Acid Rain

Indicator #9000

Disclaimer

The Acid Rain indicator report was drafted in the fall of 2004 using data that was available at that time. This version of the indicator report includes only minor modifications to the text. Since 2004, a number of Canadian and U.S. governmental reports have been released with more up-to-date information. These reports include the United States-Canada Air Quality Agreement: 2006 Progress Report and the Government of Canada Five-year Progress Report: Canada-Wide Standards for Particulate Matter and Ozone. The information and data presented in these reports (and others) will be incorporated into the 2009 Acid Rain indicator report.

Overall Assessment

Status: **Mixed**
Trend: **Improving**

Lake-by-Lake Assessment

Separate lake assessments were not included in the last update of this report.

Purpose

- To assess the sulfate and nitrate levels in precipitation
- To assess the exceedance of critical loads of sulfate to the Great Lakes basin
- To infer the efficacy of policies to reduce sulfur and nitrogen acidic compounds released into the atmosphere

Ecosystem Objective

This indicator supports both the Acid Rain Annex and the Ozone Annex of the 1991 Canada-U.S. Air Quality Agreement (Air Quality Agreement), which was established to address the transboundary flow of air pollution between the two countries. With respect to acid rain, the Air Quality Agreement sets specific sulfur dioxide (SO_2) and nitrogen oxide (NO_x) reduction targets and establishes a forum for acid rain related scientific and technical cooperation. This indicator supports Annexes 1 and 15 of the 1978 Great Lakes Water Quality Agreement. This indicator also supports The Canada-Wide Acid Rain Strategy for Post-2000, Canada's principle domestic policy tool for managing acid rain, http://www.ccme.ca/assets/pdf/1998_acid_rain_strategy_e.pdf, the long-term goal of which is "to meet the environmental threshold of critical loads for acid deposition across Canada", i.e., to ensure that no areas of Canada are receiving levels of acid deposition above which damage may occur.

State of the Ecosystem

Background

Acid rain, or "acidic deposition", is caused when two common air pollutants, sulfur dioxide (SO_2) and nitrogen oxides (NO_x), are released into the atmosphere, react and mix with atmospheric moisture and return to the earth as acidic rain, snow, fog or particulate matter. These pollutants can be carried over long distances by prevailing winds, creating acidic precipitation far from the original source of the emissions. Environmental damage typically occurs where local soils and/or bedrock do not effectively neutralize the acid.

Lakes and rivers have been acidified by acid rain, directly or indirectly causing the disappearance of invertebrates, many fish species, waterbirds and plants. Not all lakes exposed to acid rain become acidified, however. Lakes located in terrain that is rich in calcium carbonate (e.g. on limestone bedrock) are able to neutralize acidic deposition. Much of the acidic precipitation in North America falls in areas around and including the Great Lakes basin. Northern Lakes Huron, Superior and Michigan, their tributaries and associated small inland lakes are located on the geological feature known as the Canadian Shield. The Shield is primarily composed of granitic bedrock and glacially derived soils that cannot easily neutralize acid, thereby resulting in the acidification of many small lakes (particularly in northern Ontario and the northeastern United States). The five Great Lakes are so large that acidic deposition has little effect on them directly. Impacts are mainly felt on vegetation and inland lakes in acid-sensitive areas.

A report published by the Hubbard Brook Research Foundation demonstrated that acid deposition is still a significant problem and has had a greater environmental impact than previously thought (Driscol *et al.* 2001). For example, acid deposition has altered soils in the northeastern U.S. through the accelerated leaching of base cations, the accumulation of nitrogen and sulfur, and an increase in concentrations of aluminum in soil waters. Acid deposition has also contributed to the decline of red spruce trees and sugar maple trees in the eastern U.S. Similar observations have been made in eastern Canada (Ontario and eastward) and are reported in the *2004 Canadian Acid Deposition Science Assessment* (Environment Canada 2005). The assessment confirms that although levels of acid deposition have declined in eastern Canada over the last two decades, approximately 21% of the mapped area currently receives levels of acid rain in excess of what the region can handle, and 75% of the area is at potential risk of damage should all nitrogen deposition become acidifying, i.e. aquatic and terrestrial ecosystems become nitrogen saturated.

Sulfur Dioxide and Nitrous Oxides Emissions Reductions

Sulfur Dioxide emissions come from a variety of sources. The most common releases of SO_2 in Canada are industrial processes such as non-ferrous mining and metal smelting. In the United States, electric utilities constitute the largest emissions source (Figure 1), while in Canada the largest emission source is from industry. The primary source of NO_x emissions in both countries is the combustion of fuels in motor vehicles, with electric utilities and industrial sources also contributing (Figure 2).

Under *The Canada-Wide Acid Rain Strategy for Post-2000*, Canada is committed to reducing acid deposition in its south-eastern region to levels below those that cause harm to ecosystems – a level commonly called the “critical load” - while keeping other areas of the country (where acid rain effects have not been observed) clean. In 2000, total SO_2 emissions in Canada were 2.4 million tonnes, which is about 23% below the national cap of 3.2 million tonnes reiterated under Annex 1 (the Acid Rain Annex) of the Air Quality Agreement. Emissions in 2000 also represent a greater than 50% reduction from 1980 emission levels (1980 emissions were approximately 4.6 million tonnes). The seven easternmost provinces’ approximately 1.6 million tonnes of SO_2 emissions in 2000 were almost 30% below the cap of 2.3 million tonnes/year, set by the former Eastern Canada Acid Rain Program. Reductions of SO_2 are mainly attributed to reductions from the non-ferrous mining and smelting sector and electric utilities as part of the 1985 Eastern Canada Acid Rain Program that was completed in 1994. Further SO_2 reductions are being achieved through the implementation of *The Canada-Wide Acid Rain Strategy for Post-2000.*

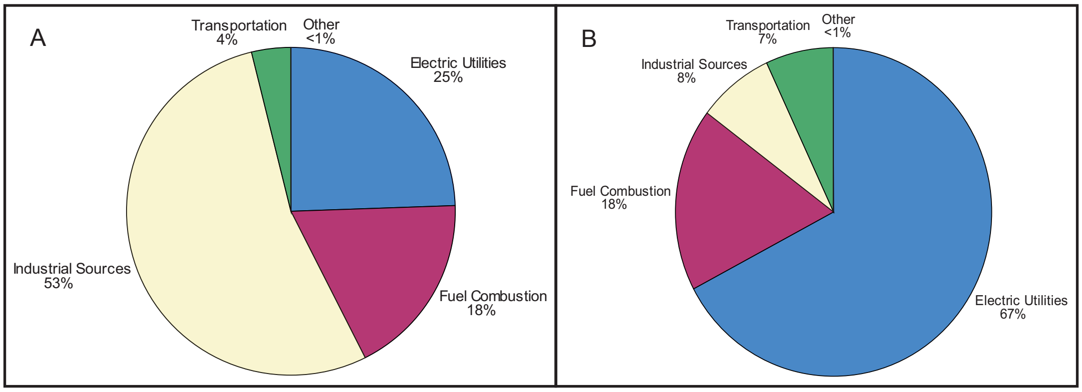

Figure 1. Sources of Sulfur Dioxide Emissions in Canada (A) and the U.S. (B), 1999.

Source: Figure 4 of Canada - United States Air Quality Agreement: 2002 Progress Report. http://www.epa.gov/airmarkets/progsregs/usca/docs/airus02.pdf and Environment Canada 1999 National Pollutant Release Inventory Data and U.S. Environmental Protection Agency 1999 National Emissions Inventory Documentation and Data

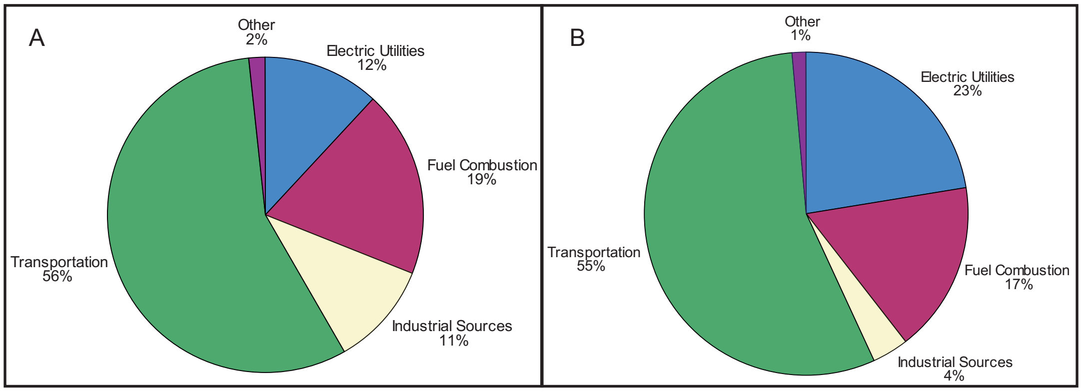

Figure 2. Sources of Nitrogen Oxides Emissions in Canada (A) and the U.S. (B), 1999.

Source: Figure 6 of Canada - United States Air Quality Agreement: 2002 Progress Report. http://www.epa.gov/airmarkets/progsregs/usca/docs/airus02.pdf and Environment Canada 1999 Pollutant Release Inventory Data and U.S. Environmental Protection Agency 1999 National Emissions Inventory Documentation and Data

In 2002, all participating sources of the U.S. Environmental Protection Agency’s (U.S. EPA) Acid Rain Program (Phase I & II) achieved a total reduction in SO_2 emissions of about 35% from 1990 levels, and 41% from 1980 levels. The Acid Rain Program now affects approximately 3,000 fossil-fuel power plant units. These units reduced their SO_2 emissions to

10.19 million tons in 2002, about 4% lower than 2001 emissions. Full implementation of the program in 2010 will result in a permanent national emissions cap of 8.95 million tons, representing about a 50% reduction from 1980 levels.

By 2000, Canadian NO_x emissions were reduced by more than 100,000 tonnes below the forecast level of 970,000 tonnes (established by the Acid Rain Annex) at power plants, major combustion sources, and smelting operations. In the U.S., reductions in NO_x emissions have significantly surpassed the 2 million ton reduction for stationary and mobile sources mandated by the Clean Air Act Amendments of 1990. Under the Acid Rain Program alone, NO_x emissions for all the affected sources in 2002 were 4.5 million tons, about 33% lower than emissions from the sources in 1990. Overall, NO_x emissions decreased by about 12% in the U.S. from 1993 to 2002. NO_x emissions have remained relatively constant in Canada since 1990, but they are projected to decrease considerably in both countries by 2010.

For additional information on SO_2 and NO_x emission reductions, including sources outside the Acid Rain Program, refer to indicator report #4202 Air Quality.

Figure 3 compares wet sulfate deposition and wet nitrate deposition (kilograms per hectare per year or kg/ha/yr) over North America between two separate year periods, 1990-1994 and 1996-2000. Focusing on eastern North America where both sulfate and wet nitrate deposition continue to be highest, a considerable difference can be observed in wet sulphate levels between the 1990-1994 and 1996-2000 average periods. For example, the large area that received 25 to 30 kg/ha/yr of sulfate wet deposition in the 1990-1994 period had almost disappeared in the 1996-2000 period. This significant reduction in wet sulphate deposition can be directly attributed to reduced SO_2 emission reductions in both countries from the 1990s. However, SO_2 emissions have remained relatively constant since the year 2000. It is therefore unlikely that sulfate deposition will change considerably in the coming decade. Sulfate deposition models predict that even by 2020, following the achievement of commitments under the Canada-US Air Quality Agreement and *The Canada-wide Acid Rain Strategy for Post 2000*, critical loads for aquatic ecosystems in eastern Canada will continue to be exceeded over a large area.

A somewhat different story occurs for nitrate wet deposition with reductions being more modest between the two periods than for sulphate. In the case of wet nitrate deposition, the highest deposition occurs around the lower Great Lakes.

Pressures

As the human population within and outside the basin continues to grow, there will be increasing demands on electrical utility companies and natural resources and increasing numbers of motor vehicles. Considering this, reducing nitrogen deposition is becoming more and more important, as its contribution to acidification may soon outweigh the benefits gained from reductions in sulfur dioxide emissions.

Management Implications

The effects of acid rain can be seen far from the source of SO_2 and NO_x generation, so the governments of Canada and the United States are working together to reduce acid emissions. The 1991 Canada - United States Air Quality Agreement addresses transboundary pollution. To date, this agreement has focused on acidifying pollutants and significant steps have been made in the reduction of SO_2 emissions. However, further progress in the reduction of acidifying pollutants, including NO_x, is required.

In December 2000, Canada and the United States signed Annex III (the Ozone Annex) to the Air Quality Agreement. The Ozone Annex committed Canada and the U.S. to aggressive emission reduction measures to reduce emissions of NO_x and volatile organic compounds. (For more information on ozone, refer to indicator report #4202 Air Quality).

The *Canada-Wide Acid Rain Strategy for Post-2000 provides* a framework for further actions, such as establishing new SO_2 emission reduction targets in Ontario, Quebec, New Brunswick and Nova Scotia. In fulfillment of *The Strategy*, each of these provinces has announced a 50% reduction from its existing emissions cap. Quebec, New Brunswick and Nova Scotia are committed to achieving their caps by 2010, while Ontario committed to meet its new cap by 2015.

Since the State of the Great Lakes 2003 Acid Rain indicator report, there has been increasing interest in both the public and private sector in a multi-pollutant approach to reducing air pollution. On March 10, 2005, the U.S. EPA issued the Clean Air Interstate Rule (CAIR), a rule that will achieve the largest reduction in air pollution in more than a decade. Through a cap-and-trade approach, CAIR will permanently cap emissions of SO_2 and NO_x across 28 eastern states and the District of Columbia. When fully implemented, CAIR is expected to reduce SO_2 emissions in these states by 73% and NO_x emissions by 61% from 2003 levels.

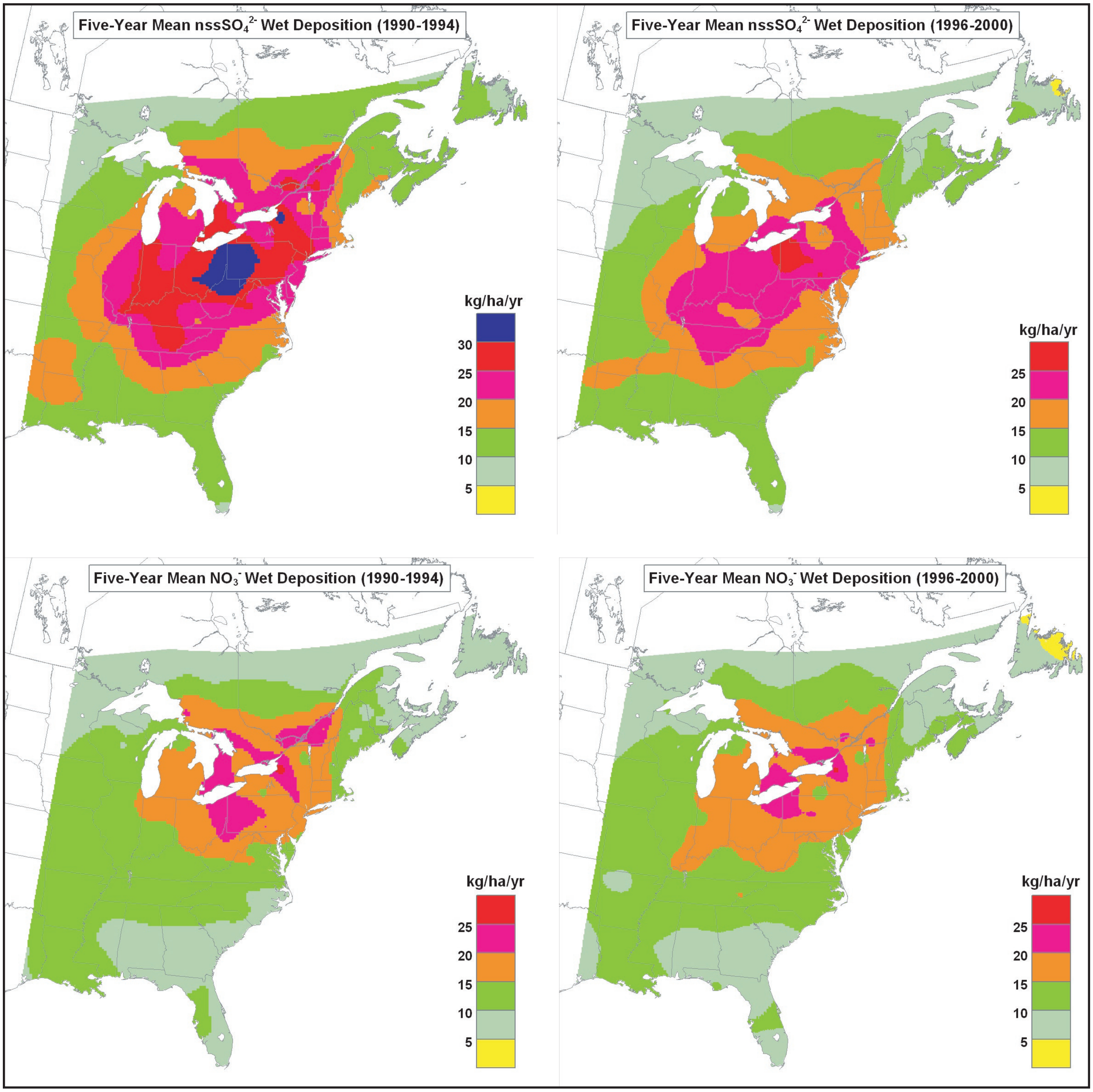

Figure 3. Five-year mean patterns of wet non-sea-salt-sulfate (nssS0$_4^{2-}$) and wet nitrate deposition for the periods 1990-1994 and 1996-2000.

Source: Figures 9 through 12 of Canada - United States Air Quality Agreement: 2002 Progress Report. http://www.epa.gov/airmarkets/progsregs/usca/docs/airus02.pdf, and Jeffries *et al.* 2003

Comments from the author(s)

While North American SO$_2$ emissions and sulfate deposition levels in the Great Lakes basin have declined over the past 10 to 15 years, rain is still too acidic throughout most of the Great Lakes region, and many acidified lakes do not show recovery (increase in water pH or alkalinity). Empirical evidence suggests that there are a number of factors acting to delay or limit the recovery response, e.g. increasing importance of nitrogen-based acidification, soil depletion of base cations, mobilization of stored sulfur, climatic influences, etc. Further work is needed to quantify the additional reduction in deposition needed to overcome these limitations and to accurately predict the recovery rate.

Acknowledgments
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Last Updated
State of the Great Lakes 2007
[Editor's Note: A complete revision of this report has not been completed since 2005. For more information, please refer to the disclaimer at the beginning of this report.]