Minnesota Pollution Control Agency

Environmental Outcomes Division

Acid rain in Minnesota

Air Quality fact sheet #1.11, January 2002

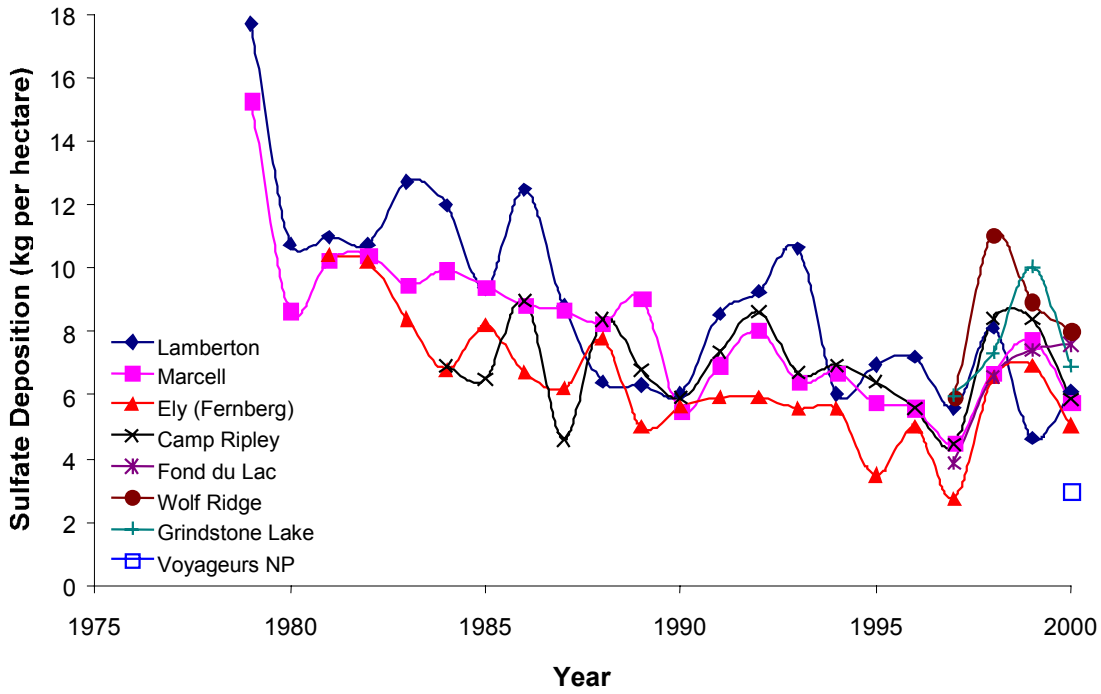
What is acid rain?

Acid rain, more accurately known as ***acid deposition***, begins with the burning of fossil fuels (such as coal, gas or oil) for energy. The resulting air pollution contains sulfur dioxide (SO_2) and nitrogen oxides (NO_x). These gases react in the atmosphere to form various acidic compounds, most often tracked as sulfate and nitrate ions. Often carried by winds for hundreds of miles, these compounds may be deposited on the Earth by ***dry deposition***, a process where acidic particles or gases settle on, or are absorbed by, plants, land, water or building materials. The acidic compounds may also be deposited through rain, snow and cloud water, pathways that are known as ***wet deposition***.

Due to state and national concern about acid rain in the 1980s, laws were passed that virtually eliminated the potential for acidification of Minnesota's water bodies. No lakes or streams in Minnesota have been acidified, but some areas of eastern North America were not so fortunate. Areas that were damaged include lakes and streams in New England and the Adirondacks of New York. Emissions of SO_2 have been reduced, and will be reduced more, yet recovery of the most-harmed lakes and soils in New England may take decades and may require further reductions in emissions from sources in North America.

The reasons for the lack of damage in Minnesota include lower emissions than

Acid deposition at NADP monitoring sites in Minnesota



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in the more industrialized East, prevailing winds that often bring us relatively clean air from the west, and more resistant geology. Acidification of lakes is just one potential consequence of the poorly controlled burning of fossil fuels and the emission of SO_2 and NO_x, which not only become strong acids, but also become small particles in the atmosphere.

Other consequences include:

- As particulates, sulfates and nitrates are a large proportion of the small particles that penetrate deep into lungs during inhalation, a significant public health concern.
- Sulfate and nitrate particles scatter and absorb light, reducing visibility, which has aesthetic effects (*e.g.*, on the vistas of some of our national parks), as well as causing problems for air traffic.
- Nitrogen deposition contributes to the eutrophication of nitrogen-limited systems, such as the Chesapeake Bay.
- Nitrogen deposition has caused nitrogen saturation of forest ecosystems in New England, Colorado, California, Canada and Europe, which can make trees more susceptible to other stresses, such as unusual cold.
- As acid rain moves through soils, it accelerates the leaching of base cations (calcium and magnesium) from them, delaying the recovery of alkalinity in lakes and steams in New England. In addition, depletion of calcium from soil in Pennsylvania has caused extensive mortality of sugar maple.
- Acid deposition degrades materials beyond natural weathering, harming buildings, monuments, bridges and automobiles, and other parts of the built environment.
- Nitrogen oxides contribute to the formation of smog and ozone, which are a health concern.

Minnesota's response to the acid rain threat

Acid rain was recognized early as a potentially serious threat to aquatic and terrestrial ecosystems in Minnesota. In response, the state legislature passed the Acid Deposition Control Act (Minn. Statutes 116.42-116.45) in 1982. This act, the first of its kind in the nation, required the Minnesota Pollution Control Agency (MPCA) to (1) identify the areas of the state containing resources sensitive to acid deposition, (2) develop a standard to protect these resources, (3) adopt a control plan to reduce SO_2 emissions and (4) ensure that all Minnesota sources subject to the control plan were in compliance by January 1, 1990. The MPCA implemented all of these steps, and emission sources were brought into compliance with Minnesota's SO_2 control plan.

In 1986, Minnesota became the only state to set an acid deposition standard to protect sensitive aquatic and terrestrial ecosystems. The standard limited the amount of sulfate in precipitation to an annual load of 11 kilograms per hectare (kg/ha), or about 10 pounds per acre. Sulfate deposition is monitored under the National Atmospheric Deposition Program (NADP). Representative deposition data, presented in the graph on the first page of this fact sheet, show a general decline since the 1970s. Note that variation in natural environmental processes produces sulfate trends that vary greatly from year to year. All NADP data from monitoring sites in Minnesota are available at http://nadp.sws.uiuc.edu/nadpdata/state.asp?state=MN .

As a result of studies conducted by MPCA staff and contractors, these conclusions have been made:

1) There is no evidence that any of Minnesota's lakes, including the 11 sensitive lakes that were monitored since the mid-1980s, have been acidified by acid rain. In fact, six of the 11 experienced statistically significant decreases in sulfate concentrations, consistent with decreases in sulfur dioxide emissions in Minnesota and the rest of North America.
2) One of the main reasons that acid-sensitive lakes in Minnesota were not acidified is because of in-lake bacterial conversion of sulfate to sulfide, which consumes the acid that comes with the sulfate. Some scientists hypothesize that these

same bacteria also convert mercury to methylmercury, the form that accumulates in fish. So, increased sulfate conversion to sulfide, which has protected Minnesota lakes from the acid in acid rain, may contribute to enhanced mercury contamination of fish in those lakes. The MPCA is examining this hypothesis with funding from the U.S. Environmental Protection Agency (EPA).

3) Even though the acidification threat to Minnesota lakes is very low, Minnesota should continue to monitor a variety of lakes so that data are available on other issues that threaten lakes, such as lakeshore development, eutrophication, toxic chemicals (*e.g.,* mercury; PCBs, or polychlorinated biphenyls; and PBDEs, or polybrominated diphenyl ethers), exotic species (examples are Eurasian milfoil and zebra mussels) and global warming.

Federal action on acid rain

Congress established the National Acid Precipitation Assessment Program (NAPAP) in 1980 to study the causes and impacts of acid deposition. In 1990, NAPAP published a report, concluding that electric power generation was responsible for two-thirds of SO_2 emissions and one-third of NO_x emissions.

In 1990, Congress created the Acid Rain Program under Title IV of the 1990 Clean Air Act Amendments (CAAA). CAAA required significant reductions of SO_2 and NO_x emissions from electric utilities. By 2010, utilities would need to lower their emissions by about half (8.5 million tons) compared to 1980 levels. They would also need to reduce their NO_x emissions by 2 million tons below what they would have been without the Acid Rain Program (beginning in 2000).

Sulfur dioxide reductions are being achieved using a cap-and-trade system. Although it was estimated in 1990 that compliance would cost industry $4.6 billion a year by 2010, actual costs are expected to be less than $1 billion a year, thanks to technological innovation and competition. National SO_2 emissions have reduced significantly since 1990, especially after 1994, as Phase I of the federal program began in 1995. Phase I affected roughly 440 of the larger, higher-emitting utility units, primarily in the East. Phase II began in 2000 and extends to all the affected sources (more than 2,000 units nationwide).

Nitrogen oxides are regulated differently. The Acid Rain Program reduces NO_x emissions by designating an emission rate for each source. However, total national emissions of NO_x have not declined, even though NO_x emission rates from individual plants have declined, because electricity production and vehicle use have increased.

For more information

For more information about acid rain-related research being conducted by the MPCA, contact Ed Swain, Environmental Outcomes Division, Minnesota Pollution Control Agency, 520 Lafayette Rd. N., Saint Paul, MN 55155-4194 (telephone 651/296-7800; email edward.swain@pca.state.mn.us).