Smoke signals

The national death toll from wildfire smoke reveals the risks posed by even very low exposure to air pollution

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Key messages

- **Wildfire smoke is a major source of air pollution in the United States, resulting in serious harm to health.**
- **Wildfire smoke travels long distances, imposing health burdens on people nationwide and making wildfire risk mitigation a national concern.**
- **The incremental mortality effects of increased air pollution are highest when the air is relatively clean.**
- **Large health benefits can likely be gained from additional improvements in air quality, even in places where air pollution levels are relatively low.**
- **Current air pollution policies that focus on the most polluted areas may benefit from incorporating these findings into their approaches.**

Extensive research over many decades has documented the serious health effects of exposure to air pollution. Based on this evidence, countries around the world set air quality standards intended to protect health. Such regulations have led air pollution levels to plummet in the United States and many other countries.

Even now, however, questions remain about what level of exposure to air pollution is safe, and whether regulations should seek to make the air cleaner. What would be the optimal policy? How much should the nation spend to further reduce air pollution, and how much would public health benefit from such efforts?

The conventional wisdom among researchers and policy makers is that the marginal effects of air pollution on health progressively increase as pollution levels grow. Under this thinking, the same level of reduction in air pollution offers greater health benefits when air pollution levels are high than when they are low. From this perspective, once air pollution levels fall below some threshold, additional reductions would offer only small or no improvements to human health.

The traditional approach to air quality regulation in the United States aligns with this premise. For example, under Clean Air Act, the U.S. Environmental Protection Agency has set standards for concentrations of fine particulate matter, microscopic particles that are small enough to be inhaled and cause serious health problems.

PHOTO ABOVE: Lava Mountain Fire, Wyoming, 2016

Areas that exceed these standards face penalties, but regulations do not require or promote further improvements beyond these standards.

> "Our findings challenge the prevailing view that low levels of air pollution exposure are safe.

Our recent research challenges conventional wisdom and standards embedded in current regulations that assume, explicitly or implicitly, that only small benefits surface from improving air quality when air pollution levels are low. Our work shows that the relationship between air pollution and health follows a distinctly different pattern and suggests that changes to how researchers and policy makers approach the problem may improve outcomes.

Small improvements in "clean" air have big incremental benefits.

We show that the health effects of exposure to air pollution are large, on average, as previous studies have found. When we compare how the impacts differ at low and high levels of pollution exposure, we find that there are larger incremental health benefits from an improvement in relatively clean air compared to a similarly sized improvement in dirtier air.

These findings come from a new, in-depth exploration of the health impacts of exposure to wildfire smoke plumes (Miller, Molitor, and Zou 2021). Our study provides insight for determining the risk to health from air pollution at both high and low levels of exposure and for devising optimal, cost-effective pollution regulations.

Where there is smoke, there is not necessarily fire.

Wildfires and the smoke they generate are a major pollution source nationwide (Figure 1). Though large, intense wildfires most frequently occur in the American West, winds carry smoke plumes from wildfires throughout the country. Smoke plumes frequently cover the Midwest, drifting from wildfires in the American West and Canada. Southern states also regularly experience smoke events from both local fires and wildfire smoke drifting up from Central and South America.

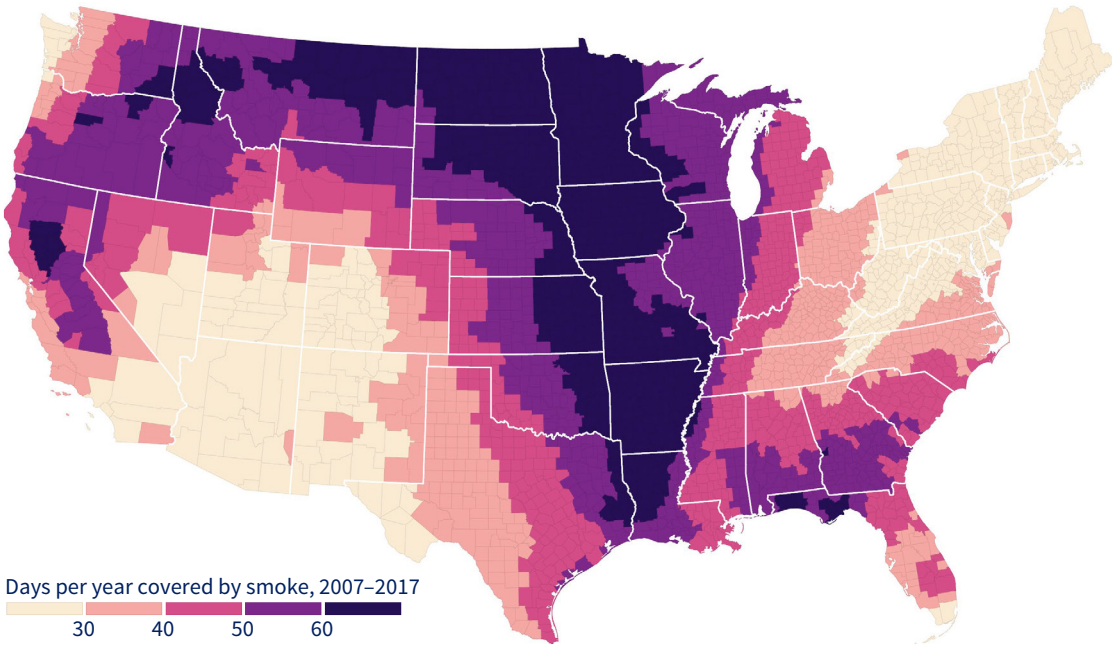

Figure 1. The figure shows the geographic distribution of days of smoke plume coverage per year across U.S. counties during the sample period, 2007–2017. On average, counties experienced 38 days of smoke coverage per year.

During the decade we studied (from 2007 to 2017), U.S. counties were covered by smoke an average of 38 days per year, amounting to roughly one out of every ten days.

The extent to which wildfires contribute to air pollution in the United States may come as a surprise. In the decade we examined, total emissions accounted for roughly 20 percent of national ambient concentrations of fine particle air pollution known as $PM_{2.5}$. These particles—so named because they are less than 2.5 micrometers in diameter, roughly 3 percent of the diameter of a human hair—are especially harmful because they can penetrate deep into the lungs and bloodstream, damaging the lungs and heart. Children, the elderly, and those with lung or heart disease are among the most vulnerable.

The impact of wildfires is projected to grow under climate change, as the number, intensity, and severity of wildfires increase.

> "The United States and other wealthy countries that already have relatively clean air should continue to work toward improving air quality.

Exposure to wildfire smoke significantly increases the number of deaths of elderly people nationwide.

To understand the health implications of wildfire smoke exposure, we combined satellite-based measures of smoke plume locations with data on deaths among adults aged 65 and older living throughout the United States. We found that exposure to wildfire smoke significantly increases deaths among this group during the three days following the arrival of a wildfire plume. This increase is not followed by reductions afterward, suggesting that smoke's damage is not merely hastening the deaths of those who are already sick. In total, exposure to smoke plumes accounts for roughly one of every 125 elderly deaths, representing over 17,000 premature U.S. elderly deaths per year.

The incremental effects of wildfire smoke pollution are highest at low levels.

To understand how the effects of air pollution differ at lower versus higher levels of exposure, we studied what happens when plumes of different intensities drift into a county. To do so, we categorized each county's smoke exposure on a given day into one of nine different categories: one category for no smoke exposure, and the other eight categories reflecting light to thick smoke exposure. Relative to no smoke exposure, the lightest smoke exposure increased ground-level air pollution concentrations in a county by less than 10%. By contrast, the thickest smoke plumes increased air pollution to a strikingly greater degree—by about 160%.

We then calculated how many premature deaths were caused by exposure to each level of wildfire smoke intensity, relative to no smoke exposure. As shown in Figure 2, premature deaths rise quickly at low levels of smoke exposure, reflecting large incremental effects of air pollution. But at higher levels of exposure, deaths increase at a slower rate, pointing to smaller incremental effects. The effect of an additional unit of pollution near the lowest exposure is more than three and a half times as large as the effect from an additional unit of pollution at higher exposures.

These findings suggest that reducing air pollution at even low levels of exposure has higher health benefits than previously has been recognized. They also suggest that the benefits from additional air quality improvements are likely to remain high or even grow as the air becomes cleaner.

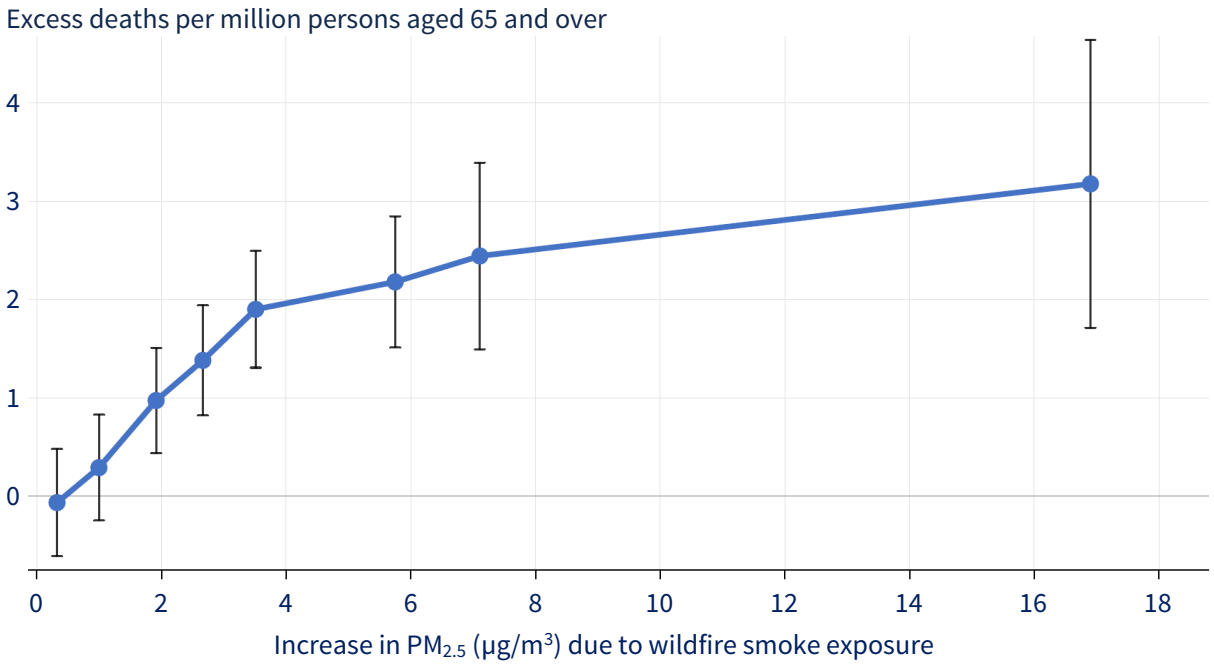

Figure 2. The figure shows the how excess elderly deaths per million relate to increases in $PM_{2.5}$ caused by exposure wildfire smoke events of varying intensities. ($PM_{2.5}$ is measured in micrograms—one-millionth of a gram—per cubic meter of air, or $\mu g/m^3$.) Incremental effects of increases in air pollution are greater when the air is relatively clean than when the air is already polluted to a greater degree.

Rethinking air pollution policy

Our work provides the most powerful evidence yet that the concept of a "safe" pollution threshold level, below which no adverse effects to health occur, is misguided. Our findings suggest that reducing air pollution below levels that are currently classified as low or "safe" may bring substantial health benefits.

Figure 3 illustrates how our findings relate to the standard economic framework for setting "socially optimal" air pollution standards. It is beneficial to allow pollution to increase whenever the benefit from doing so (depicted by the orange "marginal benefit" curve) is greater than the cost (depicted by the blue "marginal cost" curve).[1] The optimal level of pollution is therefore given by the point where the orange and blue curves meet.

The framework on the left (Panel A) illustrates the prevailing thinking that underlies current U.S. pollution regulations. In it, the marginal cost of pollution (blue line), slants up. It starts at a very low level, and then, past some "safe" threshold, angles up sharply: the incremental cost (e.g., harm to health) caused by additional pollution increases as pollution levels grow. By contrast, our results suggest that the incremental cost of additional pollution decreases with the level of pollution, implying that the blue line slants down. This case is depicted in the framework on the right (Panel B): the marginal cost imposed by additional pollution is highest when levels of pollution are low, and it declines as pollution levels increase. The result is that the intersection of the blue and orange lines occurs at a lower level of pollution than in the conventional analysis on the left.

1 Since pollution occurs as a by-product of production, the benefit of additional pollution includes the value of the additional output produced. The cost of pollution takes into account the harmful effects of pollution on health, environmental amenities, etc.

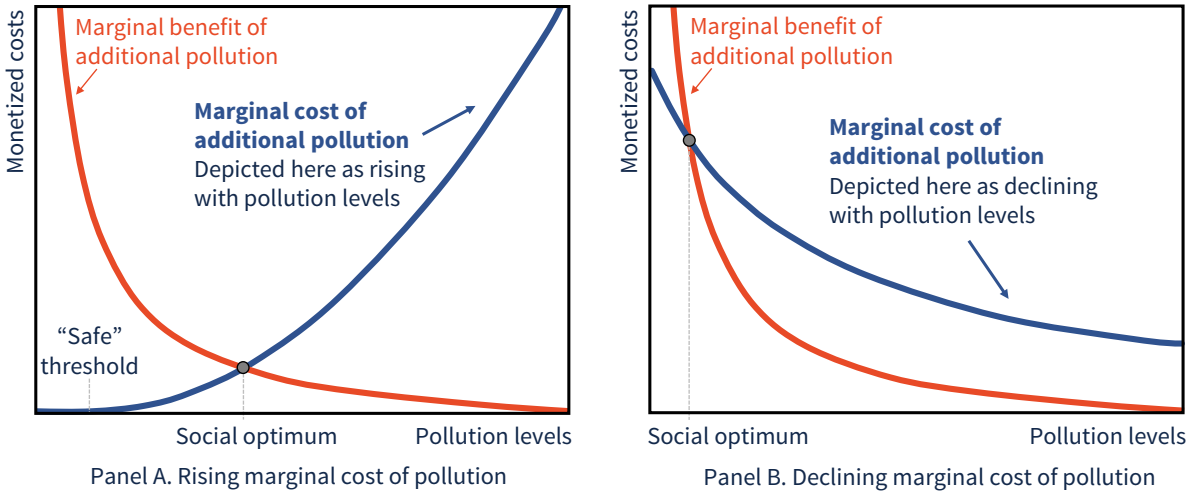

Figure 3. Figure adapted from Pope III et al. (2015). The framework at the left reflects thinking underlying current policies. The framework on the right illustrates patterns revealed by our research, illustrating that the socially optimal level of pollution is lower than previously had been thought.

We are not alone in questioning whether the benefits of pollution abatement fall as the air becomes cleaner. Prior studies have found such patterns when examining the relative mortality risk of individuals living in higher- versus lower-pollution areas, or individuals exposed to different levels of cigarette smoke (Pope III et al. 2015).[2] However, it is possible that these patterns could reflect differences in the underlying health of people who live in high-pollution settings, for reasons other than the effect of the pollution itself. Still, even as air quality in the United States has improved, studies continue to find that the damages of pollution are high (Deryugina et al. 2019). Our research builds on these prior studies by providing a direct examination of how health responses differ when individuals are exposed to lower versus higher levels of air pollution.

Based on our findings, we argue that the United States and other wealthy countries that already have relatively clean air should continue to work toward improving air quality. Air quality initiatives should continue to identify regions with poor air quality where there is substantial scope for improvement. At the same time, investments in reducing pollution should not ignore areas with relatively good air quality, where the benefits of cleaner air may be particularly high.

Conclusions

Wildfire smoke is a major source of air pollution. Plumes of wildfire smoke drift across the country, taking a toll on health nationwide—not just in the West. Our work on the health effects of wildfire smoke sheds new light on the relationship between air pollution and health. Harm from air pollution increases more quickly when pollution levels are low. By contrast, health damages begin to level off at higher levels of pollution. Our findings challenge the prevailing view that low levels of exposure are safe. They suggest that improving air quality, even in relatively clean areas, can lead to greater incremental health benefits than previously has been believed. These findings are important for understanding how to devise optimal, cost-effective policies to address air pollution.

2 For a more complete review of the related literature, see Miller, Molitor and Zou (2021).

References

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