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Feature: Pollution,Climate,Health

The list of diseases linked to air pollution is growing

As governments decide what to do about air quality, studies connect an array of health problems to dirty air

By LAURA BEIL 7:00AM, SEPTEMBER 19, 2017

BAD AIR U.S. pollution levels have come way down since the 1970s, but there's still enough smog to raise the risk for cardiovascular deaths. Researchers are also drawing new connections between dirty air and metabolic and brain disorders.

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To the residents of Donora, Pa., a mill town in a crook of the Monongahela River, the daily haze from nearby zinc and steel plants was the price of keeping their families fed. But on October 27, 1948, the city awoke to an unusually sooty sky, even for Donora. The next day, the high school quarterbacks couldn't see their teammates well enough to complete a single pass.

The town was engulfed in smog for five days, until a storm finally swept the pollution out of the valley. By then, more than one-third of the population had fallen ill and 20 people were dead. Another 50 perished in the following months.

After the Donora tragedy, the federal government began to clamp down on industries that release pollutants into the air. Environmental advocates in the coming decades fought for, and won, tighter

regulations. As a result, combined emissions of six common air pollutants have dropped by about 70 percent nationwide since the 1970 passage of the Clean Air Act, which regulates U.S. emissions of hazardous air pollutants. In 35 major U.S. cities, the total number of days with unhealthy air has fallen by almost two-thirds just since 2000. “It’s one of the great success stories of public health,” says Joel Kaufman, a physician and epidemiologist at the University of Washington School of Public Health in Seattle.

Our bodies feel the difference. One study, reported in *JAMA* last year, followed 4,602 children in Southern California between 1993 and 2012 to see how lung health correlated with three common air pollutants. As levels of ozone, nitrogen dioxide and particulate matter fell over time, so did the number of children who reported a daily cough, persistent congestion and other symptoms of irritated lungs. At the start of the study, 48 percent of children with asthma had reported bronchitis symptoms in the previous year. In communities with the greatest drop in pollutants during the study period, bronchitis prevalence fell by as much as 30 percent in children with asthma.

BAD AIR When smog rolled in to the mill town of Donora, Pa., almost 70 years ago, the pollution hovered long enough to cause dozens of deaths. Today the town claims responsibility for launching the clean air movement.
Alfred Eisenstaedt/Getty Images

But the air pollution story isn’t over. Researchers from the Harvard T.H. Chan School of Public Health in Boston recently reported on links between air quality and mortality throughout the entire U.S. Medicare population (more than 60 million people who are age 65 and older or disabled). The analysis looked at levels of two common air pollutants and death rates from 2000 to 2012, while accounting for factors that might confound the results, such as race and socioeconomic status. The analysis, published in June in the *New England Journal of Medicine*, found that when pollutant levels rose (but remained at levels below national standards), so did death rates.

Even with vast improvements in air quality since the ’70s, people haven’t stopped dying from the air they breathe. An analysis published in 2013 from researchers at MIT estimated that about 200,000 premature deaths occur each year in the United States because of fine particulate air pollution. A study published in January in *Environmental Health Perspectives* reported that daily deaths over a decade in metropolitan Boston peaked on days when concentrations of three common air pollutants were at their highest, even though those levels would currently satisfy the U.S. Environmental Protection Agency.

“We’ve made these improvements in exposure,” Kaufman says, “but what more do we need to clean up?”

Not so safe

As U.S. air pollution levels drop, studies accumulate linking even those levels considered safe to a broad range of ailments.

So despite a half-century of progress, airborne grime is still a menace — probably in ways the people of Donora never imagined. Researchers are now finding that more than the lungs are at risk, as dirty air may in fact be an accomplice to some of the greatest threats to public health, including diabetes, obesity and even dementia. Those studies are likely to inform the ongoing debate over antismog rules. The U.S. House of Representatives voted this summer to delay implementation of updated standards for the Clean Air Act.

Slow burn

As it has for more than a century, air pollution in America largely arises from power plants, industries, vehicles and other sources of fuel burning. The pollution is generally a mixture of gases — such as carbon monoxide, sulfur dioxide and nitrogen oxides — and particulate matter, microscopic solids or droplets that can be inhaled into the lungs. The pollutant that has declined the least is ozone, a hard-to-control noxious gas formed when nitrogen oxides and volatile organic compounds react with sunlight. Ozone pollution tends to soar on hot, windless summer days as the sun blazes.

Particulates come from tail pipes and smokestacks, but also consist of tiny fragments shed from tires, roads and brake pads. Fine particulates (less than 2.5 micrometers wide, or about a quarter of the width of the smallest grain of pollen) are of greatest concern because they can penetrate deeply into the lungs to reach the body's innermost nooks and crannies. A study in April in the journal *ACS Nano* demonstrated that fact. Fourteen healthy volunteers intermittently riding exercise bikes inhaled gold nanoparticles — stand-ins for particulates — and 15 minutes later, the nanoparticles were detected in the bloodstream and remained present in the body for as long as three months.

While events in Donora showed that air pollution can have immediate consequences, it took decades for researchers to realize that deaths from smog could be going undetected, lost in the background noise of mortality statistics. In 1993, Harvard University scientists published a study in the *New England Journal of Medicine* looking at mortality rates among adults in six U.S. cities. The researchers studied more than 8,000 people for 14 to 16 years. In areas with higher levels of sulfate particles in the air, a measure of pollution, mortality rates were higher. Dozens of similar studies have followed, including one published in 2003 that looked at death rates across 20 of the largest U.S. cities. That research found that the highest death rates occurred the day after particulate concentrations reached their highest levels, though the levels were subtle enough to go unnoticed at the time.

What's pollution like in your state?

Air pollution varies from state to state. To look up the pollutants at play close to home, check out the EPA's comparison map.

Scientists now know that inhaling pollutants triggers a flurry of physiological coping mechanisms throughout the body. "Until 20 years ago, we thought that air pollution affected only the respiratory system," says Petros Koutrakis, an environmental chemist who heads the EPA Harvard Center for Ambient Particle Health Effects. By 2004, the American Heart Association published a consensus statement in *Circulation* laying out "a strong case that air pollution increases the risk of cardiovascular disease," the leading cause of U.S. deaths.

Story continues below interactive pie chart

Bad air

Air pollution has several sources. Most atmospheric ammonia, which reacts with sulfur dioxide and nitrogen oxides to form fine particulates, comes from agriculture. Most carbon monoxide, lead and nitrogen oxides come from vehicles. These U.S. data are from 2014, the most recent available.

Select a pollutant below to explore its sources.

Source: *EPA National Multi-pollutant Emissions Comparison*

Filter

Pollutant source

Pollutant type

✓Click to Show All Values ✓Search

✓Show Quick Filter Context Menu

Agriculture

Dust

Fuel

Industrial

Miscellaneous

Solvent

Vegetation

Vehicles

Ammonia

Carbon monoxide

Fine particulates

Lead

Nitrogen oxides

Sulfur dioxide

Volatile organic compounds

T. TIBBITS, E. OTWELL, H. THOMPSON

More studies followed that statement, including one from Kaufman and colleagues in the *New England Journal of Medicine* in 2007. The researchers studied 65,893 women, looking for a link between exposure to fine particulates and death from heart attack or stroke, or even nonfatal heart attacks or the need for artery-clearing procedures. In the end, each increase of 10 micrograms of fine particulates per cubic meter of air increased the risk of any cardiovascular health event by 24 percent and the risk of dying from heart attack or stroke by 76 percent. In 2010, the American Heart Association updated its position: “The overall evidence is consistent with a causal relationship between [fine particulate] exposure and cardiovascular morbidity and mortality.” While the mechanism is still under study, research points to inflammation, heart rate variability and blood vessel damage.

Evidence keeps accumulating. A study by Koutrakis and colleagues, published in 2012 in *Archives of Internal Medicine*, found similar results. When particulate concentrations rose even to mild levels — those classified as a “moderate health concern for a very small number of people” by EPA standards — the risk of stroke rose by 34 percent within a day of exposure.

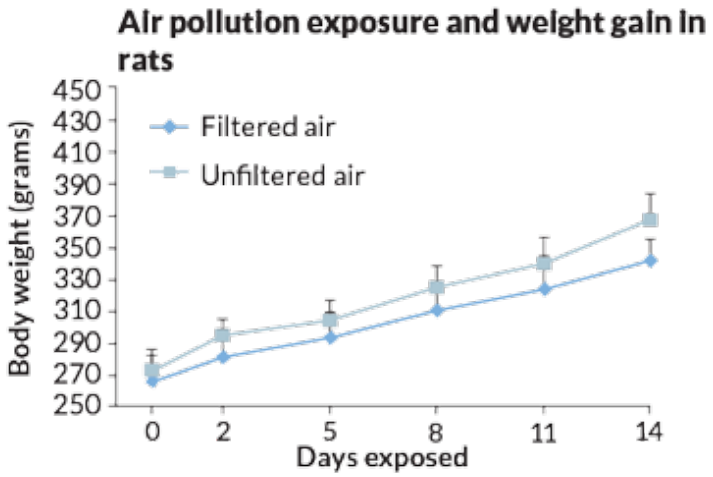
Pounds and pollution

Lately, studies have moved from cardiovascular disease into more unexpected territory. And they've turned up compelling evidence that air quality may contribute to excess body weight. Frank Gilliland, an environmental epidemiologist at the University of Southern California in Los Angeles, became intrigued when laboratory studies suggested that certain pollutants in the environment might function as "obesogens," contributing to weight gain by mimicking or disrupting the action of hormones, or having other effects. Still, he says, "I was very skeptical."

Out of curiosity, he began to look for a link between childhood obesity and living close to a major roadway. His first study, published in 2010, examined over 3,000 children across California. Although the researchers found an association, they couldn't rule out other explanations that would also lead back to cars. "Maybe the kids aren't getting exercise because there's a lot of traffic out," he says.

Dirty calories

To test whether breathing in air pollution could affect body weight, Chinese scientists exposed one group of pregnant rats to Beijing's highly polluted air and another group to filtered air. After two weeks, the rats in the dirty air were heavier.



Y. Wei et al/The Faseb Journal 2016

Newer findings are more convincing, including a 2014 study by Gilliland and colleagues. They studied body mass index among children exposed to traffic-related air pollution. Of course, as the children grew over the five-year study period, their BMIs increased from an average of 16.8 to 19.4 kilograms per square meter. But children exposed to the most air pollution, compared with those least exposed, had a 14 percent larger BMI increase, which meant an additional 0.4 kg/m^2 increase in BMI by age 10. Adults, too, appear to be affected. Researchers from Harvard Medical School and elsewhere published a study in 2016 in the journal *Obesity* looking at whether adults living with constant exposure to traffic are more likely to be overweight. In particular, people who lived within 60 meters of a major road had a higher BMI, by 0.37 kg/m^2, and more fat tissue than those who lived 440 meters from a busy road. The healthy range for an adult's BMI is 18.5 to 25 kg/m^2.

Studies in animals have started to offer hints why this might be the case. Last year in the *FASEB Journal*, Chinese researchers described an experiment in which one group of pregnant rats was raised in filtered air scrubbed of pollutants, while another breathed the usual Beijinghaze. Though they were fed the same diet, the animals living in Beijing air were heavier at the end of their pregnancies, as were their offspring that continued to breathe the dirty air eight weeks after birth. Among later autopsy findings: Rats exposed to pollution experienced higher levels of inflammation, which is thought to be a contributor to weight gain and metabolic disruption.

The relationship is probably subtle, and interwoven with genetics and lifestyle. UCLA researchers who

followed a large group of African-American women over 16 years found no association between weight and exposure to particulates. For now, the connection between obesity and pollution is still a subject of investigation. But given that 11 million Americans live along major roadways, even a small effect could have widespread consequences.

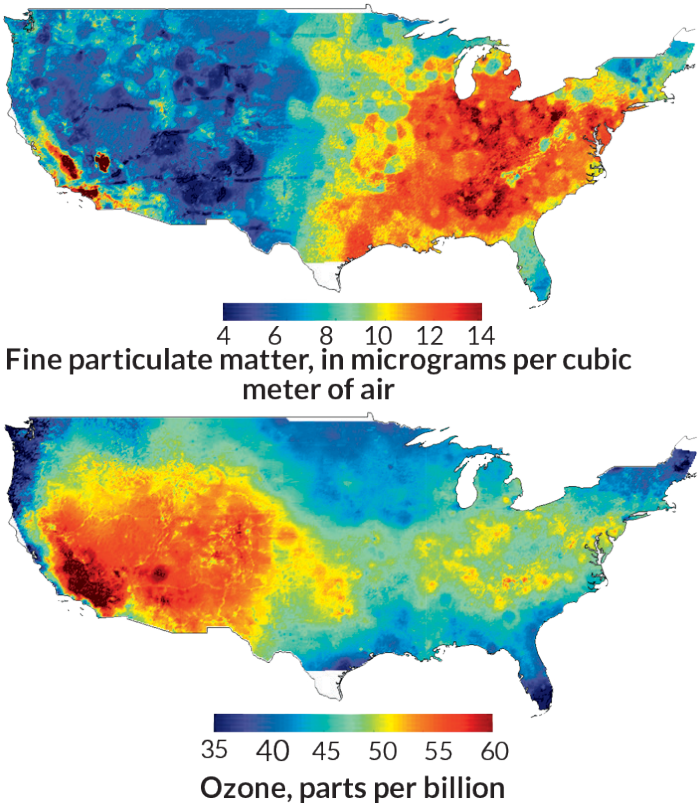
Links to diabetes

For many people, diabetes goes hand in hand with obesity. One of the earliest compelling studies to suggest a relationship between diabetes and air pollution was an animal experiment published in 2009 in *Circulation* from researchers at Ohio State University and other institutions. The test was relatively simple: Two groups of mice were fed a high-fat diet for 24 weeks. One lived in clean, filtered air; the other group was housed in enclosures polluted with air containing fine particulates, at concentrations still within EPA standards. The mice breathed the polluted air for six hours per day, five days a week for 128 days. Even though they ate the same food, the mice living in dirty air developed metabolic changes characteristic of insulin resistance while the other mice did not. Similarly, a 2013 study from EPA scientists found that mice exposed to ozone can develop glucose intolerance, a precursor for diabetes.

In July in *Diabetes*, Gilliland and colleagues published data not only finding links between air pollution and diabetes in children, but also insight into the body's physiological response. In the study, 314 overweight or obese children in Los Angeles were followed for an average of three years. At the end of the study, children who lived in neighborhoods with the highest concentrations of nitrogen dioxide and particulates had experienced greater declines in insulin sensitivity and had signs of impaired pancreatic beta cells, which produce insulin.

Location matters

Average concentrations of two major air pollutants from 2000 to 2012 varied by U.S. region. Fine particulates disproportionately affect the eastern half of the country, whereas ozone, shown here in warm months, is a bigger problem in the west.



Q. Di et al/NEJM 2017

As for adults, a study this year in *Environment International*, conducted by researchers from eight

institutions, tracked more than 45,000 African-American women across the United States. Those who were exposed to the highest concentrations of ozone were about 20 percent more likely to develop diabetes, even after adjusting for other possible explanations such as diet and exercise levels.

Brain drain

One of the latest lines of research suggests that poisons in the air might accelerate aging in the brain. Studies have long documented the connection between the nose and brain function. For reasons not yet known, for instance, one of the early signs of Parkinson's disease is a loss of the ability to distinguish smells.

During her graduate studies at Harvard, Jennifer Weuve, now an epidemiologist at the Boston University School of Public Health, wondered if airborne pollutants might be bad for the brain. "There was really intriguing data from animal studies," she says, which showed that inhaled pollutants had toxic effects on nerve cells. In 2012, she published the first study to note a faster-than-normal cognitive decline among people exposed to higher levels of particulates, both those smaller than 2.5 micrometers and even larger ones that are thought to be less harmful. Her study, published in *Archives of Internal Medicine*, analyzed data from the Nurses' Health Study Cognitive Cohort, which included almost 20,000 women ages 70 to 81, and used geographic information and air-monitoring data to estimate pollution exposure.

More recently, researchers from Sweden examined the relationship between pollution exposure and dementia, studying the records of people in northern Sweden participating in a long-term study of memory and aging. In 2016 in *Environmental Health Perspectives*, the researchers reported that people with the most exposure to air pollution were also the most likely to be diagnosed with Alzheimer's or other forms of dementia. In all, more than a dozen human studies have examined pollution's link to dementia. Last year in *NeuroToxicology*, Weuve and colleagues reviewed 18 human studies published as of late 2015, and concluded that as a whole, the evidence was "highly suggestive" and in need of more exploration. "What is it going to take for more people to take this seriously?" Weuve asks.

While the relationship is far from established, animal data may help clarify the results. One study published this year in *Neurobiology of Aging*, from researchers at the University of Southern California, examined brain changes in mice exposed to particulate air pollution at levels commonly found near freeways. After exposure to the pollution for five hours per day, three days a week for 10 weeks, the animals showed accelerated aging in the hippocampus, a region of the brain associated with memory. And a 2015 study of older women exposed to high levels of particulate matter, at levels common in the eastern half of the United States and in parts of California, showed a small decrease in the volume of white matter, the myelin-coated nerve cell projections called axons.

> What is it going to take for more people to take this seriously?
>
> **— Jennifer Weuve**

Parkinson's disease may also be linked to pollution. Danish researchers, with colleagues in the United States and Taiwan, published a study last year in *Environmental Health Perspectives* looking at people with and without Parkinson's and their exposure to nitrogen dioxide, a marker for traffic-polluted air. The scientists identified 1,828 people in Denmark with Parkinson's diagnosed between 1996 and 2009, and compared them with about the same number of randomly selected healthy people. Those exposed to the highest levels of air pollution had the greatest risk of developing the disease. The data, the researchers wrote, "raise concern given the increase in vulnerable aging populations."

If science bears out the connection between pollution and brain health, or pollution and metabolism, environmental advocates and businesses may have even more reason to push for cleaner air. Researchers hope in the future to have more data on which pollutants cause the greatest harm, and why. In Donora, the site of one of the country's biggest air pollution disasters, a sign at the Smog Museum now reads "Clean Air Started Here." No one can yet say how clean is clean enough.

This story appears in the September 30, 2017 issue of Science News *with the headline, "Bad Air: Breathing pollution may harm a lot more than our lungs."*

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