneumocytes. Smokers show enhanced gene expression of ACE2 than non-smokers, thereby increasing virus reproduction and transmission.<sup>31</sup> “The eventual engulfment of ACE2 receptor further provides the virus access to the host cells system, thus providing a flourishing environment, not just to sustain and proliferate but also to mutate and modify host evasion mechanisms”.<sup>27</sup> The up-regulation of ACE-2 receptors is brought about by increase in inhalation of NO<sub>2</sub> in smoke, along with promotion of angiotensin-II binding due to increased enzymatic conversion to the latter.<sup>28</sup> This results in systemic effects and organ damage apart from viral inflammation. Tobacco smoke causes lung inflammation, increased mucous production, cytokine storm and impaired mucociliary clearance. Inflammatory cytokine release produces fever and lung fibrosis. Smokers are the key population who may transmit and show severe forms of infection.<sup>29</sup> They are also candidates for vaccination if it is developed in near future to fight COVID-19 disease.<sup>27</sup>

Although theories supporting smoking as a major risk factor causing severe manifestations of COVID-19 are many, more recent epidemiological studies disagree with new evidence. According to an article by Rossato et al, smoking is not associated with more serious COVID-19 infections as well as hospital admissions.<sup>32</sup> Nevertheless, because tobacco use can cause non communicable diseases like Diabetes, Hypertension, Immunodeficiency and more, it indirectly predisposes to contraction of

COVID-19. It may also enable high transmission rates through droplets of saliva or discharge from the nose when an infected person cough or sneezes.<sup>33</sup>

### ***Atmospheric temperature***

It is an established fact that respiratory pathogens of human beings such as human coronavirus is seasonal and the 2003 SARS outbreak waned when the weather turned warmer, it is an analogy that meteorological conditions may have influenced the 2003 SARS outbreak.<sup>34,35</sup>

Atmospheric temperature is an important factor influencing survival of microorganisms in the external environment. Several studies report that SARS-CoV is sensitive to temperature and relatively stable at low temperatures. As an example, the influenza virus persists in cold-dry weather with no UV radiation. Winters also reduce innate immunity due to deficiency of Vitamin D and hormone melatonin. People usually prefer closed spaces where they transmit influenza to each other. The lessons learnt from other respiratory pandemics may hold true for COVID-19 too. Some experimental evidence had shown that previous SARS-CoV agent remained stable at 4 deg C, at room temperature (20 deg C) and at 37 deg C for at least 2 h without remarkable change in the infectious ability of cells, but was converted to a non-infectious state after 90-, 60-, and 30-min exposure at 56 deg C, at 67 deg C, and at 75 deg C, respectively. Therefore, air temperature may not have only or adversely affected SARS-CoV transmission. And the same theory can be induced for Covid-19 pandemic.<sup>3,7,35</sup>

Eslami et al, states that “when the minimum ambient air temperature increases by 1 deg Celsius, the cumulative number of cases decreases by 0.86%”.<sup>37</sup> Despite higher temperatures, Whittemore Paul, in his study explains that countries nearer to equator are found to be more drastically affected due to lesser production of vitamin D in darker skin people and also associated with high mortality.<sup>38</sup> Despite plenty of sunlight, vitamin D deficiency is prevalent in middle east also causing lesser immunity to this infection.

SARS-CoV-2 is an enveloped virus. Because of the lipid bi-layer surrounding the sRNA genome, the virus is better able to survive in adverse environmental conditions, like higher temperatures because of mucosal or salivary binding to the viral lipid membrane.<sup>14</sup> This explains its community transmission even in tropical countries, that too, in summer months.

### ***Humidity and air current***

Relative humidity is defined as the ratio of the water vapor content of the air to its total capacity at a given temperature. A high relative humidity and high temperature such that exists in tropical countries, is found to be a protective factor for respiratory viral infections.<sup>39</sup> The survival of virus is supported in low humidity for

days along with low temperature. Transmission of viruses via airborne routes may be affected by ambient humidity, which affects not only the virus' stability but also respiratory droplet size, as water content evaporates. The droplet size influences how the particle will quickly settle to the ground or remain airborne long enough to be inhaled into the respiratory tract of a susceptible host. For example, the relative humidity is an important variable in droplet spread of influenza virus, high relative humidity favors removal of infectious particles both by increasing the mass of water-laden droplets causing it to settle and not be suspended in air and by hastening virus inactivation. In contrast, Adenovirus and Rhinovirus were more stable at high relative humidity.<sup>40</sup> Studies suggest that a high relative humidity level may shorten the suspending time of SARS-CoV in the air, as well as high wind velocity adversely affecting virus survival. Enveloped viruses like SARS-CoV thrive longer in dry air<sup>3</sup>. There may happen prolonged transmission of Covid-19 in lower humidity regions. However, there is paucity of research to support this hypothesis in the current scenario of this pandemic.

Evidence from various laboratory-controlled experiments like animal models have elucidated potential mechanisms by which humidity and temperature affect human influenza virus transmission. As an example, in the early 1960s, Schulman and Kilbourne developed an influenza virus transmission model in mice. They observed a significant decrease in transmission efficiency with increasing relative humidity and during summer months.<sup>40,41</sup>

In the outdoor environment, high wind velocity facilitates dilution and removal of the droplets and shortens their suspending time in the air, thus reducing the transmission potential. In contrast, indoor poorly ventilated rooms do not dilute the virus and make people residing in their closed spaces susceptible to infections for most respiratory infections. So cross-ventilation plays a role in clearing off the virus. Usually, suspected carriers of the virus travelling or in contact with known Covid-19 cases must self-isolate themselves instead of becoming a potential risk for health-care workers and other close contacts especially elderly and people with co-morbidities and the immunocompromised.

As a result, several investigators have propagated the use of humidifiers in public spaces during the winter season. This may prove effective in influenza prevention, but for coronavirus, there is no robust evidence as yet.<sup>36</sup>

#### ***Effects of physical factors on survival of virus indoors***

According to Yang et al, the concentration of airborne Influenza virus resulting from a cough would be reduced by 10% if the relative humidity increases from 35%, the mean indoor relative humidity in hot weather. The chance of infection diminishes to 50%, 10 min following the cough, and by 40% after 1 hour in residential settings.<sup>41</sup>

Casanova et al, carried out an experimental study to find out the effects of air temperature and relative humidity on survival of coronavirus on surfaces of hospital.<sup>42</sup> For this purpose, two potential surrogates were evaluated: transmissible gastroenteritis virus (TGEV) and mouse hepatitis virus (MHV). They found that at 4 deg C, virus survived for 28 days. At all relative humidity levels, the infectious virus was inactivated more rapidly at 20 deg Celsius than 4 deg Celsius. The inactivation was slow at 20% relative humidity. We can imply the same characteristics to COVID-19 too but we need to support it with current evidence which is lacking still.

#### **CONCLUSION**

The physical environment plays an important role in the transmission of respiratory infections like COVID-19. We have discussed factors like air pollution, smoking, low air temperature, and low relative humidity and decreased air velocity as contributing factors. If meteorological factors are conducive to spread in our area, we need protective measures way before an outbreak can occur. We infer that during the colder and drier months or in places struck with polluted air, various preventive measures must be imbibed by the general population, both during this pandemic as well as during each season to prevent future spread of such diseases. COVID-19 is transmitted as an aerosol infection, direct contact and through infected respiratory droplets of infected individuals. Therefore, to nip in the bud, any other similar disease in future, we have to combat airborne transmission by wearing masks in highly polluted areas, practicing hand hygiene to prevent direct contraction of infections from contaminated surfaces, abstaining from active and passive smoking and maintaining distance from symptomatic individuals both at home and at work as prevention measures. Air pollution control can prevent priming of respiratory system by limiting exposure to toxic gases, which shall further protect from similar pulmonary infections. Indoor air sanitization can prevent respiratory infection transmission and may become a cost-effective technique at workplaces, schools and other indoor dwellings where there are many people in proximity.

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