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To reduce Alzheimer's disease, clean up the air

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KEY TAKEAWAYS

- Research indicates that tiny airborne particulates of diesel exhaust, organic compounds, ash, and similar materials—known as $PM_{2.5}$—can cause Alzheimer's disease and related dementias.
- A 15-year nationwide study of Medicare beneficiaries estimates that federal standards limiting airborne $PM_{2.5}$ levels led to 182,000 fewer Alzheimer's cases in 2013, producing $214 billion in benefits.
- Despite the lack of medical treatment for dementia, additional technological innovation and environmental regulations can reduce its prevalence by improving air quality.

Alzheimer's disease and related forms of dementia are devastating, irreversibly robbing people of their ability to care for themselves, recognize family and friends, and understand the world around them. These illnesses are also widespread. Figure 1 shows that their prevalence climbs sharply with age, afflicting over a third of those above age 80 in the U.S.

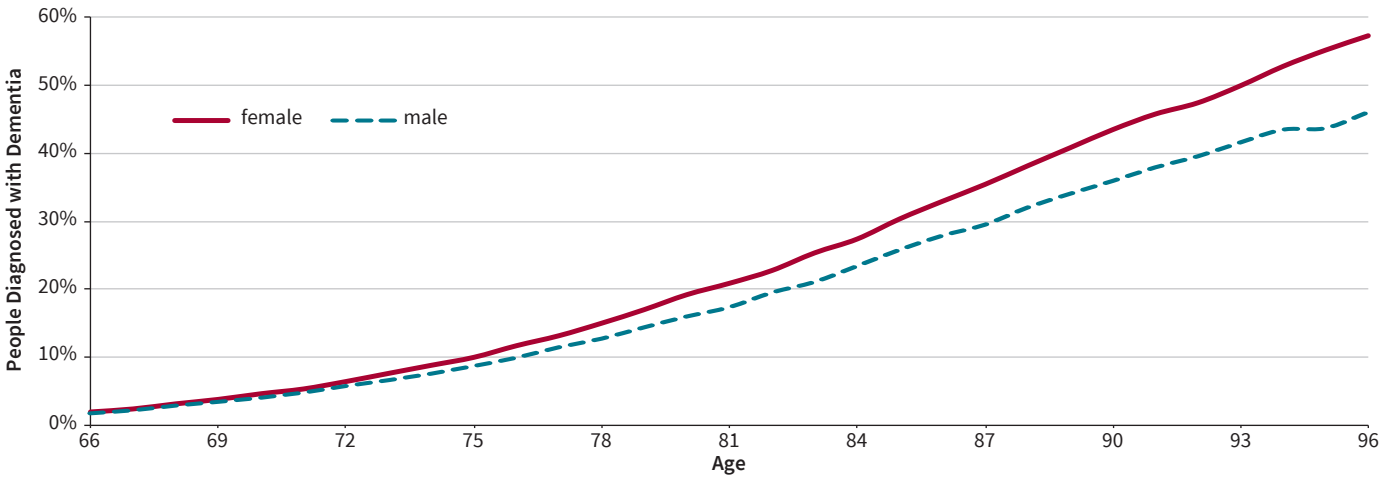
Because of its severity and prevalence combined with the aging of the U.S. population, the Centers for Disease Control has labeled dementia as a public health crisis. Over 5 million dementia patients in the U.S. spent $277 billion on health care. And the cost doesn't end there. In addition to the years and quality of life lost by those with the disease, millions of family members and others spend valuable time and effort caring for them.

The causes of dementia are not well understood. But medical research suggests that air pollution may play a role even though the precise biological pathways remain unknown.

Prior research indicates that long-term exposure to higher concentrations of airborne particles smaller than 2.5 microns in diameter ($PM_{2.5}$)—about 1/30th of the width of a human hair—is associated with higher rates of Alzheimer's and dementia diagnoses. For example, a study in London found a positive association between a neighborhood's $PM_{2.5}$ levels and the prevalence of dementia (Carey et al. 2018). Medical research has also found that tiny particles of materials such as ash, industrial waste, and diesel exhaust build up in the brain and cause inflammation, but the link between this and Alzheimer's disease remains uncertain (Maher et al. 2016; Underwood 2017).

My Arizona State University colleagues Kelly Bishop and Nicolai Kuminoff and I recently carried out the first large-scale nationwide study designed to evaluate whether $PM_{2.5}$ increases the prevalence of dementia (Bishop et al. 2019). Our research tracks the health and residential locations of more than a

Figure 1



million people on Medicare over 15 years and is designed to isolate the effects of $PM_{2.5}$ from spurious correlations that may arise for reasons other than pollution exposure causing dementia.

The results are clear: Long-term exposure to $PM_{2.5}$ substantially increases a person's risk of developing Alzheimer's disease and related dementia. We estimate that a 10 percent increase in average $PM_{2.5}$ exposure over a decade boosts the probability of developing Alzheimer's or related dementias by around 8 percent, or 1.7 percentage points. This is equivalent to the increase in risk associated with a woman aging from 75 to 76.5 and is about twice as large as the increased risk associated with having hypertension, a previously known risk factor for dementia.

These results mean that the benefits of improving air quality are greater than previously known. The good news is that during our study period of 1999 to 2013, Americans age 65 and over experienced a 40 percent average reduction in the $PM_{2.5}$ levels at their homes. These gains were due to improvements in technology, people moving to cleaner neighborhoods, and stricter regulation by the Environmental Protection Agency (EPA). The EPA began regulating counties' $PM_{2.5}$ levels in 2004, setting a threshold of 15.05 micrograms per cubic meter. Counties that failed to meet these standards were subject to additional regulations, accelerating the improvement in air quality in some neighborhoods more than others.

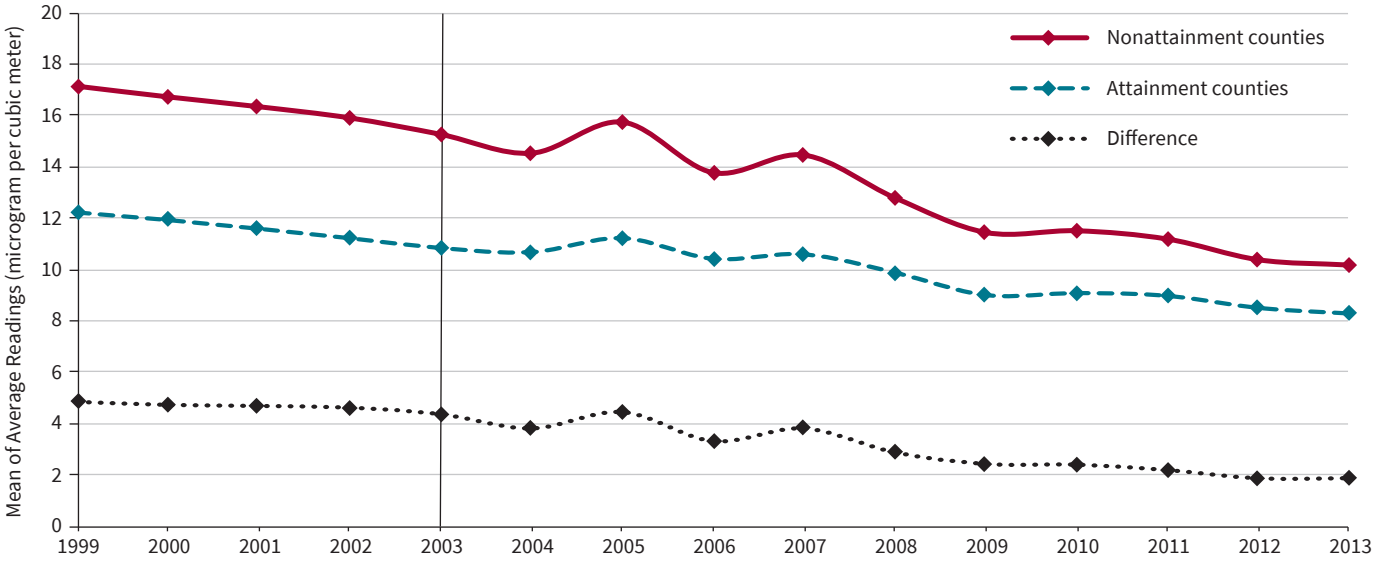
We estimate that as a result of these regulations specifically, the U.S. had 182,000 fewer cases of dementia in 2013, with a value of this reduced dementia estimated at $214 billion. We also find evidence that further tightening the EPA's $PM_{2.5}$ standards would reduce dementia rates even more.

A natural experiment

Our study is based primarily on three sources of data: (1) EPA measurements of $PM_{2.5}$ concentrations from 1,900 monitors across the country; (2) 15 years of records of Medicare beneficiaries from the U.S. Centers for Medicare and Medicaid Services (CMS), including demographic information, addresses, and medical records for each year; and (3) U.S. Census data on neighborhood characteristics.

We start with a random sample of 10 percent of all Medicare beneficiaries. We feature results from an analysis of 1.26 million people who were on traditional Medicare in 2013 and did not have dementia in 2004. When we include those who died between 2004 and 2013 or include those who were on managed-care plans

Figure 2



known as Medicare Advantage, our results show even larger effects of $PM_{2.5}$ on Alzheimer's and dementia than what we report here.

We use 2004 as the baseline year because that is when the EPA started enforcing its $PM_{2.5}$ standards. Because the EPA's enforcement affected places differently, it created a special opportunity to disentangle the effects of air pollution on dementia from the effects of other risk factors that may be associated with how much air pollution people breathe, for example due to their choices about where to live.

At the beginning of 2005, the EPA designated 132 counties in 21 states as "nonattainment" areas, meaning that air quality monitor readings in them showed that $PM_{2.5}$ concentrations were above the permitted levels. Local regulators were then required to reduce concentrations in those counties and could be penalized if they failed to do so.

In the following years, $PM_{2.5}$ levels dropped faster in the nonattainment counties. Figure 2 shows that for the Medicare population in nonattainment counties, average $PM_{2.5}$ concentrations over the next decade fell by nearly 10 percent (1.24 micrograms per cubic meter) more than for those living in places that met the EPA's standards. Furthermore, the reductions differed even within the nonattainment counties, because regulators focused their efforts on specific polluters and neighborhoods.

We leverage these differences in the reduction in $PM_{2.5}$ over the subsequent decade due to the regulation to isolate how $PM_{2.5}$ affects the probability of developing dementia. By combining our rich data from CMS and the U.S. Census with the variation in pollution exposure over the decade due to the EPA's regulation, our study accounts for the influence of confounding factors. For example, our approach rules out that the observed relationship between air pollution and dementia might arise solely because sicker or poorer people may be more likely to live in heavily polluted areas.

Our study capitalizes on the EPA regulation causing differences in the change in pollution over the decade experienced by people of the same age, race, and gender who lived in the same area and who, at the start of the decade, had received the same medical diagnoses for dementia risk factors, had the same level of gross annual medical expenditures, and lived in neighborhoods with the same levels of $PM_{2.5}$ from 2001 to 2003 and

with similar distributions of race, income, educational attainment, and property values.

Our main result is that a one microgram per cubic meter increase in average particulate matter concentrations over 10 years raises the probability of developing dementia by 1.68 percentage points. Furthermore, we observe this effect even at levels below the EPA's current regulatory threshold, which was set at 12 micrograms per cubic meter in 2012. To put this in perspective, a decade of breathing air with a one microgram per cubic meter higher concentration is equivalent to inhaling an additional 4 percent of an aerosolized paperclip made of arsenic, lead, mercury, and nickel and other materials. In the context of our study, this change in concentration is modest, equal to less than 10 percent of the average person's levels during our study period.

The federal government is required to conduct a cost-benefit analysis of environmental regulations. Our study shows that the existing analysis underestimates the benefits of the $PM_{2.5}$ regulations because the effects of air pollution on dementia were previously unknown. By combining our results with Census data on the elderly population living in nonattainment counties, we estimate that the regulations led to a 2.1 percentage point lower dementia rate in those counties, amounting to 182,000 fewer people with dementia in 2013. Using conventional assumptions about the value of life and health, we calculate that this is worth around $214 billion.

Conclusion

Even while we wait for the development of medical treatments to prevent Alzheimer's and related dementias, our research indicates that improving our air quality now—and reducing small particulate matter specifically—will reduce the burden of dementia.

Our research finds that the EPA's rule requiring $PM_{2.5}$ concentrations to remain below 15 micrograms per cubic meter reduced dementia's prevalence in the U.S. We also find evidence that the lower threshold implemented in 2012 will contribute to lower rates of dementia.

Medical science has not yet established precisely how small particulates contribute to dementia, and it may be that only certain types and sources of pollution are the culprits. Such knowledge will help us to better focus on the technology and regulations that will most effectively improve the quality of our air and ultimately our cognitive health and well-being in old age.

References

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