Current Issue Review 79-37E

ACID RAIN

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Revised 30 September 1998

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ACID RAIN*

ISSUE DEFINITION

Although it is no longer at the forefront of environmental issues, acidic precipitation, or acid rain as it is commonly called, remains a subject of concern to many Canadians. When the acidification of lakes was first described in Ontario in the early 1950s, the phenomenon was considered to be simply a local problem resulting from the lakes' proximity to nickel smelting operations in and around Sudbury. Since then, however, scientists have documented the acidification and the demise of numerous additional lakes; acidification is now acknowledged to be widespread and a major environmental problem.

Acidic precipitation is derived principally from emissions of sulphur and nitrogen oxides which are released to the environment during the combustion of fossil fuels and the smelting of sulphide ores. As the pollutants are transported for hundreds, or perhaps thousands, of kilometres through the atmosphere, the oxides enter into a complex series of chemical reactions to form acids. Sulphuric and nitric acids are the most frequently found types.

Freshwater ecosystems are most vulnerable to the harmful effects of acidic precipitation but damage can be inflicted on man-made structures and artifacts as well. The effects of acidic precipitation on terrestrial ecosystems, including agricultural crops and forests, are still not well-defined although most authorities agree that a potential for damage exists.

Although acid rain is not believed to pose a direct risk to human health, there is evidence that the inhalation of acid aerosols can irritate the respiratory tract and aggravate respiratory ailments. The issue is made more complicated, however, by the fact that the effects of acidic pollutants may be difficult to separate from those of other atmospheric pollutants such as

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* The original version of this Current Review was published in November 1979; the paper has been regularly updated since that time.

ground-level ozone. Human health may also be harmed indirectly by elevated levels of toxic metals in drinking water and food which can occur as a result of acid deposition.

BACKGROUND AND ANALYSIS

A. Historical Perspective

Acid rain is not a new phenomenon although public awareness of the problem is a more recent development. In the mid-seventeenth century, Evelyn (in 1661) and Gaunt (in 1662) noted the influence of industrial emissions on the health of plants and people and the transboundary exchange of pollutants between England and France. They suggested remedial measures including the placement of industry outside of towns and the use of taller chimneys to spread the "smoke" into "distant parts." In 1872, Smith, in a pioneering publication entitled "Air and Rain: The Beginnings of a Chemical Climatology", first used the term "acid rain" and described many of the concepts we now consider part of the acidic precipitation problem.

Current awareness of the scope of the acid rain problem has its origins in observations, made in Scandinavia in the 1950s and 1960s, of the increasing acidity of rainfall and of instances of decreasing fish populations. The Scandinavian observations prompted an OECD program to extend measurements over a wider area of Europe. The program, which ran from 1972 to 1977, confirmed the long-range transport of sulphur compounds and pointed to the need for international cooperation to combat the problem.

In Canada, abnormal acidity in precipitation and in Nova Scotia lakes was detected in the mid-1950s. It was hypothesized that the acidity was due to airborne pollution from distant sources. In the mid-1960s, losses of fish populations in lakes southwest of Sudbury, Ontario, were attributed to acidification caused by acid rain.

In 1978, in response to mutual interests and concerns, the Governments of the United States and Canada established a United States-Canada Research Consultation Group to study the problem of the long-range transport of air pollutants (LRTAP). This Group was to study LRTAP and the related phenomenon of acidic precipitation and to aid in the coordination of research studies and the exchange of scientific information between the two countries. A preliminary report released by Environment Canada in October 1979 "identified acidic precipitation as the problem of greatest common concern at the present time." On 5 August 1980, Canada and the United States signed a "Memorandum of Intent Concerning Transboundary Air Pollution" as a preliminary step in the development of a bilateral agreement on air quality which would deal effectively with such pollution and, at the same time, combat acidic precipitation.

As concern mounted over the widespread damage caused by acid rain, major initiatives to decrease acid rain-causing emissions were introduced. In July 1985, 21 countries including Canada signed the Helsinki Protocol, which called for a 30% reduction of SO_2 emissions from 1980 levels as soon as possible and at the latest by 1993. The Canadian Acid Rain Control Program was introduced in the same year. Its objective was to reduce SO_2 emissions in eastern Canada by 50% from the 1980 level of 4.6 million tonnes.

Progress in the United States was initially somewhat slower, but in 1990 the United States brought in the very comprehensive *Clean Air Act Amendments*. Title IV of the Amendments will cut SO_2 emissions by 9.1 million tonnes by the year 2000.

On 13 March 1991, Canada and the United States signed a bilateral Air Quality Agreement which commits both countries to specific schedules for the reductions of acid-forming emissions. The significance of the Agreement is much broader than acid rain in that it establishes a framework for dealing with other transboundary air pollution problems.

B. Formation of Acid Rain

Natural unpolluted rain is not pure water; it is a dilute solution of carbonic acid, which forms when atmospheric carbon dioxide dissolves in water. This acid dissociates in water to release only enough H+ ions to lower the pH of precipitation from 7 to about 5.6; thus, the acidic precipitation which arises from man's pollution of the atmosphere has a pH below 5.6. (A pH of 7 represents neutrality. Each unit decrease of pH corresponds to a ten-fold increase in acidity.)

Acid rain is formed when pollutant compounds, primarily the oxides of sulphur and nitrogen, react with oxygen and moisture in complex reactions in the atmosphere to form acids. Although the details of the chemical reactions which take place in the atmosphere are not completely understood, some of the oxides of sulphur and nitrogen are converted to sulphuric and nitric acids, respectively. These are strong acids and they dissociate completely in water releasing hydrogen ions to solution; thus, they can lower the pH of precipitation significantly. One of the most acidic rainfalls yet recorded fell in Scotland in 1974 and was measured at 2.4 on the pH scale

-- roughly the pH of vinegar (dilute acetic acid) and over one thousand times as acidic as natural rain. In December 1982, a sample of fog taken at Corona del Mar in Southern California had a pH of 1.69. This extremely high acidity developed after a two-day ground-level temperature inversion in the Los Angeles basin which prevented air pollution from dispersing.

C. Emissions of Acidic Pollutants in North America

In the base year, 1980, Canadian emissions of SO_2 totalled some 4.6 million tonnes, with slightly less than 50% coming from the non-ferrous smelting sector. Emissions of SO_2 in the United States amounted to 24 million tonnes; thermal power generation contributed about two-thirds of this total. On a per-capita basis, Canada produces about twice as much SO_2 as does the United States. SO_2 emissions in both countries have a strong regional character: about 80% of total emissions come from provinces east of the Manitoba-Saskatchewan border and from the 31 states east of the Mississippi River in the U.S.A.

Emissions of NO_x in 1980 are estimated to have been 21 and 1.7 million tonnes in the United States and Canada, respectively. In both countries, the transportation sector and electric power generation are the largest contributors, the latter being particularly significant in the U.S.A. Emissions of NO_x are more uniformly distributed than those of SO_2, but more than 60% of emissions are contributed by the eastern regions. On a per-capita basis, the United States produces more NO_x than does Canada.

The acid-forming potential of SO_2 emissions in eastern North America is approximately twice that of NO_x emissions. Natural (versus anthropogenic) emissions of SO_2 and NO_x probably contribute to the acid rain phenomenon, but this contribution is small in eastern North America compared to the quantities of anthropogenic emissions. Although emissions of NO_x contribute to the acidity of precipitation, NO_x is not a major cause of acidification of surface waters in eastern Canada.

Since 1980, emissions of SO_2 have dropped significantly while emissions of NO_x have remained relatively constant.

D. Acid Deposition

Deposition patterns and loadings (the amount of pollutant deposited on a unit area) are important considerations in the acid rain scenario. During the preparation, several years ago, of the Memorandum of Intent Work Group Reports, the target loading of 20 kilograms per hectare per year (20 kg/ha/yr) of wet sulphate in precipitation was proposed as a level that would provide protection for the aquatic environment, except for the most acid-sensitive lakes and rivers. These most sensitive aquatic ecosystems may not be protected if total (wet plus dry) sulphate deposition exceeds 12 kg/ha/yr.

In recent years, southern and central Ontario and Quebec have had a wet sulphate loading in excess of 20 kg/ha/yr, as has most of the United States east of the Mississippi Valley. In Canada's Atlantic Provinces, the wet deposition rate is close to the 20 kg mark and is slightly exceeded in some places in some years. In western Canada, loading appears to be below 20 kg/ha/yr and the same is true for the United States.

Between 1980-82 and 1985-87, the area of North America receiving loadings of wet sulphate in excess of 20 kg/ha/yr shrank significantly; however, nitrate loadings did not change significantly over the same period.

E. Environmental Effects of Acid Rain

More is known about the effects of acid rain on some sectors of the environment than on others. A good deal is known about the effects of acidification on aquatic ecosystems but much less is known about the effects on terrestrial ecosystems, agricultural crops, or human health.

1. Aquatic Ecosystems

Aquatic organisms vary greatly in their ability to tolerate fluctuations in the acidity of their environment. Some species are very sensitive to acidification and, as the pH of lakes, rivers and groundwaters decreases, the least-tolerant species disappear first, followed by less sensitive species as the pH continues to drop. Studies have shown that the number and diversity of fish species decrease in lakes when the pH drops below 6.0. In Ontario, a well-documented sequence of decline follows the order: lake trout, brook trout and walleye, with perch being one of the more resistant species.

Other organisms are affected by acidification. Algal communities become less diverse in lakes as the pH drops below 6.0 and the survival of rooted plants is generally diminished in acidified lakes, while the growth of benthic (bottom-growing) mosses and attached algae is usually enhanced. As the pH falls, the number of invertebrates in the water column and in the sediments decreases, the rate of decomposition of organic matter decreases, and fungi begin to replace bacteria as the dominant decomposer organisms. These developments can lead to a reduction in nutrient cycling in a lake, and this in turn can result in reduced productivity.

The loss of species from an ecosystem reduces its diversity and may make the whole community progressively more unstable. Thus, even an acid-resistant species may be lost, if its natural prey is acid-sensitive and disappears from the environment.

Surveys have indicated that approximately 14,000 Canadian lakes are currently acidified. Computer models predict that a further 10,000 to 40,000 lakes will be acidified in eastern Canada if wet sulphate deposition in the most heavily impacted regions is not decreased.

There is at present a paucity of direct evidence of changes in aquatic ecosystems in the sensitive areas of Canada as a result of acid deposition. However, loss of Atlantic salmon populations in several rivers in southwestern Nova Scotia has been recorded and fish population losses and declines have been recorded in lakes in Ontario. Moreover, extensive fish surveys in eastern Canada have confirmed that species diversity and richness are reduced in acidified surface waters.

Limited information now suggests that aquatic biological communities can recover fairly quickly from acidification (in years rather than decades) once the level of acid loading is reduced. The artificial "liming" of acidified waters has had some success in decreasing acidification and re-establishing some fish populations. However, the procedure is expensive and liming does not precisely reverse the acidification process.

2. Terrestrial Ecosystems

At the present time, there is incomplete understanding of how acidic precipitation affects terrestrial ecosystems. Terrestrial ecosystems are inherently extremely complex; so many factors influence the growth and development of land-based ecosystems that it is difficult to isolate and characterize the effects of acid rain alone. Some facts are known, however. Acid rain can: damage foliage; accelerate the erosion of the waxy covering of leaves which may lead to the loss of water or which may reduce a plant's ability to resist the attack of disease-causing organisms; inhibit the germination of seeds and the growth of seedlings; decrease the respiration of organisms living in the soil, which may in turn affect the availability of some nutrients; increase the leaching of nutrient ions from the soil; and enhance the solubilization of aluminum in the soil, which can have negative effects on biological processes. On the other hand, it is not known to what extent the ill-effects listed above might be counterbalanced by the nutrient input which could be derived from the sulphur and (especially) the nitrogen compounds which are found in acidic precipitation.

Through the late 1970s and the 1980s, concern was raised over the decline of sugar maples. The phenomenon was most severe in Quebec and acid rain was suspected as a factor. Recent evidence from the North American Sugar Maple Decline Project has shown that the health of sugar maples improved between 1988 and 1990 and suggests that drought and insect defoliation, rather than acid rain, were the primary causes of the decline.

The evidence to date suggests that forest decline in several parts of the world is due, at least in part, to air pollution, including acid rain. Direct association is not possible because so many factors impact on forest ecosystems, including insects, disease, adverse weather and climate, in addition to air pollutants.

Acidic precipitation has not yet been shown to damage agricultural crops directly, but air pollution in general does inhibit the growth of some commercial species. A related issue concerns the damaging effect of ozone on sensitive agricultural crops, which is now well documented. Ozone is a major component of photochemical smog, of which nitrogen dioxide is a precursor. Thus, a reduction in NO_x emissions could have the two-fold beneficial effect of reducing both acid rain and ozone pollution.

3. Human Health

Although direct effects of acid rain on human health have yet to be unambiguously demonstrated, some health authorities feel it may be injurious to some people. However, evidence that sulphate air pollution affects human health is now widely accepted by medical authorities.

Extremely small particulates, formed in the atmosphere by the oxidation of sulphur dioxide, are capable of penetrating deeply into the human respiratory system. Acidic particulates can cause chronic bronchitis or emphysema, with the resultant difficulty in breathing leading to increased strain and, possibly, eventually to heart disease. Oxides of nitrogen can suppress the action of pulmonary scavenger cells whose function it is to purify the lungs by removing insoluble particulates. This effect could also lead to increased susceptibility to respiratory ailments.

A study in 1983, using eight years of data, showed an association between increased hospital admissions for respiratory illnesses in southwestern Ontario and increased ambient levels of sulphate, ozone, and temperature. Another study compared the chronic health effects of exposure to air pollution in school children residing in Tillsonburg, Ontario (a high LRTAP community) and Portage La Prairie, Manitoba (a low-pollution community). The children in Tillsonburg had a small (2%) but statistically significant decrease in lung function and had a higher incidence of a number of respiratory symptoms. These findings are regarded as suggestive rather than conclusive with respect to the harmful effects of air pollutants.

Evidence of the impact of acidic particulates on human health continues to mount. The results of a study by Health Canada, Environment Canada, and Statistics Canada, which was published in 1994, showed statistically significant, positive associations between admissions to Ontario hospitals for respiratory ailments and atmospheric ozone and sulphate levels on the date of admission, and up to three days prior. Ozone was found to be a stronger predictor of admissions than sulphate. Of daily respiratory admissions in the months of May to August, 5% were associated with ozone and an additional 1% were associated with sulphate. All age groups were affected but the largest impact of the ozone-sulphate mix (15% of admissions) was on infants up to one years old.

A recent study by the U.S. Environmental Protection Agency attempts to assess the benefits to human health from reducing sulphate particulates. In addition to direct health costs such as hospital admissions and lost wages, the model tries to put financial values on indirect costs such as pain and discomfort. The model estimates that the human health benefits of the U.S. Acid Rain Program alone in the Windsor-Quebec corridor falls within a range of US$290 million to US$1,868 million with a mean estimate of US$955 million, well in excess of Cdn$1 billion a year.

In a 1995 Policy Paper entitled “Clean Vehicles and Fuels for British Columbia,” the British Columbia Government estimates that the cost of atmospheric pollution to human health in the Lower Fraser Valley was $830 million in 1990; it is projected to rise to $1.5 billion by 2005.

4. Man-Made Structures

Acidic precipitation can contribute to the processes of materials erosion. Thus, buildings, roads, paint, sculptures and other man-made structures can be aesthetically and functionally damaged. The dollar costs of these damages to the urban environment are difficult to calculate, however. In 1985, the value of Canadian construction was $61 billion; $11 billion of this total was for repairs and maintenance. The question is, what portion of the observed corrosion and deterioration is due to the effect of acid rain? At the present time, no useful estimate can be made. The most that can be said, in advance of the extensive research needed in this area, is that air pollution has an effect on materials deterioration and acid deposition is one component of that complex situation.

F. Areas of Canada Susceptible to Acidic Precipitation

"Buffering capacity" is the ability to neutralize hydrogen ions with basic or alkaline materials so that there is little change in pH. An environment which has a large buffering capacity can neutralize acid rain, rendering it incapable of harming ecosystems. Buffering capacity in the environment is related to the amount of calcareous materials (such as limestone) in soils and rocks and dissolved bicarbonate in water. In parts of the country in which non-calcareous rock formations predominate, the environment has little buffering capacity and can consequently neutralize only limited amounts of acidic precipitation. For example, some lakes in the Haliburton-Muskoka region have lost 40 to 75% of their buffering capacity in less than a decade. Once the buffering capacity has been eliminated, acidic precipitation can no longer be neutralized, the pH of the system drops rapidly, and the ecological effects noted earlier begin to appear.

A large portion of eastern Canada particularly is based on granitic and silicious bedrock. This rock is non-calcareous and extensive glaciation has removed most of the younger calcareous deposits which may have been present prior to the Ice Ages. This has left vast areas impoverished in terms of calcareous deposits, although glacial deposits of calcareous material have produced some areas of overburden which considerably augment buffering capacities. Large areas of Nova Scotia and New Brunswick, almost all of Newfoundland, most of Quebec and large areas of Ontario are particularly susceptible to the deleterious effects of acid rain. Parts of the Northwest Territories, Manitoba and southern British Columbia are also suspected to be susceptible to acidification. It has been estimated that some 43% of Canada's land area is sensitive to acid deposition.

Areas of Canada which are likely to suffer the most damage are located in Ontario, Quebec and Labrador because of the prevailing westerly winds over most of eastern North America. This pattern varies to some extent with season and, in the Great Lakes region, air often flows to the south in the winter and to the north in the summer.

G. Acid Rain Controls

Despite widespread public concern in the early 1980s there were no comprehensive programs for the abatement of acid rain. That situation changed significantly with the introduction of the Canadian Acid Rain Control Program in 1985, the passage of the *Clean Air Act Amendments* in the U.S. in 1990 and the signing of the Canada-U.S. Air Quality Agreement in March 1991.

1. The Canadian Acid Rain Control Program

In March 1985, Prime Minister Brian Mulroney announced the Canadian Acid Rain Control Program. This program represented a cooperative undertaking by the federal and provincial governments and industry to reduce SO_2 emissions in eastern Canada by 50% by 1994 from an allowable base of 4.516 million tonnes in 1980. The program took a three-pronged approach consisting of reductions of SO_2 emissions according to set targets and schedules, the development of new cost-effective technologies to reduce emissions, and an extensive research and monitoring program. The goal of the program was to cap SO_2 emissions in eastern Canada at 2.300 kilotonnes per year by 1994. That goal was met ahead of schedule in 1993.

The original federal-provincial agreements lapsed in 1994. New agreements, which would cap SO_2 emissions at 2,300 kilotonnes until year 2000 when the national program begins, are still in the process of being negotiated with the provinces. So far, agreements with New Brunswick, Nova Scotia and Quebec have been signed. The current total of provincial objectives still stands at 2,349 kilotonnes, 49 kilotonnes over the cap; however, this is not a major issue since actual emissions have been below the 2,300 kilotonne cap since 1993.

In 1996, emissions of SO_2 from the eastern provinces amounted to 1,741 kilotonnes, 24% below the cap and down slightly from 1995 levels. All the eastern provinces, with the exception of Newfoundland, met their targets in 1996. Smelters accounted for 51% of emissions while fossil-fuelled power plants accounted for 16%. **In 1997, SO_2 emission continued to be well below the cap.**

The three western provinces will become part of the program by the year 2000, when the national cap will be set at 3,200 kilotonnes. The federal and provincial governments are currently working with stakeholders through the National Air Issues Steering and Coordination Committees (NAISCC) to develop a new National Strategy on Acidifying Emissions to take effect after the year 2000. The strategy is intended to protect acid sensitive areas, human health, and atmospheric visibility. **In October 1997, The Acidifying Emissions Task Group submitted its report *Towards a National Acid Rain Strategy* to the National Air Issues Coordinating Committee. The report responds to the request of the Energy and Environment Ministers for federal and provincial governments to develop a long-term acid rain strategy to mitigate the environmental and human health effects of acidifying emissions.**

The Task Group states that, even with full implementation of the Canadian and U.S. programs, an area of almost 800,000 km^2, equivalent to the combined land mass of the U.K. and France, will continue to receive harmful levels of acid rain (i.e., above the critical load for aquatic systems) as a result of which, 95,000 lakes in southeastern Canada will remain damaged by acid rain.

Lake monitoring has shown that while sulphate levels in most lakes in Ontario and Quebec have fallen and are stable in the Atlantic region, acidity remain high. Climatic conditions, such as high temperatures and drought, are believed to have contributed to re-acidification or delayed recovery of lakes. The Task Group notes that acidification of lakes poses a serious threat to biodiversity in eastern Canada. Nitrate deposition, which also contributes to acidification, has barely changed since 1980. This is consistent with the NO_x emissions in Canada and the U.S., which have remained almost constant during the same period. Continued nitrate deposition may undermine the benefits of controlling SO_2 emissions.

The key finding of Task Group, based on computer modelling, is that very large reductions of SO_2 emissions will be required on both sides of the border to solve the acid rain problem in eastern Canada. To reach a level of emissions that would protect

virtually all of eastern Canada would require reductions of 75% beyond current caps for Ontario and Quebec and reductions of up to 30 and 50% for New Brunswick and Nova Scotia. It would also require reductions of 75% beyond current requirements in the U.S. *Clean Air Act* for the midwest and eastern U.S. States. The model indicates that without major reductions in U.S. emissions, Canada will not be able to protect sensitive areas from acidification.

The Task Group reported the estimated costs of achieving reductions beyond the present caps for Ontario and Quebec, although it did not achieve consensus on the figures. These estimates indicate that the cost of compliance escalates rapidly with the level of reductions. For example, in Ontario the cost of a 25% reduction in SO_2 emissions below the present cap was estimated to be $200 per tonne; however, the cost of a 75% reduction was estimated to be in the range of $1,600 to $1,900 per tonne, close to an order of magnitude greater.

The Task Group also attempted to quantify the benefits of further emissions reductions by using the Air Quality Valuation Model (AQVM) to monetize human health benefits, through it acknowledged that placing monetary values on health benefits is controversial. While some members of the group strongly advocated including health benefits in the strategy to reduce SO_2, others challenged the methodology employed and the implications of the results. They also argued that, without fully understanding what the numbers actually represent, it is inappropriate to use this information as a basis for the development of new policies related to acidifying emissions.

Although the Task Group did not reach a consensus on a schedule for further emissions reductions, it did make recommendations in six principal areas including:

- **The need for further SO_2 emissions reductions;**
- **Pollution prevention;**
- **Endorsement by Ministers of the “Keeping clean areas clean” policy;**
- **Consideration by federal and provincial governments of multilateral or bilateral agreements as a means of codifying commitments made in the report and negotiations with the U.S. to reduce SO_2 emissions there;**

- **Continued cooperation in reviewing science research into acid rain issues and monitoring programs; and,**

- **An Implementation Plan to ensure that commitments made by governments on acid rain are met and regularly reported to the public.**

The NAISCC forecasts that total Canadian SO_2 emissions will remain relatively stable at just over the 1995 level of 2,805 kilotonnes (down from 3,305 kilotonnes in 1995) to the year 2010. Nitrogen oxide emissions are forecast to decline slightly from the 1990 level (2106 kilotonnes) in 1995 and climb slowly thereafter to reach 2,187 kilotonnes in 2010. There is concern that nitrogen-based acidification might in the future negate the benefits of reducing SO_2 emissions.

In its consultation paper "Responsive Environmental Protection," the Ontario government has proposed to streamline the province's environmental regulations. The current 80 regulations would be reduced, in some cases by combining those that are related, to about 47. The four "Countdown Acid Rain" regulations (660/85, 661/85, 663/85, and 355) affecting Inc, Falconbridge, Algoma and Ontario Hydro would be consolidated into a single regulation outlining the current requirements and deleting the sections that have been completed. **On 27 November 1997, The Ontario Ministry of the Environment released a comprehensive review package of environmental regulations that included the consolidation of the four acid rain regulations into a single regulation.**

2. Ontario Hydro

Following the release of an "Integrated Independent Performance Assessment" of its nuclear operations, Ontario Hydro announced, on 13 August 1997, that it would lay up indefinitely seven of its 19 operating nuclear power stations (the four Pickering A units and the remaining three Bruce A units). To replace the electricity generated by these Pickering and Bruce units, Ontario Hydro announced that it would operate existing fossil plants such as Nanticoke and Lambton at higher levels and bring the mothballed units at the Lennox station back on stream.

The increased burning of fossil fuels is expected to add about 80 kilotonnes/year to Ontario Hydro's SO_2 emissions. As these emissions are currently about 85 kilotonnes/year, it is anticipated that Ontario Hydro will continue to operate within its regulated limit of 175 kilotonnes SO_2. Total emissions for Ontario will also increase but will remain within the limit set by the Eastern Canada Acid Rain Program.

3. The U.S. Acid Rain Program

On 15 November 1990, President Bush signed Amendments to the *Clean Air Act*. Title IV of the Amendments authorized the Environmental Protection Agency (EPA) to establish an Acid Rain Program, the overall goal of which is to reduce SO_2 and NO_x emissions. The program will primarily affect electric utilities, which account for 70% of sulphur dioxide emissions and 30% of nitrogen oxide emissions in the U.S. The legislation proposes to cut annual emissions of SO_2 and NO_x by 9.1 and 1.8 million tonnes by the year 2000.

The strategy to cut sulphur dioxide emissions will be implemented in two phases. In the first phase, which lasts from 1995 through 1999, 110 coal-burning electric utility plants located in 21 eastern and midwestern states will be regulated. In Phase II, which starts in 2000, smaller and cleaner plants burning coal, oil or gas will also be regulated. All existing units with an output capacity of 25 or more megawatts will be affected. In addition, annual emissions limits on the large coal-burning plants will be tightened.

A key element of the U.S. program is an emissions allowance trading system. This enables the federal government to set the overall limits for emissions but makes use of the market place to find the most efficient means of meeting the limits through the economic incentive of the tradeable allowances. The EPA originally estimated that the market-based system would save industry $1 billion compared to more traditional methods; however, the U.S. General Accounting Office has now estimated that the allowance trading program will save the Acid Rain Program $2-3 billion annually.

The emissions trading system is based on a set of regulations known as the "core rules," which consists of rules on an Allowance System, Permits, Continuous Emissions Monitoring, Excess Emissions and an Administrative Appeals Process. The core rules were published in January 1993 and a further rule on Phase II allowances was published in March 1993.

According to the U.S. EPA, implementation of Phase I of the U.S. Acid Rain Program is proceeding successfully. The Agency has reported that all of 445 utility units undergoing annual reconciliation (the process of determining compliance) for 1995, the first year of Phase I, had met their compliance obligations. Actual emissions, measured by continuous emission monitoring systems, have been reduced by more than half from the 1980 level of 10.9 million tons (9.9 million tonnes) of SO_2 to 5.3 million tons (4.8 million tonnes), 39% below the 1995 allowable emissions limit of 8.7 million tons (7.9 million tonnes) required by the *Clean Air Act* for Phase I units. Total U.S. SO_2 emissions in 1995 were reduced to approximately 17.5 million tons (15.9 million tonnes) from 26 million tons (24 million tonnes) in 1980.

Of the 445 units, 263, at 110 utilities, were specifically designated by Congress in the 1990 Amendments to the *Clean Air Act* to participate in Phase I reductions. These units, referred to as "Table 1" units, accounted for 57% of all utility emissions in 1985. The additional 182 "substitution and compensating" (S&C) units were not required to participate until Phase II but elected to participate in Phase I as part of multi-unit compliance plans.

The success of the program is also reflected in the cost of SO_2 allowances which, estimated at $500-600/ton at the time the Act was passed, by 1996 were trading as low as $70/ton; by mid-1998, prices had risen again but were still only between $100 and $200/ton. Reasons for the reduction include lower scrubber costs, better removal efficiencies, and lower than anticipated costs associated with increased use of low-sulphur coals. The U.S. General Accounting Office has estimated that the allowance trading program will save the Acid Rain Program $2-3 billion annually.

The U.S. Geological Survey has also reported that rainfall in the Eastern U.S. is significantly less acidic as a result of implementation of the first year of the Acid Rain Program. A 27 June 1996 study shows a drop of 10-25% in rainfall acidity, particularly for sites at some Mid-West, Northeast, and Mid-Atlantic locations.

4. Canada-U.S. Air Quality Agreement

On 13 March 1991, Prime Minister Mulroney and President Bush signed the Air Quality Agreement between Canada and the United States, which addresses shared concerns about transboundary air pollution. The first air pollution issue the Agreement tackles is acid rain. Sulphur dioxide emissions will be permanently capped in both countries to approximately 13.3 million tonnes by 2010 in the U.S. and 3.2 million tonnes by 2000 in Canada. Precise commitments and schedules are specified in Annex 1 of the Agreement. Other requirements include the scheduled reduction of nitrogen oxide emissions over the next 10 years, tighter emission standards for new motor vehicles, the monitoring of sulphur dioxide and nitrogen oxide emissions, and specific actions to protect both countries' pristine wilderness areas from transboundary air pollution. Annex 2 of the Agreement describes the coordination of research and monitoring activities and the exchange of scientific and technical information which will improve understanding of transboundary air pollution and the ability to control it.

The Agreement established a joint Air Quality Committee to assist with the implementation of the Agreement and to report on progress. The Air Quality Committee held its inaugural meeting on 26 November 1991 in Washington, DC and released its first progress report on 17 June 1992.

The third report of the Canada-U.S. Air Quality Committee was released in 1996. The 1996 Report states that the first five-year review of the Agreement concluded that, "overall, the two countries have been successful in fulfilling their obligations as set forth in the Air Quality Agreement, particularly regarding the implementation of the acid rain control programs of each country." The report goes on to say, however, that the control of transboundary air pollution has not been established to the extent necessary to fully protect the environment.

Key findings in the 1996 Report include the following:

- Wet sulphate deposition continues to decrease, correlated with reductions in SO_2 emissions, but wet nitrate deposition shows no consistent change.

- The acidity of precipitation has not shown a consistent change. This is believed to be the result of a widespread decline in the calcium and magnesium concentrations in precipitation.

- A "Regional Acid Deposition Model" predicts that most of the northeastern U.S. and lower eastern Canada will experience a 30% or greater reduction in total sulphur deposition by the year 2010.

- Decreases in surface-water sulphate, linked to decreased sulphur deposition, have led to limited improvements in water quality; in other words, a few waters show increases in pH. Declining sulphate concentrations are, however, often accompanied by declining concentrations of base cations, including calcium, magnesium and potassium.

- Field experiments and modelling studies indicate that continued nitrogen deposition at current levels could result in the erosion of the benefits of sulphur emissions controls in both countries.

The report also notes that eastern North American hardwood forest is generally in good health and that there is no evidence of widespread forest decline associated with acid deposition; however, it also notes that acidic deposition can cause discernible effects in forests suffering from other forms of stress.

The report also confirms a growing consensus that acidic aerosols and other types of particulate matter have an adverse health effect on large segments of the population.

Although the report notes that both countries are moving to address the problem of ground-level ozone, it points out that the Agreement currently does not focus on serious transboundary air pollutants such as ground-level ozone, air toxics, and inhalable particles. It reports that the Parties have begun studying regional ozone management and are evaluating what role they might play regarding air toxics.

The fourth report of the Canada-U.S. Air Quality Committee is expected to be released in the fall of 1998.

5. Second International SO_2 Protocol

A second international Protocol to reduce SO_2 emissions was signed in Oslo, Norway, on 14 June 1994. The Protocol, which was negotiated through the United Nations Economic Commission for Europe, commits Canada to continue controlling its sulphur emissions in order to protect human health and the environment; to support the long-term aim of working toward achieving critical loads; to establish a Sulphur Oxide Management Area (SOMA) for southeastern Canada; and to support the establishment of a multinational Implementation Committee to review the implementation of the Protocol and compliance by the Parties.

Unlike the first Protocol, which committed all parties to an across-the-board 30% reduction of SO_2 emissions, the second Protocol sets out sulphur emissions ceilings that vary by country, with decreasing ceilings set for many countries for the years 2000, 2005, and 2010. Canada's national target remains 3,200 kilotonnes for the year 2000. The SOMA will have a ceiling of 1,750 kilotonnes SO_2 for that year. Canada has now ratified the Second International SO_2 Protocol.

PARLIAMENTARY ACTION

A. Sub-committee on Acid Rain

The House of Commons Standing Committee on Fisheries and Forestry established a Subcommittee on Acid Rain by Order of Reference of Wednesday, 30 April l980 to enquire into the costs and effectiveness of finding solutions to the acid rain problem. The Report of the Sub-committee, STILL WATERS, was made public on 8 October 1981 and among other things recommended that the *Clean Air Act* be amended to enable the federal government to develop National Emission Standards to cover sources of sulphur dioxide and nitrogen oxides resulting in interprovincial air pollution and acid rain.

The Subcommittee was reappointed in March 1983 following receipt of an Order of Reference by the Standing Committee on 9 March 1983. The Subcommittee's final report on acid rain, TIME LOST, was released on 7 June 1984 and contained 16 recommendations. With the tabling of this report, the Subcommittee was dissolved under the terms of its Order of Reference of 9 March 1983.

On 4 June 1985, a Special Committee on Acid Rain was appointed by the House of Commons to "hold hearings to review all aspects of acid rain." The Committee was chaired by Stan Darling, M.P. and had seven members, consisting of five Progressive Conservatives, one Liberal and one NDP.

On 13 February 1986, the Special Committee on Acid Rain tabled its First Report in the House. The Committee stated that it "views the Report (of the Special Envoys on Acid Rain) as having failed to adequately address critical elements in the control of acid rain," principally because the Report asks for more research and does not set targets and dates for emission reductions.

On 29 September 1988, the Committee tabled a report that summarized the activities of the Special Committee on Acid Rain since 1986, discussed the major issues that arose during hearings, and provided an overview of the Canadian position and progress on acid rain.

In June 1991, a new Subcommittee on Acid Rain of the House of Commons Standing Committee on Environment was established, under the Chairmanship of Mr. Stan Darling, M.P. Mr. Darling was previously Chairman of the Special Committee on Acid Rain. The agenda for the Subcommittee included an evaluation of the status of the Canadian Acid Rain Control

Program, and other aspects of the acid rain problem. The Subcommittee tabled its report "From Words to Action" in December 1992.

B. *Clean Air Act*

On 16 December 1980, the House of Commons passed Bill C-51, An Act to amend the Clean Air Act. The amendment empowered the Minister of Environment Canada to recommend appropriate emission standards to control air pollutants from Canada which "may reasonably be expected to constitute a significant danger to the health, safety or welfare of persons in a country other than Canada." This amendment harmonized Canada's *Clean Air Act* with the comparable U.S. law, which had a similar provision with regard to transboundary air pollution. The *Clean Air Act* is now incorporated into the *Canadian Environmental Protection Act* (CEPA).

CHRONOLOGY

1950s - The acidification of lakes was described in Canada for the first time in the Killarney area near Sudbury in Ontario.

1976 - The Canadian Network for Sampling Precipitation (CANSAP) began monitoring rainfall in 1976.

9-11 July 1979 - The Great Lakes Science Advisory Board warned that aquatic and terrestrial ecosystems in the Great Lakes Basin were being threatened by acid rain.

15 October 1979 - The Governments of Canada and the United States jointly released the first report of the United States-Canada Research Consultation Group (RCG) on the Long-Range Transport of Air Pollutants (LRTAP). The report recognized acidic precipitation as a problem of great common concern.

13 November 1979 - Canada, the United States, and the other 32 member nations of the Economic Commission for Europe signed the international "Convention on Long-Range Transboundary Air Pollution (LRTAP)". The signatories agreed to exchange data on sulphur dioxide emissions and on long-range industrial policies likely to affect these emissions. The Convention lacks an enforcement mechanism and does not compel the signatories to effect abatement procedures.

5 August 1980 - Canada and the United States signed a Memorandum of Intent Concerning Transboundary Air Pollution as a preliminary step in the development of a bilateral cooperative agreement on air quality which would deal effectively with transboundary air pollution.

15 June 1982 - Acid rain negotiations under the Memorandum of Intent collapsed.

February 1983 - The final reports of the Canada-United States Work Groups established in August 1980 under the Memorandum of Intent were released. The Canadian team maintained its position that the acceptable level of sulphate (from sulphur dioxide pollution) is 20 kilograms per hectare per year, and can only be achieved by halving current emission levels.

June 1983 - A series of reports on acid rain from groups in the United States was issued and, in the main, confirmed the principal points raised earlier by the Canadian government with respect to the threat posed by acidic deposition and the link to industrial SO_2 emissions. The U.S. groups included the National Academy of Sciences and the President's Office of Science and Technology Policy.

5 February 1985 - The federal government and the seven provinces east of Saskatchewan agreed to reduce annual emissions of SO_2 by 1.89 million tonnes (from a total of 4.5 million tonnes), a 42% reduction, by 1994.

6 March 1985 - The federal government stated it would contribute up to $150 million over 10 years to help modernize the smelting industry to reduce SO_2 emissions. An Environment Canada official estimated that the smelting industry could need up to $750 million in capital improvements to reduce SO_2 emissions sufficiently to meet the government's stated goals for 1994.

July 1985 - Representatives from 21 countries signed a protocol in Helsinki calling for a 30% reduction in emissions or transboundary movement of sulphur dioxide by 1993 from U.N. Economic Commission for Europe (ECE) Convention on long-range transboundary air pollution. Among the parties to the agreement are Canada, West Germany and Sweden. The United States and the United Kingdom declined to sign the protocol.

17 December 1985 - The Ontario Government announced an $85-million acid rain program, named "Countdown Acid Rain", to cut SO_2 emissions in the province by 1994 to 665,000 tonnes from the 1980 level of 1,993,000 tonnes, a reduction of 67%. Major reductions would be effected at Inco's Sudbury smelter, the Falconbridge smelter near Sudbury, Algoma Steel's iron ore plant at Wawa, and at Ontario Hydro's coal-fired power stations.

9 January 1986 - United States and Canadian envoys, Drew Lewis and William Davis, appointed in March 1985, released their report on acid rain. The report did not recommend a cleanup program; instead, it recommended an expenditure of $5 billion (U.S.) over five years to research more efficient technologies by which U.S. power plants could burn coal, a major source of Canada's acid rain. Critics of the report stated that suitable technologies already exist and that the funds should be directed towards controls.

14 March 1986 - The National Research Council of the U.S. National Academy of Sciences released a study by U.S. and Canadian scientists which concluded that there is a causal relationship in eastern North America between SO_2 emissions and the wet deposition of sulphate and the progressive acidification of lakes and streams.

19 March 1986 - President Reagan gave his full endorsement to the Report of the Special Envoys on Acid Rain at the conclusion of his summit meeting in Washington with Prime Minister Mulroney.

26 March 1986 - Transport Canada published in the *Canada Gazette Part II* (Vol. 120, No. 8) an amendment to the Motor Vehicle Safety Regulations respecting emission standards for light- and heavy-duty motor vehicles, including automobiles, light-duty trucks, and heavy-duty vehicles. More stringent emission standards for cars and light-duty trucks would become effective on 1 September 1987, for the 1988 model year. They set lower limits for NO_x, hydrocarbons and carbon monoxide. Environment Canada estimated that the new standards would bring about a 45% reduction in automobile pollution by the year 2000.

10 March 1987 - Environment Minister Thomas McMillan signed an agreement with Ontario on acid rain control, formalizing a February 1985 agreement to reduce eastern Canada's sulphur dioxide emissions by 50% by 1994. Prince Edward Island and Newfoundland signed similar agreements on 9 March 1987. Negotiations were continuing with New Brunswick and Nova Scotia.

20 March 1987 - The federal and Quebec Governments signed an acid rain control agreement. Noranda Inc. was to reduce sulphur dioxide emissions from its Horne Smelter in Rouyn-Noranda by 50% when a new sulphuric acid plant came into operation in 1989. The company would be assisted by more than $83 million in loans from the two governments.

10 April 1987 - Environment Minister Thomas McMillan and Manitoba's Environment Minister, Gerard Lecuyer, signed an agreement to reduce the province's SO_2 emissions by 25% from allowable 1980 levels by 1994. The agreement included an offer by the federal government to contribute $20 million to the Hudson Bay Mining and Smelting Company smelter at Flin Flon to help achieve emission reductions.

May 1987 - Ontario Environment Minister James Bradley announced in the legislature that the emissions banking provision for Ontario Hydro would be deleted from provincial regulations. The announcement followed a unanimous recommendation from the legislature's Select Committee on the Environment on 11 May.

17 September 1987 - The United States National Acid Precipitation Assessment Program (NAPAP) presented its interim report. The report's Executive Summary tended to downplay the seriousness of acid rain in the United States and the E.P.A. said that the evidence presented in the report indicated that increased acid rain controls were not necessary. The Canadian Environment Minister described the NAPAP report as "flawed, incomplete and misleading" and "out of step with prevailing scientific judgment and expert opinion". Other critics in the U.S.A. and Canada said the report's Executive Summary was a politically biased document that did not fairly represent the scientific facts. A senior U.S. State Department official said that the NAPAP report supported Administration policies on acid rain.

8 October 1987 - The New Brunswick government signed a written agreement with the federal government to reduce SO_2 emissions in 1994 by 16%, from 1980 allowable levels. The agreement was signed by Premier Richard Hatfield, who was defeated in a general election five days later.

November 1987 - After a meeting in Geneva of the United Nations Economic Commission for Europe (ECE), held to discuss a draft protocol for NO_x emissions, Canadian negotiators received negative publicity in the media for an apparent refusal to support an across-the-board 30% reduction. In fact, these discussions were at an early stage and Canada was proposing to link nitrogen deposition to environmental consequences. Also, the deposition of nitrogen compounds in many areas in Europe is six to ten times what it is in Canada and, therefore, a percentage reduction in NO_x emissions appropriate for Europe is not necessarily appropriate for Canada.

12 February 1988 - The federal and Nova Scotia governments signed an agreement respecting an acid rain reduction program. The purpose of the agreement was to reduce wet sulphate deposition in Eastern Canada in accordance with the Federal/Provincial Environment Ministers' Agreement of 5 February 1985. In a parallel action, taken to assist the provincial government financially, the federal government reduced the price of coal purchased by the province from the Cape Breton Development Corporation to fuel its power plants. Nova Scotia was now committed to reducing its annual SO_2 emissions to 204,000 tonnes before 31 December 1994, the date on which the agreement expires.

16 February 1988 - Environment Canada released a "National Sensitivity Assessment" map showing that 46% of Canada has a low ability to neutralize acidic precipitation. All regions of Canada have acid-sensitive areas but Quebec is the most sensitive, with 82% of its area having the lowest rating for neutralizing capacity. Newfoundland, Nova Scotia, and Ontario's Muskoka and Haliburton regions are also highly sensitive.

29 March 1988 - Ontario Hydro gave an environmental assessment study to the provincial environment minister which estimated the capital cost of retrofitting its three major coal-fired generating plants with scrubbers at $3 billion. The three plants are Lambton near Sarnia, Lakeview in and Nanticoke on Lake Erie southeast of Hamilton; they account for 93% of Ontario Hydro's coal-fired generation and are designed to burn medium-sulphur coals from the United States. If power demand is higher than anticipated during the 1990s, however, the capital cost could rise to $5.5 billion because as many as 20, rather than eight, scrubbers would be required to effect the necessary reduction in emissions.

10 February 1989 - During his visit to Ottawa, President Bush stated his "determination to move forward with setting limits (on acid rain precursor pollutants), with (domestic) legislation and then moving to a discussion with Canada leading to an accord that I think will be beneficial for both countries." There was general agreement among observers that a Canada-U.S. accord on acid rain would have to follow domestic U.S. legislation.

20 April 1989 - The Ministers of Environment and Transport announced that the federal government was starting an assessment of environment and health benefits, socio-economic impacts, and technical feasibility of new emission controls for all internal combustion engines. The objective of this initiative is "to put in place, within five years, the most stringent regulations that technology will allow to control

emissions (including NO_x and volatile organic compounds) from internal combustion engines that burn fossil fuels." New regulations could be in place within 48 months.

12 June 1989 - In Bill H.R. 3030, President Bush proposed amendments to the U.S. *Clean Air Act* which would be "a comprehensive program to provide clean air for all Americans." The proposals would bring about a reduction of SO_2 emissions of 10 million tons from 1980 base levels, by the year 2000. NO_x levels would be frozen at about 1987 levels. Canadian officials generally welcomed the proposals as meeting Canada's environmental needs; they also would form the basis for eventual negotiations on a bilateral air quality agreement.

19 October 1989 - The Canadian Council of Ministers of the Environment announced that the federal ministers of Environment and Transport would, within the next month, publish notice of their intent to issue a regulation aimed at achieving the proposed California standards for hydrocarbons (0.25 grams per mile), carbon monoxide (3.4 grams per mile) and nitrogen oxides (0.4 grams per mile) for the 1994 model-year cars. Also, provincial Ministers would undertake to implement by 1992 vehicle inspection and maintenance programs in provinces with ozone problems.

23 May 1990 - The United States House of Representatives passed its version of amendments to the *Clean Air Act*, H.R. 3030. The Senate passed a similar bill, S. 1630, in April. The legislation was expected to obtain presidential signature before the 1990 mid-term elections.

16 July 1990 - The Minister of Environment Canada, Robert de Cotret, and the Administrator of the Environmental Protection Agency, William Reilly, announced that a Canada-U.S. Air Quality Agreement would be developed to manage a comprehensive range of transboundary pollutants. Among its goals, the Agreement would give priority to emissions of SO_2 and NO_x, and establish a means for impartial oversight and dispute settlement.

28 August 1990 - Negotiations to develop a Canada-U.S. Air Quality Agreement commenced in Ottawa.

October 1990 - On 20 October, the United States Senate passed the bill amending the *Clean Air Act* by an 89-10 margin. The House of Representatives passed the bill on 26 October by a 401-25 vote.

15 November 1990 - President Bush signed the bill amending the *Clean Air Act* into law. The new legislation mandated significant reductions in sulphur dioxide and nitrogen oxides and, by extension, in acid rain.

13 March 1991 - President Bush and Prime Minister Mulroney signed the Canada-United States Air Quality Agreement in Ottawa. The bilateral accord built on the U.S. *Clean Air Act* of 1990 and the Canadian Acid Rain Control Program of 1985. It committed the two governments to a series of targets and schedules for the control of transboundary pollutants. In addition to the control of acid rain precursors, the accord provided for the prevention of significant air quality deterioration from transboundary air pollution, and protection of visibility, particularly for parks and wilderness areas.

23 September 1991 - Canadian Environment Minister Jean Charest announced $30 million in Green Plan funds to support Canada's acid rain control program. The funds were to be used to implement the federal-provincial cap on SO_2 emissions in Canada, to verify the effectiveness of the Canada-U.S. Air Quality Agreement and to support scientific efforts to improve understanding of the effects of acid rain.

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