Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Air pollution reduction and mortality benefit during the COVID-19 outbreak in China

To control the coronavirus disease 2019 (COVID-19) outbreak, China adopted stringent traffic restrictions and self-quarantine measures, first in Wuhan and neighboring cities beginning Jan 23, 2020, and then 2 days later in all provinces in China (figure). The countrywide ban on traffic mobility greatly reduced transportation emissions, whereas emissions from residential heating and industry remained steady or slightly declined. In this Comment, we examine the change in air pollution and the potentially avoided cause-specific mortality during this large-scale quarantine.

As of March 14, 2020, new confirmed cases of COVID-19 in China reported by the National Health Commission decreased to 20 (four cases from Wuhan) (figure). By this time, most Chinese provinces had lowered the level of emergency responses. We thus defined the quarantine period as Feb 10 to March 14 and the period before quarantine as Jan 5 to Jan 20. Based on evidence from previous years, we excluded the Chinese New Year holidays to avoid reductions in air pollution that were unrelated to the quarantine (figure). We obtained daily concentrations of nitrogen dioxide (NO2) and PM2·5 in 367 Chinese cities from Jan 1, 2016, to March 14, 2020. We focused on NO2 and PM2·5 because both are traffic-related air pollutants whose emissions were substantially reduced as a result of the traffic bans and home quarantine, and both had well established concentration-response functions (CRFs) from one of the largest epidemiological studies in China on short-term mortality effects. In addition to total non-accidental and cardiovascular mortality, the cause-specific mortality for hypertensive disease, coronary heart disease, stroke, and chronic obstructive pulmonary disease (COPD) was also calculated. The attributable fraction (AF) method was used to estimate the daily avoided cause-specific mortality from the air pollution reduction. AF is defined as follows:

\[
AF = 1 - e^{-\beta \Delta c}
\]

\(\beta\) is the cause-specific coefficient of the CRF and \(\Delta c\) is the air pollution changes due to the quarantine. AF is then multiplied by the daily cause-specific number of deaths and the total number of days during the quarantine period (34 days) to estimate the cause-specific avoided deaths.

We found that, because of the quarantine, NO2 dropped by 22·8 µg/m³ in Wuhan and 12·9 µg/m³ in China. PM2·5 dropped by 1·4 µg/m³ in Wuhan but decreased by 18·9 µg/m³ across 367 cities (appendix p 3). The smaller reduction in PM2·5 in Wuhan is due to a similar decreasing trend in PM2·5 in 2016–2019. The pronounced decline in NO2 across China during the quarantine period was also detected by the Copernicus Sentinel-5P satellite with the NO2 tropospheric column density (figure).

We estimate that improved air quality during the quarantine period avoided a total of 8911 NO2-related deaths (95% CI 6950–10 866), 65% of which were from cardiovascular diseases (hypertensive disease, coronary heart disease, and stroke) and COPD (figure, appendix p 4). Furthermore, we estimate that reduction in PM2·5 during the quarantine period avoided a total of 3214 PM2·5-related deaths (95% CI 2340–4087) in China, 73% of which were from cardiovascular diseases.
and COPD. Similar estimates were found with an alternative before quarantine period from Jan 1 to Jan 20 (appendix pp 3–4).

Our estimates should be interpreted with caution because of the potential overlap between PM$_{2.5}$ and NO$_2$-related mortality and the effect on mortality rate from disrupted health-care systems during the quarantine, which could have impacted the timely treatment of patients with chronic diseases. We used cause-specific CRFs from single-pollutant models because coefficients from two-pollutant models were not available.\(^2\) Although there might have been some risk of double counting, results from published literature suggest that this risk is small because effect estimates for NO$_2$ and PM$_{2.5}$ were similar between single-pollutant and two-pollutant models.\(^3,6\) Moreover, similar to previous epidemiological studies with outdoor air pollution,\(^7\) exposure measurement error is inevitable since most people stayed indoors.

Our estimates suggest that interventions to contain the COVID-19 outbreak led to improvements in air quality that brought health benefits in non-COVID-19 deaths, which could potentially have outnumbered the confirmed deaths attributable to COVID-19 in China (4633 deaths as of May 4, 2020).\(^8\) Our findings show the substantial human health benefits related to...
Comment

...vascular disease morbidity and mortality that can be achieved when aggressive control measures for air pollution are taken to reduce emissions from vehicles, such as through climate mitigation-related traffic restrictions or efforts to accelerate the transition to electric vehicles.

We declare no competing interests. KC and MW contributed equally. KC had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Editorial note: the Lancet Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

Copyright © 2020 The Author(s). Published by Elsevier Ltd. This is an Open Access article under the CC BY 4.0 license.

*Kai Chen, Meng Wang, Conghong Huang, Patrick L Kinney, Paul T Anastas
kai.chen@yale.edu
Yale School of Public Health, New Haven, CT 06520, USA (KC, PTA); University at Buffalo School of Public Health and Health Professions, Buffalo, NY, USA (MW, CH); Boston University School of Public Health, Boston, MA, USA (PLK); and Yale School of Forestry and Environmental Studies, New Haven, CT, USA (PTA)

1 China Ministry of Ecology and Environment. Heavy air pollution in Beijing-Tianjin-Hebei and surrounding areas and five experts answering the cause of pollution. 2020. http://www.mee.gov.cn/xxgk2018/xxgk/xgjz/202011/20201125_62584.html (accessed March 15, 2020; in Chinese).
2 Chen R, Yin P, Meng X, et al. Fine particulate air pollution and daily mortality: a nationwide analysis in 272 Chinese cities. Am J Respir Crit Care Med 2017; 196: 73–81.
3 Chen R, Yin P, Meng X, et al. Associations between ambient nitrogen dioxide and daily cause-specific mortality: evidence from 272 Chinese cities. Epidemiology 2018; 29: 482–89.
4 Zhang Q, Zheng Y, Tong D, et al. Drivers of improved PM2.5 air quality in China from 2013 to 2017. Proc Natl Acad Sci 2019; 116: 24463.
5 Anenberg SC, Horowitz LW, Tong DQ, West JJ. An estimate of the global burden of anthropogenic ozone and fine particulate matter on premature human mortality using atmospheric modeling. Environ Health Perspect 2010; 118: 1189–95.
6 Liu C, Chen R, Sera F, et al. Ambient particulate air pollution and daily mortality in 652 cities. N Engl J Med 2019; 381: 705–15.
7 Wang M, Aaron CP, Madrigano J, et al. Association between long-term exposure to ambient air pollution and change in quantitatively assessed emphysema and lung function. JAMA 2019; 322: 546–56.
8 National Health Commission of China. Update on the novel coronavirus pneumonia outbreak. 2020. http://www.nhc.gov.cn/xcs/yqtb/list_gbdl. shtml (accessed May 5, 2020; in Chinese).