Research shows Clean Air Act is likely responsible for dramatic decline in atmospheric organic aerosol

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The air we breathe contains particulate matter from a range of natural and human-related sources. Particulate matter is responsible for

thousands of premature deaths in the United States each year, but legislation from the U.S. Environmental Protection Agency (EPA) is credited with significantly decreasing this number, as well as the amount of particulate matter in the atmosphere. However, the EPA may not be getting the full credit they deserve: new research from MIT's Department of Civil and Environmental Engineering (CEE) proposes that the EPA's legislation may have saved even more lives than initially reported.

"In the United States, the number of premature deaths associated with exposure to outdoor particulate matter exceeds the number of car accident fatalities every year. This highlights the vital role that the EPA plays in reducing the exposure of people living in the United States to harmful pollutants," says Colette Heald, associate professor of CEE and Earth, Atmospheric and Planetary Sciences.

The EPA's 1970 Clean Air Act and additional amendments enacted in 1990 address the health effects of particulate matter, specifically by regulating emissions of air pollutants and promoting research into cleaner alternatives. In 2011 the EPA announced that the legislation was responsible for a considerable decrease in particulate matter in the atmosphere, estimating over 100,000 lives saved every year from 2000 to 2010. However, the report did not consider organic aerosol, a major component of atmospheric particulate matter, to be a large contributor to the decline in particulate matter during this period. Organic aerosol is emitted directly from fossil fuel combustion (e.g. vehicles), residential burning, and wildfires but is also chemically produced in the atmosphere from the oxidation of both natural and anthropogenically-emitted hydrocarbons.

The CEE research team, including Heald; Jesse Kroll, an associate professor of CEE and of chemical engineering; David Ridley, a research scientist in CEE; and Kelsey Ridley SM '15, looked at surface

measurements of organic aerosol from across the United States from 1990 to 2012, creating a comprehensive picture of organic aerosol in the United States.

"Widespread monitoring of air pollutant concentrations across the United States enables us to verify changes in air quality over time in response to regulations. Previous work has focused on the decline in particulate matter associated with efforts to reduce acid rain in the United States. But to date, no one had really explored the long term trend in organic aerosol," Heald says.

The MIT researchers found a more dramatic decline in organic aerosol across the U.S. than previously reported, which may account for more lives saved than the EPA anticipated. Their work showed that these changes are likely due to anthropogenic, or human, behaviors. The researchers' findings were published in a paper, "Causes and Consequences of decreasing atmospheric organic aerosol in the U.S." in the *Proceedings of the National Academy of Sciences* the week of December 25.

"The EPA report showed a very large impact from the decline in particulate matter, but we were surprised to see a very little change in the organic aerosol concentration in their estimates," explains David Ridley. "The observations suggest that the decrease in organic aerosol had been six times larger than estimated between 2000 and 2010 in the EPA report."

Using data from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network, the researchers found that organic aerosol decreased across the entire country in the winter and summer seasons. This decline in organic aerosol is surprising, especially when considering the increase in wildfires. But the researchers found that despite the wildfires, organic aerosols continue to decline.

The researchers also used information from the NASA Modern-Era Retrospective Analysis for Research and Applications to analyze the impact of other natural influences on organic aerosol, such as precipitation and temperature, and found that the decline would be occurring despite cloud cover, rain, and temperature changes.

The absence of a clear natural cause for the decline in organic aerosol suggests the decline was the result of anthropogenic causes. Further, the decline in organic aerosol was similar to the decrease in other measured atmospheric pollutants, such as nitrogen dioxide and carbon monoxide, which are likewise thought to be due to EPA regulations. Also, similarities in trends across both urban and rural areas suggest that the declines may also be the result of behavioral changes stemming from EPA regulations.

By leveraging the emissions data of organic aerosol and its precursors from both natural and anthropogenic sources, the researchers simulated organic aerosol concentrations from 1990 to 2012 in a model. The researchers found that more than half of the decline in organic aerosol is accounted for by changes in human emissions behaviors, including vehicle emissions and residential and commercial fuel burning.

"We see that the model captures much of the observed trend of organic aerosol across the U.S., and we can explain a lot of that purely through changes in anthropogenic emissions. The changes in organic aerosol emissions are likely to be indirectly driven by controls by the EPA on different species, like black carbon from fuel burning and nitrogen dioxide from vehicles," says Ridley. "This wasn't really something that the EPA was anticipating, so it's an added benefit of the Clean Air Act."

In considering mortality rates and the impact of organic aerosol over time, the researchers used a previously established method that relates exposure to particulate matter to increased risk of mortality through

different diseases like cardiovascular disease or respiratory disease. The researchers could thus figure out the change in mortality rate based on the change in particulate matter. Since the researchers knew how much organic aerosol is in the particulate matter samples, they were able to determine how much changes in organic aerosol levels decreased mortality.

"There are costs and benefits to implementing regulations such as those in the Clean Air Act, but it seems that we are reaping even greater benefits from the reduced mortality associated with particulate matter because of the change in organic aerosol," Ridley says. "There are health benefits to reducing organic aerosol further, especially in urban locations. As we do, natural sources will contribute a larger fraction, so we need to understand how they will vary into the future too."

More information: D. A. Ridley el al., "Causes and consequences of decreasing atmospheric organic aerosol in the United States," *PNAS* (2017). www.pnas.org/cgi/doi/10.1073/pnas.1700387115

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