Atmospheric Environment and COVID-19 Pandemic

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Since the COVID-19 outbreak, the scientific community has been trying to clarify various problems, such as the mechanism of virus transmission, environmental impact, and socio-economic impact. The spread of COVID-19 in the atmospheric environment is variable and uncertain, potentially resulting in differences in air pollution. Many scholars are striving to explore the relationship between air quality, meteorological indicators, and COVID-19 to understand the interaction between COVID-19 and the atmospheric environment. COVID-19 and air quality, meteorological factors affecting the spread of COVID-19, air pollution, and human health are the main topics. Environmental variables have a certain impact on the spread of SARS-CoV-2, and the prevalence of COVID-19 has improved the atmospheric environment to some extent.

COVID-19 metrology atmospheric environment pollution

1. Introduction

The COVID-19 pandemic caused by SARS-CoV-2 has been recognized as a global public health emergency by The World Health Organization [1]. The outbreak and continued prevalence of COVID-19 has had a severe impact on all aspects of human life worldwide. In response to the strong infectivity and spread of COVID-19, many countries have adopted policies of lockdown and restriction of activities to strictly control the occurrence of the infection. Lockdown is the most direct way to stop COVID-19, but it cannot be sustained in the context of a global pandemic. Research into specific drugs to prevent or treat COVID-19 have yet to yield results [2]. Vaccination is the most effective and cost-effective intervention to control the spread of COVID-19, but the continuous emergence of new variants of SARS-CoV-2 undoubtedly poses another great challenge to vaccine development [3].

Under the current circumstances, COVID-19 is likely to coexist with humans for a long time. Its normalization will lead to a significant decrease in the mobility of the population, making a big change in the way people live and travel, and having a great impact on the functioning of society and the policies of the state. Both natural and human behavioral changes resulting from COVID-19 have direct or indirect effects on the atmospheric environment. These influences are multifaceted, with many positive and negative influences. Also, the atmospheric environment has an important relationship to the spread of COVID-19. Understanding the interrelationship between air quality, meteorological indicators, and COVID-19 is significant for saving human lives.

2. COVID-19 and Air Quality

The COVID-19 outbreak has had a significant impact on almost every aspect of people's lives around the globe, resulting in a variety of direct and indirect impacts on the atmospheric environment. Shutdowns or closures of factories have reduced the amount of pollution, with an estimated 50 percent reduction in N_2O and CO due to the closure of heavy industry during China's lockdown [4]. Restrictions on travel, reduced mobility of people, and reduced transport and related activities have significantly reduced mobile pollution sources and pollutant emissions. $PM_{2.5}$, PM_{10}, CO_2, and NO_2 concentrations have all declined to various degrees during the lockdown period compared to those before the lockdown [5][6][7]. Volatile organic compounds (VOCs), including benzene, are mainly produced by vehicular traffic and other incomplete combustion processes that lockdown has increasingly limited [8]. NO_2, one of the main indicators of world economic activity, shows signs of decline in many countries, including the United States, Canada, China, India, Italy, and Brazil [1][4][9]. At the same time, reduced activities following the lockdown have led to a broad reduction in greenhouse gas emissions. One estimate suggests that global daily CO_2 emissions during the lockdown were 17 percent lower than the 2019 average [10]. It can be seen that the environmental conditions of various countries have changed greatly during the COVID-19 pandemic, indicating that policy intervention has played a great role.

Different studies have shown that urban lockdowns have led to considerable improvements in air quality. The positive impact of urban lockdowns on air quality is greater in cities with larger economies, more industrial activities, and higher traffic volumes [10]. According to data from the Meteorological bulletin of the atmospheric environment, the national average number of haze days in 2020 and 2021 will decrease by 1.5 and 4.4 days, respectively, compared with 2019. In 2020, the meteorological data of Shanghai during the lockdown period and before and after the lockdown were consistent. The comparison of 14 trace elements in $PM_{2.5}$ found that the concentration of trace elements in most fine particles showed a "V" shape trend, indicating that the lockdown measures had a significant impact [11]. Comparing the air quality index (AQI) results before and after the impact of COVID-19 across India shows that most pollutant concentrations (PM_{10}, $PM_{2.5}$, CO, SO_2, NO_x) show different patterns of gradual to rapid decreases [12][13]. A wavelet analysis of COVID-19 confirmed data and weather data in California from 1 March to 24 May 2020 found that AQI and COVID-19 showed negative correlation circles during the observation period, suggesting that COVID-19 leads to better AQI and less environmental pollution [14].

However, with the end of the lockdown and the resumption of normal activities, pollutant emissions rebounded somewhat, and air pollution gradually returned to near pre-COVID-19 levels. NO, NO_2, and NO_x all exhibit abrupt decreases at the time the United Kingdom locked down. But the return of vehicles to the road during early lockdown has already offset much of the air quality improvement seen when locked down [15]. Most of the lockdown's impact on the atmosphere is short-term, but changes in human activities caused by the ongoing COVID-19 pandemic can also have lasting effects on the atmosphere.

COVID-19 has also had some adverse effects on the atmospheric environment, with changes in O_3 due to changes in NO_x and VOC_s emissions. The significant reduction of NO_x during the lockdown was the main reason for the significant increase in O_3. Compared with the same period of the previous year, O_3 in most parts of the world showed various degrees of increase during the epidemic lockdown period [16][17][18]. AQI results in some parts of India comparing the 2020 lockdown period with 2019 show a sharp decrease in NO_2 and an increase in O_3 [5][12].

During the nationwide implementation of restrictions in China in 2020, NO_x generated during transportation decreased significantly (>50%), O_3 concentration in the air increased significantly, and the atmospheric oxidation capacity (AOC) in the Yangtze River Delta region increased significantly (up to 25%), which was also a major reason for the increase of O_3 level during city lockdown [19].

3. Meteorological Factors Affecting the Spread of COVID-19

Meteorological factors are unstable and diverse, and the impact of meteorological indicators on the spread of COVID-19 is comprehensive and complex. Analysis of Canadian meteorological data and COVID-19 confirmed cases for 2020 revealed a direct negative correlation between air quality, temperature, humidity, and COVID-19 infection [20]. A study of meteorological data and COVID-19 data in Istanbul and other regions also came to the same conclusion that air quality and temperature significantly affect the number of COVID-19 deaths in Istanbul [21]. In the same analysis of Wuhan, there was also a significant agreement between AQI, humidity, and mortality rates. Humidity was negatively correlated with related COVID-19 deaths [22]. Temperature is the only significant meteorological indicator that has a significant correlation with the spread of COVID-19 [23]. Although only in the short term, daily temperatures in Madrid, Spain, and California, the United States show a negative correlation between COVID-19 outbreaks and death rates [14][24]. This means that temperature plays an important role in limiting COVID-19, suggesting that temperature may help contain COVID-19. Overall, empirical results suggest that rising temperatures may reduce transmission of the SARS-CoV-2.

Statistical analysis of confirmed COVID-19 data and local meteorological variables in Manaus revealed that low solar radiation cycles may lead to increased COVID-19 deaths due to reduced solar radiation. Dry spells may impair nasal functions that prevent viruses and bacteria from entering the body, leading to increased mortality from COVID-19 [25]. A study in Italy found that cities with high wind speeds had fewer COVID-19 infections, and inland cities with low wind speeds and high air pollution had higher COVID-19 infections [26]. Low wind speeds and high concentrations of air pollutants may contribute to the persistence of virus particles in urban air and thus to the indirect transmission of SARS-CoV-2.

4. Air Pollution and Human Health

Air pollution is one of the biggest environmental threats to human health. It is harmful to the human body in many ways, mainly in the form of respiratory diseases and physiological disorders. It is of great practical significance to study the impact of air pollution on aggravating COVID-19 infection in the population. People living in areas with high levels of pollutants are more likely to develop chronic respiratory diseases and infections with pathogens [27].

An analysis of the link between air pollution and COVID-19 in Indian cities found an asymmetric relationship between $PM_{2.5}$ and COVID-19 cases, where the positive impact of $PM_{2.5}$ concentration intensifies the spread of COVID-19. Environmental pollutants CO, O_3, and NO_2 are also positively correlated with confirmed cases and

deaths of COVID-19 [28]. Atmospheric particulate matter, upon exceeding the satisfactory level, serves as an important cofactor in increasing the risk of SARS-CoV-2 transmission and related mortality [29].

Data from Tehran also shows a significant link between COVID-19 mortality and exposure to environmental pollution, with increased $PM_{2.5}$ levels in the air likely to increase SARS-CoV-2 mortality [30]. A similar study conducted in Germany showed that $PM_{2.5}$, O_3, and NO_2 were significantly correlated with COVID-19 outbreaks [23]. In many Italian provinces, long-term air quality data are significantly associated with COVID-19 cases, further demonstrating that long-term exposure to air pollution may be an enabling environment for virus transmission [31]. Data from Wuhan also points to an increase in deaths due to poor air quality [22]. Environmental pollution is an important factor affecting the incidence and death of COVID-19. Areas with higher levels of environmental pollution are prone to respiratory syndrome, which reduces the immunity of residents and affects their susceptibility to COVID-19 [32]. The mortality rate decreases more significantly in countries with high levels of greenery than in countries with low levels of greenery. A good air environment and a green environment are conducive to human survival and development [33].

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