

Appendix D

Existing Domestic and International Approaches

- D.1 INTERSTATE AND INTERNATIONAL PROVISIONS OF THE CURRENT CLEAN AIR ACT (p. 300)**
- D.2 INTERNATIONAL PROGRAMS FOR CONTROLLING EMISSIONS OF SULFUR DIOXIDE (p. 305)**
- D.3 MITIGATING THE EFFECTS OF ACID DEPOSITION ON AQUATIC ECOSYSTEMS (p. 312)**

D.1 INTERSTATE AND INTERNATIONAL PROVISIONS OF THE CURRENT CLEAN AIR ACT

Provisions in the existing Clean Air Act (CAA) address both interstate and transboundary pollution; however, the effectiveness of these statutory mechanisms is subject to question. The act also provides affected parties with a means to seek remedy for interstate pollution not adequately regulated by existing control programs. It does not directly provide other nations a means of remedy for transboundary (international) pollution; however, actions taken by the previous administration under the act's international provision may have created a right to legal recourse. In addition, avenues other than the CAA could potentially be pursued to remedy transboundary pollution.

Interstate Pollution Control and the Clean Air Act

The Environmental Protection Agency (EPA) and the courts have taken action under the interstate provisions of the CAA to abate interstate air pollution resulting from local sources. However, considerable uncertainty exists over how these provisions should be interpreted with regard to longer range transported air pollutants. EPA currently takes the position that analytical techniques addressing transported pollutants are not reliable for regulatory purposes; the courts have yet to rule on this issue. The statutory language of the interstate provisions does not provide a direct means of controlling acidic deposition.

The NAAQS SIP Process

The CAA requires that States adopt implementation plans to: 1) attain and maintain national ambient air quality standards (NAAQS) within their borders and 2) prevent significant deterioration (PSD) in areas already meeting NAAQS. Section 110 also specifically requires that State implementation plans (SIPs) include provisions prohibiting any stationary source from emitting pollutants that would prevent attainment and maintenance of NAAQS or interfere with PSD measures in another State. The Administrator may not approve a SLP that does not comply with these interstate control requirements.

Utility of the interstate Provision for Controlling Transported Air Pollutants

LIMITATIONS OF SECTION 110

Section 110 has several limitations for controlling interstate pollution: It applies only to air pollution, and offers no direct means of controlling acidic deposition. It gives little guidance as to how much interstate air pollution is prohibited, and does not outline the level of proof of causation required to substantiate regulation by EPA. As written, the section leaves open such questions as: 1) whether pollution must be linked to individual sources to justify control, and 2) whether analytical techniques (including models) that estimate the relationship between emissions from "source" re-

gions and the resulting air quality of “receptor” regions can be used to justify regulating individual sources. Finally, the section applies only to stationary sources; it does not control mobile-source emissions.

THE INTERSTATE PROVISION AS APPLIED BY EPA

Since section 110 was enacted in 1977, EPA has initiated no review of SIPS to assess their compliance with the provision. The agency has issued no regulations to spell out how a State can determine if its SIP complies with section 11 O(a)(2)(E). EPA has reviewed and approved a number of revisions to SIPS since 1977, but the agency has not articulated definitive policies for determining whether an individual source relaxation complies with section 11 O(a)(2)(E). Current EPA procedures, however, limit the scope of SIP review to that portion of the plan undergoing revision. Hence, where SIP revisions propose emissions relaxations for individual plants, EPA considers only the local air quality impact resulting from the change in emissions for these plants.

EPA also has taken the position that there are no adequate tools to assess long-range transport effects, and EPA practices reflect this position. First, in reviewing emissions limitations with respect to the interstate provisions, the agency only considers impacts that can be estimated by models approved under its modeling guideline. This effectively limits consideration of impacts to within 50 km of the source, because there are no approved models to estimate long-range transport impacts. Second, the agency does not consider potential impacts of the transformation products of the pollutant for which a SIP relaxation is being considered. For example, the agency reviews the interstate effect of a sulfur dioxide emissions relaxation solely for its impact on sulfur dioxide air concentrations in downwind states. However, sulfur dioxide also is transformed to particulate sulfates in the atmosphere. Sulfates cause visibility degradation, and contribute to total suspended particulate (TSP), for which there are national air quality standards. EPA does not consider the effect of increased sulfur dioxide emissions on total suspended particulate levels or on visibility.

REMEDIES FOR INTERSTATE POLLUTION UNDER THE CLEAN AIR ACT

CAA currently contains two means of remedy for interstate air pollution. The first relies on general judicial review provisions under section 307 allowing litigants to challenge EPA actions. The second initially relies on administrative review provisions under section 126, allowing States and political subdivisions to petition EPA on matters dealing specifically with inter-

state pollution. Since 1977, a number of suits and petitions have been filed under these provisions of the act to remedy interstate air pollution. Early actions sought remedy for interstate air pollution in situations where pollutants were traceable to individual sources in the near vicinity. In later actions, attention has shifted from the ‘local-source problem’ and focused on interstate pollution allegedly caused by long-range transport.

JUDICIAL REMEDIES: SECTION 307 SUITS INVOLVING THE TRANSPORTED AIR POLLUTANTS

States and other litigants seeking remedies for interstate pollution have challenged EPA approval of SIP revisions for single sources under section 307 of the act. In these suits, litigants have attempted to obtain judicial review of EPA’s practice of not addressing regional emissions through the SIP process. They also have attempted to compel EPA to use models and other techniques to assess long-range transport effects.

Litigants have advanced the following reasons for challenging EPA approval of the SIP revisions: 1) the Administrator failed to properly review the long-range effects of the individual source for which a relaxation was approved; 2) EPA failed to consider the air quality impacts of the transformation products of sulfur dioxide; and 3) the Administrator failed to review the whole SIP to determine whether the cumulative emissions of sources governed by the SIP do not cause pollution in violation of section 110.

SECTION 126: THE ADMINISTRATIVE PETITION PROCESS

Section 126 is a companion section to 110. It requires States to provide notice to nearby States of sources that ‘may significantly contribute’ to air pollution in excess of NAAQS. In addition, it provides an administrative remedy for interstate pollution through petition to the EPA Administrator. The section provides in part that:

... a State or political subdivision may petition the Administrator for a finding that any major source emits or would emit any air pollutants in violation of the prohibition of section 110.

Within 60 days of receipt of a petition, the act requires the Administrator to hold a public hearing and either make such a finding or deny the petition.

PETITIONS UNDER SECTION 126 SEEKING REMEDY FOR TRANSPORTED AIR POLLUTANTS

States seeking remedy for interstate pollution caused by the long-range transport of emissions from multiple sources have filed section 126 petitions in tandem with suits under section 307. At least nine petitions of

the State of New York, and the petitions of Pennsylvania and Maine, have been consolidated into a single proceeding, which places before EPA the gamut of issues involved in the long-range transport controversy.

The consolidated petitions claim that sulfur dioxide and particulate emitted by sources governed by SIPS in Illinois, Indiana, Kentucky, Michigan, Ohio, West Virginia, and Tennessee are causing interstate pollution in violation of section 110. The petitioners allege that such pollution prevents attainment and maintenance of NAAQS for both total suspended particulate and sulfur dioxide, and interferes with PSD requirements. Petitioners further allege that the conversion of sulfur dioxide to particulate sulfates contributes to the aforementioned problems and, in addition, that sulfates present a hazard to health and cause acid rain, resulting in damage to aquatic and terrestrial ecosystems. Maine specifically claims that transformed products of sulfur dioxide cause visibility degradation in the mandatory Class I area of Acadia National Park in violation of the act. These three States have asked that EPA review the SIPS for long-range transport effects and have requested major reductions in emissions in the Eastern United States.

These States have presented extensive information on: the air quality problems and alleged environmental problems resulting from acid rain in their States; air quality data and modeling results allegedly demonstrating that interstate pollution contributes significantly to these problems; air quality models and analytical techniques available to assess the long-range transport of air pollutants; the relative stringency of emissions controls in the Midwestern States versus New York, Pennsylvania, and Maine; and finally, the different levels of emissions limitations that petitioners claim are needed to control interstate pollution.

Extensive comments have been filed concerning the information presented by the petitioners and the issues raised. Although the New York-Pennsylvania-Maine petitions were filed between fall, 1980, and summer, 1981, as yet, EPA has issued no preliminary findings in the proceeding. Six Northeastern States recently sued EPA (March 1984) to rule on the outstanding petitions, but no court action has yet been taken.

REVIEW AND REMEDIES UNDER SECTION 307, SIP CHALLENGES, AND SECTION 126 PETITIONS

A recent court ruling suggests that the types of review obtainable under judicial and administrative remedy provisions may differ. EPA has asserted, and the Second Circuit Court of Appeals has ruled, that EPA is not required to review the whole SIP for its compliance with the Act when it *reviews* proposed revisions amending only portions of the SIP. Accordingly, plaintiffs might

not be able to obtain review of an implementation plan as a whole in the context of SIP revisions for individual sources. Thus, section 126 administrative proceedings may be the only way for States to seek remedy for pollution caused by cumulative emissions from all stationary sources regulated by a SIP.

It is not clear what relief the petitioners could win in the suits pending before the courts or in the section 126 proceedings before the agency; however, a wide range of results is possible. Neither route offers a means to compel direct control of acidic deposition. Litigants under section 307 seeking EPA review of SIP relaxations might obtain court decisions requiring the agency to consider long-range transport effects using "state-of-the-art" techniques. The scope of the New York-Pennsylvania-Maine section 126 petitions is wider; the petitioners could, if successful, win a reversal of EPA SIP review policies, leading EPA to require broad-scale reductions in emissions of sulfur dioxide and particulate from Midwestern States.

An appeal from **any** EPA determination on the New York-Pennsylvania-Maine section 126 petition could come before the District of Columbia Court of Appeals. Thus, in the absence of further congressional direction to EPA and the courts on long-range transported pollutants, the appeals court could become the arbiter of pollution-transport controversies between the Midwestern and Northeastern States.

Control of Transboundary Pollution: The U.S.-Canadian Context

The problems of interstate and transboundary pollution control are strongly linked. Winds that transport pollutants over State lines can also carry them across the border between Canada and the United States, from both sides. A number of mechanisms are currently in place for resolving transboundary pollution issues. Means of control are potentially available: 1) through a bilateral accord, 2) under the CAA, and 3) under both domestic common law and international law. The efficacy of these mechanisms to deal with transboundary pollution depends substantially on the combined commitment of the United States and Canada to control such pollution.

Diplomatic/Legal Context of the U.S.-Canadian Transboundary Air Pollution Issue

The United States and Canada have a long history of cooperation concerning environmental affairs and joint commitments to principles for controlling transboundary pollution. Beginning with the Boundary Wa-

ters Treaty of 1909, the two countries have expended considerable efforts to negotiate and/or arbitrate transboundary pollution problems, most recently in negotiations culminating in the 1978 Great Lakes Water Quality Agreement. Both the U.S. Congress and the executive branch have made repeated commitments to bilateral research, consultation, and negotiations on transboundary air pollution, as well as to the multilateral Declaration of the U.N. Conference on the Human Environment (Stockholm Declaration 1972), and the 1979 Economic Commission for Europe's "Convention on Long-Range Transboundary Air Pollution.

No agreement between the United States and Canada directly governs transboundary air pollution; however, cooperative activities have culminated in a Memorandum of Intent.¹ Under the Memorandum the two countries have agreed to begin negotiations to reach a bilateral accord. The Memorandum also states the two countries' commitments to take interim control actions. Although the status of the Memorandum is unclear, it does not appear to be legally binding on Canada or the United States. Its force derives from the good intentions of both countries.

The MOI also established several Work Groups to prepare technical information as a background for conducting negotiations. Final drafts of three Work Group reports—impact assessment, atmospheric sciences and analysis, and emissions costs and engineering assessment—were released in February 1983.

U.S. Government officials state that reasonable progress toward reaching a bilateral accord is being made. However, many Canadian officials are dissatisfied with the progress made in the negotiations and, in 1982, threatened to withdraw from the talks altogether.² Federal and provincial Ministers of the Environment have recently pledged to reduce sulfur dioxide emissions 50 percent (from 1980 levels) in Eastern Canada by 1994 and have urged the United States to do the same. Acidic precipitation resulting from the long-range transport of air pollution has emerged as one of the most significant bilateral issues between Canada and the United States.

Transboundary Pollution Control Under the Clean Air Act

SECTION 115

Congress adopted section 115 of CAA to provide a mechanism for dealing with transboundary air pollu-

¹ Memorandum of Intent between the Government of Canada and the Government of the United States of America concerning Transboundary Air Pollution, Aug 5, 1980

² L. Mosher, "Congress May Have to Resolve Stalled U.S.-Canadian Acid Rain Negotiations," *National Journal*, Mar 13, 1982, p 456, "Canada May End Talks With U.S for Accord to Combat Acid Rain," *The Wall Street Journal*, June 16, 1982, pp 1-7, col 3

tion. The section is invoked by the Administrator of EPA on his own initiative or at the request of the Secretary of State. The Secretary must allege, or the Administrator must determine, that pollution emitted in the United States causes or contributes to air pollution that "may reasonably be anticipated to endanger public health or welfare in a foreign country. The section provides that the Administrator can make such a determination "upon receipt of reports, surveys or studies from any duly constituted international agency"; however, it does not specify how the Secretary of State will be apprised of a problem.

Once the Secretary of State has requested the Administrator to activate the section 115 process, or the Administrator has made a finding of 'endangerment, the statute requires the Administrator to give formal notice to the Governor(s) of the State(s) in which the emissions causing the pollution originate. The Administrator must take this step, however, only if he "determines the foreign country receiving the pollution has given the United States essentially the same rights with respect to the prevention or control of air pollution occurring in that country as is given that country by [section 115]. " Thus the Administrator must make a determination of reciprocity to trigger the mandatory duty under section 115.

Section 115 relies on the SIP revision process as the means to abate international pollution prohibited by the section. Section 115 provides that notice given to the governor constitutes a finding with respect to section 110(a)(2)(E)—i.e., that the State implementation plan is inadequate to comply with the requirements of the CAA and must be revised.

UTILITY OF SECTION 115 FOR CONTROLLING TRANSPORTED AIR POLLUTANTS

Section 115 can be construed to permit the control of transboundary pollution caused by acidic deposition. However, the language of section 115 provides no guidelines on how to implement the section. It does not detail the procedures for the Administrator to follow in identifying which State or States are the source of the transboundary emissions, and offers no guidance on allocating control responsibilities when emissions from more than one State create transboundary problems. The legislative history of section 115 is also silent on these issues.

EPA's current practices for reviewing the SIP control of interstate pollution, if applied to transboundary pollution, would limit the efficacy of section 115 for controlling possible acidic deposition and air pollution in Canada. As yet, EPA has not chosen to activate the transboundary pollution control provision of the act.

ACTIVITY UNDER SECTION 115

The Mitchell Request.—The Canadian Clean Air Act was amended by unanimous vote in both Houses of Parliament in December 1980 to provide clear authority for the Canadian Federal Government to take steps to control the emission of pollutants affecting another country. The amendment was designed primarily to allow “mutual recourse between Canada and the United States.”

On December 23, 1980, Senator George Mitchell of Maine sent letters to the Administrator of EPA and the Secretary of State calling their attention to the recently enacted legislation, and to reports prepared by the International Joint Commission (IJC) and the U.S.-Canada Research Consultation Group on Long-Range Transboundary Air Pollution (RCG). The Senator reviewed the information in the reports and concluded his letters with a strongly worded request that action be taken under section 115.

The Costle Response: Determination To Activate Section 115.—In January 1981, Administrator Costle of EPA responded to the Mitchell request and sent letters to both the Senator and the Secretary of State announcing his findings.³ He found, based on his review of the IJC reports and CAA, that section 115 could be activated to control acidic deposition in Canada. He also determined that the Canadian Clean Air Act provides Canada with authority to give the United States essentially the same rights as Canada under section 115, and that at present Canada was so interpreting the act. He noted that this second aspect of EPA's determination is necessarily a dynamic one and would continue to be influenced by Canadian actions. Thus, having made the requisite determination to activate section 115, the Administrator instructed EPA staff to begin work to identify which States should receive formal notification, and to lay the groundwork to assist those States in appropriately revising their SIPS.

There have been no indications that the work initiated by Administrator Costle is proceeding under the present EPA administration. As yet, section 115 notification has not been given to any State, and EPA appears not to have continued the process leading up to notification. EPA has issued no statement, however, that reverses the Costle determination. No court has yet reviewed the legal significance of Costle's action.

Remedies for Transboundary Pollution

RECOURSE UNDER THE CLEAN AIR ACT

The initial decision to activate section 115 clearly is discretionary. Thus, the statute does not explicitly pro-

³Letters from Douglas Costle, EPA Administrator, to Edmund Muskie, Secretary of State, Jan 13, 1981, and to Senator George Mitchell, Jan. 15, 1981.

vide a course of action that Canada or others could pursue in domestic courts to remedy transboundary pollution. An argument can be made, however, that the actions of former Administrator Costle “activated” section 115 and created a legal obligation for the present Administrator to revise SIPS to control acidic deposition in Canada.

Section 304 of CAA authorizes “any person” to bring suit to compel the Administrator to perform nondiscretionary duties under the act. Under this citizen suit provision a number of different groups could bring suit to compel action under section 115—among them are environmental organizations and Northeastern States that might “benefit” from activation of the section. The eligibility of Canada or the Province of Ontario to bring suit is less clear. Section 302(e) does not specifically mention foreign governments, and the issue of whether foreign governments are considered to be “persons” under sections 302(e) and 304 remains unsettled.⁴ However, standing to sue would not be a barrier to litigation by plaintiffs having interests similar to those of Ontario or Canada.

If a suit were initiated under section 304 to compel the present Administrator to notify States under section 115 to revise their SIPS, a court could be faced with the question of whether Costle's determinations were arbitrary and capricious, or in excess of statutory authority and, as such, unlawful. The present Administrator would have the burden of convincing a court that the previous Administrator's determinations were invalid. Since the statute gives the Administrator great discretion, and courts as a rule defer to administrative determinations, this would be a difficult burden to overcome.

RECOURSE THROUGH DIPLOMATIC CHANNELS

The Canadian Government could choose to link the transboundary issue to other areas of bilateral concern in an effort to encourage adoption of policies to reduce the long-range transport of air pollution. Canada is an important ally and neighbor. The United States's involvement with Canada is probably greater than with any other foreign country. The two-way trade is about \$77 billion, which is greater than that between the United States and all the countries of the European Community. The two countries are allies in NATO and

⁴It can be argued that foreign governments are considered to be “persons” under sees 302(e) and 304. Sec. 302(e) could be construed as inclusive of possible litigants rather than defining the complete set. Such a construction was placed on a similarly worded definition under the antitrust laws and thus the definition in the statute was not a mandate to reverse the longstanding presumption that foreign nations are entitled to sue in courts of the United States *Pfizer, Inc. v. Government of India* 434 U.S. 308 (1978). Accordingly the Court in *Pfizer* found that India was a “person” within the meaning of sec. 4 of the Clayton Act in spite of the fact that the section did not include foreign governments in the list of those authorized to sue.

have a unique military joint command, the North American Air Defense Command.

RECOURSE UNDER DOMESTIC COMMON LAW AND INTERNATIONAL LAW

In theory, domestic common law and international law also provide a means of legal recourse should Canada or others be dissatisfied with U.S. control efforts.

In practice, however, domestic common law may not, and international law does not, provide an effective means to compel U.S. control efforts. In the case of domestic common law, recent court decisions as well as problems surrounding proof-of-causation may limit the use of this avenue; in the case of international law, there are no effective means to enforce legal doctrines.

D.2 INTERNATIONAL PROGRAMS FOR CONTROLLING EMISSIONS OF SULFUR DIOXIDE

As in the United States, air quality laws in Western Europe, Canada, and Japan focus primarily on ambient concentrations of air pollutants within the locale of emission sources, rather than on pollutant deposition. However, over the past decade, increasing awareness of acid deposition as a potential problem has led several countries to develop and adopt further control policies. Working within the existing regulatory framework for controlling sulfur dioxide (SO₂), Canada, West Germany, and the Scandinavian countries have initiated further SO₂ emissions limitations and restricted the level of sulfur in fuel in order to address acid deposition.

European nations have established extensive cooperative monitoring programs to gather information on the nature and extent of acid deposition and other transported air pollutants. Some accords dealing with transboundary pollution have been reached, and negotiations are in progress in others.

This appendix describes the international organizations and accords that deal with transboundary pollutants. In addition, it outlines the existing policies of the countries of Scandinavia, the United Kingdom, West Germany, Canada, and Japan concerning acid rain and transboundary air pollution.

International Organizations and Accords Dealing With Transboundary Pollution

Considerable international effort has been expended to address transboundary air pollution and acid rain over the last decade. At the urging of the Scandinavian countries, transboundary pollution problems have been discussed in such international forums as the U.N. Economic Commission for Europe (ECE), the European Economic Community (EEC), and the Organization for

Economic Cooperation and Development (OECD); these organizations have also launched research efforts to study the problem. In March 1984, Environmental Ministers from nine European nations and Canada signed an agreement to reduce national sulfur dioxide emissions at least 30 percent by 1993 in an effort to curb transboundary air pollution. The countries signing the agreement—referred to as the “30 percent Club”—were Canada, Austria, Denmark, West Germany, Finland, France, the Netherlands, Norway, Sweden, and Switzerland. They also agreed to urge that other signatories to the Convention on Long Range Transboundary Air Pollution of the UN Economic Commission for Europe (ECE) take similar action.

Economic Commission for Europe (ECE) and the Convention on Long-Range Transboundary Air Pollution

The ECE, comprised of all European United Nations (U. N.) members plus Canada, the United States, and the U. S. S. R., is one of five regional economic commissions of the U. N. It began to address the transboundary pollution issue as early as 1969, when a working group on air pollution recommended reducing SO₂ emissions. ECE negotiations began in 1977, with Sweden and Norway pressing members to, at a minimum, hold SO₂ emissions to current levels, and to lay the groundwork for abating SO₂ levels by a fixed percentage.

In 1978, the Committee of Senior Advisors to the ECE established the Special Group on Long-Range Transboundary Air Pollution, instructing the *group* to draft proposals for the consideration of future senior advisory sessions. Extensive negotiation produced a convention substantially modified from that originally proposed by the Nordic countries; the modified convention

was accepted at a high-level meeting of the ECE in November 1979. The ECE convention was the first multilateral agreement to address specifically the problem of transboundary air pollution caused by long-range transport, and was the first major environmental accord involving the nations of Eastern and Western Europe and North America.

The accord requires the signing countries to develop policies and strategies "as far as possible" to reduce air pollution gradually, including long-range transboundary air pollution, employing "best available technology which is economically feasible. The convention defines long-range transboundary pollution as pollution traveling to another nation from such a distance that "it is not generally possible to distinguish the contribution of individual emission sources or groups of sources. While the convention clearly addresses acid deposition, it mandates no emission limitations. Since the convention does not establish numerical goals, limits, or timetables, or contain enforcement provisions, the signing countries do not have to alter their pollution-control policies unless they choose to do so.

However, the convention is important as a basis for coherent research and international management of transboundary pollution. The signatories agreed to cooperate in conducting research on control technologies, monitoring and modeling techniques, and effects of air pollutants (e. g., sulfur compounds) on human health and the environment. The ECE countries agreed to exchange information for advancing international research efforts such as data on emissions and results of domestic research efforts, and further agreed to support the ongoing international monitoring program established by the U.N. Environment Program. This program has established monitoring sites to measure SO_2 and particulate sulfate in the air, and acidity in precipitation, with stations in some 20 European countries.

The European Economic Community (EEC)

The EEC was formed in 1957 and presently includes ten European countries of the Common Market—West Germany, France, Italy, Belgium, the Netherlands, Luxembourg, Ireland, the United Kingdom, Greece, and Denmark. The EEC was formed initially to deal with economic issues among member countries; however, it has also been used as a forum for discussing international air quality issues. While the EEC has never directly addressed the long-range transboundary air pollution issue, it has developed and issued directives dealing with SO_2 emissions generally. A directive on the sulfur content of certain liquid fuels was issued in 1975; a directive establishing health protection standards for

SO_2 was submitted to the governing Council of Ministers for approval in 1976 and was finally adopted in 1980. The standards are relatively lenient by comparison to current World Health Organization and U.S. standards. The directive requires that member countries adopt measures to meet the standards by April 1983, but allows nonattainment areas 10 years to achieve compliance.

The directive also requires countries to establish an air-quality monitoring network, and establishes common procedures for the network and for exchanging data and information. Although the EEC directive does not directly address long-range transport and acidic deposition, the resolution accompanying the directive is an indication of the EEC awareness and concern for these issues. In language similar to the ECE Convention, the resolution states that EEC members:

. . . will endeavor, in accordance with objectives of the above mentioned Directive, and taking due account of the facts and problems involved, to limit, and, as far as possible, gradually reduce and prevent transboundary air pollution . . .

The EEC directive is more significant as a symbol of commitment to controlling transboundary and domestic air pollution than as a means of implementing control measures for SO_2 . Less than 5 percent of EEC's land mass will exceed the health standard in 1983. Despite the goals of the EEC directive, it appears to do little to further the role of either the EEC or its members in reducing and preventing transboundary air pollution.

The Organization for Economic Cooperation and Development (OECD)

The OECD was founded in 1961 as a 'Western' alliance for promoting economic growth. Its members include the United States, Japan, Canada, West Germany, the United Kingdom, and the Scandinavian countries. Although all decisions within the OECD are nonbinding, the Organization has been highly influential in developing international law and policy concerning transboundary air pollution. The OECD has also produced some important research on transported air pollution.

In 1972, the OECD established the "Cooperative Technical Program to Measure the Long-Range Transport of Air Pollutants. The program measured SO_2 emissions in 11 European countries, as well as air concentrations of SO_2 , particulate sulfate, and sulfate in precipitation. Computer models were used to estimate domestic and foreign contributions to each country's sulfur deposition. The effort, coordinated by the Norwegian Institute for Air Research, was among the first to rely extensively on long-range transport models; re-

suits were published initially in 1977 and in an expanded version in 1979. The study concluded that more than half of the deposition in five countries was caused by transboundary pollution.

The OECD has also produced reports on the legal aspects of transboundary pollution. By adopting the Principles Concerning Transfrontier Pollution the OECD Council urged member countries to follow guidelines in developing international law to deal with transfrontier pollution. Specifically, the Principles recommend: 1) a country in which transboundary pollution originates should address the problem as it would if the pollution occurred within its borders; 2) equal rights should be granted to foreigners in administrative and judicial proceedings; and 3) other nations should be informed of actions that a country believes might increase transboundary pollution. In addition, the Council also espoused the principle that the producers of pollution should pay for its control even when effects are felt outside the country of origin.

The Nordic Environmental Protection Convention

In 1974, Finland, Denmark, Norway, and Sweden signed the Nordic Environmental Protection Convention. The convention essentially eliminates international boundaries with respect to controlling pollution from stationary sources, and can be construed to deal with acid deposition from transboundary pollution. In many respects the Nordic Convention resembles the principles on transboundary pollution approved by the Council of OECD. It provides that permit decisions for pollution sources should weigh any adverse effects the source might have on a foreign country as though such effects would occur domestically. The Convention also adopts the principle that a foreigner has a right to institute proceedings in the country of emission concerning the permissibility of the emissions and to seek compensation for damages.

Multilateral European Monitoring Efforts

international research efforts in Europe began over a decade ago. Three monitoring networks have provided information on air and precipitation chemistry on long-range transport of air pollutants: the European Atmospheric Chemistry Network (EACN), the Organization for Economic Cooperation and Development Study on Long Range Transport of Air Pollutants (OECD/LRTAP), and the Economic Commission for Europe's cooperative program for monitoring and evaluating transported air pollutants in Europe (EC E-EMEP).

The EACN, begun in 1950 by Swedish scientists, consisted at its peak of 120 stations in 12 countries

analyzing air quality and wet deposition monthly. Data from this network showed an expanding area with highly acidic precipitation and led to the creation of OECD/LRTAP, operating from 1972 to 1977.⁵

Results of OECD/LRTAP suggested that future studies should include all European countries. EMEP, organized under ECE, in cooperation with the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO), was begun in 1977. Its main objective is to 'provide governments with information on the deposition and concentration of air pollutants, as well as on the quantity and significance of long-range transmission of pollutants and transboundary fluxes.'⁶

About 65 stations in 20 European countries are currently in operation. The monitoring sites have been selected primarily to represent rural areas. The EMEP sampling network relies principally on 24-hour sampling of SO₂ and particulate sulfate in air, and sulfate and acidity in precipitation. In addition, nitrate and ammonium in precipitation are measured in more than half the countries. The EMEP program is projected to issue semiannual reports for several years.

Approaches to SO₂ Control in Canada, Scandinavia, West Germany, the United Kingdom, and Japan

CANADA

Acid rain has become a major public policy issue in Canada. Particularly in the Eastern Provinces, there is deep and widespread concern over the possible damage to Canadian lakes and forests, and to the extensive tourist, recreational, and forestry industries they support. Due to transboundary transport of pollutants between the United States and Canada, acid rain has become a major issue in relations between the two countries.

Total SO₂ emissions in Canada in 1980 were about 5.3 million tons a year, approximately one-fifth the amount emitted by the United States. Most of these emissions come from two source categories: nonferrous smelters and coal-fired utilities. Although utilities contribute much less to Canada's total SO₂ emissions than smelters, Canadian powerplants could have a disproportionate effect on transboundary pollution because the majority of plants are located close to the U.S. border.

Canada and the United States are formally committed to developing a bilateral strategy to control transbound-

⁵I. Granat, "Sulphate in Precipitation as Observed by the European Atmospheric Chemistry Network," *Atmospheric Environment* 12, 413-424, 1978

⁶H. Douland, "European Networks—Operation and Results, Sulfur in the Atmosphere. Proceedings of an International Symposium in Dubrovnik, Yugoslavia, Sept 7-14, 1977

ary air pollution. In August 1980, the two nations signed a Memorandum of Intent (MOI) establishing five scientific and technological workgroups and pledging both countries to formal treaty negotiations. Three of the five workgroups under the MOI have completed their work and released their results on February 22, 1983.

Canadian air pollution control programs tend to be undertaken flexibly, with minimum use of formal legal measures, emphasizing government/industry cooperation instead. The legal basis for controlling air pollution in Canada lies in its Clean Air Act, most recently "amended in December 1980. Although the act now provides the Canadian Federal Government with the authority to control transboundary pollution originating in Canada, the Federal role is mainly one of guidance and demonstration to the relatively autonomous Provinces.

The Canadian Clean Air Act of 1980 exhibits distinctive differences from, but important similarities to, the U.S. Clean Air Act:⁷

- The national ambient air quality objectives contained in Canada's Clean Air Act, like those of the United States, are concerned primarily with local, ground-level effects, rather than regional or long-range transport impacts.
- As in the United States, the act does not directly address sulfates and nitrates (the main components of acid deposition), because they are largely formed in the air, rather than being emitted directly.
- Unlike those of the U.S. Clean Air Act, Canada's Federal standards are only guidelines and are not binding on Provinces. The Provinces have absolute discretion in the Canadian regulatory process. The Provincial governments often negotiate with industry to attain emissions reductions. Canadian courts are not involved in this process.
- Not all Provinces of Canada have adopted ambient standards. Standards for those that have—Alberta, Manitoba, New Brunswick, Ontario, and Saskatchewan—are far more stringent than the comparable U.S. primary standards.
- Cost effectiveness is a major consideration in developing most Provincial air pollution control programs. Less costly measures, such as the use of low-sulfur coal, and dispersion techniques such as tall stacks and siting, are the major means used to avoid excessively high ambient concentrations from powerplants. No scrubbers are in use in Canada today.
- The Canadian Clean Air Act empowers the Federal Government to set national guidelines only for

new sources and pollutants determined to have health effects. These guidelines are not mandatory.

- In 1981, Canada passed a program for coal-fired powerplants analogous to U.S. New Source Performance Standards. Other new sources are not as stringently controlled; emphasis has focused on controlling existing sources.

The Canadian Parliament, in December 1980, amended the Canadian Clean Air Act to grant the Minister of the Environment authority to recommend site-specific standards for sources "that may reasonably be anticipated to constitute a significant danger to the health, safety, or welfare of persons in another country. Provinces are given the first opportunity to enforce standards to "eliminate or significantly reduce" transboundary pollution. The Government-in-Council (essentially, the Federal Cabinet) may implement the standards if the provinces have not acted expeditiously.⁸

In March 1984, federal and provincial Ministers of the Environment agreed to reduce SO₂ emissions by 50 percent in eastern Canada by 1994, using 1980 as a base case year.

Formerly, Canada had been committed to a 25 percent emissions reduction east of Saskatchewan by 1990 to be achieved primarily by controlling Ontario Hydro and the International Nickel Co. (INCO) smelters.

Ontario Hydro, the provincially controlled utility system and largest aggregate source of utility emissions in Canada, was to reduce total SO₂ and NO_x emissions 43 percent from 1982 levels.

Ontario's Government-in-Council (i.e., the Provincial Cabinet) restricted emissions from the largest single source of Canada's SO₂, INCO's massive smelters at Sudbury, Ontario, to 1,950 tons/day in 1983. This represented a decrease from a maximum of 7,200 tons per day in the late 1960's.⁹

The control measures imposed on INCO, and Ontario Hydro may be changed when implementation plans for the recent decision to reduce emissions 50 percent in eastern Canada are developed.

SWEDEN

Swedish authorities consider acidification to be the most serious environmental problem of the decade, and are continuing their efforts both in Sweden and internationally, to reduce acid deposition. Of about 85,000 Swedish lakes classified as medium to large in size, more than 18,000 are currently acidified. About 4,000 of them are very seriously acidified and have suffered extensive biological damage. In about 9,000 lakes, mainly in

⁷G. Wetstone, "Review of Approaches to Long-Range Transport Control in the United States, Canada, Europe, and Japan, report prepared by the Environmental Law Institute for the OTA, March 1981

⁸Clean Air Act 522.1, House of Commons 1st Session, 32d Parliament, 29 Elizabeth II, 1980, Bill 151.

⁹Written communications from Bruce Jutzi, First Secretary, Embassy of Canada, Mar. 10, 1983, and Sept 13, 1983.

southern and central Sweden, damage to fish stocks range from minor upsets in lifecycles to extinction of trout and crayfish species. 10 Swedish scientists believe that several thousand more lakes will be threatened if acid deposition continues at present rates.

Sweden has decided to control its own SO₂ emissions stringently, although it is estimated that 70 percent of Sweden's pollutant deposition originates from sources outside the country. Since the early 1970's, when the problems of acidification first attracted notice, Sweden has introduced emission controls that have lowered emissions substantially in recent years. In 1970, SO₂ emissions in Sweden totaled about 450,000 metric tons (tonnes). Currently, Sweden is emitting about 250,000 tonnes of SO₂ a year. New control limits for powerplants effective October 1, 1984, will set maximum emissions of 0.24 gram of sulfur/megajoule of fuel—about 1.1 lb SO₂/million Btu fuel burned. Nineteen of twenty-four Provinces in Sweden currently meet that standard.

In the spring of 1981, the Swedish Parliament adopted an interim measure limiting maximum emissions of sulfur from any installation to 1,600 tonnes/day. This emissions cap has required two flue-gas desulfurization (FGD) units to be installed on a 400-megawatt (MW) and 700-MW powerplant. The Swedish Parliament has set a goal of reducing industrial sulfur discharges from 200,000 tonnes of SO₂ a year to half that amount by 1985. According to Sweden's National Environmental Protection Board, emissions probably will be reduced to about 85,000 tonnes by 1985. A special committee on coal, health, and the environment is currently preparing a report expected to lead to new proposals for a much lower industrial emissions standard in the spring of 1984.

Sweden has also embarked on an ambitious liming program to restore acidified lakes. A total of 3,000 lakes, 3,000 kilometers of streams, and 500 watersheds have been limed from the program's inception through July 1983. Total program costs have reached \$17 million to date, including approximately \$4 million to lime 500 lakes in fiscal year 1983. The program is financed by a tax on fuel oil. Although liming has been shown to be successful in temporarily preventing acidification and restoring natural acidity to surface waters, the Swedish Government has adopted the policy that liming is a stop-gap measure and cannot substitute for controlling acidifying emissions at their source.¹⁰

¹⁰ "Acidification Today and Tomorrow, Swedish Ministry of Agriculture, Environment 1982 Committee, 1982, pp. 50 and 130.

¹¹ Written communication from Carl Johan Liden, Counselor, Embassy of Sweden, Jan 7, 1983

NORWAY

Norwegian officials currently consider acid deposition to be their single most significant pollution problem. Extensive acid-deposition damage has been found in Southern Norway, where recent studies of 5,000 lakes have shown losses of fish populations in 1,750 lakes, with another 900 lakes projected to undergo serious acidification. As much as 90 percent of Norway's acidic deposition has been estimated to originate from sources outside its borders—the highest estimated percentage of pollution import of any European country.¹²

Overall emissions of SO₂ have been reduced in Norway following the enactment of new fuel-sulfur limitations in the late 1970's. Under the Neighbor Act of 1961, air pollution sources are required to use fuel oil with a maximum sulfur content of 2.5 percent (about 2.7 lb SO₂/million Btu). Amendments to the act in 1977 and 1979 imposed a maximum sulfur content of 1 percent (about 1.1 lb SO₂/million Btu) for all fuel oils used by new sources or by expansions of existing sources. In addition, existing sources were required to reduce annual SO₂ emissions by 20 percent from 1977 emissions levels.¹³ These more stringent requirements apply only to the nine southern and most populated counties of Norway. Further reductions in SO₂ emissions are expected over the next 5 years; however, Norwegians assert that no national-level controls will be sufficient to rectify the damage to their environment caused by acid deposition.

Norwegian concern over the effects of acid precipitation prompted major government-sponsored research beginning in 1972. The multidisciplinary research project, entitled "Acid Precipitation—Effects on Forests and Fish," culminated in an International Scientific Conference in March 1980 in Sandefjord, Norway. Norwegian officials believe that reports from this conference conclusively link emissions of SO₂ to environmental damage.

Over the past 10 years, the Norwegian Government has worked to achieve a gradual reduction of total sulfur emissions from the member countries of the ECE. This goal was most recently articulated at the Stockholm 1982 Conference by Wenche Frogn Sellaeg, Norwegian Minister of the Environment, who called for: 1) reducing sulfur emissions in the countries of Europe and North America, and 2) ensuring that no new powerplant or industrial source is constructed without effective controls on sulfur emissions.

¹² Written communication from Stein Seeberg, Counselor, Royal Norwegian Embassy, Sept 7, 1983

¹³ "Norwegian Strategies and Policies for the Abatement of Air Pollution Caused by Sulphur Compounds," *A Major Government Review of 1982*, Oslo, June 1982

DENMARK

Unlike other Scandinavian countries, Denmark contains large areas with soils capable of buffering the high levels of acid deposition it receives. However, Danish researchers have found evidence of lake acidification in some poorly buffered areas. Acting on this evidence, Federal and local government officials, along with power company executives, have formed a task force to examine ways to reduce emissions of SO_2 and NO_x .

Denmark emits about 450,000 tonnes of SO_2 annually. Two-thirds of these emissions come from oil-fired powerplants and oil-heated homes. Half of all sulfur deposition in Denmark is thought to originate in other countries, principally West Germany and the United Kingdom.

Denmark is presently in the midst of major switches from oil to coal use, but this fuel change is expected to cause SO_2 emissions levels to decline. Oil containing up to 2.5 percent sulfur has met over 80 percent of Denmark's energy needs since the early 1970's. The imported coal replacing the oil will have a much lower sulfur content. However, maximum allowable sulfur levels for coals have not yet been established.¹⁴

Denmark's air pollution is regulated by the Environmental Protection Act of 1973. The act sets standards for maximum sulfur levels for oils at 0.8 percent for light oil and 2.5 percent for heavy oil (about 0.9 and 2.7 lb SO_2 /million Btu, respectively). A stricter limit of 1.0 percent for all oil was established in the metropolitan area of Copenhagen. The act is implemented by municipal and county authorities under the guidelines of the National Agency for Environmental Protection. The act required major polluters to receive permits from the municipal or county officials.

Although Denmark is mainly concerned with reducing emissions to levels that do not contribute to adverse health conditions in the country, it is actively participating in developing international-level controls. Denmark cosponsored the draft proposal that led to the ECE Convention on Long-Range Air Pollution in November 1979.¹⁵

THE FEDERAL REPUBLIC OF GERMANY

West Germany is the second largest producer of SO_2 in Western Europe, and is believed to be a substantial contributor to acid deposition in Scandinavia. West Germany has established an ambitious air pollution control program. It is currently the only country in Europe to rely on scrubbers to abate sulfur pollution from new sources and presently operates eight FGD units.

Air pollution in West Germany is regulated under the Federal Emission Protection Act of 1974 (FIPA). Embodied in the Act are detailed nonbinding guidelines entitled 'Technical Instructions for Air' or TA-Luft. The responsibility for meeting these requirements rests with each State or "Lander." Legislative proposals are under consideration to make the TA-Luft legally binding on the Landers.

The first phase of planned revisions to FIPA was approved by the Bundesrat on February 4, 1983. In particular, the new regulations reduce SO_2 emissions limits for new sources by about 35 to 40 percent. It is estimated that this will reduce West Germany's emissions from electricity generation by 1 million tonnes by 1988.

West Germany emitted about 3.9 million tonnes of SO_2 in 1982, primarily from coal-fired powerplants and from industries burning oil and coal. West Germany is also believed to receive substantial amounts of pollution from other nations: about half of the sulfur deposited in West Germany is estimated to be of non-domestic origin.¹⁶

In recent years, environmental officials and the general public have become increasingly concerned about the possible effects of acid deposition on German forests.¹⁷ Because forestry is one of the country's leading industries, recent reports that air pollution—both local and transported—is severely damaging the nation's pine, fir, and spruce trees have aroused major concern. In response to this new evidence, the Federal Government has recently passed (July 1983) an ordinance on large firing installations to reduce total SO_2 emissions by 50 percent over the next 10 years. Additionally, West Germany has recently shifted its position from opposing international accords to promote control of transboundary air pollution to willing participation in international efforts.

UNITED KINGDOM

The United Kingdom is the largest emitter of SO_2 in Western Europe and is believed by some scientists to be the largest contributor to acid deposition in Scandinavia. An OECD study concluded that the United Kingdom is a significant exporter of pollutants to downwind nations, and calculates that it is the largest contributor of acid deposition to Norway, as well as the second-largest outside contributor of acid deposition to Sweden, after West Germany.

¹⁴ Written communication with Evy Jordan, Vice Consul, Royal Danish Embassy, Oct. 1, 1982.

¹⁵Ibid

¹⁶Instatement b,th,Federal Republic of Germany's Interior Minister at the "Conference on Acidification," Stockholm, June 27, 1982.

¹⁷Written communication with Detlef Boldt, Aug. 23, 1982

¹⁸Elam, "Present and Future Levels of Sulfur Dioxide Emissions in Northern Europe, prepared for the Swedish Ministry of Agriculture, June 1979,

Air pollution regulations in the United Kingdom date back to the Alkali Act of 1863, and are based on the concept of regulating emissions via the ‘best practicable’ means of control. The approach is designed to allow flexibility and evolving standards as control technologies improve—a wide range of emission standards are enforced by a central government inspectorate. However, for SO₂ and NO_x emissions, Britain’s principal control strategy is dispersion. Backup strategies include regional use of low-sulfur fuel, coal washing, siting industrial plants in nonurban areas, and developing nuclear power. FGD is not used to control SO₂ in the United Kingdom at the present time.

Britain relies on coal to produce almost 70 percent of its electric power, and powerplants account for almost 60 percent of its total SO₂ emissions. Total SO₂ emissions in the United Kingdom have already declined during the past 10 years from 6 million to 4.5 million tonnes; they are estimated to remain about constant or possibly decrease slightly in the future.

The British Government takes the position that significant uncertainties exist about the atmospheric processes leading to acid rain formation and about its reported effects. It asserts that more research is needed before a firm case can be established for policies to further reduce SO₂ emissions. However, international action within the UNECE convention, the Stockholm 1982 Conference, and the EEC may influence future U.K. policy with regard to transported air pollutants.¹⁹

JAPAN

Although Japan is not typically a focus of discussion for long-range transported air pollutants, its stringent control program and success in reducing ambient concentrations make it worth noting. Japan has the most rigorous SO₂ control policies in the world. Control requirements are geared to an ambient standard of 100 µg/m³ for a daily averaging time, compared to the U.S. standard of 365 µg/m³. In 1981, 98 percent of the monitoring stations in Japan met that standard. In 1974,

¹⁹Written communication from Mike Norton, First Secretary, Embassy of Great Britain, Aug 20, 1982

Japan instituted an emissions fee for large SO₂ sources in polluted areas. The proceeds are used in designated areas for the medical care of patients affected by air pollution.

About 1,362 FGD units were in operation in Japan during 1982. Most are small units installed primarily on industrial plants producing chemicals or pulp and paper products. Sixty-three of the units are installed on powerplants, accounting for 40,000 MW of electrical generating capacity. Unlike the United States and West Germany, where coal-fired plants are the focus of FGD controls, 29 of the Japanese units have been installed on coal-fired boilers and 34 on oil-fired plants.²⁰

According to the Japanese Government, these FGD units have not created a sludge disposal problem, because such materials as gypsum produced by scrubbers have been highly salable in Japan. The use of FGD was in fact promoted by the short supply of sulfur materials, creating a favorable market for these products. However, rapid expansion in the production of these goods has recently outstripped the market demand, which may make scrubber-byproduct disposal a land-use problem. Other countries are now beginning to follow Japanese techniques for regenerating FGD sludge.

Government subsidies and the expansion of the Japanese economy have contributed to the rapid increase of FGD use. The Government provides low-interest loans and allows accelerated depreciation for facilities that install control devices. The total investment in SO₂ control, including FGD and hydro desulfurization of oil, was about \$3.7 billion in 1977 U.S. dollars.

Ambient SO₂ concentrations have declined substantially in major urban areas as a result of the abatement program. From a 1965 level of about 150 µg/m³, the 1978 annual ambient average on a 24-hour basis dropped to about 40 µg/m³,²¹ a figure comparable to the 1978 urban ambient average in the United States.

²⁰‘Environment in Japan 1981’, Environment Agency, Government of Japan, December 1981

²¹Written communication with Seiji Ikkatai, Second Secretary, Embassy of Japan, Feb 23, 1983

D.3 MITIGATING THE EFFECTS OF ACID DEPOSITION ON AQUATIC ECOSYSTEMS

Introduction

Available strategies for controlling acid deposition and its ecological consequences include both further controlling pollutant emissions at their source and mitigating effects on sensitive resources—in particular, reducing the acidity of sensitive lakes and streams. Ameliorative measures such as liming affected lakes, streams, and watersheds have been proposed in several bills introduced during the 97th and 98th Congresses. Research is also underway on developing acid-tolerant strains of fish and aquatic plant life.

Proposed emissions control strategies are likely to require several years from enactment to implementation. “Likewise, biological experimentation to develop acid-resistant aquatic life will require many years. Thus, few prospects exist for a short-term solution to the acid deposition problem. Alleviating the **symptoms of the problem—decreasing the acidity of soil or water and restoring normal buffering capacity by adding lime or limestone—** may save or restore many important recreational and commercial fisheries while long-term solutions are developed and implemented.

Important biological or chemical effects of acid deposition on water quality or fish populations have been reported in New York, Massachusetts, New Hampshire, Maine, Pennsylvania, West Virginia, North Carolina, and Tennessee, as well as in Ontario, Quebec, and Nova Scotia. Almost all States and Provinces in the Eastern United States and Canada are thought to contain some sensitive surface waters, based on analyses of their soils and geology.

The most sensitive lakes and streams generally are located in areas that receive high levels of acid deposition, have steep topography, and are covered with thin and poorly buffered soils. If these soils are depleted of their limited capacity to neutralize incoming acidity, acid accumulates in lakes and streams within the watershed, and, in turn, mobilizes toxic metals. Eventually the water body becomes unable to support its normal range of plant and animal life. Temporarily restoring the buffering capacity of a lake or stream by applying lime or limestone can often allow aquatic life to be restored. For most mitigation efforts to date, the primary objective has been to improve water quality sufficiently to maintain reproducing fisheries.

Liming has been effective in counteracting surface water acidification in parts of Scandinavia, Canada, and the United States. Although its effects are only tempo-

rarily, the material is inexpensive, the dosage required fairly well known, and the technology of applying lime simple.

However, not all lakes and streams respond sufficiently to liming to reestablish aquatic life. In particular, lakes with rapid water flow in comparison to their volume (i. e., with water ‘retention time’ of less than a year), and running waters with great variation in flow, are very difficult to lime effectively. Moreover, it is impossible to determine the effectiveness of a liming application without extensive monitoring of the chemical and biological changes that follow. The results of individual applications will remain uncertain until more is known about how liming affects various types of water bodies. On the average, however, the buffering capacity that a single application of lime restores to a lake or stream will be depleted over a period of 3 to 5 years, after which the effectiveness of the application must be reconsidered, and a decision made whether to continue mitigation efforts.

Possibly of greater concern with regard to establishing a wide-scale liming program is that scientists do not know how periodic realterations of water body chemistry through liming will affect aquatic ecosystems over the long term. For example, a number of substances that normally are found in a biologically inert form in neutral waters become unbound, or soluble, in acidified waters. If, several years after liming, the lake again begins to acidify, accumulated metals that have been rendered insoluble over a period of time may again become soluble and create a serious toxic condition. In addition, little is known about the effects of periodic or even single applications of liming on other living organisms in the water body. While liming has enhanced fish survival in a number of lakes and streams, its long-term implications for the food chain on which fish depend are uncertain.

Though it is neither possible nor desirable to lime all acid-sensitive aquatic ecosystems in the Eastern United States, liming can be an effective stopgap measure to restore or preserve water bodies of particular value from the effects of acid deposition. Some characteristics to consider in choosing which water bodies to lime are:

- the current or historic ability of the system to support a viable and important fishery;
- recreational importance and public access to the waters;
- present chemical condition, i.e., pH, alkalinity, acid loadings, watershed buffering capacity;

- physical factors—water retention time, geographic location; and
- economic constraints—costs of material, application, and frequency of reapplication.

Such characteristics must be assessed on a site-specific basis before the feasibility of liming can be determined. Figure D-1 presents a series of criteria suggested by a report to U.S. Fish and Wildlife Service for evaluating the appropriateness of liming a water body. All of these criteria must be met for liming to be an appropriate mitigating strategy.

Liming Materials

Many alkaline materials can be used to neutralize acidified surface waters. These include lye, soda ash, olivine, and lime compounds, as well as several byproducts and wastes of industries such as cement dust and sludge from water treatment plants. However, while industrial byproducts are low in price, they frequently have a high level of such impurities as heavy metals, which may exacerbate the already-elevated metal concentrations typically present in acidified waters. Lime compounds are much more chemically uniform and have been the neutralizing material of choice for the majority of water bodies.

The term 'lime' is generally applied to several compounds of calcium and magnesium that are highly capable of neutralizing acid. The three most often used calcium compounds are limestone (calcium carbonate), quicklime (calcium oxide), and hydrated or slaked lime (calcium hydroxide). Available magnesium-based compounds include dolomite, dolomite lime, and dolomite hydrated lime. Calcium lime is used more commonly than dolomite. Dolomites have a slightly higher neutralizing value by weight than the nonmagnesium lime, but if their magnesium carbonate content is greater than 10 percent, they may dissolve too slowly to be of value in neutralizing acidified lakes and streams.

Crushed limestone, or "aglime," is currently the primary alkaline material used in experimental liming programs in the United States and Canada and in more wide-scale programs in Scandinavia. The more acidic the water, and the finer the limestone is ground, the more quickly it will dissolve. Limestone is a relatively inexpensive natural material and is less caustic than quicklime or hydrated lime. In general, limestone goes into solution more slowly than either quicklime or hydrated lime, but remains effective longer. The differences between lime and limestone are shown in figure D-2.

Response to Liming

Chemical Changes

Adding a liming agent causes the pH of the water body to rise and restores alkalinity—i.e., the ability to neutralize further acid inputs. If a very soluble base such as quicklime is added, pH rises sharply, and the highest pH is reached shortly after the treatment. In a New York State lake, for example, adding lime initially raised pH from 5 to 9—a ten-thousandfold decrease in acidity before the water body reached equilibrium at a lower pH value. The shock from such chemical changes, if too rapid, can be lethal to a variety of aquatic life, especially fish. When a less soluble agent such as limestone is added to a water body, the rise in pH is less dramatic. The pH generally will not exceed 7, even during the initial period after limestone is added. Applied as a powder or finely crushed stone, it will settle readily to the bottom and dissolve slowly.

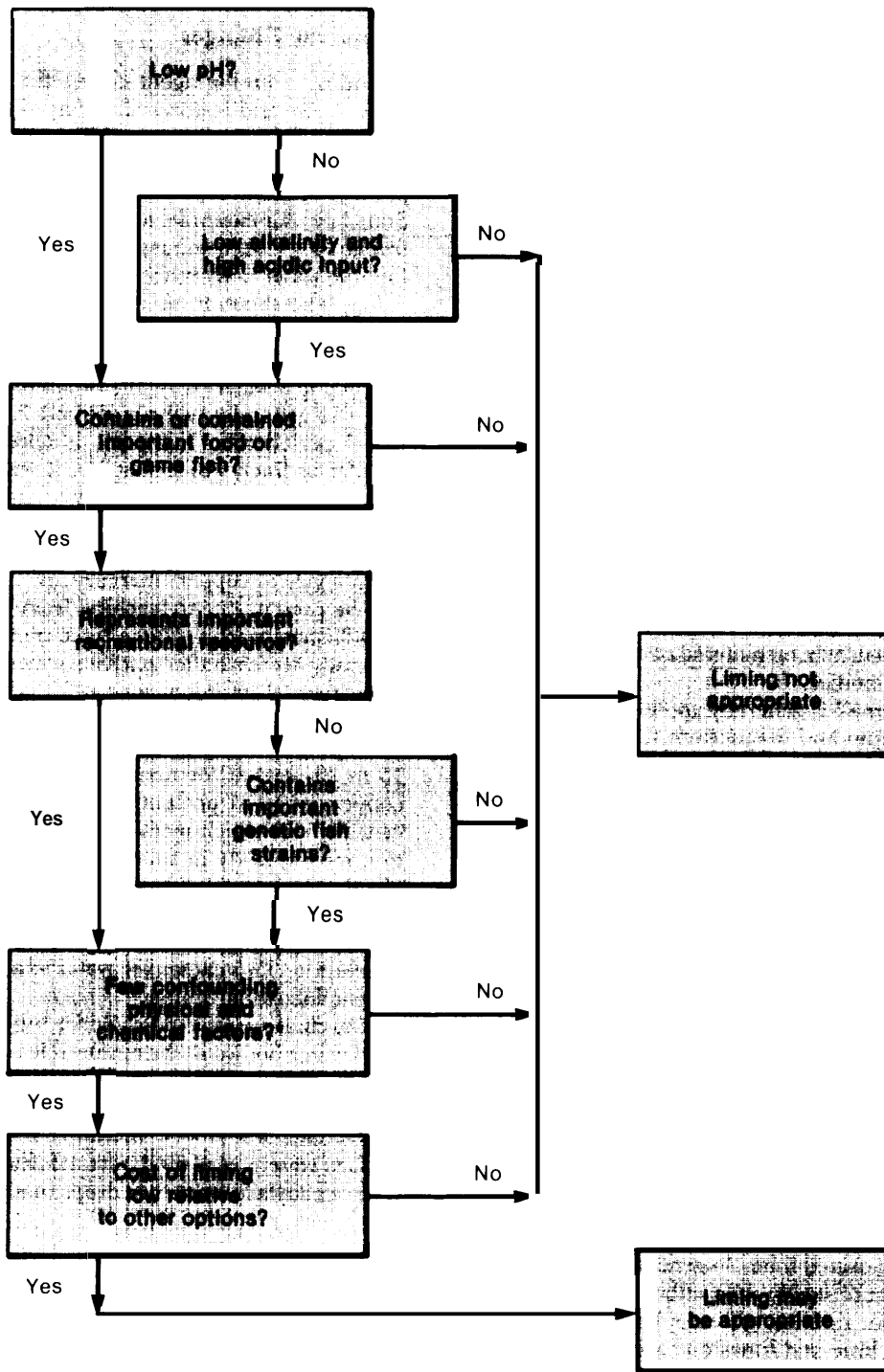
Aluminum, manganese, and zinc frequently are found in elevated concentrations in acidified waters. High levels of copper, mercury, nickel, and iron may also be present due to leaching from surrounding soils or industrial wastes. These trace-metal concentrations generally decrease after acidified waters are limed. After experimental liming at four lakes near Sudbury, Ontario, decreases in metal concentrations ranged from 66 to 91 percent for aluminum, 23 to 73 percent for zinc, 15 to 79 percent for manganese, 32 to 95 percent for copper, 23 to 81 percent for nickel, and 15 to 89 percent for iron. Such metals will precipitate out of solution most quickly in small shallow lakes where liming agents mix thoroughly in a short time. Dissolved organic material, which usually gives water a brownish tint, also will be removed as the metals precipitate out of solution. This causes the water to appear more transparent following liming.*

The chief agent responsible for fish mortality in acidified water bodies is aluminum released by acid percolating through watershed soils. Although aluminum is the most prevalent metal in the Earth's crust, the concentrations of soluble aluminum compounds are low in surface waters with moderate acidity levels (above pH 5.5). As surface-water pH drops to about 5, aluminum

*J. E. Fraser and D L Britt, *Liming of Acidified Waters A Review of Methods and Effects on Aquatic Ecosystems*, U S Fish and Wildlife Service, Division of Biological Services, Eastern Energy and Land Use Team, FWS/OBS 80/40. 13, 1982

*Acidification of water bodies also may make them clearer as phytoplankton (tiny plant life) die off

Figure D-1.—Criteria for Evaluating a Water Body for Suitability of Liming



Confounding physical and chemical factors include high flushing rates, high metal concentrations, extensive accumulations of snowpack, rapid aluminum leaching from watershed soil, predominance of soft sediments, and presence of humic substances.

SOURCE: Adapted by Office of Technology Assessment from J. E. Fraser and D. L. Britt, *Liming of Acidified Waters: A Review of Methods and Effects on Aquatic Ecosystems*, U.S. Fish and Wildlife Service, Division of Biological Services, Eastern Energy and Land Use Team, FWS/OBS 80/40.13, 1982.

Figure D-2.—Comparison of Lime and Limestone

Neutralizing materials Charac- teristics	Lime		Limestone (CaCO ₃)	
	Quicklime (calcium oxide)	Hydrated lime (calcium hydroxide)	Aglime (pulverized limestone)	Limestone rock
Effect on pH	Rapid rise in pH	Rapid rise in pH	Less rapid rise in pH than lime	Less rapid rise in pH than aglime
Corrosivity	Extremely caustic	Less caustic than CaO	Not caustic	Not caustic
Reactivity in water	High reactiv- ity: less quantity re- quired than limestone	High reactiv- ity: less quantity re- quired than limestone	Lower reactivity than lime ^a	Lower reactivity than lime ^a
Length of effectiveness	Short	Short	Longer than lime	Longer than lime

^aUncertainty exists as to whether the CaCO₃ that does not go into solution becomes reactive at a later date or becomes nonreactive.

^bRelative neutralizing value if pure CaCO₃ is assigned a value of 100%.

SOURCE: Adapted by Office of Technology Assessment from J. E. Fraser and D. L. Britt, *Liming of Acidified Waters: A Review of Methods and Effects on Aquatic Ecosystems*, U.S. Fish and Wildlife Service, Division of Biological Services, Eastern Energy and Land Use Team, FWS/OBS 80/40.13, 1982.

becomes much more soluble and more toxic to fish. Below pH 4.5, aluminum appears to have less effect on fish, but acidity levels themselves are so high that few species can survive. If a water body of less than pH 5 is limed, it will pass again through the critical pH range at which aluminum is especially toxic—and for a brief time fish mortality will be of concern. As the pH increases beyond this range, the aluminum will precipitate out of solution and settle to the bottom.

The pH of surface waters will gradually decrease if significant acidic inputs continue from precipitation, streamflow, ground water infiltration, or perhaps even from the lake sediments as they use up the buffering capacity of the water above them. Liming will generally prevent acidity from increasing for about 3 to 5 years. However, once acidity increases again, aluminum and other soluble metals that have been precipitated out of the water are again 'mobilized. The water may contain greater concentrations of metals following reacidification than in its original acidified state several years

earlier. This is because the sediments will release both those metals initially precipitated out of solution by adding lime as well as those that entered the lake or stream and settled to the bottom while the lime provided buffering capacity. Continued liming must be timed carefully to prevent such toxicity from recurring. Table D-1 displays water quality changes in an acidified Ontario lake immediately prior to, and for 6 years following, the addition of lime.

Biological Changes

Acidification of aquatic ecosystems reduces the diversity of the normally present biological community. The total number of plant and animal species often decreases significantly. Species sensitive to acidic conditions are eliminated while tolerant species proliferate. Acidification inhibits the bacteria normally responsible for decomposition, thereby slowing the rate of nutrient cy -

Table D-1.—Changes in Chemistry of Lohi Lake, Ontario, Canada, Following Addition of Neutralizing Agents in 1973 (hydrated lime), 1974 (hydrated lime and limestone)

Parameters	1973	1974	1975	1976	1977	1978	1979
pH	4.39	6.04	6.09	6.09	5.27	4.79	4.76
Copper (mg/m ³)	—	—	—	84	44	43	37
Aluminum (mg/m ³)	—	140	110	120	100	160	—
Water transparency (Secchi disk, m)	—	8.8	5.6	5.7	5.7	6.9	9.3
Alkalinity (µeq/l)	0	46	102	44	0	0	0

SOURCE: National Research Council Canada, "Acidification in the Canadian Aquatic Environment: Scientific Criteria for Assessing the Effects of Acidic Deposition on Aquatic Ecosystems," Ottawa, Canadian Environmental Secretariat, 1981,

cling. Aluminum toxicity associated with acidification eliminates **various fish species**.

Liming drastically decreases the density of acid-tolerant phytoplankton (e. g., algae). Normal populations generally will be established within about a year. Normal zooplankton populations (animals that feed on the phytoplankton) may take much longer to recover. Fish populations, in turn, feed on the zooplankton; thus, several years may be required to reestablish a viable fishery. Liming experiments so far have shown enhanced survival of natural populations of brook trout in Adirondack lakes; lake trout, brook trout, and smallmouth bass in an Ontario lake; and Atlantic salmon in a Nova Scotia stream.

Biological diversity in limed water bodies might be enhanced by adding organic carbon and/or phosphorus in nutrients (organic humus or perhaps biologically treated wastewater). Phosphorus, an important element in phytoplankton nutrition, is often in short supply in acidic waters. Limited success has been reported when phosphorus was added following liming in Canadian lakes. The effect of adding organic carbon is highly speculative. If these nutrient additions prove effective in enhancing recovery of limed acidified water bodies, they could be applied at little cost.

Costs and Methods of Applying Liming Materials²³

The techniques available for liming aquatic systems depend on the type of neutralizing material used, the availability of dispersal equipment, and the target area being limed. The major application methods used to date in the United States, Canada, and Scandinavia are outlined in figure D-3.

The accessibility of the water body may determine the appropriate liming method. For example, a remote lake can be limed only by aircraft, while an accessible water body can be limed by truck or boat. Directly liming the water body appears to be the most economically efficient technique. It is currently the most commonly used method for lakes, and is appropriate as long as the water retention time (a measure of how rapidly the lake is replenished) is longer than 1 year. If the water retention time is short, the added alkalinity will quickly leave the system (although it may neutralize water bodies downstream). Liming tributary streams might provide downstream lakes and rivers with longer term buffering capacity, and enhance fish spawning.

Researchers have yet to determine whether acidified aquatic resources may be restored more effectively by liming watersheds or lakes and streams themselves.

However, to achieve comparable acid-neutralizing capacities in surface water, 100 times more lime must be applied to a watershed than directly to a water body. Despite this, Sweden has applied 40 percent of its total tonnage of lime on land.

For maximum effect, lime should be added shortly before critical periods of peak acidity and biological activity, i.e., during early spring, for surface waters that still support fish populations. Spring snowmelt often flow directly into water bodies without experiencing the potential neutralizing effects of soils. In much of the Eastern United States and Canada, this snowmelt has a pH of less than 4.5. The acidity that has been stored in snows throughout the winter reaches water bodies when sensitive embryos and fish fry are developing. Alternatively, liming lakes slightly later in the season, during the spring overturn, takes advantage of lake circulation patterns to enhance mixing and distribution of neutralizing agents.

Table D-2 outlines costs of limestone materials, transport, and application in Sweden in 1981. Normally, 1 to 2 tons of limestone are added per acre of surface water. The Government of Sweden has undertaken the most extensive liming program to date—3,000 lakes, 3,000 kilometers of streams, and 500 watersheds from the program's inception through July 1983. Total program costs have reached \$17 million to date, including approximately \$4 million to lime 500 lakes in fiscal year 1983.

Several waterway deacidification experiments have taken place in North America. Since 1973, the Ontario Ministry of the Environment has limed four acidified lakes in the Sudbury region. The treatments have been successful in returning pH to normal levels.

The most extensive program in the United States was begun by the New York State Department of Environmental Conservation in 1959. It initially targeted small, naturally acidic ponds in heavily used recreational areas, and expanded to treating selected acidified lakes with significant potential to support recreational fishing during the mid-1970's. The program is quite small in scope; only about 60 lakes in total (covering approximately 1,000 acres) have been treated to date. It has significantly improved water quality at a number of lakes and ponds, and permitted self-propagating sport fishing populations to be maintained and/or reintroduced. Costs for liming ponds and lakes under the program have ranged from approximately \$50 to \$300/acre for each application, depending on the size and accessibility of the water body. Between 1 and 2.2 tons of lime are normally added per acre of surface water to be treated—costs for transporting the material to the lake site constitute a significant portion of overall expenses.

Currently, only Massachusetts and New York have formal surface water mitigation projects. Since 1957,

²³This section is based in part on Fraser and Britt, *op. cit.*, 1982.

Figure D-3.—General Comparison of the Various Liming Application Techniques

Technique	Countries employing various techniques	Receptor type	Advantages	Disadvantages
Boats	• Canada • Sweden • United States	• Lakes	<ul style="list-style-type: none"> • Simple and relatively inexpensive technique • Allows choice of elementary to sophisticated distribution options 	<ul style="list-style-type: none"> • Application is a relatively slow process if bag dumping or slurry techniques are used • Difficult to use at remote bodies of water
Sediment injection	• Sweden	• Lakes	<ul style="list-style-type: none"> • Reported to be 5 to 7 times as efficient as adding lime directly to lakes on an equivalent basis 	<ul style="list-style-type: none"> • Expensive • Need large sophisticated equipment • Only applicable to lakes accessible by roads
Truck and spreaders or blower	• Norway • Sweden	<ul style="list-style-type: none"> • Lakes • Streams • Watershed soils 	<ul style="list-style-type: none"> • Can distribute large amounts of lime in a relatively short period 	<ul style="list-style-type: none"> • Can only be applied in areas accessible by roads
Aerial applications	• Canada • Sweden • United States	<ul style="list-style-type: none"> • Lakes • Streams 	<ul style="list-style-type: none"> • Facilitates access to remote sites • Less labor • Can apply large amounts of lime in a relatively short period 	<ul style="list-style-type: none"> • Expensive
Silos (mechanical release)	• Sweden	• Streams	<ul style="list-style-type: none"> • Allows for more precise maintenance of pH, since liming material is applied as needed 	<ul style="list-style-type: none"> • Need regular maintenance, as existing silos continually break down • Overall, relatively expensive to build and maintain
Diversion wells	• Norway • Sweden	• Streams	<ul style="list-style-type: none"> • Simple and relatively inexpensive 	<ul style="list-style-type: none"> • Not adaptable to slow-flowing streams • Efficiency not known
Limestone barriers in streams	• Canada • Sweden • United States	• Streams	<ul style="list-style-type: none"> • Simple and relatively inexpensive technique • Once applied, the limestone is present for a relatively long time 	<ul style="list-style-type: none"> • Technique only suitable for easily accessible sites • Technique fails during high water flows • Controversy over long-term buffering capabilities
Rotary drums filled with limestone gravel	• United States	• Streams	<ul style="list-style-type: none"> • Effective maintenance of stream pH because controlled by stream flow • Continual abrasion of limestone prevents coating by iron hydroxide and calcium sulfate precipitates 	<ul style="list-style-type: none"> • Not adaptable to slow-flowing streams • Still in prototype stage, may need some design changes • Hopper reloading required, regular maintenance

SOURCE: Adapted by Office of Technology Assessment from: J. E. Fraser, D. Hinckley, R. Burt, R. Rodensky Severn, and J. Wisniewski, *Feasibility Study to Utilize Liming as a Technique to Mitigate Surface-Water Acidification* (Palo Alto, Calif.: Electric Power Research Institute, 1982), EPRI EA-2362.

Table D-2.—Range of Costs for Limestone Materials, Transport, and Application in Sweden 1981

Liming parameters	costs
Materials:	
Bulk limestone	\$20-\$30/ton
Bagged limestone	\$40/ton
Transport of limestone	\$10-\$20/ton
Application techniques:	
Truck	\$4-\$6/ton
Pontoon boat with blower	\$10-\$16/ton
Helicopter	\$30-\$40/ton
By hand	\$20-\$60/ton

SOURCE: National Fisheries Board of Sweden, *Rad och Riktlinjer for Kalkning av Sjoar och Vattendrag*, Report No. 1, 1982

Massachusetts has limed about 40 small ponds covering 2,000 acres. Funded for liming is quite limited, however, and future projects are uncertain. New York has developed a 6-year liming plan. During this time, 33 lakes will receive a lime treatments, and extensive chemical and biological monitoring will be conducted. A recent study of liming requirements in the Adirondack region of New York estimated that a 5-year program for liming all the known acidified lakes in the region would cost from \$2 to \$4 million per year, depending on the targeted buffering level.²⁴ This estimate represents

²⁴ F. C. Menz and C. T. Driscoll, "An Estimate of the Costs of Liming to Neutralize Acidic Adirondack Surface Waters," Contribution # 11, Freshwater Institute, June 1983.

materials and labor only; it does not include costs for fish restocking or continued monitoring which can be considerable. Particularly in the initial stages of a liming program, frequent monitoring for chemical and biological changes in treated water bodies is necessary. Annual costs may range from \$3,000 to \$20,000 per lake. When a sufficient data base exists to develop a generic treatment protocol for various aquatic ecosystems—water bodies of differing geological, chemical, and biological characteristics—monitoring costs may be reduced significantly.

No direct Federal support is currently being provided to States, localities, or other organizations that undertake to treat acidified surface waters. Federal involvement in mitigation research began in 1982 under the direction of the Fish and Wildlife Service (FWS), as provided for in the National Acid Precipitation Assessment Plan. * To date, the Federal research effort has produced a technical report on liming²⁵ and an agenda of further

research needs determined by participants in an international mitigation conference. Current plans for field research include monitoring the effects of liming on fish populations in several lakes in the Adirondack Mountains, as part of the research program on water chemistry sponsored privately by the Electric Power Research Institute. FWS is also supporting a pilot scale liming project on 10 acidified lakes in the Adirondack region in an attempt to understand the variation in response of fish populations and to evaluate the success of restocking strategies. Total Federal funding for such efforts in fiscal year 1983 amounted to about \$225,000. The administration recently proposed about \$.5 million for liming research for fiscal year 1985. Such funding increases would permit researchers to study the effects of liming on water bodies with differing geological, chemical, and biological characteristics throughout the Eastern United States, and to investigate the effectiveness of alternative mitigation measures.

*Chapter 6 discusses the National Acid Precipitation Assessment Program and Federal research on mitigation techniques in greater detail

²⁵Fraser and Britt, 1982.