# Air pollution and COVID-19: clearing the air and charting a post-pandemic course: a joint workshop report of ERS, ISEE, HEI and WHO

Zorana J. Andersen[1], Barbara Hoffmann[2], Lidia Morawska[3], Martin Adams[4], Eeva Furman[5], Arzu Yorgancioglu[6], Dan Greenbaum[7], Maria Neira[8], Bert Brunekreef[9], Francesco Forastiere[10], Mary B. Rice[11], François Wakenhut[12], Erika Coleen[13], Hanna Boogaard[7], Ulrike Gehring[9], Erik Melén[16], Brian Ward[17] and Sara De Matteis[18,19]

[1]Environmental Epidemiology Group, Section of Environmental Health, Dept of Public Health, Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark. [2]Institute for Occupational, Social and Environmental Medicine, Centre for Health and Society, Medical Faculty, Heinrich-Heine-University of Düsseldorf, Düsseldorf, Germany. [3]International Laboratory for Air Quality and Health (ILAQH), School of Earth and Atmospheric Sciences, Queensland University of Technology, Brisbane, Australia. [4]European Environment Agency, Copenhagen, Denmark. [5]Finnish Environment Institute, Helsinki, Finland. [6]Celal Bayar University Medical Faculty, Dept of Pulmonology, Manisa, Turkey. [7]Health Effects Institute, Boston, MA, USA. [8]World Health Organization, Geneva, Switzerland. [9]Institute for Risk Assessment Sciences (IRAS), Utrecht University, Utrecht, The Netherlands. [10]Imperial College, London, UK. [11]Division of Pulmonary, Critical Care and Sleep Medicine, Beth Israel Deaconess Medical Center, Boston, MA, USA. [12]Clean Air Unit, Directorate-General Environment, European Commission, Brussels, Belgium. [13]Belgian Asthma and Allergy Association, Brussels, Belgium. [16]Dept of Clinical Sciences and Education, Karolinska Institutet, Södersjukhuset, Stockholm, Sweden. [17]European Respiratory Society, Brussels, Belgium. [18]Dept of Medical Sciences and Public Health, University of Cagliari, Cagliari, Italy. [19]National Heart and Lung Institute, Imperial College London, London, UK.

Corresponding author: Zorana Andersen (zorana.andersen@sund.ku.dk)

Shareable abstract (@ERSpublications)
**The potential role of air pollution in the worsening of health impacts of COVID-19, and the influence of the pandemic on air pollution levels in Europe is explored. This editorial outlines the major lessons learned to chart a healthy post-pandemic course.** https://bit.ly/3hmbaya

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## Introduction

Air pollution is now recognised by governments, international institutions and civil society as a major global public health risk factor. The health burden of air pollution is large: 509 000 premature deaths every year in Europe [1] and serious aggravations of heart and lung diseases that affect millions of patients, both children and adults. The European Environmental Agency estimated that in 2018 there were 417 000 premature deaths attributable to particulate matter with diameter <2.5 µm ($PM_{2.5}$), 55 000 to $NO_2$, and 20 600 to $O_3$ in Europe (table 10.1 in EEA Report 9/2020 [2]). In addition, 4 805 800 years of life lost could be attributed to $PM_{2.5}$, 623 600 to $NO_2$, and 246 700 to $O_3$ (table 10.2 in [2]). This "silent killer" is one the most important determinants of health, surpassed only by high blood pressure, tobacco use and poor diet. The coronavirus disease 2019 (COVID-19) pandemic has raised concerns about whether air pollution can increase the severity of disease and risk of death after infection, as well as facilitate the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Chronic lung disease patients are in the epicentre of the current crisis, as they are more vulnerable to both the adverse effects of a SARS-CoV-2 infection and air pollution exposure, as well as their possible interactions. At the same time, the lockdown measures to control the spread of COVID-19 brought historical short-term reductions in air pollution levels around the globe, and increasing general public interest and demand for clean air policies [3]. The COVID-19 pandemic, an emerging infectious disease probably caused by a spill over from animals, and its possible interactions with air pollution, is an existential reminder that we are a part of a larger ecosystem, and that human health is closely connected with the health of our environment and planet. Here we provide a short summary on the potential role of air pollution in the spread and worsening

**TABLE 1** Main highlights on air pollution and coronavirus disease 2019 (COVID-19): clearing the air and charting a post-pandemic course

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| Long-term exposure to outdoor air pollution can increase the risk of infection and death from COVID-19 |
| Ambient air pollution particles do not transmit SARS-CoV-2 virus |
| The COVID-19 crisis highlights the close link between human and planetary health |
| COVID-19 lockdown measures have resulted in unprecedented short-term reductions in air pollution, showing a glimpse of what can be achieved |
| Bold and ambitious policies moving away from fossil fuels are needed to ensure long-term reductions in air pollution |
| Strict air pollution policies help tackle climate change by reducing greenhouse gases emissions |
| Cleaner air will provide immediate health benefits to European populations and, in the long run, ensure more healthy and resilient populations, environment and the planet |

of health impacts of COVID-19, and on the influence of the pandemic on air pollution levels in Europe. Moreover, we outline the major lessons learned to chart a healthy post-pandemic course. This work summarises the key messages from a workshop that took place on 2 December, 2020, organised by the European Respiratory Society (ERS), the International Society for Environmental Epidemiology (ISEE) and the Health Effects Institute (HEI), endorsed by the World Health Organization (WHO), and hosted by the European Parliament Lung Health Group and the European Commission (table 1).

## Does air pollution increase COVID-19 severity?

Ecological studies showing simple correlations between regional long-term air pollution levels and COVID-19 mortality rates have given rise to the hypothesis of increased susceptibility of populations living in areas with high air pollution towards COVID-19 [4]. However, these studies, as well as more sophisticated ecological assessments, where mean air pollution levels in an area (county, municipality, *etc*.) were linked to the COVID-19 mortality or case-fatality rates in that area, are inadequate for assessing the potential association between air pollution and COVID-19 [5, 6]. The major limitation of these studies is that they are based on aggregated data for a group and lack detailed information on an individual level, and that results of these types of studies can be erroneously used for inference at the individual level, leading to so-called "ecological fallacy". Statistically, a correlation tends to be larger when an association is assessed at the group level than when it is assessed at the individual level, implying that "ecological fallacy" can lead to overestimation of real effects [7]. Furthermore, results of these studies should be interpreted with caution, as many were published ahead of rigorous peer-review, and may have methodological flaws, such as lack of adjustment for social contacts and mobility, which are important drivers of the COVID-19 epidemic. For example, a US study raised headlines globally in May 2020 by showing that a small increase of 1 $\mu g \cdot m^{-3}$ in long-term average county-level concentrations of $PM_{2.5}$ was associated with a sizeable 15% increase in the county-level COVID-19 death rate [5]. Notably, this estimate was soon corrected to 8% when taking into account dynamics of the disease, in terms of the time of virus introduction in each county, demonstrating the necessity of correcting for those factors. Notably, another US study using the same data, but with more complete control for confounding and spatial autocorrelation, found no associations with $PM_{2.5}$ [6]. Another reason for concern about the generalisability of these early studies conducted during the first months of the pandemic is the dynamics of the geographical differences in COVID-19 burden within the same country, where typically, higher urban COVID-19 burden compared to other areas (coinciding with higher air pollution levels in more urban areas), was reduced or diminished later on. These early studies, using very early, highly aggregated population data, have motivated calls for individual level (cohort) data with careful control for relevant confounders and underlined the importance of rigorous research on air pollution and COVID-19 [8, 9]. A single cohort study with individual-level data was based on US veterans and found a 10% increase in risk of hospitalisation among those who tested positive for COVID-19, for each 1.9 $\mu g \cdot m^{-3}$ increase in $PM_{2.5}$ [10]. Consequently, with the current lack of a substantial number of individual-level studies, attempts to quantify the fraction of global COVID-19 deaths attributed to $PM_{2.5}$ [11] is premature and imprecise [12].

Nevertheless, an association of long-term exposure to air pollution with an increased COVID-19 infection risk and severity is biologically plausible [13]. Experimental studies show that particulate matter exposure can impair cell immunity and weaken host defence mechanisms, increasing susceptibility to respiratory infections [14]. This is caused by direct cellular damage, and indirectly, *via* oxidative stress and inflammation in the lung and systemically [15–17]. Furthermore, $PM_{2.5}$ was found to cause over-expression of ACE (angiotensin-converting-enzyme)-2 receptors [18], the key target of SARS-CoV-2

for human cell entry, thereby promoting viral entry and damage to the cell [19]. The so-called "double hit" model of air pollutants and SARS-CoV-2 interaction therefore proposes that air pollution increases susceptibility to infection and severity of disease *via* facilitating viral entry as well as reducing host defences [20]. Consistent with this, epidemiological studies conducted prior to the COVID-19 pandemic have linked long-term exposure to air pollution to increased risk of respiratory infections such as pneumonia [21]. Furthermore, it is well known that air pollution increases the risk of a number of chronic (respiratory, cardiometabolic) diseases, the same ones reported as the comorbidities increasing the risk of being hospitalised or dying from COVID-19 [22].

## How did COVID-19 lockdown affect air pollution levels in Europe?

Lockdown measures to control the COVID-19 pandemic in Europe in 2020 have resulted in significant reductions in air pollutant emissions and concentrations within days and weeks, though with notable differences between pollutants, countries and cities [2]. The largest decreases in monthly averages of up to 70% in $NO_2$, compared with expected concentrations in the absence of lockdown measures, were observed at traffic monitoring stations in Spain and Italy, while reductions in background $NO_2$ concentrations for selected countries ranged from an average 61% in Spain to 20% in Czech Republic. In some cities, $NO_2$ levels remained relatively low even after lockdown measures were lifted (Milan, Italy), while in others (Athens, Greece) they rapidly returned to "normal" [2]. For $PM_{2.5}$, decreases in background concentrations ranged from 30% in Spain to 9% in the Czech Republic, compared to expected levels. Reductions in $PM_{2.5}$ levels were smaller and less consistent than those for $NO_2$, owing to the generally more varied sources of $PM_{2.5}$, especially in urban areas, including the combustion of fossil fuel for heating, industrial activities, long-range transportation of particles, road traffic and secondary particle formation. Importantly, these reductions were largely short term, with levels rebounding as economic activity increased again.

## What is the role of ambient air pollution in transmission of COVID-19?

There has been speculation that particles in the air may serve as a carrier of SARS-CoV-2 virus-laden respiratory particles, thereby enhancing transmission in areas with higher levels of particulate matter pollution. There have been several studies published linking ambient air pollution ($PM_{2.5}$ or $NO_2$ concentrations) and the number of infection cases based on simple correlation analysis. However, without considering other critical factors driving the pandemic, and in particular severely limited human interactions during lockdowns (for the purpose of halting the spared of the pandemic), the relationships uncovered are likely proxies for other factors, in particular reduction in traffic and industrial activities, hence reduction in the emissions to the air, and in turn concentrations of pollutants in the cites where lockdowns where implemented. Most outdoor air particles are small, within the lower submicrometre size range [23, 24]. A "naked" SARS-CoV-2 virus measures approximately 0.12 µm, however, virus-laden respiratory particles also contain water, mucus and salts [25] and measure up to a few micrometres [26, 27]. Thus, since an aerosolised virus in the air is not "naked", the majority of particles in urban air, which are small [28] cannot be carriers of such bigger, virus-laden particles. Furthermore, the interaction between same size particulate matter and SARS-CoV-2 virus particles is very slow, because their respective concentrations in outdoor air are low, in contrast to indoor air, where the majority of human exposure to SARS-CoV-2 virus occurs. Hence, ambient air pollution particles likely do not play a role in the transmission of SARS-CoV-2.

## What did COVID-19 teach us about planetary health?

The world today is highly interconnected with intensive global flows of people, natural resources and pollution between all parts of the world. This causes major destruction in wildlife populations and ecosystems and increases contact between human populations and wildlife reservoirs of potentially pathogenic bacteria and viruses. Ecosystem destruction leads to species loss and population decline. The disturbed system now starts to favour species with high reproductive rates and short life cycles. They form highly dense populations, typically also highly conductive and prone to transmit diseases. When natural food webs are disturbed, the resource use behaviour in higher trophic levels changes, making them prone to high mutation rate pathogens, such as SARS-CoV-2 type RNA viruses. Reaching a new cyclic balance, *e.g.* for COVID-19, may take at least two years [29]. The unprecedented scale at which animals are raised for food production nowadays also increases the risks of infectious disease spill over from animal to human populations. The COVID-19 crisis highlights the link between human health and healthy ecosystems, underlining the need to take a more comprehensive and planetary approach to health. The Helsinki Declaration of Planetary Health [30] calls upon impact-oriented actions in policies much beyond the health sector, both in the long and short term, and emphasises that both the health of human civilisation and the state of natural systems on which it depends, must become the driver of all policies. This requires knowledge about emergence to spread, health impact, socio-political response and recovery plan from multidisciplinary research.

The tragedy of COVID-19 exposes our vulnerability as a global society and our dependence on healthy ecosystems. The pandemic has made us reflect on how we can repair the systemic failure that brought us here, and how can we restore a healthy human–nature relationship to best protect ourselves and future generations from the next man-made crisis, whether it is caused by infectious agents, climate change or pollution. The "WHO Manifesto for a Healthy Recovery from COVID-19" [31] provides six prescriptions for a green recovery, including: 1) recovering relationship with our nature through biodiversity; 2) providing access to safe water and basic hygiene; 3) accelerating transition to renewable energy and stopping fossil fuel combustion; 4) promoting sustainable food production, consumption and waste management; 5) building healthy and sustainable cities with health in focus of urban planning; and 6) making sure that stimulus packages for economic recovery are not funding the fossil fuel-based economy. Tackling causes of air pollution is intricately connected with some of these prescriptions, and is an urgently needed investment that will reduce susceptibly and mortality from COVID-19 and other respiratory pathogens, while also reducing the 6.7 million premature deaths due to air pollution annually globally.

Even before it emerged that air pollution may be a risk factor for more severe illness from COVID-19, the pandemic alerted us to a number of issues: 1) the importance of lung health, and our vulnerability to infectious respiratory pathogens that can spread rapidly in our highly mobile society; 2) the massive disparities in social determinants of health that are clearly visible around the world; and 3) society's remarkable willingness to make severe personal and economic sacrifices for the sake of health, especially when decision-making is transparent and evidence-based. In the joint statement "Bounce Back Better: Sustainable Strategies for a Healthy Recovery from the Pandemic" [32] from the ERS, American Thoracic Society and ISEE, professional societies dedicated to promoting respiratory and environmental health, the COVID-19 pandemic is viewed as a historic opportunity to rethink societal priorities towards clean energy and sustainability in all areas. Similarly, "COVID-19 Pandemic: A Wake-Up Call for Clean Air" calls for that cleaning up of air as a necessary ingredient of post COVID-19 recovery, for improving respiratory health and equality worldwide [33].

The European Commission adopted a European Green Deal (EGD) in December 2019, just ahead of the COVID-19 crisis, as a strategy to be the first climate neutral (reducing greenhouse gas emissions as much as possible and compensating for any remaining emission) continent in the world. An integral part of the EGD is "A Zero Pollution Ambition", at the core of which is clean air. Within the EGD, the European Commission has proposed to revise the EU Air Quality Standards to align them more closely with the WHO Air Quality Guideline recommendations [34], of which a new update will be published in 2021. It will be important that the latest scientific evidence on the health effects of air pollution is presented and considered in the legislative discussions. The impact of COVID-19 lockdowns on air quality was notable, but came at a significant short-term economic disruption. Seeing that we can achieve drastic air pollution reductions, we need to build those into structural changes as part of a long-term green recovery strategy, including the key principles of "do no harm", zero pollution and clean air objectives.

## Conclusion

Air pollution can increase the severity and risk of death from COVID-19 infection, by compromising the individual immune system's ability to fight infections and by increasing the risk of predisposing chronic diseases. We need carefully designed studies at the individual level, preferably from several countries using the same protocols and design, in order to quantify the burden of COVID-19 due to air pollution. The COVID-19 pandemic has painfully demonstrated the close interconnectedness of a fossil fuel-based economy, climate change, air pollution and emerging infectious diseases, and provides compelling additional motivation for stricter air pollution regulation, as an integral and imperative part of post pandemic policies, ensuring more healthy and resilient populations. The unprecedented decreases in air pollution around Europe during the COVID-19 lockdown showed an example of what can be achieved. As air pollution is increasing again back to pre-pandemic levels, we need bold policies and structural changes in our cities, transportation, industry, agriculture and energy systems to ensure long-term reductions in air pollution and greenhouse gases, moving away from fossil fuels. As cleaner air policies will provide immediate substantial health benefits to European citizens, their co-benefits in tackling climate change crises make them central to ensuring more healthy and resilient populations, environment and the planet.

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