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(Review Article)

Influence of air pollution and meteorological parameters on COVID-19: An overview

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Abstract

The spread of Covid-19 has been rampant across the globe, and studies have indicated a connection between the spike in infection and air pollution. The literature review has shown that the link between the SARS-CoV-2 virus causing the disease and air pollutants is still inconclusive. Current evidence from the studies point out two main contributing mechanisms for the spread of the virus: (1) the weakening of the human natural defence mechanism by the air pollutants facilitates virus entry and replication; (2) particulate matter facilitates the airborne transport of vectors. Meteorological parameters also play a significant role in the transmission of the virus. Ultraviolet radiation was negatively correlated with the number of COVID-19 cases, while wind speed was positively correlated. Temperature and humidity increases were associated with a decrease in the number of infections. Some studies have also shown no relationship between humidity and COVID-19 case numbers. Similarly, rainfall predominantly showed no significant correlation. More studies in this area are suggested to further understand the air pollutants effect on the virus, its interaction and the influence of meteorological parameters.

Keywords: Cilia; Nitrogen dioxide; Particulate matter; Temperature; Viral transport

1. Introduction

The COVID-19 outbreak began in Wuhan, China, sometime during November-December 2019 [1]. Later, in March 2020, the outbreak was classified as a pandemic by the World Health Organization [2]. Until recently, over 250 million people have been infected globally, leading to more than 5.1 million deaths [3]. The pathogen causing COVID-19 is SARS-CoV-2 (severe acute respiratory syndrome coronavirus-2), which belongs to the coronavirus family [4]. Unlike the current pathogen, its predecessors MERS-CoV (Middle East respiratory syndrome coronavirus) which emerged in 2012, and the SARS-CoV (severe acute respiratory syndrome coronavirus) which appeared in 2003, were less contagious and the death toll was limited to 881 [5] and 774 [6]. The common symptoms exhibited by COVID-19 infected patients are, fever, cough, sore throat, runny nose, breathing difficulty, fatigue, body pain, headache, nausea, and diarrhoea [7]. With many of the symptoms resembling flu virus, there has been confusion and panic among patients across the world. Due to the virulence of the virus, many of the cities around the world went under lockdown for weeks to months, disrupting the economy and trade, while the benefit of the lockdown was the sudden decrease in atmospheric air pollutants.

It has been known that air pollutants have been connected to inducing various diseases and also found to aggravate existing medical conditions. Some ailments connected to exposure to air pollutants are, chronic obstructive pulmonary disease (COPD), asthma, and cardiovascular diseases [8]. In addition to road emissions, industrial accidents also contribute to existing air pollutant loads and pose a risk to people living in urban areas. Furthermore, meteorological factors also have been found to exacerbate the spread of COVID-19 infection. The objective of this study was to determine the association between air pollutants and COVID-19, and the influence of meteorological parameters towards the spread of coronavirus disease.

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2. Air pollutants

Air pollutants in a region vary depending on the source. In addition to the particulate matter, nitrogen dioxide, sulphur dioxide, and carbon monoxide produced by the industries, they are also the cradle of numerous chemical compounds in the surrounding locality. The commonly measured criteria air pollutants are particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO) and ozone (O_3), a secondary pollutant. The focus of this study is on these five pollutants, which have significant effects on human health and are associated with the spread of COVID-19.

2.1. Effect of particulate matter on human health

Primary sources of particulate matter are from combustion sources, especially from vehicles and industrial processes. Petrochemical reactions with gaseous pollutants (volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxides (NO_x), sulphur oxides (SO_x), and ozone (O_3)) also result in fine particles [9]. Important natural sources are wildfires and volcanoes. PM is further classified based on particle size. $PM_{2.5-10}$ (diameter of particles between 2.5 μm to 10 μm) particles predominantly deposit in the primary bronchi of the lungs. The fine particles (0.1 μm to 2.5 μm), can penetrate deeper into the lungs and reach the terminal bronchioles and alveoli. The ultra-fine particles (< 0.1 μm) could cross cell membranes and can interact with the cells [10-12]. The PMs effect on the human respiratory system is explained based on five mechanisms, $PM_{2.5-10}$: (1) it can activate immune response in nasal epithelial cells causing inflammation, (2) it can induce antigen-presenting cell-mediated inflammatory responses in the airway thereby suppressing the macrophages in the alveoli, $PM_{2.5}$: (3) induces oxidative stress in asthma, (4) leads to apoptosis and autophagy in asthma, ultra-fine particles: (5) can cause severe inflammation in asthma, resulting in alveolar macrophage chemotaxis and induce eosinophilic inflammatory responses [13-15].

2.2. Effect of nitrogen dioxide on human health

The main source of NO_2 is combustion sources emitted from automobile engines and power plants. Symptoms associated with exposure to NO_2 are, eye, throat, nose, and lung irritation [16]. It also causes burning sensations, spasms, and tissue swelling in the throat and respiratory track [17]. It increases the chances of asthma attacks and also aggravates medical conditions in patients with asthma [18,19]. Furthermore, it is linked to respiratory conditions such as, coughing, wheezing, dyspnea, bronchospasm, and pulmonary edema. It can cause an immune response when exposed to high concentrations. Chronic lung diseases and loss of sense of smell are also connected to exposure to NO_2 [16].

2.3. Effect of carbon monoxide on human health

CO is produced when combustion of fossil fuels is incomplete. When a high concentration of CO builds up in the bloodstream, it results in CO poisoning. This is because of its high affinity towards hemoglobin compared to oxygen, which replaces oxygen in red blood cells. Typical early symptoms of poisoning are dizziness, headache, fatigue, and nausea. Progressed symptoms include confusion, blurry or double vision, vomiting, shortness of breath, chest pain, and loss of consciousness [20].

2.4. Effect of sulphur dioxide on human health

Sources of SO_2 in the atmosphere include, burning fossil fuels containing sulphur in industrial activities, vehicles (especially diesel engines), and volcanic eruptions. SO_2 can dissolve in water and when inhaled, it can form sulphurous and sulphuric acids [21]. These acids irritate the respiratory track and cause a burning sensation. This leads to bronchitis and asthma resulting in wheezing, phlegm, chest tightness and shortness of breath. Exposure to high levels reduces the lung's ability to function [22].

2.5. Effect of ozone on human health

Tropospheric ozone is formed from chemical reactions between volatile organic carbon and nitrogen oxides in the presence of ultraviolet light. Inhaled ozone has the ability to travel deeply into the lungs due to low water solubility [23]. It can cause coughing and throat irritation, breathing difficulty and pain, inflammation of the airways, and also has the potential to aggravate asthma, emphysema, and chronic obstructive pulmonary disease. Long-term exposure is also connected to the development of asthma [24,25].

2.6. Effect of air pollutants of human respiratory system

The bronchus is the pathway to the lungs, which consists of cilia (hairy projections). The cilia aid in moving pollutant particles and pathogens out of the airway. This is achieved through the goblet cells present in the cilia, which secrete mucus and play an important role in mucociliary clearance [26]. Impairment of cilia function and structure can affect mucociliary clearance and result in the contracting of various lung diseases [27]. Many studies have suggested that air pollutants affect the airway cilia and result in abnormalities of the mucociliary clearance leading the way to pathogenic infection and lung diseases [21,28-30]. Research conducted in 195 countries in 2015 indicated air pollutants to be a significant contributor to respiratory tract infections [31]. Higher concentrations of air pollutants also increased the occurrence of respiratory viral infections. Diseases associated with air pollution include, influenza, measles, respiratory syncytial virus, asthma, chronic obstructive pulmonary disease (COPD), bronchiolitis, acute respiratory distress syndrome (ARDS), and restrictive lung parenchyma diseases [32-35].

2.7. Association between air pollution and COVID-19

Initial association between increase in PM_{10} pollution (> 50 $\mu g \cdot m^{-3}$) and COVID-19 cases was observed in Italian provinces during February-March 2020 [36]. Study by Pansini and Fornacca [37] in eight countries have shown an increase in SARS-CoV-2 infections in regions with high $PM_{2.5}$ and NO_2 levels. Another study in China has shown that 10 $\mu g \cdot m^{-3}$ increase in particulate matter ($PM_{2.5}$ and PM_{10}) had a rise in COVID-19 confirmed cases by 2.24 % and 1.76 % [38]. Similar observation was also noticed in more than 70 cities in China, and the effect was greater with $PM_{2.5}$ [38]. Studies in Italy, Spain, Germany, France and the USA have shown increasing COVID-19 fatalities with higher NO_2 levels [39,40]. A significant correlation between COVID-19 cases and deaths in California was observed with increases in NO_2 concentrations [41]. Another study in China showed that with an increase in 10 $\mu g \cdot m^{-3}$ of NO_2 resulted in a 6.94 % increase in the daily counts of COVID-19 cases [38]. An increase in CO concentration by 1 $mg \cdot m^{-3}$ was associated with an increase in COVID-19 cases by 15.11 % in China [38]. An opposite trend was observed with SO_2 pollutant, as an increase in SO_2 concentration by 10 $\mu g \cdot m^{-3}$ was associated with the decrease in COVID-19 cases by 7.79 %. However, studies by Travaglio et al. [42] in England showed that when air quality was poor with NO and SO_2, an increased rate of COVID-19 related deaths was observed. Urban O_3 was also positively correlated with an increase in COVID-19 cases. An increase in O_3 concentration by 10 $\mu g \cdot m^{-3}$ resulted in an increase of 4.76 % in daily counts of confirmed cases in China [38]. The study of the relationship between air pollutants and COVID-19 morbidity and mortality has shown that both COVID-19 and the air pollutants affect the same organs. The air pollutants can facilitate the entry of the virus into the body [43]. With weakening of the respiratory system, the severity of COVID-19 infection increases. The virus infects the ciliated cells present in the nasal epithelium, resulting in the loss of cilia [44]. The air pollutants are also connected to cardiovascular mortality and impairment of the neurological system [45,46].

3. Meteorological parameters

Early studies have shown that climatic conditions can affect disease transmission [47]. The meteorological factors of a location vary from region to region and can influence the spread of coronavirus. Recently, various studies have analysed the influence of meteorological parameters on the spread of COVID-19 and have shown its relationship and significance [48-54]. The meteorological parameters considered in this study were ultraviolet radiation, temperature, humidity, rainfall, and wind speed.

3.1. Airborne transport of COVID-19 and meteorological parameters

The diameter of the SARS-CoV-2 virus is estimated to be approximately 0.1 μm [55]. The virus becomes airborne through coughing and sneezing from infected patients through macro-droplets. The size of these aerosols (solid or liquid) can vary and particle size connected to COVID-19 transmission is less than 5μm [56,57]. Studies have shown that SARS-CoV-2 can persist in air even after three hours or more after being emitted [58-60]. In the presence of air pollutants in the atmosphere, the virus can mix with the particles and can be suspended in the air [10,61]. Meteorological factors also play an important role in the virus transmission mechanism. Ultraviolet (UV) radiation and high temperature have an antibacterial effect on the COVID-19 virus [43]. Studies conducted in the USA (New York), Italy, China (17 different cities) and Indonesia have shown a decreasing trend in the number of COVID-19 cases with increasing temperature, while a study in Iran highlighted no significant relationship with temperature [49-53]. The presence of particulate matter in the air can reduce UV penetration ability and further aid the spread of infection [62]. Humidity and rainfall hydrate aerosol particles for virus persistence and sustenance and enhances transmission [63]. Studies conducted in Turkey and China (all provincial capitals) have shown a negative relationship with increase in humidity, which denotes a decrease in the number of confirmed cases, while a study conducted in the USA (New York) has shown no significant association between humidity and COVID-19 cases [49,51,54]. Similarly, studies in Iran and Indonesia (Jakarta) have shown no significant correlation with rainfall, while a study in Italy showed increased disease transmission with rainfall [50, 52, 53]. Wind speed has been shown to have a positive correlation with the spread of the infection in studies conducted in the USA, Iran and Turkey [49, 53, 54, 64]. Dry air also facilitates viral transport and cold conditions can affect the function of the ciliated cells in the airway, aiding infection [65].

4. Conclusion

The literature review has shown a positive connection between air pollution episodes and the COVID-19 pandemic. The study revealed that different air pollutants can have a synergic negative effect on the human respiratory system. Air pollutants have the ability to weaken the body's natural defence mechanisms, which facilitates the entry of the virus. Air pollutants can also harbour and aid in its transport. On the contrary, sulphur dioxide has been found to decrease the spread of the infection. Meteorological conditions also tend to facilitate airborne transmission and thereby increase the infection rate. UV radiation has a negative correlation as higher temperatures can decrease virus transmission, while no significant relationship between temperature and COVID-19 has also been reported. Low temperatures on the other hand, can enhance the spread of infection. Humidity was either negatively correlated or with no significant correlation. Rainfall was predominantly shown to have no significant correlation with COVID-19 cases, whereas wind speed was positively correlated with the spread of the virus.

Compliance with ethical standards

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Disclosure of conflict of interest

The author declares no conflict of interest.

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