Plummeting air pollution and CO2 emissions during the COVID-19 pandemic: Lesson learned and future equity concerns of post-COVID recovery

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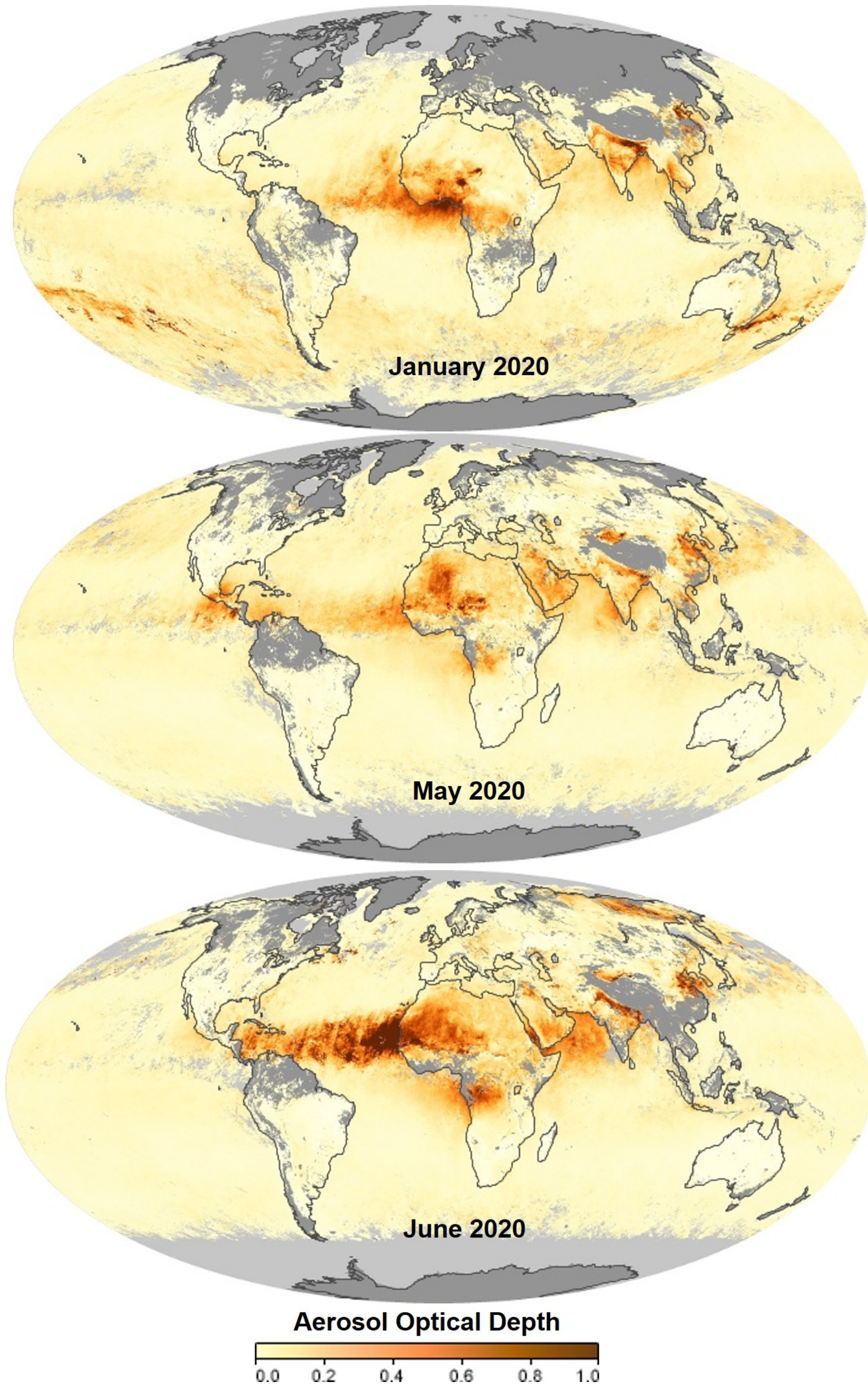
The COVID-19 pandemic lockdowns and quarantines have led to significant industrial slowdowns among the world's major emitters of air pollutants, with resulting decreases to air pollution and greenhouse gas emissions. However, there are major concerns that these decreases in atmospheric pollution can be hampered as economies are reactivated. Historically, countries have weakened environmental legislations following economic slowdown to encourage renewed economic growth. Such a policy response now will likely have disproportionate impacts on global indigenous people and marginalized groups within countries, who have already faced disproportionate impacts from COVID-19. Bold government decisions can restart economies while pre-empting future inequities and committing to environmental protection.


January 2020
May 2020
June 2020
Aerosol Optical Depth
0.0 0.2 0.4 0.6 0.8 1.0

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Abstract

The COVID-19 pandemic lockdowns and quarantines have led to significant industrial slowdowns among the world's major emitters of air pollutants, with resulting decreases to air pollution and greenhouse gas emissions. However, there are major concerns that these decreases in atmospheric pollution can be hampered as economies are reactivated. Historically, countries have weakened environmental legislations following economic slowdown to encourage renewed economic growth. Such a policy response now will likely have disproportionate impacts on global indigenous people and marginalized groups within countries, who have already faced disproportionate impacts from COVID-19. Bold government decisions can restart economies while pre-empting future inequities and committing to environmental protection.

1 Introduction: COVID-19 impacts on atmospheric pollution

The response to the 2020 COVID-19 pandemic led to massive lockdowns and quarantines, as well as slowdowns of human activity patterns, causing economy and industrial shutdowns and closures, with the aim to halt the spread of the virus worldwide, mainly in highly populated nations such as China, India, and United States. As a result of these events, The COVID-19 pandemic and air quality have become intertwined as quarantines, home isolation, and less land and air traffic have likely improved the ambient air quality in China, India and United States, the world's largest current emitters of air pollution (Afshari, 2020; McGrath, 2020; NASA, 2020a; NASA, 2020b). Following the emergence of COVID-19 pandemic, important consideration has reasonably been allocated on the relationship between COVID-19 and atmospheric pollution or/and carbon dioxide (CO_2) emissions, the main greenhouse gas driving climate change, by some government agencies such as NASA, NOAA, and the European Space Agency (ESA). However, minor attention on this subject has been invested by universities and the industrial sector. This should be a scientific issue of pressed importance and a research front of higher priority in academia and non-government organizations

In fact, air pollution have substantially declined in the countries aforementioned, as detected by the NASA-Earth Observatory and ESA satellites' data during the COVID-19 pandemic (NASA, 2020a; NASA, 2020b). Significant decreases in airborne nitrogen dioxide

(NO_2) over China (*1*) and aerosols (particulate matter: $PM_{2.5}$ or PM_{10}) in India (*2*) were observed, while reduction in carbon monoxide (CO) and CO_2 emissions has been reported in New York, NY (McGrath, 2020).

In China, the mean tropospheric density of NO_2 (μmol/m^2) has significantly dropped in early 2020. When comparing the NO_2 concentrations measured on February 10-25, 2020 (during the quarantine) and those observed on January 1-20, 2020 (before the quarantine) a significant decline in NO_2 concentrations, from 0 to 125 μmol/m^2 was observed in eastern and central China, as seen in Figure 1. Excluding the air pollution "holiday effect" resulting from the Chinese New Year, the decrease of NO_2 concentration was 10 to 30% lower in China relative to the average concentration reported in previous years (2005-2019) at that time period (NASA, 2020a). Conversely, the NO_2 levels commenced to rebounding from late April to early May as the lockdowns in this nation ceased (Figure 1).

Likewise, NO_2 levels along the northeastern coast of US significantly plummeted in average by 30% across this region in March 2020 relative to the NO_2 mean concentrations of the 2015-2019 period (Figure 1). NO_2 is an air pollutant primarily emitted from burning fossil fuels (e.g., diesel, gasoline, coal) and can presumably be an indicator linked to reductions in fossil fuels use.

Similarly, airborne particles have dramatically plummeted over India from 2016 to 2020 (Figure 2), considering the March 31-April 5 period of each year, as measured by the aerosol optical depth (AOD), i.e., a satellite measurement of aerosols optical thickness to measure how visible and infrared light is absorbed or reflected by airborne particles as it travels through the atmosphere (NASA, 2020b). As illustrated in Figure 2, the AOD was basically 0.1 or relatively close to 0.05 (clean conditions) in most of India's territory as shown by the 2020 anomaly, i.e., comparisons of AOD values in 2020 relative to the AOD average values for 2016-2019 (NASA, 2020b). The COVID-19 lockdown in India had an indeed an effect on atmospheric pollution in this country

In the United States, researchers from Columbia University in the city of New York (CUNY Next Generation Environmental Sensor Lab-NGENS Observatory) conducted air quality monitoring research by measuring the composition and changes of urban gases, including CO_2, methane (CH_4) and carbon monoxide (CO), in New York (McGrath, 2020). The preliminary data indicated that CO and CO_2 emissions dropped by ~50% and 10-35% due to reduced vehicles' traffic during the COVID-19 emergency in New York during the COVID-19 shutdown (McGrath, 2020). Conversely, the global atmospheric CO_2 concentrations have not yet plummeted as shown by the monthly mean CO_2 measurements (i.e., 414.50 ppm in March 2020 relative to 411.97 ppm in March 2019) reported at Hawaii's Mauna Loa Observatory (NOAA, 2020a) and the global monthly mean recorded over marine surface sites by the NOAA-Global Monitoring Division (NOAA, 2020b). Despite the global decline of many fossil fuel/carbon burning-activities in urban and industrial areas due to COVID-19, changes in CO_2 emissions are not evident since CO_2 levels are influenced by the variability of plant–soil carbon cycles (i.e., bio-geochemical cycling) in tandem with the nature of the carbon budget, i.e., atmospheric CO_2 concentrations will continue to increase unless annual emissions are set to net-zero (Ehlert & Zickfeld, 2017; Evans, 2020; Le Quéré et al., 2020; Matthews et al., 2017). However, CO_2 emission changes are expected as the year 2020 evolves (Evans, 2020; NOAA, 2020a; NOAA, 2020b). For instance, a drop equivalent to 5.5% of 2019-global total emissions has been projected in 2020 (Evans, 2020), while a more concerted assessment, considering COVID-19 forced confinement, projected an annual CO_2 emission reduction by 4% if prepandemic conditions return by mid-June 2020 or by to 7% if some restrictions remain worldwide until the end of 2020 (Le Quéré et al., 2020). However, the global emissions of CO_2 must drop by 7.6% annually (Evans, 2020; United Nations Environment Programme, 2019) in order to do not exceed the 1.5°C global temperature above pre-industrial levels as this is the threshold indicating a temperature limit within the most dangerous climate threats (IPCC, 2018; Le Quéré et al., 2020).

In the light of these data and observations, questions linger as to whether the global lockdowns and economic slowdowns due to the COVID-19 pandemic can have a lasting impact to reducing atmospheric pollution and greenhouse gas (GHG) emissions.

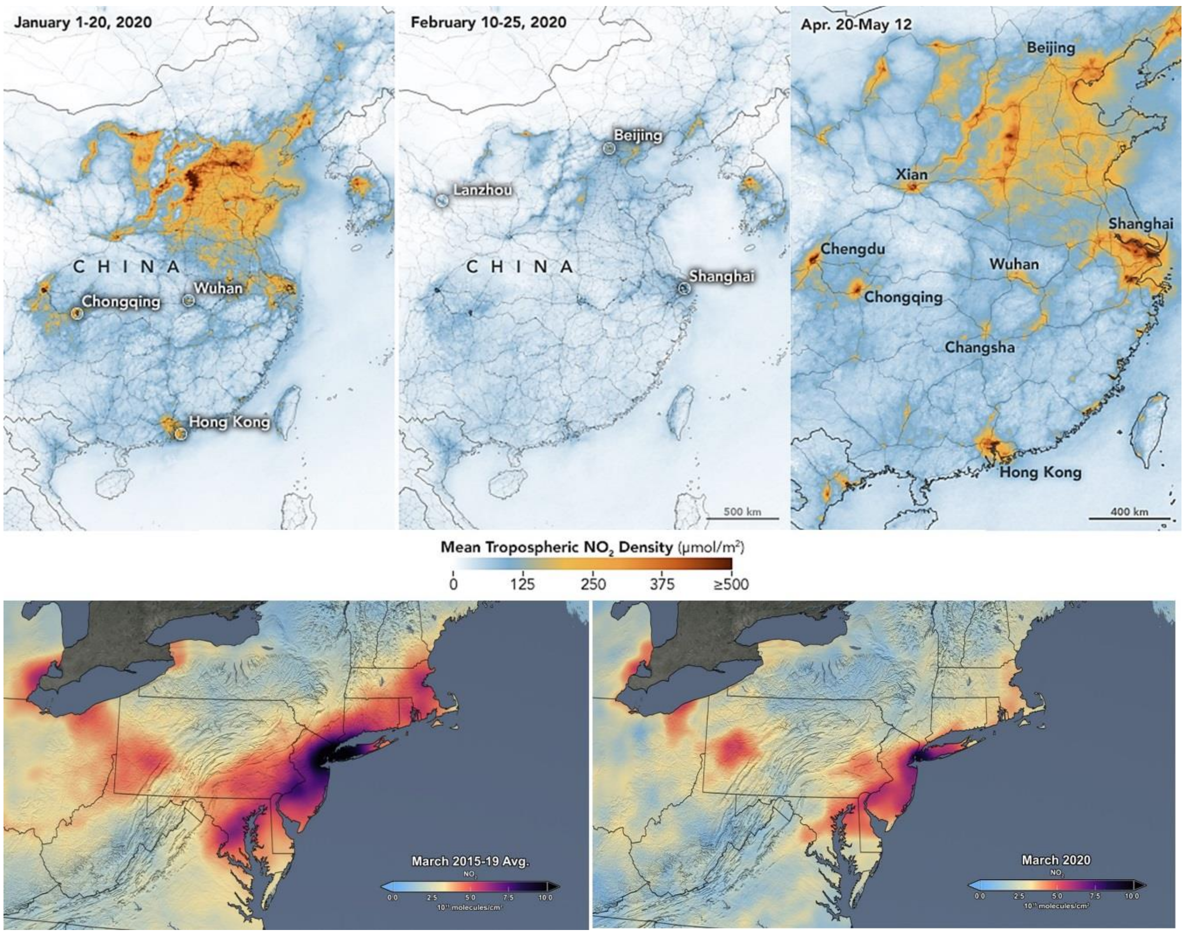

Figure 1. Preliminary satellite-derived emission estimates for tropospheric density of NO_2 over China and the northeastern coast of United States (US). Top image: mean tropospheric density of NO_2 (μmol/m^2) over China throughout January 1-20 (before the quarantine), February 10-25 (during the quarantine) and April 20 to May 12 (after the quarantine) in 2020. The data were retrieved by the Tropospheric Monitoring Instrument (TROPOMI) on ESA's Sentinel-5 satellite, and the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite, which has been making similar measurements. Bottom image: mean tropospheric density of NO_2 (molecules/m^2) along the Northeast US coast (i.e., I-95 corridor from Washington D.C., to Boston) as measured by NASA's Aura satellite OMI for the period March 2015-2019 and March 2020. NASA Earth

Observatory images by Joshua Stevens, using modified Copernicus Sentinel 5P data processed by the European Space Agency; and Joanna Joiner, NASA/GSFC, based on NO_2 measurements from the Aura Ozone Monitoring Instrument (OMI). Image Credits: NASA's Earth Observatory https://earthobservatory.nasa.gov/images/146362/airborne-nitrogen-dioxide-plummets-over-china; and, Aura Ozone Monitoring Instrument (OMI) https://airquality.gsfc.nasa.gov/

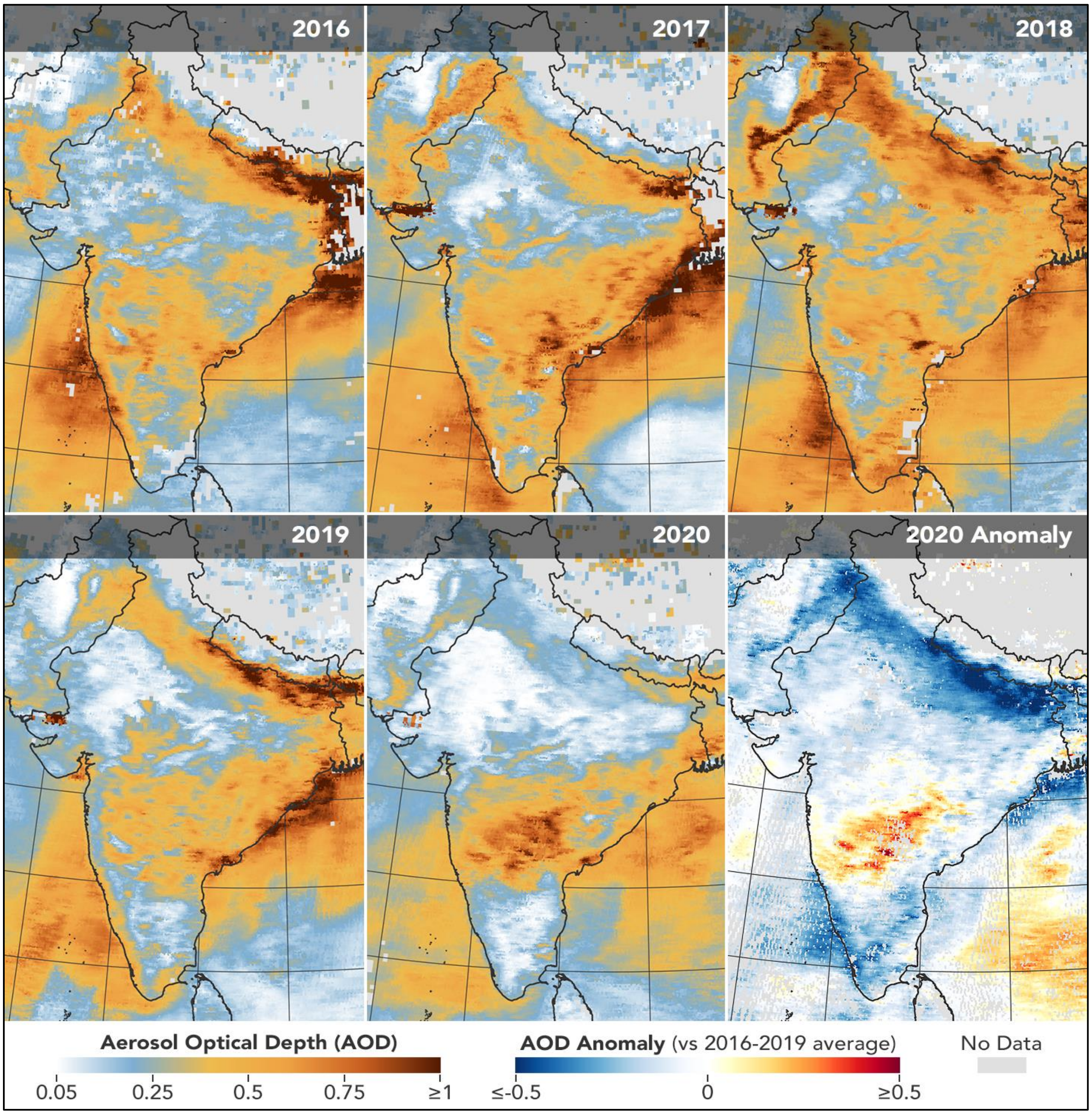

Figure 2. Aerosol optical depth (AOD) measurements over India from 2016 to 2020 during the same March 31 to April 5 period for each year, and the AOD anomaly in 2020 (i.e., AOD in 2020 relative to the AOD average for 2016-2019). An optical depth, or thickness of <0.1 (palest yellow) over the entire atmospheric vertical column is considered clean ("crystal clear sky") with maximum visibility, whiles a value ≥ 1 (reddish brown) indicates very hazy conditions. The data were retrieved by the Moderate Resolution Imaging Spectroradiometer (MODIS: https://modis.gsfc.nasa.gov/) on NASA's Terra satellite. Image Credit: NASA's Earth Observatory https://earthobservatory.nasa.gov/images/146596/airborne-particle-levels-plummet-in-northern-india

2 Post COVID-19 Environmental Policy and Pollutant Management Implications

Though the air pollutants and GHG emissions have been significantly reduced from the direct effects of national quarantines, these reductions may be extremely short lived. The second order effects of the COVID-19 pandemic and its shutdown may lead to weakened environmental legislation in the world's top emitters (which happen to be some of the world's largest economies) in order to accelerate economic growth. Measures to curtail environmental legislation can be long-lasting and offset any pollution reductions that occurred during lockdown. For example, the United States has rolled back environmental regulations and is interested in stimulating the fossil fuel industry (Rosenbloom & Markard, 2020). Reviewing the history of environmental policy changes after economic downturns and recessions shows that many nations (including major emitters like USA, UK, Canada, and Australia) slashed environmental legislation and streamlined environmental impact assessment (EIA) processes, allowing more development projects to proceed without EIA and limiting public involvement and consultation on development projects (Bond et al., 2014). The political and economic pressures to opportunistically de-emphasize environmental legislation and tools have been documented around the world across time (Bond et al., 2020). While there are some calls to emerge from COVID-lockdowns embracing pro-environmental development policies such as calls to affirm "Green Deal" approaches (Rosenbloom & Markard, 2020), historical accounts suggest that post-COVID economic recoveries that are environmentally sustainable are not likely (Bond et al., 2014; Bond et al., 2020).

Post-COVID recovery strategies also have implications for international health and cultural equity considerations. Internationally, some estimates place developing and least developed nations as most vulnerable to climate change impacts, and indigenous communities in the Arctic as facing some of the largest changes to temperature and precipitation changes (IPCC, 2018). The loss of sea ice from climate change in the Arctic has severe implications to the culture and livelihoods of communities in the Arctic (IPCC, 2018). Environmental pollutants disproportionately affect minority communities and indigenous groups. While pollution is the largest environmental cause of premature death in the world, and low income and middle income nations face the brunt of pollution-associated death, indigenous people often face some of the worst effects of pollution (Landrigran et al., 2018). For example, Indigenous people face the worst air pollution in Canada, and indigenous groups face severe environmental (i.e., air, water, and land) pollution risks in other regions of the world where there are conflicts between indigenous peoples and resource extraction projects, or where they rely on seafood as a major food source (Landrigran et al., 2018).

Environmental and social injustice is also prevalent within many countries, including the United States, as racial, inequity and ethnic disparities result in greater exposure to harmful environmental pollutants (Landrigran et al., 2018). While COVID has undoubtedly relaxed some of the exposures of these vulnerable groups to pollutants, a post-COVID recovery that maintains low levels of emissions would dampen these pollution and health inequities without having to suffer a pandemic to achieve it. However, promoting post-COVID recovery strategies that weaken environmental legislation will undoubtedly disproportionately affect vulnerable groups like ethnic minorities, who have also been worse affected by COVID (Liverpool, 2020).

Thus, improved air quality along with climate change mitigation and adaptation should be urgently implemented and/or continued fostered and implemented by developed and developing nations to lessen the exacerbation of respiratory diseases and spread of pathogenic infections by strengthening public health, ultimately reducing the COVID-19 pandemic severity (Afshari, 2020; IPCC, 2018; World Health Organization, 2016).

3 Lesson and reflections from the global COVID-19 experience

Acute air pollution and climate change are two global anthropogenic stressors negatively affecting human health in the long-term (World Health Organization, 2016, 2018; Smith et al. 2014). While ambient air pollution by particulate matter ($PM_{2.5}$) is responsible for an estimated >4 million deaths per year (Cohen et al., 2017), the COVID-19 pandemic has already claimed the lives of ~670,000 people with more than 18 million confirmed cases (morality rate of ~4%) by early August 2020, according to the interactive database to track COVID-19 in real time from the John Hopkins University's Coronavirus Resource Centre (https://coronavirus.jhu.edu/map.html; Dong et al. 2020). As we write this commentary, the ongoing reopening of socio-economic and industrial activities in many developed nations will increase emissions and counteract some of the atmospheric pollution and GHG emissions reached thus far during the COVID-19 global lockdown (Le Quéré et al., 2020). Despite the fact that significant reductions in air pollution emissions were detected by the satellite data aforementioned, it is still insufficient to offset climate change's impacts on public health, biodiversity and oceans. The lesson learned from the COVID-19 effect on atmospheric pollution can serve as a compelling reminder that even if all CO_2 or GHG emissions are mitigated and ceased today, nations will still have to proactively implement strategic actions to curtail and eliminate airborne pollution in tandem with climate change solutions to reduce emissions and sequester carbon for years to come.

The global citizens living in urban, suburban, rural, and remote areas as well as indigenous communities from developed and developing countries have common and unique health issues in the face of air –pollution, climate change and COVID-19 (i.e., environmental and health education, hygiene and health prevention measures) and in accessing the environmental protection and health care that they need (e.g., lack of pollution abatement and environmental justice, testing, medical treatment and therapy). Prioritizing the environmental health, promoting new approaches to protect human health, diffusing public messaging and health education programs are of paramount importance in an era of COVID-19, pollution and climate change. In this context, our "new normal" remain nimble enough to allow us to fine-tune our interventions and research tools to quickly enough to stay ahead of the pandemic trajectory to combat and mitigate pollution and climate change, respectively. New collaborative research frameworks are vital to ensure that the health needs of people living in cities, rural and remote communities can be assisted with appropriate access to health education program, and ground-breaking technological research.

A call out addressing grand challenges in environmental science research on this topic to investigate the fate and behaviors of aerosols, CO_2, and several others atmospheric pollutants (e.g., volatile persistent organic pollutants [POPs], gaseous elemental mercury vapor [Hg^0] and inorganic divalent mercury [Hg^{2+}]), as well as additional greenhouse gases (e.g., atmospheric methane [CH_4], Nitrous Oxide [N_2O], Sulpher Hexaflouride, [SF_6]) is also urgently needed as the COVID-19 progresses. Solutions-oriented research and precautionary approaches will be indeed needed to combat the cumulative impact and health effects of atmospheric pollution, climate change and global epidemics of emerging infectious respiratory diseases.

4 Conclusion

The current pandemic is teaching us the ultimate need for behavioral and innovative changes at the individual, community and corporate/industrial levels and that we may be missing a great opportunity, if precautionary actions to prevent, and reduce air pollution and CO_2 emissions are not implemented now. Carbon emissions will be on the rise and surging back as COVID-19 lockdowns are uplift or relaxed amidst the re-opening of economics and industrial activities, mainly in developed nations. Meanwhile, pending the end of this pandemic, researching governments' decisions on how to reactivate economies in an environmentally sustainable and socially equitable way will be crucial to keep locking down carbon emissions and reduce and eliminate air pollution, which are essential for global environmental health inequity and justice, the protection of biodiversity and the conservation of planet Earth.

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Schematic Ilustration.


January 2020
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Aerosol Optical Depth
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