Climate change, environmental factors, and COVID-19: Current evidence and urgent actions

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The novel coronavirus disease (COVID-19) has triggered an international health crisis that began in late 2019. The number of COVID-19 cases globally remains at the highest levels, and variants of the SARS-CoV-2 being reported around the world have caused special concern. The COVID-19 pandemic requires a regular global response.

As is the case with other infectious respiratory diseases, COVID-19 may be affected by climatic, meteorological, and environmental factors, including temperature, humidity, and air pollutants. The interactive effects of these factors on population health are complicated. Furthermore, policy responses to COVID-19 have substantially affected socio-economic systems and people’s lifestyles, which in turn had an impact on climate by reducing emissions and population adaptations under the background of climate change, and even further affected the human health. Immediate actions are needed to respond to both climate change and COVID-19, and in turn the climate impacts of the COVID-19 pandemic.

Relationships between climate and the COVID-19 pandemic

Impact of climatic, meteorological, and environmental factors on COVID-19. Existing studies mostly focus on the complex relationship between meteorological conditions (temperature, humidity) and COVID-19 (confirmed cases, basic reproduction number \( R_0 \)) under the short-term exposure window. However, a particular contradiction has been identified in current evidence. Some studies have reported that low temperatures and dryness increase the health risks of COVID-19, the underlying mechanism is explained as the impact of meteorological conditions on SARS-CoV-2, and immune system resistance. However, the opposite conclusion is that the trend of the epidemic and seasonal changes is more attributed to the effectiveness of epidemic prevention measures over time. The short research period of early studies limits their analysis of the impact of varied meteorological conditions on the COVID-19 epidemic.

Air pollutants, such as PM\(_{2.5}\), PM\(_{10}\), NO\(_2\), SO\(_2\), and O\(_3\), were linked to confirmed cases, \( R_0 \) and the fatality rate of COVID-19. Middle- or long-term exposure to air pollutants (monthly or annual averages) was of great concern. In the United State, an increase of 1 \( \mu \)g/m\(^3\) in the long-term average PM\(_{2.5}\) was associated with a statistically significant 11% increase in the county’s COVID-19 mortality rate; and per interquartile range increase in NO\(_2\) (4.6 ppb) was associated with 11.3% and 16.2% increase of COVID-19 case fatality rate and mortality rate, respectively. Under long-term particulate matter exposure, the overexpression of alveolar angiotensin-converting enzyme 2 receptor and impairment of host defenses may be triggered. Chronic NO\(_2\) exposure may induce inflammation and enhance oxidative stress.

Impact of the COVID-19 pandemic on climate and environment. The implementation of lockdown measures for COVID-19 leads to a significant decline in human activities and energy consumption, which also affects meteorological factors and air pollution. Due to a decline in surface transport emissions, global fossil fuel CO\(_2\) and total NO\(_x\) emissions decreased, contributing to a short-term cooling since the start of 2020. However, the global temperature response will probably be small because it does not reflect structural changes in the economy or transport and energy systems. Emissions reductions are also reflected in air pollution levels. During the quarantine period in China (February 10 to March 14, 2020), NO\(_2\) and PM\(_{2.5}\) dropped to 12.9 and 18.9 \( \mu \)g/m\(^3\), which further prevented related death. Moreover, the coupling relationship may exist among different air pollutants, leading to various shifting trends.

Urgent response actions

Recognize risks and protect vulnerable populations based on more evidence from epidemiological studies. Current COVID-19 studies are not comprehensive enough to fully assess the relationships and interactions between meteorological factors, air pollution, or other environmental factors and COVID-19. The studies related to seasonal patterns, middle- and long-term effects during the pandemic are limited. Methodological advancements, such as multi-site and individual-level studies using novel statistical methods and comprehensive control of potential confounders (such as the timeline of response measurements, the level of the epidemic...
prevention policy, healthcare policy and quality, and the population migration), are needed. Further study of sensitive populations and their specific risks is also needed to support targeted policy-making for vulnerable groups. Furthermore, more communication and cooperation between researchers working in climate science and infectious disease epidemiology are needed to avoid deviations in research conclusions due to disciplinary differences.

**Take response measures for compounded extreme weather and COVID-19 risks.** The interactive nature of climate-attributable risks and the global COVID-19 crisis may continue for a long time. Countermeasures for extreme events will have an impact on COVID-19 control measures, such as the maintenance of social distancing for COVID-19 and the gathering in emergency shelter for extreme events. Furthermore, due to a legacy of racial discrimination and under-investment in healthcare, vulnerable populations, particularly the poor, are susceptible to both extreme weather and COVID-19. This presents a huge policy challenge in accurately identifying health risks and protecting vulnerable populations.

**Establish a framework for early warning and projection of health risks.** The human health and economic losses caused by COVID-19 have exposed the current inadequacies of disaster response systems. Precautionary approaches, including preemptive technical assistance and funding are needed. A framework based on multi-department collaboration with clear rights and responsibilities is indispensable to formulate suitable emergency response measures and recommendations for protection of the public. Early warning systems and long-term projections of future pandemics are required to prevent or mitigate potential public health crises in a changing climate. The Global Influenza Surveillance and Response System, which monitors the spread and evolution of influenza, has contributed significantly to country-level diagnostic and sequencing capabilities throughout the COVID-19 response. On the basis of reliable epidemiological evidence, monitoring and response systems need to comprehensively consider the potential impacts of climate and environmental factors on the development of disease epidemics, so as to make promptly early warnings and scientific planning.

**Mitigation and adaptation are effective measures in response to the COVID-19 crisis under the changing climate**

Although the response to the COVID-19 pandemic is currently the highest priority action in the world, a long-term and sustainable strategy, coping with climate change, should not be underestimated when considering the interaction between varied environmental factors and COVID-19. The mitigation strategy, which include reducing anthropogenic emissions and adopting a low-carbon socio-economic development pattern, has demonstrated its effectiveness in controlling global warming and air pollution during the lockdown period. In the future, under the scenario of promoting the transformation of economic structures and following the path of sustainable development, two adaptive policies are suggested. Firstly, the government should strengthen the protection of the most vulnerable populations who are susceptible to both climate change and infectious respiratory diseases. Secondly, the public should further strengthen awareness of self-protection measures to deal with the risks of climate change and future pandemics.

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**DECLARATION OF INTERESTS**

The authors declare no competing interests.