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Agency

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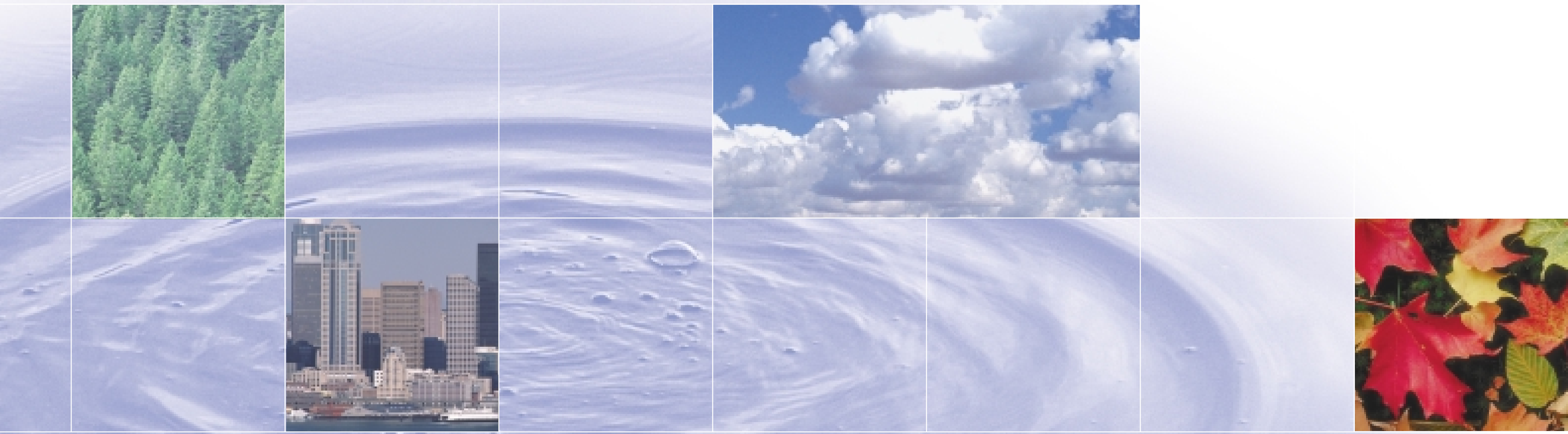
EPA

Progress Report on the EPA Acid Rain Program



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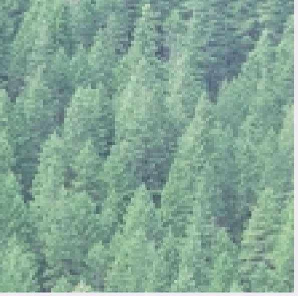
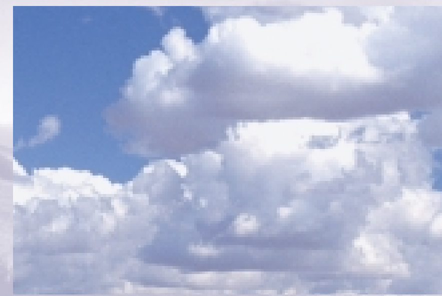


Introduction

The Acid Rain Program: A success in reducing emissions and costs. How is the environment responding?

In 1990, Congress established the Acid Rain Program under the Clean Air Act. The principal goal of the program is to achieve reductions of 10 million tons of sulfur dioxide (SO_2) and 2 million tons of nitrogen oxides (NO_X), the primary components of acid rain. These pollutants, in their various forms, lead to the acidification of lakes and streams rendering some of them incapable of supporting aquatic life. In addition, they impair visibility in our national parks, create respiratory problems in people, weaken forests, and degrade monuments and buildings.

These environmental and public health problems caused by acid rain have affected us for several decades. We have, however, started on the path to recovery. Through efforts made by the United States Environmental Protection Agency's (EPA's) Acid Rain Program, emissions of SO_2 and NO_X are declining. The centerpiece of the Acid Rain Program is a creative, market-based approach for bringing about significant, cost-effective reductions in SO_2. As a result of the program and its innovative approaches, we will enjoy multiple environmental and health benefits in a cost-effective manner.



The Acid Rain Program

To address the problem of acid rain—more accurately known as acid deposition—Congress established the National Acid Precipitation Assessment Program (NAPAP) in 1980 to study the causes and impacts of acid deposition. This research revealed acid deposition's broad environmental and health effects and also documented that the pollution causing acid deposition can travel hundreds of miles, crossing state and national boundaries. In addition, these studies identified electric power generation as responsible for two-thirds of SO_2 emissions and one-third of NO_x emissions.

With NAPAP's scientific underpinning, Congress created the Acid Rain Program under Title IV (Acid Deposition Control) of the 1990 Clean Air Act Amendments. The long-range transport of acid deposition and the amount of emissions linked to electric power generation led Congress to require significant reductions of SO_2 and NO_x emissions from electric utilities. By 2010, utilities would need to lower their emissions by 8.5 million tons compared to their 1980 levels. In addition, they would need to reduce their NO_x emissions by 2 million tons each year compared to levels before the Clean Air Act Amendments.

Marketing Emission Reductions: The Cap and Trade Program

For SO_2, the Acid Rain Program places a mandatory ceiling, or cap, on emissions nationwide from electric utilities, and allocates emissions to these pollution sources in the form of allowances. An allowance is an authorization to emit 1 ton of SO_2. At the end of the year, sources must hold an allowance for each ton of SO_2 they emitted. Extra allowances may be banked (or carried over) for future use or sold to other companies. This system of emissions trading, known as “cap and trade,” is innovative in its use of the market to achieve greater environmental results for a given cost than are possible through traditional approaches. Traditional approaches might include requirements to install specific pollution control equipment. In addition to providing an economic incentive to reduce SO_2, this system allows utilities the flexibility to decide how they will achieve the necessary emission reductions. For example, they could install pollution control equipment such as “scrubbers,” switch to less polluting fuel, conserve energy, rely more on renewable energy, trade SO_2 allowances, or use any combination of these options. Furthermore, utilities can change their approach as new opportunities arise, without needing government approval. This freedom allows them to determine for themselves the most cost-effective timing and method of emission reductions.

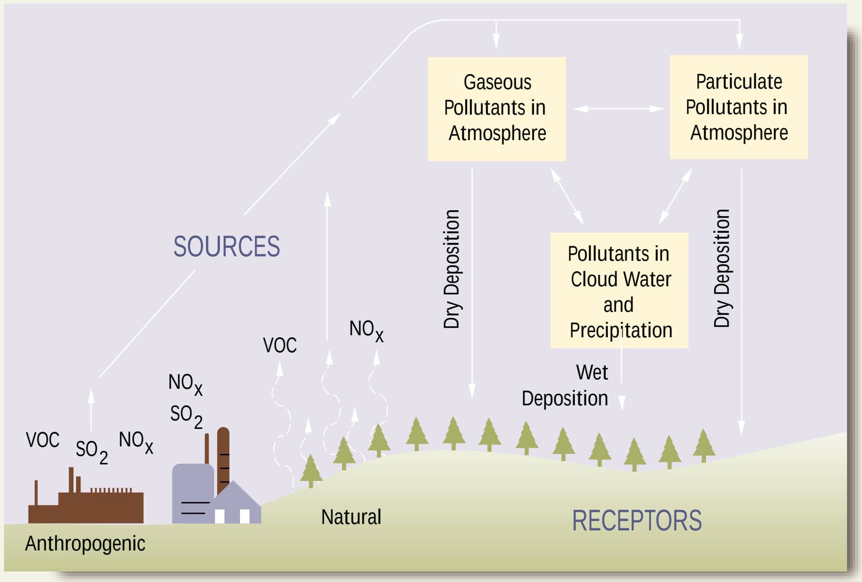
In return, sources must continuously measure and report their emissions, providing emissions information unprecedented in its accuracy and completeness. Detailed measurement ensures that emission goals are attained and that sources are in compliance. Since the start of the program in 1995, no company in the trading program has failed to comply.

NO_X is treated differently. Rather than using a cap and trade program, the Acid Rain Program reduces NO_X emissions by designating an emission rate for each source. The program gives utilities the opportunity to find cost efficiencies while ensuring that overall emission reductions are achieved by allowing emission rates to be averaged across a utility’s boilers. The primary difference between the NO_X and SO_2

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 SO_2 and NO_X. These gases react in the atmosphere with water, oxygen, and oxidants to form various acidic compounds, most often tracked as sulfate, nitrate, and hydrogen ions. Often carried by winds for hundreds of miles, these compounds may be deposited on earth as *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, which is known as *wet deposition*. In other words, there are many pathways by which acid “rain” reaches the earth.

Figure 1. Origins of Acid Rain

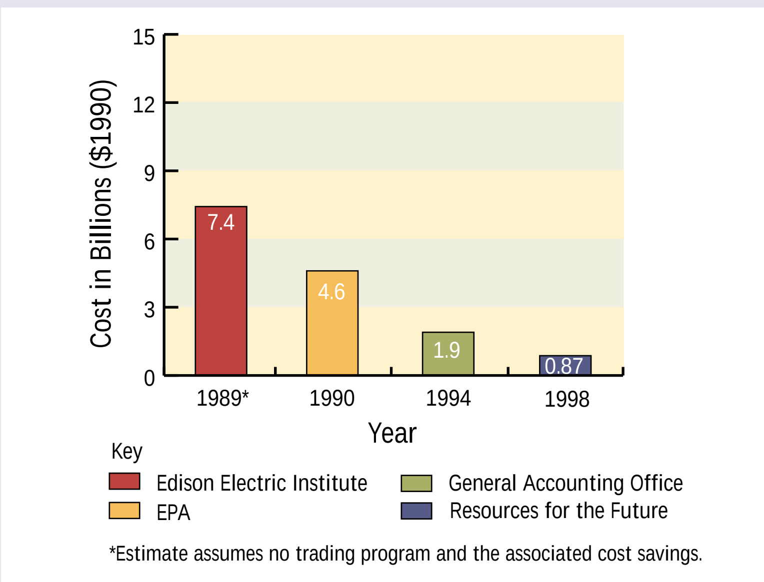


A combination of natural and manmade activities result in the deposition of acidic compounds.

Predicted costs for reducing acid rain continue to decline...

In 1990, EPA estimated that complying with the program's SO_2 emissions reduction goals would cost utilities approximately $4.6 billion per year by 2010 (the date when the annual 10 million ton emissions reduction is expected to be reached). In 1994, the cost was reevaluated by the General Accounting Office and the estimate was lowered to about $2 billion by 2010. Based on recent compliance cost information, a 1998 Resources for the Future report estimated costs of SO_2 emissions reductions to be less than $1 billion by 2010. These independent studies show that real-life experiences with the program reveal greater cost savings than initially expected.

Figure 2. Estimated Cost of the Acid Rain Program at Full Implementation (2010)

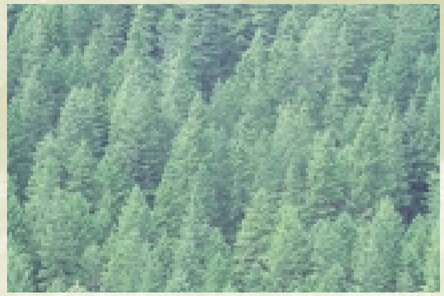


Cost estimates of implementing the Acid Rain Program have declined.

programs is that the SO_2 cap and trade approach ensures total power plant emissions never exceed the mandated ceiling.

The program's ultimate objective is to protect the environment and improve human health by reducing both SO_2 and NO_x emissions. EPA believes these reductions will benefit the nation by:

- Restoring acidified lakes and streams so they can once again support native aquatic life.
- Protecting air quality and public health.
- Improving visibility, especially at scenic vistas in national parks.
- Reducing the damage to forests along the mountain ranges of the East Coast.
- Protecting our historic buildings and monuments from degradation.



What Has the Program Achieved so Far?

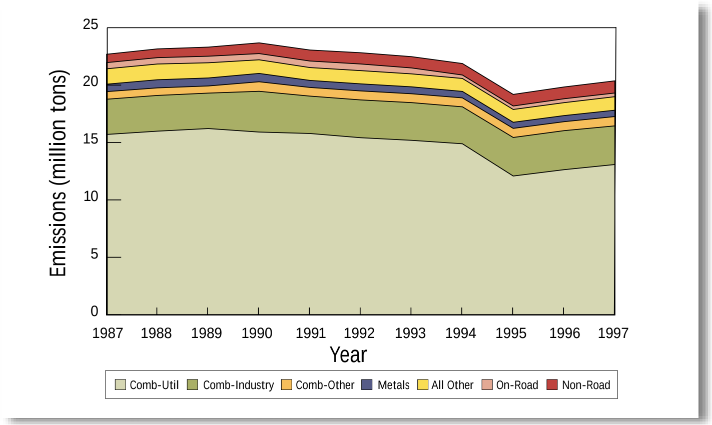
Emission Trends

The first step in protecting the environment and human health from acid rain is reducing emissions. The Acid Rain Program is proving to be extremely effective in this regard. In 1995, the first year of compliance under the program, $S0_2$ emissions dropped dramatically, by 3 million tons, reducing total $S0_2$ emitted nationally as shown in Figure 3. Over the first 4 years of the program, emissions from the largest, highest emitting utility units were about 5 million tons below their 1980 levels, as shown in Figure 4.

These deep cuts in emission levels include reductions of about 30 percent below the allowable emission levels made in advance of future limits. These early reductions mean environmental benefits can begin sooner. Figure 5 presents another encouraging sign: the largest emission reductions are occurring in the heaviest emitting areas, particularly the Midwest.

While overall $N0_x$ emissions have remained constant since the 1980s (see Figure 6), the average emission rate of utilities participating in Phase I of the $N0_x$ program has decreased by 42 percent since 1996.

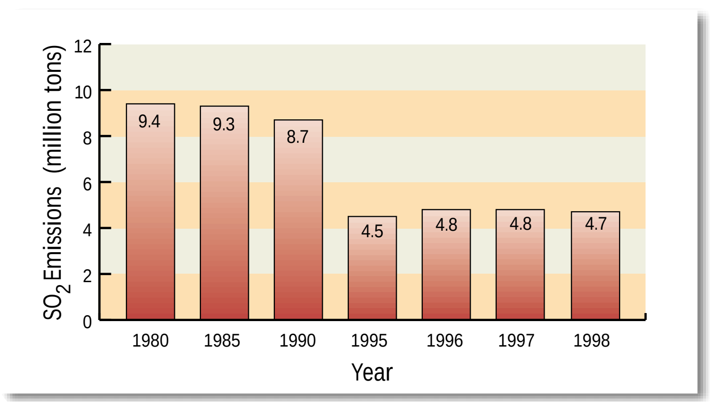
Figure 3. Trend in Sulfur Oxide Emissions for Six Principal Source Categories, 1987 to 1997



National emissions of SO_2 have been decreasing over the past decade, punctuated by a significant decrease attributable to the start of the Acid Rain Program in 1995. Utilities account for about 67 percent of the total estimated SO_2 emissions. Other contributors include industrial sources and metallurgical processes as well as cars, trucks, and construction equipment.

Source: EPA. 1998. *National Air Quality and Emission Trends Report.*

Figure 4. SO_2 Emissions From 263 Large Utility Units



Emission reductions have been substantial since the program began in 1995. Ultimately, the program will result in a 10 million ton reduction in SO_2 from 1980 levels in 2010.

Source: EPA, Acid Rain Program.

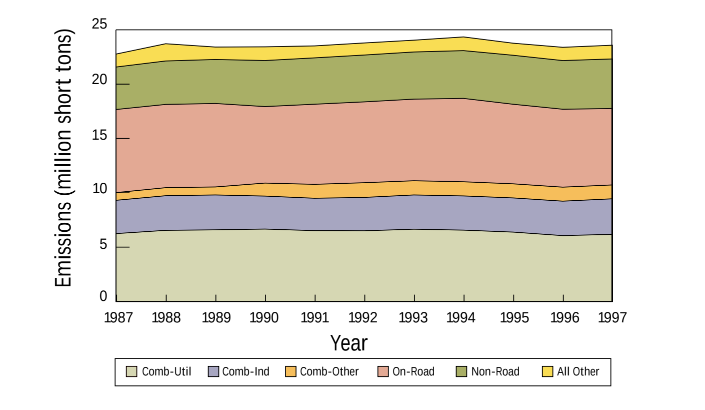
This reduction translates to a 35 percent drop in actual NO_x emissions from electric utilities currently affected by the Acid Rain Program.

Starting in 2000, additional utility units will be affected with more stringent SO_2 emissions limitations nationwide. NO_x rates (i.e., the amount of NO_x emitted per unit of coal used) will be reduced to between 0.40 and 0.86 lbs/mmBtu, depending on the boiler type.

Air Quality

Emission reductions from the Acid Rain Program are contributing to improved air quality. Data collected for the past 10 years, shown in Figure 7, indicate that ambient SO_2 concentrations are declining, as are ambient SO_4, or sulfate, concentrations. Sulfates are compounds formed from SO_2 emissions and are transported long

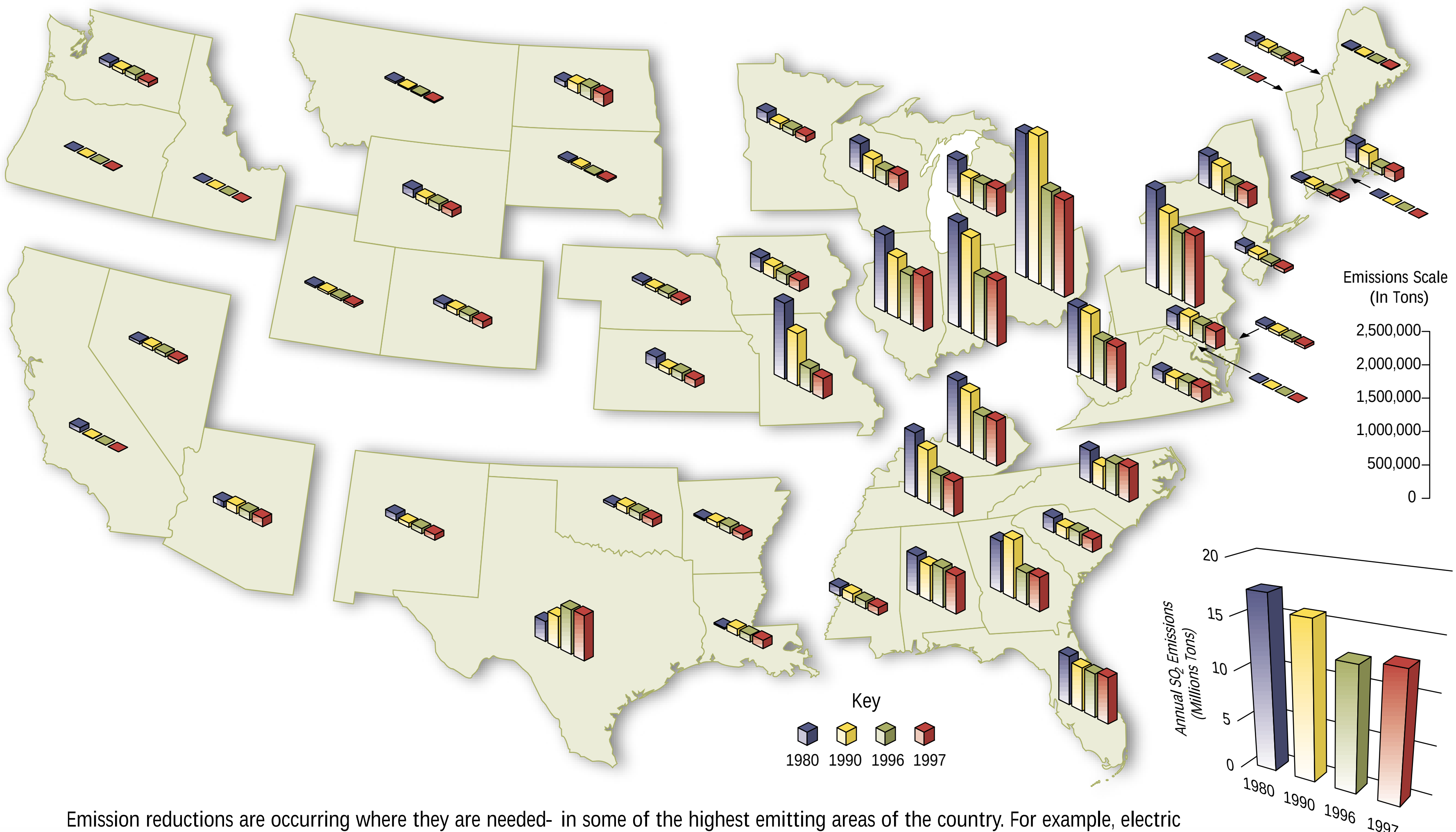
Figure 6. Trend in Nitrogen Oxide Emissions for Five Principal Source Categories, 1987 to 1997



National NO_x emissions have not declined. They have remained at around 23 million tons per year since the 1980s. Electric utilities generate about 30 percent of the total estimated NO_x emissions, while motor vehicles and other industrial sources also contribute significantly. Although NO_x emission rates have declined and cleaner technologies are being used, total NO_x emissions have not decreased significantly because electricity generation and vehicle use-and, therefore, fuel combustion-have increased.

Source: EPA. 1998. *National Air Quality and Emission Trends Report.*

Figure 5. 1980 to 1997 SO_2 Emissions From Utilities



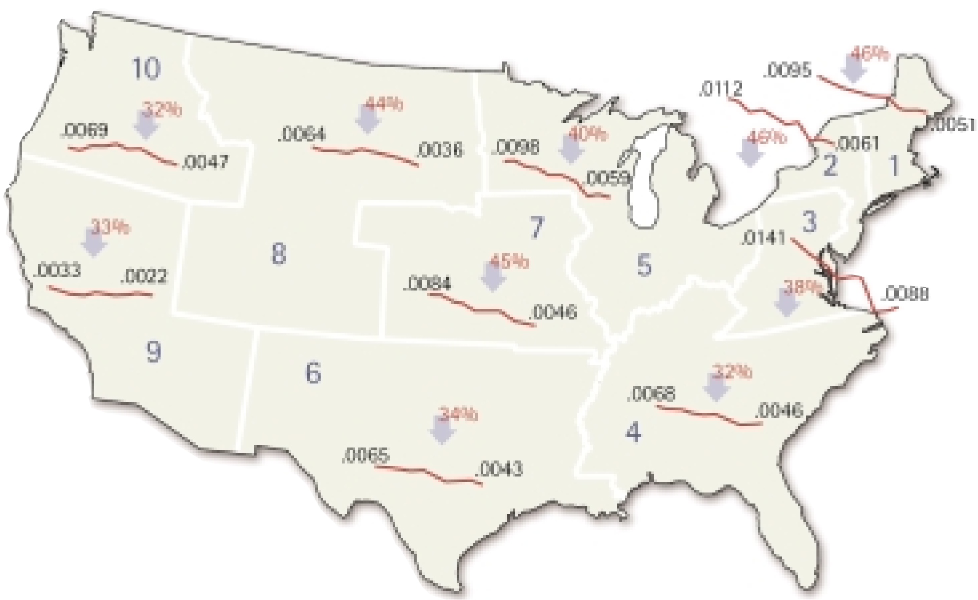
Emission reductions are occurring where they are needed- in some of the highest emitting areas of the country. For example, electric utilities affected by the Acid Rain Program in 1997 in both Ohio and Indiana reduced SO_2 emissions by about 44 percent and 50 percent, respectively, from 1990 levels. This decrease is important environmentally, but it also supports an economic premise of the Acid Rain Program's market-based approach: the highest emitting plants have more incentive to make substantial emission reductions because they can achieve these reductions at a lower cost per ton. Experience is validating this expectation, and concerns that the biggest emitters of SO_2 would simply buy allowances and continue to emit at their historical levels have proved unwarranted thus far.

Source: EPA, Acid Rain Program.

distances. These fine particles aggravate respiratory health, can lead to premature mortality, and degrade visibility, resulting in a hazy view of the horizon.

Downward trends in SO_2 emissions lead to decreases in airborne sulfate particles and improved air quality in areas distant from the original source of air pollution. The relationship between regional SO_2 emissions and sulfate concentrations in air quality in the Northeast is illustrated in Figure 8. This graph compares long-term trends (1978 through 1996) in annual mean aerosol sulfate concentrations at two rural locations in New York State (Mayville and Whiteface Mountain) with upwind SO_2 emissions for the Midwest (Minnesota, Wisconsin, Illinois, Michigan, Indiana, Ohio, West Virginia, Kentucky, and western Pennsylvania). The underlying trend in sulfate concentrations parallels SO_2 emissions, with both trends decreasing. Sulfates declined sharply in 1995, corresponding to a 36 percent reduction in regional SO_2 emissions. Air quality improved by approximately 30 percent for Mayville, New York, and an impressive 47 percent for the more distant Whiteface Mountain, New York, location.

Figure 7. Regional SO_2 Trends 1988 to 1997

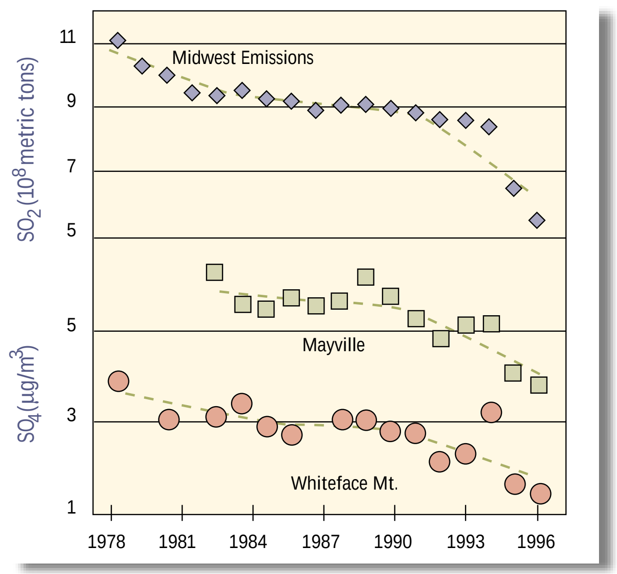


Alaska is in EPA Region 10; Hawaii, EPA Region 9; and Puerto Rico, EPA Region 2. Concentrations are PPM.

Percentage is the percent drop in SO_2 concentration in that Region. Trend line shows changes in SO_2 concentration from 1988 on the left side to 1997 on the right side. Trends are decreasing in all Regions, with most prominent trends occurring in the Northeast and Mid-Atlantic states.

Source: EPA

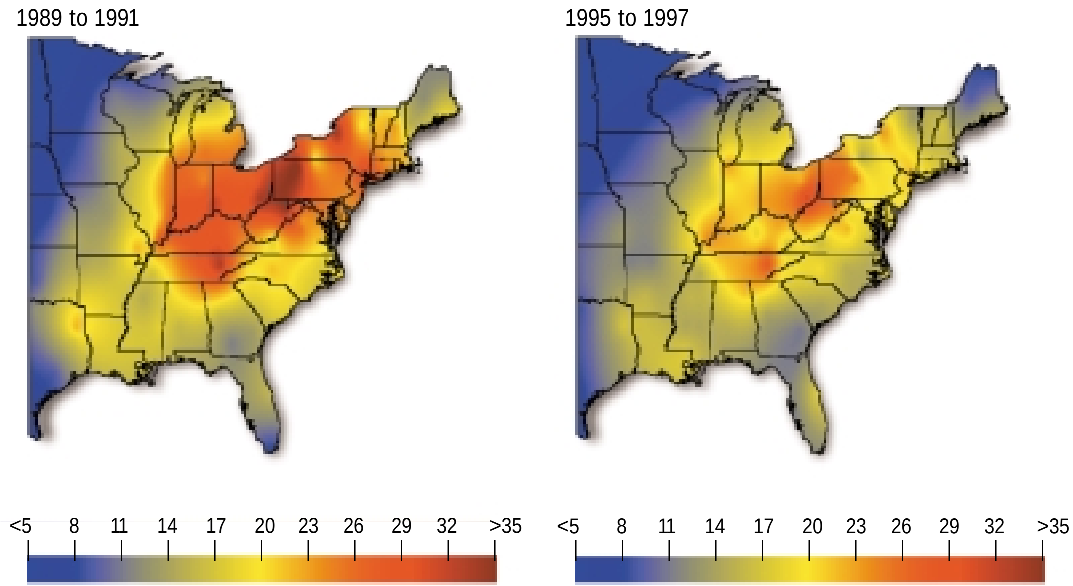
Figure 8. Relationship Between Emissions and Air Quality



Declining emissions in the Midwest correlate to improved air quality in Mayville and Whiteface Mountain, New York. Ambient sulfates dropped significantly in 1995, the first year of Title IV implementation.

Source: Husain, L., Dutkiewicz, V.A., and Dass, M. 1998. Evidence for Decrease in Atmospheric Sulfur Burden in the Eastern United States Caused by Reduction in SO_2 Emissions. *Geophysical Research Letters* Vol. 25 No. 7.

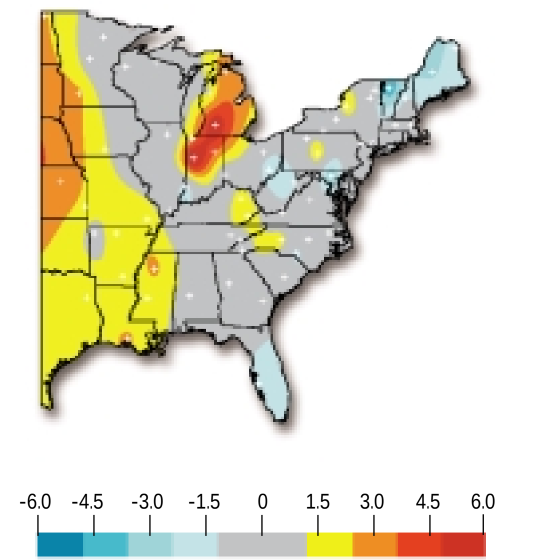
Figure 9. Wet Sulfate Deposition in Acid Rain Reduced (kg/ha)



These maps represent snapshots of wet sulfate deposition over time. As illustrated in the 1995 to 1997 map, following the 1995 implementation of the Acid Rain Program, total sulfate deposition fell in a dramatic and unprecedented reduction of up to 25 percent over a large area of the Eastern United States. The greatest reductions occur in the Northeastern United States, where many of the most acid sensitive ecosystems are located. (Units are in kilograms per hectare).

Source: Lynch, J.A., Bowersox, V.C. and Grimm, J.W., 1999. Changes in Sulfate Deposition in Eastern U.S.A. Following Enactment of Title IV of the Clean Air Act Amendments of 1990. Submitted to *Atmospheric Environment*. In Press.

Figure 10. Nitrate Concentration in Acid Rain Unchanged (**μeq/L**)



As compared to the 1983 to 1994 trend, in both 1995 and 1996, nitrate concentrations have been estimated to be about the same as levels expected. White crosses indicate locations of NADP/NTN sites used in this analysis. (Units are in microequivalents per liter (μeq/L).)

Source: Lynch, J.A., Bowersox, V.C. and Grim, J.W. Acid Rain Reduced in Eastern U.S.A. Submitted to *Environmental Science & Technology*. In Review.

Lower Emissions Mean Less Acid Deposition

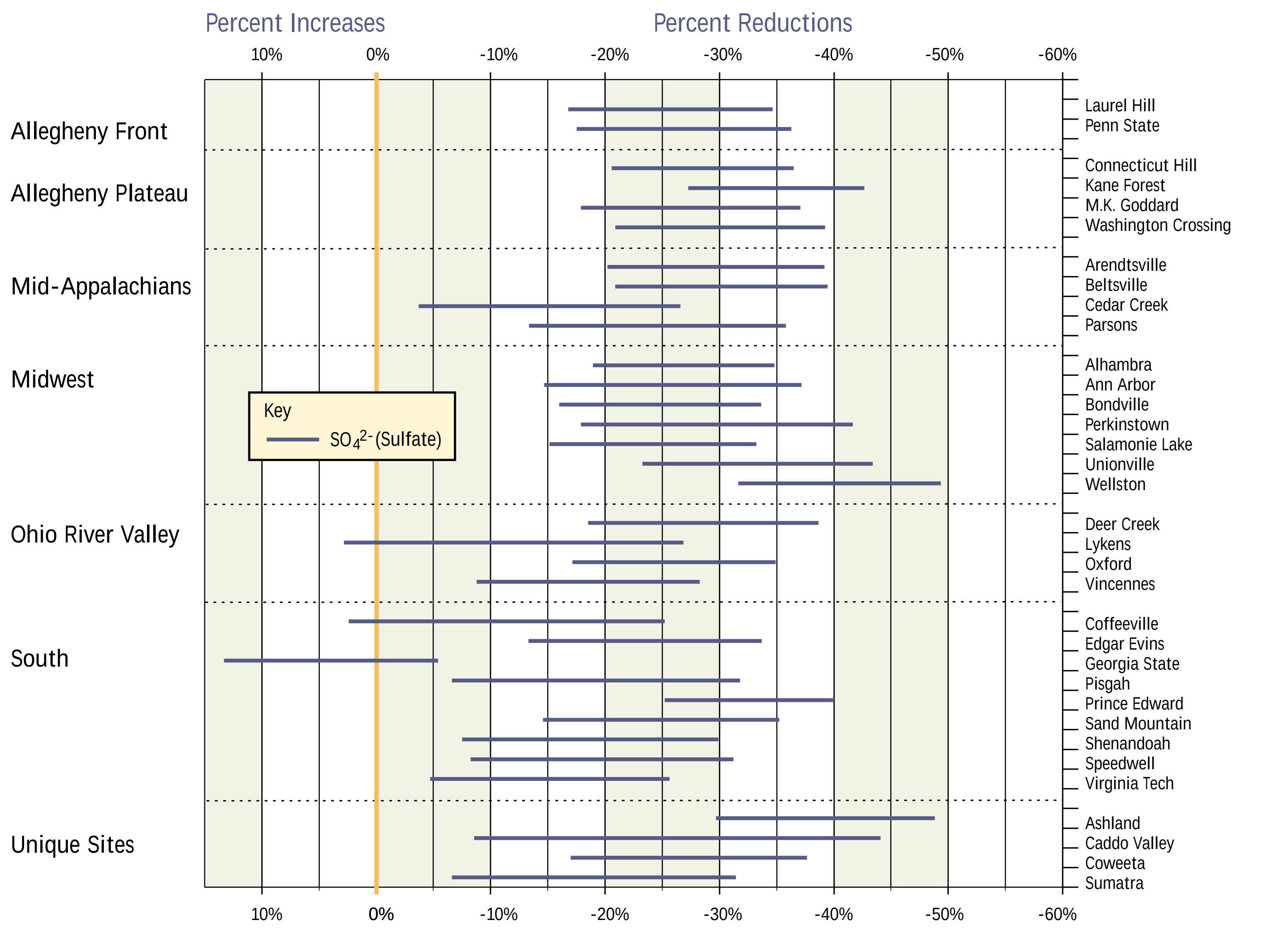
Declining emissions from fossil fuel combustion will bring about decreases in concentration of acidic compounds and total acid deposition. Measured as sulfate, nitrate, and hydrogen ions, acid deposition is tracked by scientists and EPA with the use of data from several monitoring networks.

Field data collected by the National Atmospheric Deposition Program/National Trends Network (NADP/NTN), a network of more than 200 monitoring stations, show that sulfate levels in precipitation have declined sharply since the Acid Rain Program began requiring emission reductions in 1995. As shown in Figure 9, sulfate deposition levels have fallen by about 25 percent in the Northeast and Mid-Atlantic regions, where ecosystems have proven more sensitive to acidic deposition. Figure 10 shows that no dramatic regional changes in nitrate concentration levels have been recorded due to steady NO_X emissions levels.

The Clean Air Status and Trends Network (CASTNet) measures dry deposition[1] of sulfur and nitrogen, among other pollutants, at approximately 70 sites. CASTNet data show that dry deposition sulfate concentration levels also have declined by up to 30 percent in the Northeast and the Mid-Atlantic (see Figure 11). As anticipated, no statistically significant regional trends have been measured for nitrate concentration levels.

[1]Actual measurement of dry deposition (acid deposition in the form of particles or gases) is very complex. CASTNet measures concentration levels and meteorology and then estimates what is deposited on the surface.

Figure 11. Widespread Reductions in Sulfate Concentrations at CASTNet Sites Between 1989 and 1995 (µg/m³)



Source: Holland, D.M., Principe, P., and Sickles, J.E, II. 1999. Trends in Atmospheric Sulfur and Nitrogen Species in the Eastern United States. *Atmospheric Environment*, Vol. 33, 37-49.

Acid Deposition and the Environment

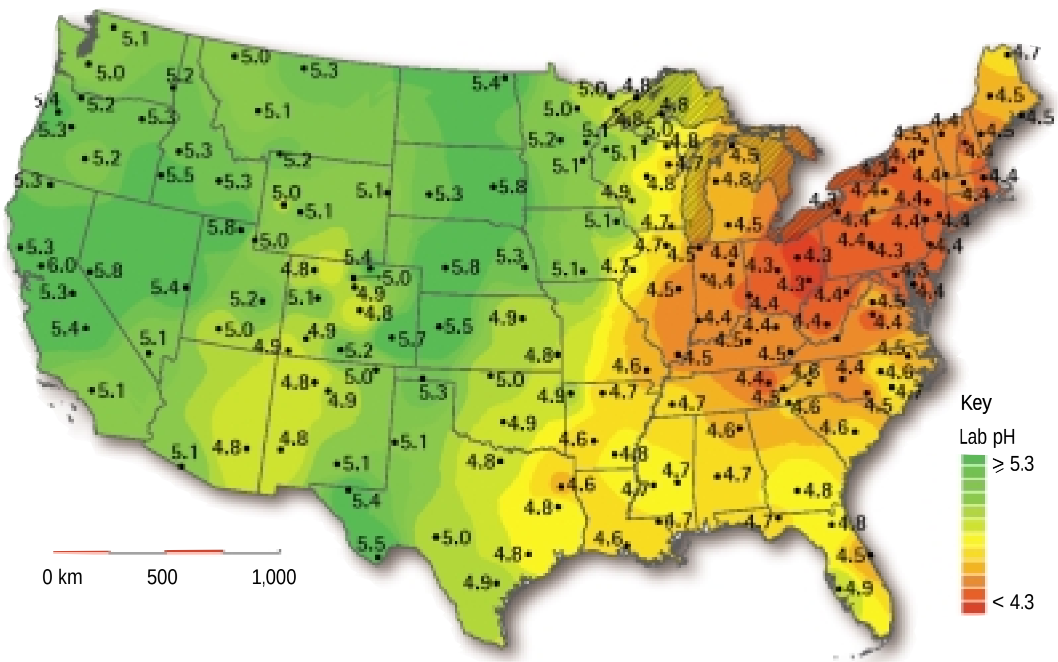
The ultimate consequence of acid deposition is its impact on the environment and public health. In both wet and dry forms, acid rain has multiple effects, sometimes through mechanisms that scientists are still trying to understand. In general, the chemical composition of rainwater varies from place to place, often due to air pollution and other chemicals found in a particular area. Figure 12 presents the pH, a measure of acidity, of precipitation measured by the NADP network in 1997.

The following sections discuss areas that will benefit from the Acid Rain Program's emission reductions: surface water, visibility, forests, human health, and materials and structures.

Surface Water: Lakes and Streams

In a national surface water survey conducted under NAPAP in the mid-1980s, acid rain was the dominant cause of acidification in 75 percent of the acidic lakes and about 50 percent of the acidic

Figure 12. 1997 Estimated Acidity (pH) of Precipitation at NADP Sites



Estimated pH of precipitation sampled at more than 200 sites nationwide. Most acidic precipitation is found in the Midwest and Northeast. Normal pH for rainfall is about 5.5.

Source: National Atmospheric Deposition Program/National Trends Network

streams (NAPAP, 1991). Acid deposition can deplete the ability of lakes and streams to sustain some fish and other aquatic species' capability to grow, reproduce, or survive. Although the diversity and abundance of fish species present in a body of water is related to many factors, in some cases, the types of species able to survive can be directly correlated to surface water acidity. Figure 13 shows critical pH levels below which various species of fish cannot survive.

The loss of fish occurs primarily in surface waters resting atop shallow soils that are not able to buffer, or counteract, acidity, most commonly in the Northeast and Mid-Atlantic regions (see Figure 14). Furthermore, as acidity increases, aluminum is leached from the soil causing concentrations in lakes and streams to increase. Aluminum, particularly inorganic aluminum, is highly toxic to aquatic life. The Adirondack Mountains in New York and the Mid-Appalachian highlands contain many of the U.S. waters most sensitive to acidification. Other sensitive areas include Florida, the upper Midwest, and the high-elevation West. In eastern Canada, where the soil is similar to that found in the Adirondacks, the Canadian government estimates that about 14,000 lakes are acidic.

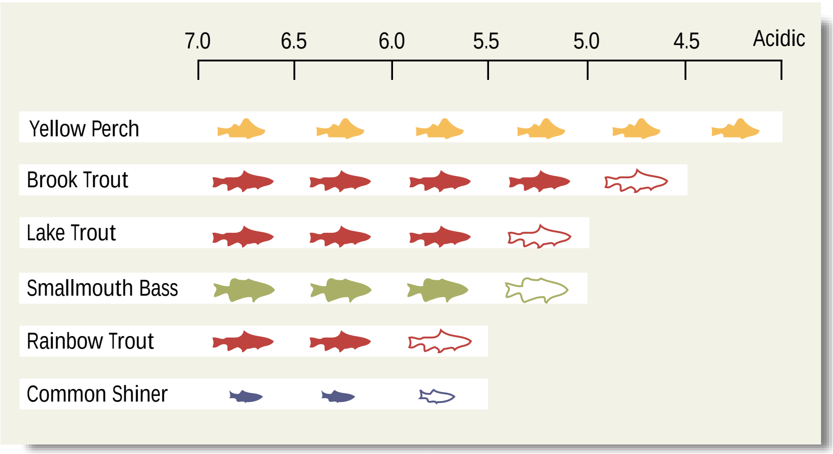
Acidification can be chronic or episodic. Lakes and streams suffering from *chronic* acidification have a constantly low capacity to buffer acids over a long period of time. The NAPAP survey found that more than 500 streams in the Mid-Atlantic Coastal Plain and more than 1,000 streams in the Mid-Atlantic Highlands are chronically acidic, primarily due to acidic deposition. In the New Jersey Pine Barrens area, more than 90 percent of streams are acidic, the highest rate in the nation. Many streams in that area have already experienced trout losses due to the high level of acidity. Hundreds of lakes in the Adirondacks have acidity levels unsuitable for the survival of sensitive fish species [see inset on Adirondacks]. In some sensitive lakes and streams further south, acidification has severely depleted even the hardiest species, such as the brook trout [see inset on streams in the southern Appalachians].

Episodic acidification is the rapid increase in surface water acidity, resulting from large surges of nitrate and/or sulfate, which typically occur during snowmelt or the heavy rains of early spring. Preventing these surges in winter and early spring is critical because fish and other aquatic organisms are in their vulnerable, early life stages.

Though temporary, episodic acidification can affect aquatic life significantly and has the potential to cause “fish kills.”

Episodic acidification increases the number of lakes and streams that are susceptible to acid rain. Approximately 70 percent of sensitive lakes in the Adirondacks may be at risk of episodic acidification. This amount is more than three times the number of chronically acidic lakes. About 30 percent of sensitive streams in the mid-Appalachians are likely to become acidic during an episode. This level is seven times the number of chronically acidic streams in that area. High-elevation lakes in the Western United States also are at risk.

Figure 13. Critical pH for Selected Fish in Lakes and Streams



PH is a measure of acidity. The lower the pH, the more acidic the water. Fish species have different abilities to withstand excess acidity.

Solid symbols for each type of organism are placed in favorable pH ranges; empty symbols are placed in less favorable ranges. No symbol is placed in pH ranges that generally do not support populations of a particular type of organism.

Source: National Acid Precipitation Assessment Program. 1991. *1990 Integrated Assessment Report*. NAPAP Office of Director, Washington, DC.

Acid Neutralizing Capacity

Whether surface waters can resist acidification depends on the ability of the water and watershed soil to neutralize the acid deposition it receives. The best measure of this ability is acid neutralizing capacity (ANC), which is determined by the amount of dissolved compounds that will counteract acidity. Surface water with an ANC of 200 micro equivalents per liter is normal. ANC less than 50 micro equivalents

Adirondacks: Slow to Recover

In spite of declining emissions and even declining surface water sulfate concentrations in the Adirondacks, lakes in this region are not showing any measurable increase in acid neutralizing capacity. Why have other Northeastern lakes, such as those in New England, begun to recover, but not Adirondack lakes?

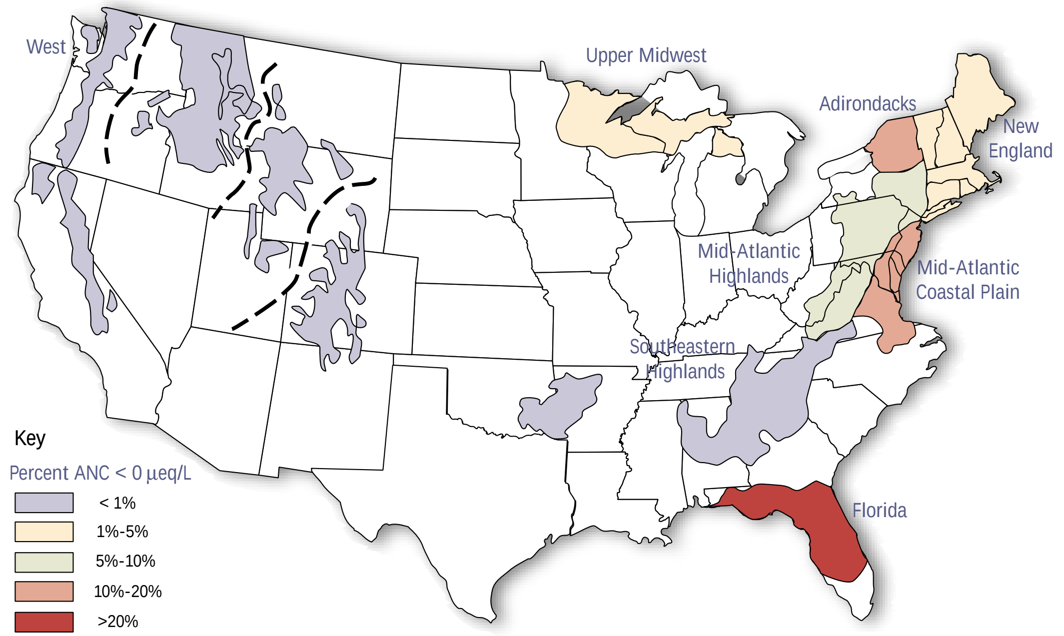
Recovery of Adirondack surface waters may be affected by several factors: relatively constant deposition and presence of nitrate in surface waters, loss of soil’s ability to neutralize excess acidity (“base cation depletion”), naturally occurring acid sources, underestimated dry deposition, and lengthy lag time between deposition reduction and ecosystem recovery.

Recent research and modeling efforts suggest that although conditions would likely have been substantially worse without the Acid Rain Program, full recovery of the Adirondack ecosystems may require reductions in sulfur and nitrogen beyond those currently expected. Watershed dynamics are proving to be complex, highlighting the need for continued environmental monitoring in order to fully evaluate the effects of controlling atmospheric sulfur and nitrogen deposition.

Fresh Water Fish and Rising Acidification

Compared to the Adirondacks, streams in Shenandoah National Park are in the early stages of acidification. Recent declines in fish population and species diversity indicate, however, that episodic acidification is taking its toll. In a University of Virginia study on trout reproduction in the Southern Appalachian Mountains, researchers found nearly 100 percent death in the trout eggs and newly hatched fish after a severely acidic rainfall and steep increase in stream water acidity. This sharp acidic surge, due to acidic rainfall, altered stream chemistry, resulting in conditions fatal to fish at young and vulnerable stages. [Trout Unlimited, 1998.]

Figure 14. Percentage of Acidic Surface Waters in Surveyed Regions



Source: NAPAP. 1991. 1990 Integrated Assessment Report.

per liter is considered highly sensitive to acidification. An ANC of zero or less is acidic. Surface water pH is another direct measure of the balance of acid and base ions in a lake or stream. However, pH does not indicate whether the cause of the acidity is acid deposition or other sources, like organic soils or drainage from mining activities.

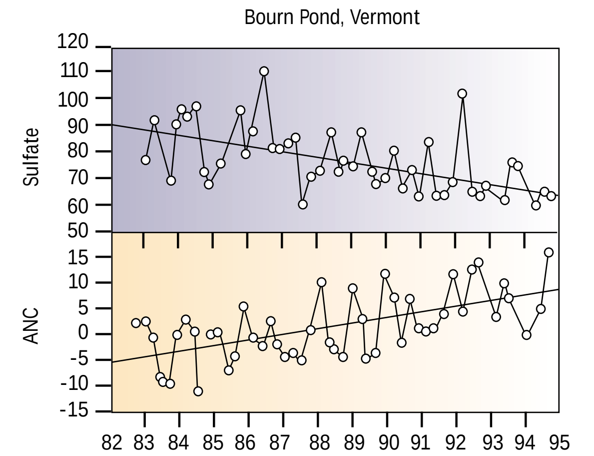
ANC depends largely on the surrounding watershed's physical characteristics such as geology, soils, and size. Waters that are acidic tend to be located in small watersheds that have few alkaline minerals and shallow soils. Conversely, watersheds that contain alkaline minerals, such as limestone, tend to have waters with a high ANC. Deposition reductions from the Acid Rain Program are expected to benefit surface water chemistry. Recently, many acidic surface waters have shown declines in sulfate concentrations consistent with the program's emissions reductions.

Recovery in New England

The Acid Rain Program has led to significant emissions cuts from Northeastern and Midwestern utilities. These reductions can be expected to spur the recovery of lakes and streams in the Northeast, particularly in New England. Some acidified ecosystems are already showing signs of improvement as emissions and acid deposition decline. A recent study examining acidified lakes in the Northeast found that lakes atop thin gravel soils (and thus sensitive to acid rain) in New England have shown statistical decreases in surface water sulfate concentrations and concurrent increases in ANC. These trends (as shown in Figure 15) are significant because ANC indicates an ecosystem's long-term ability to resist acidification.

The study of New England lakes used surface water data from EPA's Environmental Monitoring and Assessment Program's Long-Term Monitoring Project, which provides estimates of the recovery of lakes and streams exposed to large-scale emissions reductions. Ecosystem recovery speed depends heavily on at least three factors: 1) emissions and acid deposition reduction rates; 2) ANC; and 3) time delay for ecosystem response.

Figure 15. Improvements in Surface Water Acidity For Bourn Pond, Vermont



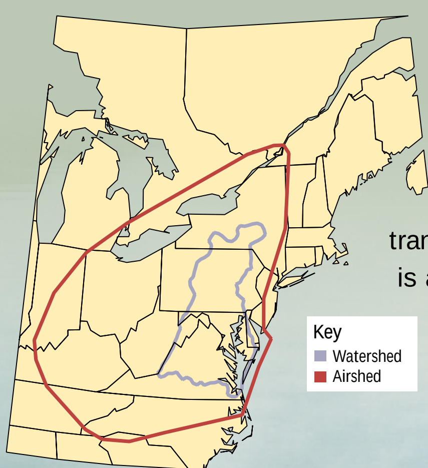
Surface-water chemistry data indicated that acidic conditions are improving in this New England lake. Acidic compounds are decreasing while acid neutralizing capacity is increasing.

Source: Stoddard, Driscoll, Kahl, and Kellogg. 1998. Can site-specific trends be extrapolated to a region? An acidification example for the Northeast, Ecological Applications 8 (2) 1998.

Chesapeake Bay

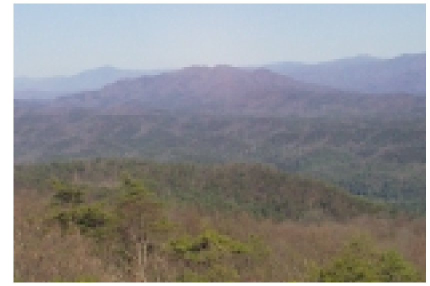
Nitrogen plays a significant role in both short- and long-term acidification of surface waters. In addition, new research reveals that atmospheric nitrogen deposition may have significant adverse impacts on estuaries (where the ocean meets fresh water), other coastal waters, and large river basins. Nitrogen is a key cause of the eutrophication (oxygen depletion) of water bodies, which occurs when excess nutrients enter an estuary and cause excess algae growth. This additional growth limits the amount of light and oxygen available to other organisms in the estuary, making it difficult to survive. Further losses in available oxygen occur once the algae begins to die off.

Figure 16. Chesapeake Bay Airshed and Watershed

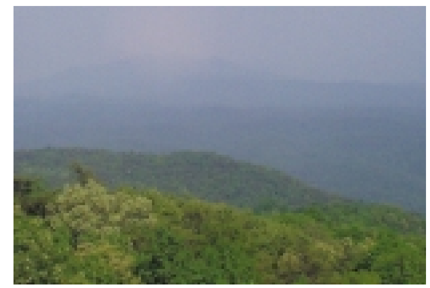


Most of the excess nutrients entering the Chesapeake Bay and its tributaries come from drainage waters, such as pollutant discharge and run-off from farms. Still, scientists estimate that up to 25 percent of the nitrogen in the Chesapeake Bay comes from atmospheric deposition. Long-range transport of atmospheric nitrogen deposition is also an important factor. The Acid Rain Program will help reduce these airborne sources that contribute to eutrophication.

Visibility



Good visibility day in Great Smoky Mountains. Visual range is 100 miles.



Bad visibility day at same location. Visual range is 20 miles.

Source: National Park Service

The pollutants associated with acid deposition also reduce visibility. Visibility impairment occurs when particles and gases in the atmosphere, including sulfates and nitrates, scatter and absorb light. Visibility tends to vary by season and geography because it also is affected by the angle of sunlight and humidity. High relative humidity heightens pollution's effect on visibility because particles, such as sulfates, accumulate water and grow to sizes at which they scatter more light, creating haze.

Sulfate particles from SO_2 emissions account for more than 50 percent of the impaired visibility in the Eastern United States, particularly in combination with high summertime humidity. In the West, nitrogen and carbon also impair visibility, and sulfur has been implicated as a major cause of visibility impairment in many of the Colorado River Plateau national parks, including the Grand Canyon, Canyonlands, and Bryce Canyon.

The Interagency Monitoring of Protected Visual Environments (IMPROVE) network monitors visibility primarily in the nation's national parks. Reductions in particulate sulfate, usually correlated to visibility improvements, have been measured at 13 eastern IMPROVE sites (see Figure 17). It is too soon to tell how much of these improvements can be attributed to the Acid Rain Program.

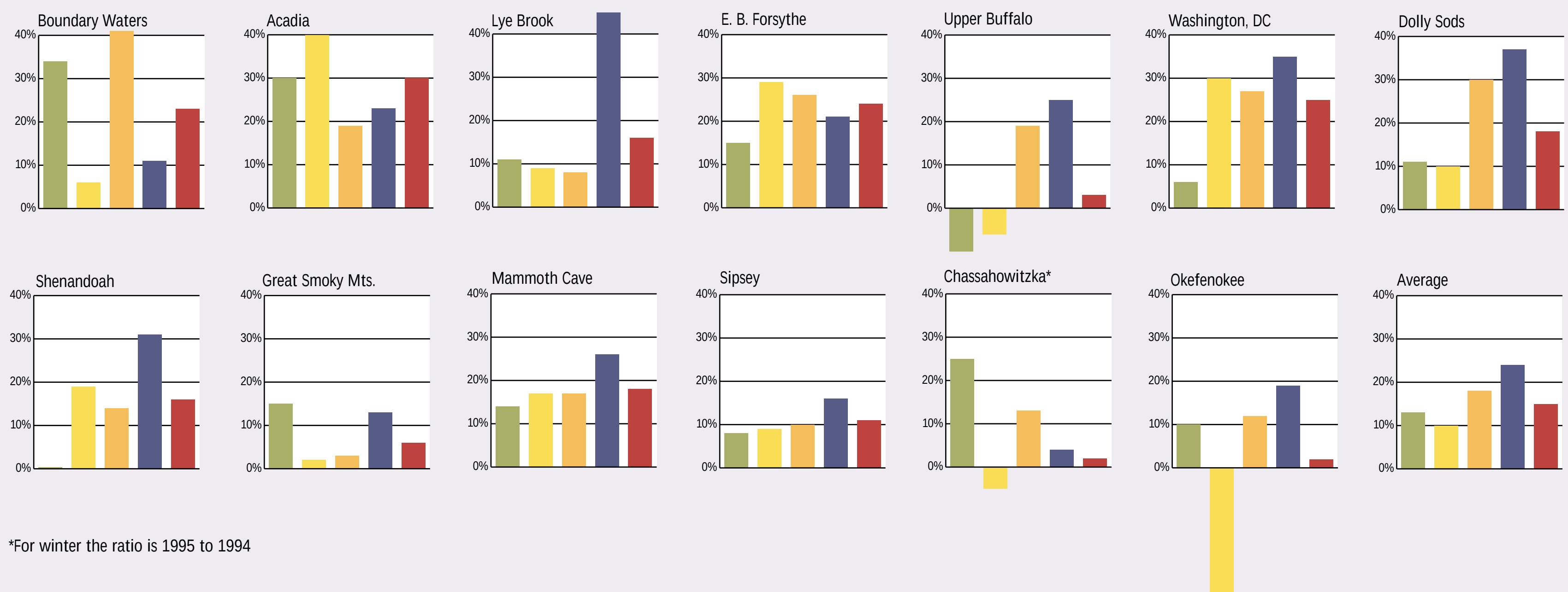
Figure 17. Visibility Improvements in National Parks

Improvements in visibility at our national parks correspond to reductions in the seasonal averaged sulfate concentrations. Percent reduction in particulate sulfate concentrations is calculated by comparing 1995 data to the 1993 to 1994 mean of the IMPROVE network sites.

Source: NAPAP. 1998. *NAPAP Biennial Report to Congress: An Integrated Assessment*.

Key

Spring
Summer
Fall
Winter
Annual



*For winter the ratio is 1995 to 1994

Figure 18. Relationship Between Soil Acidity and Nutrients

As soil and deposition acidity increases, nutrients, such as base cations, are leached from the soil and are not available for plant growth.

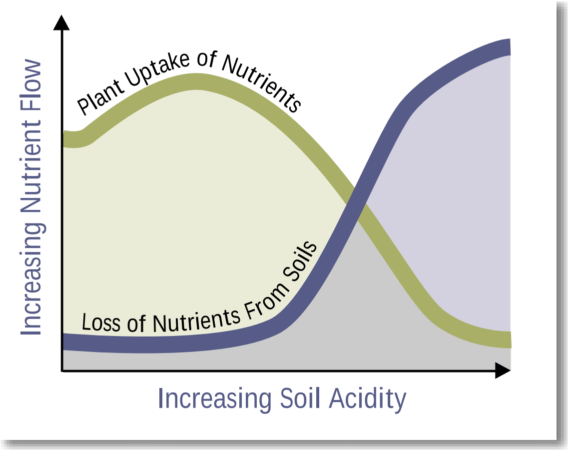
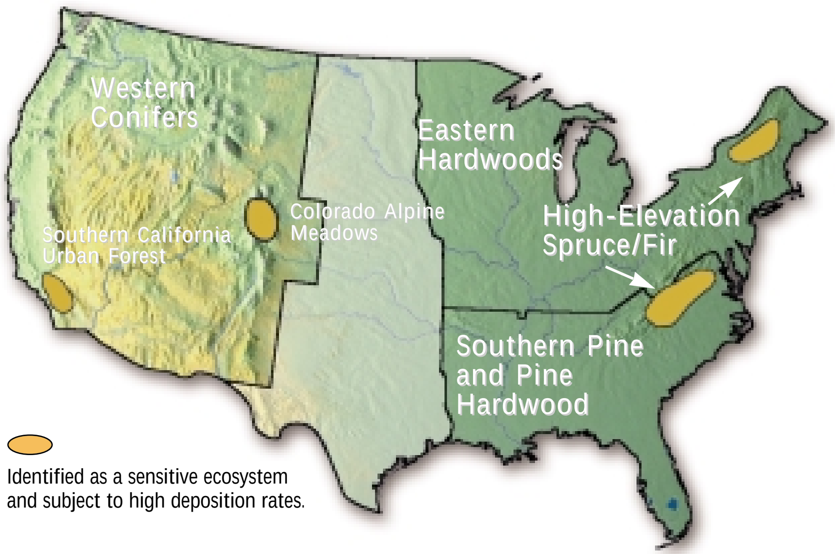


Figure 19. Sensitive Forest Ecosystems



Four major forest types assessed by NAPAP.

Source: NAPAP. 1996. *NAPAP Biennial Report to Congress: An Integrated Assessment*, National Science and Technology Council Committee on Environment and Natural Resources.

Forest Ecosystems

Acid deposition, combined with other pollutant and natural stress factors, can damage forest ecosystems. Damage could include increased death and decline of Northeastern red spruce at high elevations and decreased growth of red spruce in the southern Appalachians. In some cases, acid deposition is implicated in impairing a tree's winter hardening process, making it susceptible to winter injury. In other cases, acid deposition seems to impair tree health beginning with the roots. As acid rain moves through soils, it also can strip nutrients from the soil and increase the presence of aluminum ions, which are toxic to plants.

Long-term changes in the chemistry of some sensitive soils may have already occurred. In some regions, nitrogen deposition in forests can lead to *nitrogen saturation*, which occurs when the forest soil has taken up as much nitrogen as possible. Saturated, the soil can no longer retain nutrients and they are leached away (shown in Figure 18). Nitrogen saturation has been observed in a number of regions including Northeastern forests, the Colorado Front Range and mountain ranges near Los Angeles, California. Effects also have been seen in Canada and Europe. This phenomenon can create nutrient imbalances in the soils and roots of trees, leaving them more vulnerable to the effects of air pollutants such as ozone, climatic extremes such as drought and cold weather, or pest invasion. Figure 19 shows the location of forests sensitive to acid deposition. The Acid Rain Program can be expected to reduce the stress to forest ecosystem health.

Human Health Effects

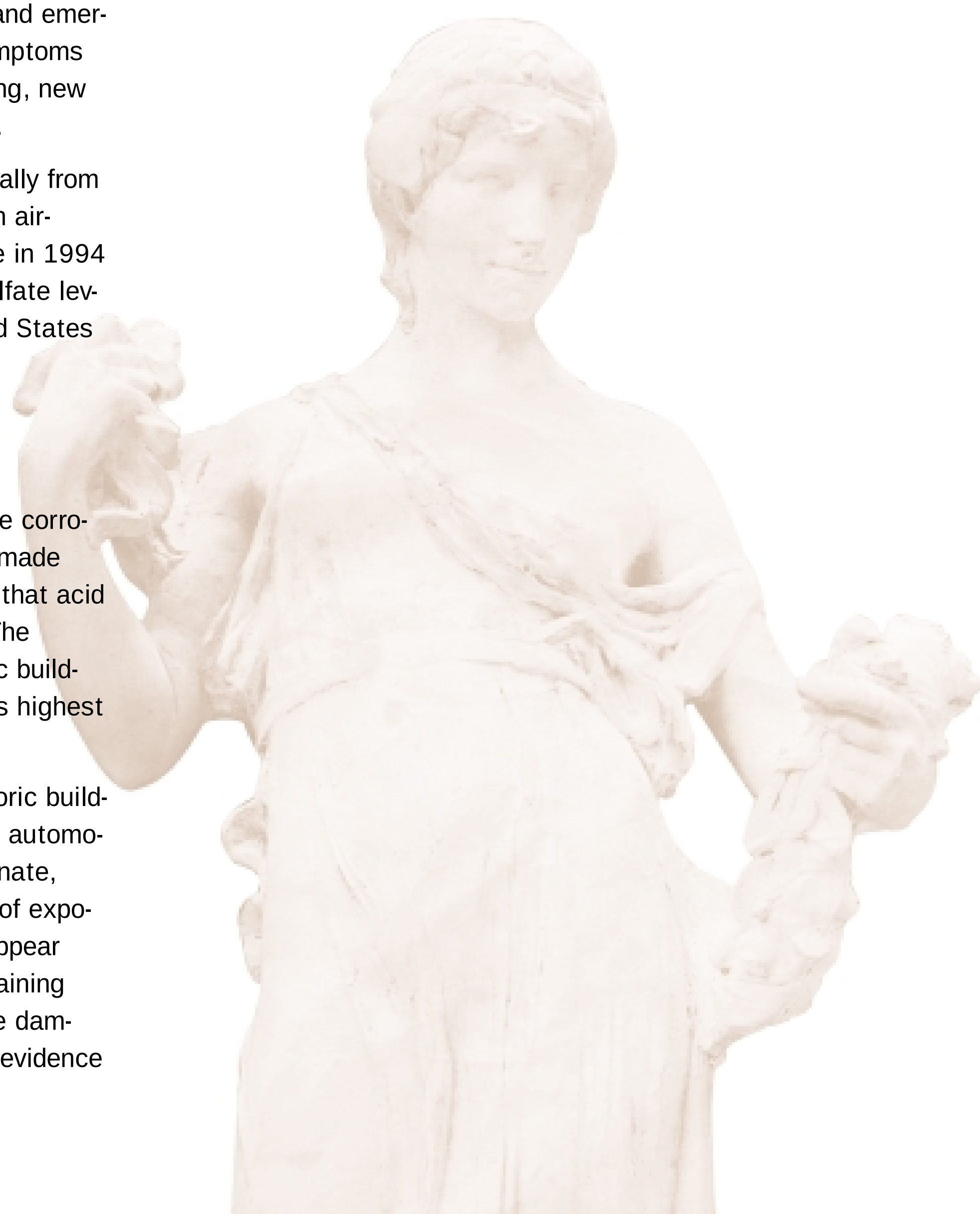
In the atmosphere, SO_2 and NO_X gases are transformed into fine particles of sulfates and nitrates. These particles—the same that impair visibility—have serious health effects as well. Particulate matter (PM) is the term used for the mix of particles that, when airborne, may appear as haze, dust, or soot. Within that mix, particles are divided by size; coarse PM is less than 10 microns in diameter, while fine PM is less than 2.5 microns. Although both fine and coarse particles are of health concern, fine particles are particularly important because they easily penetrate the deepest portions of the lungs. Recent studies have found an association between exposure to fine PM and increased health problems, including premature death, cardiac and respiratory-related hospital admissions and emergency room visits, aggravated asthma, acute respiratory symptoms such as aggravated coughing and difficult or painful breathing, new cases of chronic bronchitis, and work and school absences.

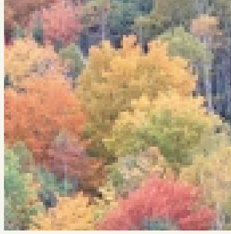
The Acid Rain Program's reductions of SO_2 and NO_X, especially from coal-burning utilities, have brought about significant drops in airborne concentrations of fine PM. The estimated mean value in 1994 dollars of the health benefits associated with decreased sulfate levels and associated fine PM reductions in the Eastern United States is $10 billion for 1997 and $40 billion per year by 2010.

Materials and Structures

Sulfur dioxide, sulfates, and, to a lesser degree, nitrates, are corrosive to most materials, and thus can severely damage manmade objects exposed to the atmosphere. NAPAP found evidence that acid deposition degrades materials beyond natural weathering. The Eastern United States, with its high concentration of historic buildings and outdoor monuments, also has some of the nation's highest levels of acid deposition.

Materials potentially damaged include monuments and historic buildings; outdoor structures such as bridges and buildings; and automotive paints and finishes. For some materials, such as carbonate, steel, or nickel, the effects are apparent after about 1 year of exposure; for others, including copper and paints, effects may appear after about 4 years. Research suggests that materials containing calcium carbonate, such as limestone and marble, are more damaged by dry acid deposition than wet deposition. Anecdotal evidence suggests the same is true for car paints. Ultimately, cultural preservation as well as significant monetary benefits from avoided damage will accompany reductions in SO_2 and NO_X.





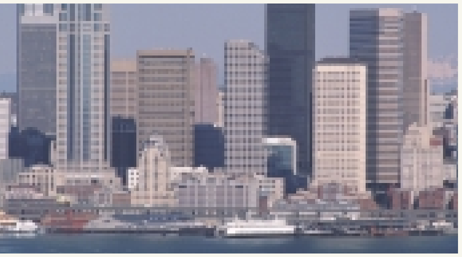
Summary of Accomplishments and Next Steps

Progress in Solving the Acid Rain Problem...

- Phase I of the Acid Rain Program began achieving significant reductions of SO_2 emissions from large electric power generators in 1995. The emissions trading program has proven to be an extremely cost-effective mechanism, and is facilitating 100 percent compliance by affected sources and stimulating early emissions reductions.
- Phase II of the Acid Rain Program begins in the year 2000. Emission reductions will be achieved for a greater number of smaller plants, and emissions from larger plants will be further reduced. By 2010, we will attain a SO_2 emissions cap on electric utilities of 8.95 million tons (a level approximately one half of the industrywide emissions in 1980).
- About 350,000 tons of NO_x emissions have been eliminated. In 2000, these reductions are expected to exceed 2 million tons compared to levels without EPA controls. Absent an emissions cap, however, NO_x emissions could be expected to rise in the future as electrical production increases.

The Environment's Response to Date...

- In the Northeast and Mid-Atlantic regions of the United States, where ecosystems are most sensitive to acidic deposition, sulfate levels in precipitation (wet deposition) have declined by up to 25 percent, mirroring the reductions in SO_2 emissions achieved through the implementation of the Acid Rain Program. No distinct regional trends in wet deposition of nitrate have been detected. This is consistent with NO_x emission trends, which have remained fairly constant over the past decade. Trends in dry deposition of sulfur and nitrogen are comparable.



- While in most cases it is too early to assess the ecological benefits of the Acid Rain Program, some surface water chemistry trends in New England are showing signs of recovery, as indicated by a rise in acid neutralizing capacity in some lakes.
- Ecosystems most severely impacted by acid deposition, such as the Adirondacks, have not yet shown signs of recovery. Some scientists believe that further reductions in SO_2 and NO_x may be necessary for full recovery of these sensitive ecosystems.

Where Do We Go From Here?

- Efforts are under way to better coordinate research, monitoring, and assessment activities to further our understanding of the environmental response to the Acid Rain Program and other air quality control efforts. In addition, these activities will enable better predictions of the environmental benefits from future policies under consideration such as the implementation of the new ozone and particulate matter standards.
- Due to the Acid Rain SO_2 trading program's success in cost savings and unprecedented levels of emission reductions, other air quality efforts include cap and trade programs. For example, EPA is administering a NO_x cap and trade program for large stationary sources in 12 Northeastern states and has offered to administer a similar program for 23 states and the District of Columbia. EPA also is working with these states to reduce NO_x during summer months to reduce regionwide ozone (smog) levels in the Midwest and Eastern United States. These NO_x reductions and expected reductions from the transportation sector may also provide some benefits for a number of other nitrogen-related environmental concerns (e.g., acid rain and eutrophication of coastal waters). A trading program also has been discussed as a possible approach to facilitate future greenhouse gas emissions reductions.

For more information contact...

EPA's Acid Rain Division:
www.epa.gov/acidrain

National Acid Precipitation Assessment Program:
www.nnic.noaa.gov/CENR/NAPAP/NAPAP_96.htm

National Atmospheric Deposition Program:
nadp.sws.uiuc.edu

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