Pandemic air quality due to weather, not just lockdowns

June 23 2021

Credit: Unsplash/CC0 Public Domain

Headlines proclaiming COVID lockdowns drastically reduced pollution were mostly referring to nitrogen dioxide, NO_2, a reactive gas emitted from burning fuel. There had been less understanding of how lockdowns affected PM2.5, tiny particulate matter that can penetrate a person's lungs, leading to a host of health problems, including increased risk for heart attack and cancer.

"PM 2.5 is the leading global environmental determinant of longevity. It is a key pollutant of concern for health," said Randall Martin, the Raymond R. Tucker Distinguished Professor in the Department of Energy, Environmental & Chemical Engineering in the McKelvey School of Engineering at Washington University in St. Louis.

New research from Martin's lab, in collaboration with the Goddard Space Flight Center, California Institute of Technology and Dalhousie University in Nova Scotia, mapped PM 2.5 levels across China, Europe and North America. Using satellite data, ground-based monitoring and an innovative computer modeling system, researchers found mostly slight changes in PM 2.5—with one exception.

The majority of changes they found were not driven by lockdown, but by the natural variability of meteorology. Their results were published June 23 in the journal *Science Advances.*

The meteorological effects that we experience everyday also affect PM2.5 variability, Martin said.

"The shorter time period, the more susceptible PM 2.5 is to meteorology," he said.

During the pandemic, among the images of overflowing ICUs and empty grocery store shelves, there were some photographic bright spots: before and after pictures accompanied articles proclaiming air quality improved because people were staying home.

The visuals were striking—both on the ground, where blue skies shone over LA highways, and from space—data from NASA satellites made clear atmospheric reduction in nitrogen dioxide.

"People automatically started wondering, 'What's the picture for PM 2.5?'" said Melanie Hammer, a visiting research associate in Martin's lab. That was the obvious question not just because particulate matter often comes from the same sources as NO_2, but because NO_2 can form PM 2.5.

"NO_2 is considered a secondary source of PM 2.5," Hammer said. When it's emitted, NO_2 interacts with other chemicals in the atmosphere and can form PM 2.5. A few early studies looked at data gathered from ground monitoring sites, which test the surrounding air, but those ground sites are few and far between and incapable of piecing together a bigger picture.

Only about a fraction of the world's population live in countries that have more than three PM 2.5 monitors per million people. Most of the population live in areas with no monitoring.

"We decided to look again, using a more complete picture from satellite images," Hammer said. The images, provided by NASA, contain data for columns of atmosphere spanning the ground to the edge of space. These data, referred to as aerosol optical depth, related to surface PM 2.5 concentrations using the chemical transport model GEOS-Chem, which simulates the composition of the atmosphere; the reactions and relationships of its different constituents; and the way they move through the air.

Researchers focused on three regions that do have extensive ground monitoring systems in place: North America, Europe and China, and compared monthly estimates of PM 2.5 from January to April in 2018, 2019 and 2020.

When they compared PM 2.5 levels over the three years during the months that coincided with each region's lockdown phases, there weren't many clear signals over North America or Europe.

"We found the most clearly detectable signal was a significant reduction over the North China Plain, where the most strict lockdowns were concentrated," she said.

To figure out whether lockdown was responsible for that signal, and several smaller ones dotted around the areas surveyed, the team ran "sensitivity simulations" using GEOS-Chem, changing parameters to see which scenario most closely matched reality.

They simulated a scenario where emissions were held constant and meteorology was solely responsible for year over year changes in PM 2.5.

"We found that that explained a large part of the differences we were seeing," Hammer said. They also ran a simulation in which they reduced transportation-related emissions and other man-made sources of NO_2, mirroring lockdown, when fewer people were driving and fewer industrial sites were operational.

"On its own, that actually didn't really explain much at all," Hammer said. But combining the two, "That's when the signal over the North China Plain stood out."

Hammer suspects that the change in PM 2.5 levels over the North China Plain was so striking because of how polluted it tends to be in "normal" times. "You're probably more likely to see a larger reduction in a region that has higher concentrations to begin with."

In a way, that highlights a relevant point that may not at first be intuitive:

Average PM 2.5 levels have been dropping steadily in North America and Europe. "It's just harder to perturb really low concentrations," Hammer said.

But it also underscores the complex relationship between NO_2 and PM 2.5. Although NO_2 does interact with other atmospheric chemicals to form PM 2.5, the two do not have a linear relationship; twice as much NO_2 in the atmosphere does not necessarily lead to twice as much PM 2.5.

Hammer said, intuitively, she did expect to see more of a reduction in PM 2.5 levels. "It was kind of a surprise that meteorology played such a dominant role.

"Turns out, it's a pretty complex relationship and it doesn't always behave how you would expect."

More information: "Effects of COVID-19 lockdowns on fine particulate matter concentrations" *Science Advances* (2021). advances.sciencemag.org/lookup … .1126/sciadv.abg7670

Provided by Washington University in St. Louis