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Pollutants

Acid Deposition

Key Findings

- Acid deposition (commonly called acid rain) degrades the quality of forests, coastal ecosystems, lakes and soils; harms wildlife; and corrodes building materials. Acidifying emissions can cross national and provincial or state boundaries, affecting ecosystems hundreds of kilometers away.
- Sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are acidifying emissions that contribute to acid deposition. These chemicals are emitted mainly by human activities such as metal smelting and fossil fuel combustion in electricity generation and transportation.
- Since 1990, emissions of SO_2 in North America are down by one-third and those of NO_x have declined by just over one-fifth. Sulfate deposition in the eastern United States and Canada has decreased substantially over the last 15 years, whereas the reduction in nitrate deposition has been less dramatic.
- Despite the considerable progress made toward reducing emissions and the deposition of acidifying pollution, many sensitive ecosystems are still receiving levels of acid deposition above the threshold levels that cause long-term damage. Furthermore, some regions previously affected by high levels of acid deposition are not recovering as expected.

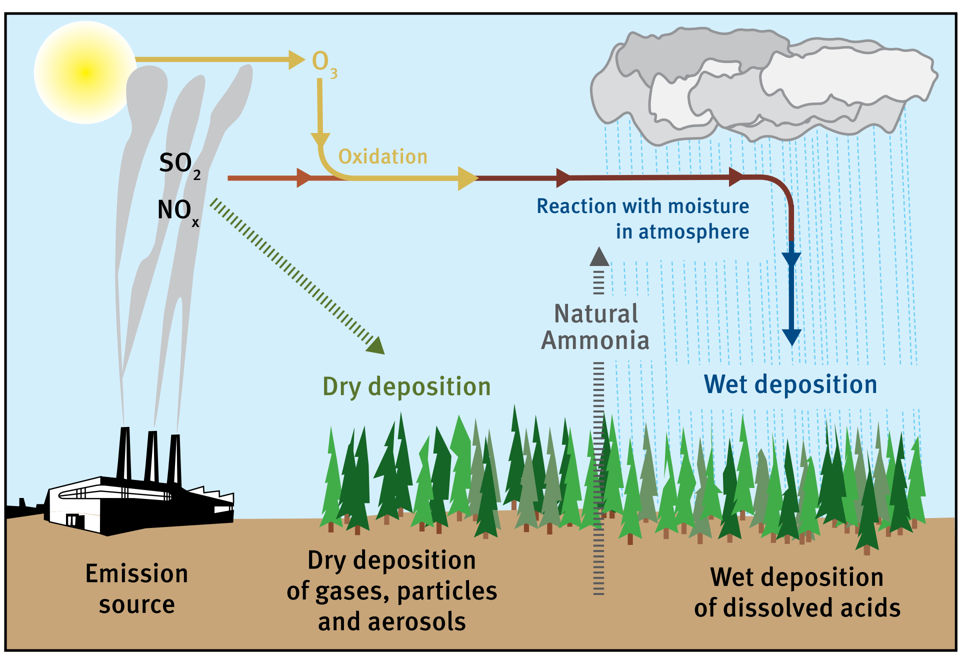
***Acid deposition* primarily results from the transformation of air pollutants such as sulfur dioxide and nitrogen oxides into secondary pollutants such as sulfuric acid, ammonium nitrate and nitric acid. Acidic particles and vapors can be deposited on the earth's surface as acid precipitation (wet deposition) or via particles such as fly ash, sulfates, nitrates, and gases (dry deposition).**

What Is the Environmental Issue?

Acid deposition has already damaged North American forests, lakes, soils, buildings and historic monuments—in some cases, irretrievably. The air pollutants giving rise to acid deposition affect human health and air quality as well. But the problem is not just a North American one. Because acidic pollutants can travel great distances through the atmosphere to be deposited in ecosystems hundreds and even thousands of kilometers away, acid deposition is a global problem. Emissions from North America travel as far as Europe, and pollution from Asia affects human health and the environment in North America.

Air pollutants, particularly emissions of oxides of sulfur and nitrogen, are the precursors of acid deposition. In North America, sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are emitted by anthropogenic sources such as metal smelting and fossil fuel combustion in electricity generation and transportation, as well as by natural sources such as volcanoes, forest fires and lightning. However, the vast majority of SO_2 and NO_x emissions that contribute to acid deposition are a product of human activities (see illustration of acid deposition process).

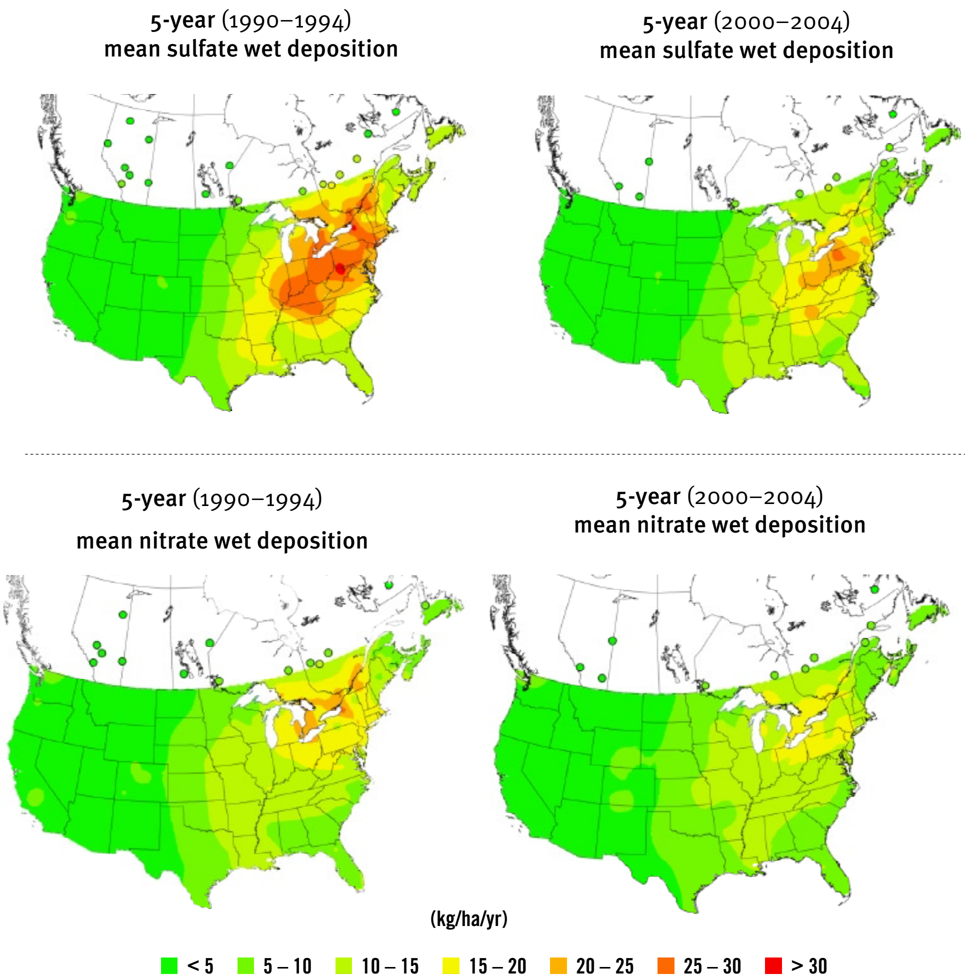
The acid deposition process



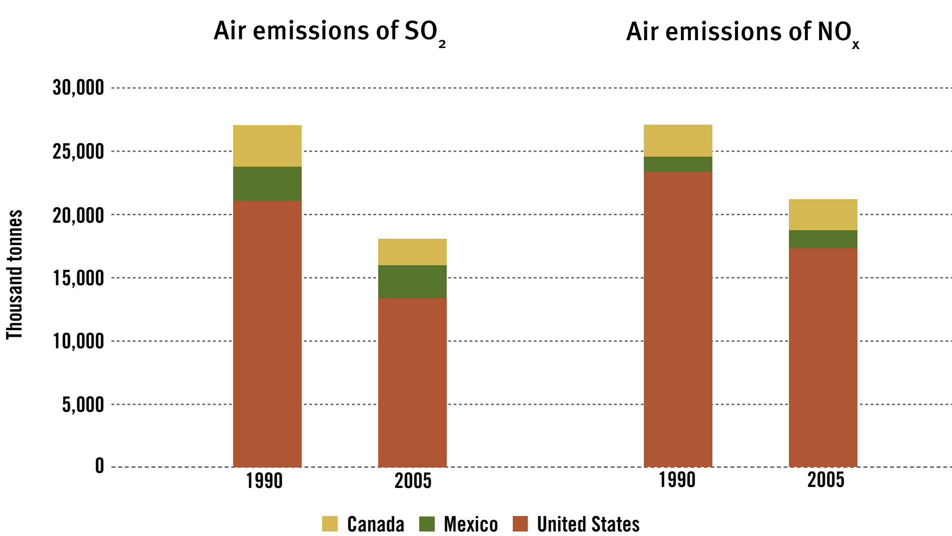
Adapted from: Michael Pidwirny, Physical Geography.net—Fundamentals of Physical Geography, <http://www.physicalgeography.net/fundamentals/8h.html>.

Note: This publication was prepared by the Secretariat of the Commission for Environmental Cooperation.
The views contained herein do not necessarily reflect the views of the governments of Canada, Mexico or the United States of America.

Wet sulfate and wet nitrate deposition in the United States and Canada



Source: NAtChem. Maps courtesy of Chul-Un Ro, Environment Canada.



Sources: Environment Canada, *Instituto Nacional de Ecología* (latest data from Mexico from 2002, not 2005), US Environmental Protection Agency.

Acidification of ecosystems occurs when the deposition of acidic compounds exceeds the neutralizing capacity of the receiving environment. Clean rainwater is slightly acidic, with a pH of about 5.6, because it contains dissolved carbon dioxide from the air. Acidic pollution has a pH lower than this, normally ranging between 4 and 5. A decrease in a single pH unit represents a tenfold increase in acidity. Thus rainwater with a pH of 4.2 is about 25 times more acidic than clean rain. By making soil and water more acidic, acid deposition harms plants, animals and ecosystem integrity in affected areas. It also damages buildings, monuments and painted surfaces.

In a lake, acid deposition creates a cascade of effects that reduce fish populations and may even completely eliminate a fish species from a water body. As acid rain flows through soils in a watershed, metals such as aluminum are released into the lakes and streams in that watershed. Both low pH and increased aluminum levels are directly toxic to fish. In addition, they cause chronic stress that, although it may not kill individual fish, does lead to lower body weight and smaller size and makes fish less able to compete for food and habitat. Acidification of lakes and streams can also increase the amount of methyl mercury available in aquatic systems. In certain lakes in Canada and the United States that have a low pH, the common loon, a duck-like waterbird, has been found to have elevated blood mercury levels.

In forest soils, excess acid deposition increases the susceptibility of forests to stresses from pests, pathogens and climate change, resulting in poorer forest health, lower timber yields and eventual changes in the composition of forest species. Acid rain weakens trees by damaging their leaves, limiting the nutrients available to them or exposing them to toxic substances slowly released from the soil. Quite often, these effects of acid rain, in combination with one or more additional threats, injure or kill trees.

Finally, the pollutants that cause acid rain are harmful to human health. In the air, they join with other chemicals to produce smog, which can irritate the lungs and make breathing difficult, especially for people suffering from asthma, bronchitis or other respiratory conditions. Fine particulate matter, containing sulfate derived from SO_2, is thought to be especially damaging to the lungs.

Why Is This Issue Important to North America?

The effects of acid deposition across North America can be addressed only in cooperation with the neighboring jurisdictions that contribute to acidifying emissions. The issue of acid rain first caught the public's attention in the late 1970s and early 1980s when its devastating impacts on ecosystems in eastern North America were publicized. In 1980 Canada and the United States began working together to address this transboundary issue. The two countries signed the Canada-US Air Quality Agreement in 1991 to promote scientific understanding and pollution reduction in both countries.

Efforts to Reduce Emissions

Canada and the United States gave priority to SO_2 emissions because lowering these emissions was understood to be most important in lessening damage to sensitive ecosystems. Since 1990, SO_2 air emissions in North America have declined by almost one-third (see graph). At present, electric power generation accounts for the largest emissions of SO_2 in the United States, while in Canada the dominant emitting sector is base metal smelting.

Over the same period, air emissions of NO_x have declined by just over one-fifth (see graph). Mobile sources such as cars and trucks are the most significant sources of NO_x emissions in North America, with the remainder coming from power plants and other sources.

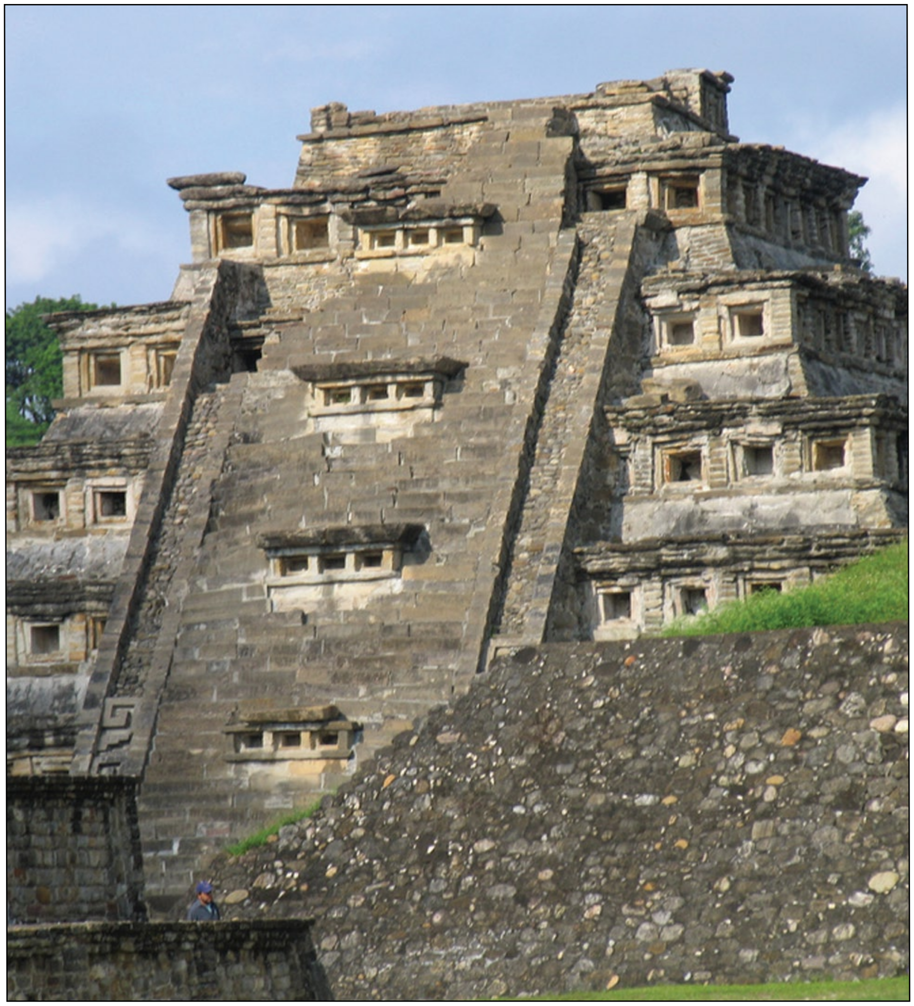
Results

In response to emission reductions, levels of sulfate deposition in the eastern United States and Canada decreased substantially over the period 1990–2004, whereas changes in levels of nitrate deposition have been less dramatic (see maps).

Affected Areas

Many of the water and soil systems in eastern North America cannot neutralize acid naturally. As a result, these areas are sensitive to acid deposition. To understand the capacity of ecosystems to absorb acid deposition, scientists have developed the concept of "critical load"—that is, an estimate of the amount of deposition that a particular ecosystem can receive below which no harmful effects occur. The critical load depends on the quantity of acid-neutralizing bases, such as calcium and magnesium salts, in a region's water and in the surrounding rocks and soils.

Case Study – Acidification at El Tajín, Mexico



Pyramid of the Niches, El Tajín, Veracruz, Mexico. Source: Luiz Castro.

Located in the present-day municipality of Papantla de Olarte in Veracruz, Mexico, El Tajín was one of the most important cities in the Mesoamerican Gulf zone. Its archaeological zone contains constructions dating back to 100 A.D. From 600 to 1150 A.D., the city reached its maximum size and influence.

Humberto Bravo Álvarez and the section on environmental contamination at the *Centro de Ciencias de la Atmósfera*, *Universidad Nacional Autónoma de México*, are studying the effects of acid rain on archaeological and historical sites at El Tajín. From 18 August 2002 to 9 April 2003, they collected 40 rain samples at the El Tajín archaeological site and applied atmospheric trajectory analysis to each precipitation sample to determine air transport pathways corresponding to the precipitation events. Trajectory models are useful in identifying upwind regions likely to contribute to the pollutant burden at downwind receptors.

The analyses indicated that 85 percent of the precipitation events sampled at El Tajín were acidic ($pH < 5.62$). The back trajectory analysis of these acidic events showed a great variation, indicating there was no apparent directional preference for transport during these events and suggesting the importance of local sources. The El Tajín archaeological zone is surrounded by possible sources of acid rain precursors in the form of industries burning fuel oil with a high sulfur content (such as electric power plants and refineries). Thus both these sources and more distant ones may be important contributors to rainfall acidity at El Tajín.

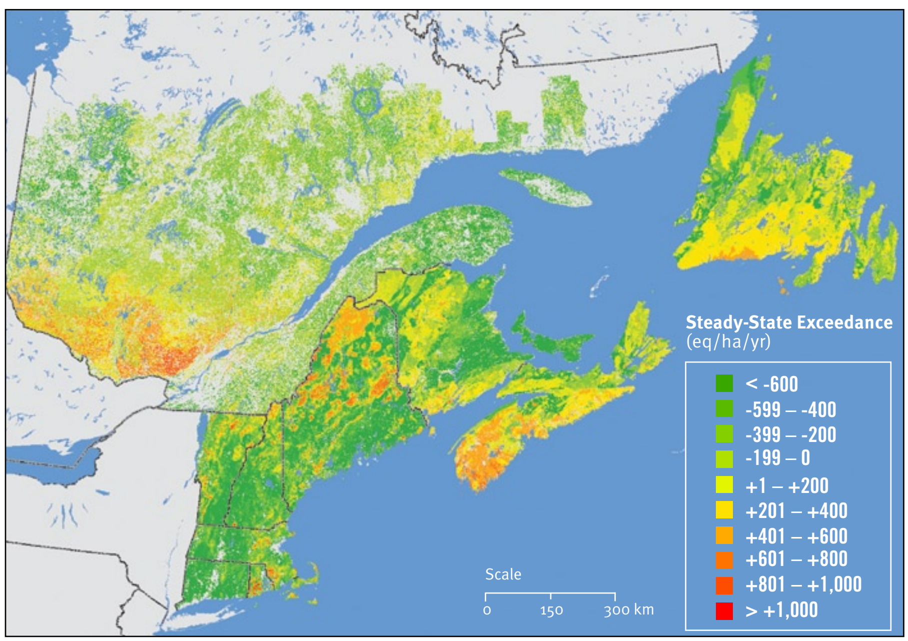
Case Study – Forest Sensitivity to Sulfur and Nitrogen Deposition

Although sulfur emissions in the United States and Canada have fallen in response to control programs, the continued emissions of acidifying sulfur and nitrogen compounds present a serious long-term threat to forest health and productivity in parts of northeastern North America. This conclusion was reached by a study of the northeastern United States and eastern Canada conducted by the Conference of New England Governors and Eastern Canadian Premiers Forest Mapping Group.

According to the Forest Mapping Group's study, the atmospheric deposition of sulfur and nitrogen from 1999 to 2003 exceeded the critical load in more than one-third of the study area (see map). In the eastern Canadian provinces, the most sensitive forest areas occur in southern Quebec, especially in the Lower-Laurentides north of the St. Lawrence River, in southeastern Nova Scotia, and in southern Newfoundland. In New England, the most sensitive forest areas occur in the mountain ranges and coastal areas where soils are poor and weathering rates low, and where there is greater demand for nutrients due to more intensive harvesting.

Based on forest monitoring in Quebec and the known effects of acid deposition, the Forest Mapping Group's study concludes that high exceedances of critical loads lead directly or indirectly to reduced forest growth and health.

Forest areas sensitive to acid deposition in the New England states and eastern Canadian provinces



Source: Conference of New England Governors and Eastern Canadian Premiers Forest Mapping Group.

Despite the progress in reducing acidifying emissions, some ecosystems are making a slower-than-expected recovery. In the United States, acidic surface waters are still found in the upper Midwest, Adirondack Mountains and northern Appalachian regions. In Canada, the areas receiving depositions higher than their critical loads are in provinces that are part of the Canadian Precambrian Shield. In Ontario, Quebec, New Brunswick and Nova Scotia, the susceptible hard rock (granite) areas lack the natural capacity to neutralize or buffer acid rain effectively. Historically, lower levels of industrialization combined with natural factors such as eastwardly moving weather patterns and soils with buffering capacity have largely protected western prairie ecosystems in Canada and the United States from the impacts of acid rain.

Although similar maps are not available for Mexico, the effects of acid deposition are evident in national parks near Mexico City where acid rain has damaged forests and soils, as well as in the damage to monuments and historic buildings in Mexico City and elsewhere (see case study, previous page).

What Are the Linkages to Other North American Environmental Issues?

Scientists' initial concerns about the effects of acid deposition on forests and building materials have now expanded to include the relationship of acidifying pollution to biodiversity and sensitive coastal ecosystems.

Biodiversity

The various species that inhabit lakes, rivers and wetlands differ in their abilities to tolerate acidity. Acidification primarily reduces the variety of life inhabiting a lake and alters the balance among surviving populations. Changes in the mix of species inhabiting water bodies also affect birds and other species farther up the food chain, as some kinds of food resources become scarcer and others become more abundant. Scientists cannot say whether species that have disappeared from an acidified lake will ever return—even if pH levels return to normal.

Coastal Ecosystems

Linked to acid deposition is the effect of nitrogen deposition on coastal ecosystems, where nitrogen is often the limiting nutrient. Higher levels of nitrogen in coastal waters can cause significant changes to those ecosystems. Some 60 percent of estuaries in the United States suffer from overenrichment of nitrogen, a condition known as eutrophication. Symptoms of eutrophication include changes in the dominant species of plankton (the primary food source for many kinds of marine life), which can cause algal blooms, low levels of oxygen in the water column, fish and shellfish kills, and cascading population changes up the food chain. In addition, the higher levels of turbidity in the water because of the large amounts of algae can kill off submerged aquatic vegetation, which is an important habitat for many estuarine fish and shellfish species. Although a large number of the most highly eutrophic estuaries are along the US Gulf and Mid-Atlantic coasts, overlapping many of the areas with the highest nitrogen deposition, eutrophic estuaries can be found in every region of the conterminous US coastline.