G.J. Heij and J.W. Erisman (Editors). Acid Rain Research: Do we have enough answers?

Lessons learned in acidification research: Implications for future environmental research and assessments

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Abstract

The purpose of this paper is to summarize lessons that are available to be learned from the American experience in acidification research. During the years between 1975 and the early 1990s, various acidification research and policy-focused assessment programs were initiated in the United States and Canada. The objectives of these programs were to better understand the phenomenon of acid precipitation and its effects on lakes, streams, fish, crops, forests, visibility, human health, engineering materials, and cultural resources in North America. The most comprehensive of these programs were the Memorandum of Intent (MOI) Work Group Processes initiated in 1978, the Office of Technology Assessment (OTA) Report completed in 1984, and the National Acid Precipitation Assessment Program (NAPAP) completed in 1990. These were the first efforts by governments in Canada and the United States to develop scientific and policy-focused assessments of alternative strategies for management of environmental risks on a continental scale. As such, they provide a useful basis for evaluation of: 1) scientific learning about atmosphere/biosphere interactions, and 2) social learning about the interface between science and public policy.

1. INTRODUCTION

Many insights developed in this paper are outgrowths of an international research project at Harvard University's Kennedy School Of Government. This project, entitled "*Social Learning in the Management of Global Environmental Risks*" is led by Dr. William Clark. The purpose of the project is to compare and contrast the processes used in various countries as they make decisions about what each nation should do, if anything, about certain contemporary environmental risks. Dr. Clark asked that I prepared the "Evaluation" chapter for the "Acidification" case study for the United States (Cowling, 1994). This chapter was developed using the following protocol which was designed by an international committee of experts within the Social Learning Project:

Three environmental risks were selected as case studies:
1) Global climate change,

2) Depletion of stratospheric ozone, and
3) Acidification and long-range transport of air pollutants.

Nine nations on three continents were selected for inclusion in the Social Learning Project. Risk assessment and risk management efforts in each country were studied by teams of researchers working under the guidance of the following national team leaders:
1) The Netherlands --Josee van Eijnhoven, University of Utrecht, Utrecht, The Netherlands
2) Germany -- Jill Yeager, International Institute for Applied Systems Analysis, Laxenburg, Austria
3) United Kingdom -- Brian Wynne, University of Lancaster, United Kingdom
4) Hungary -- Ferenc Toth, Potsdam Institut für Klimafolgenforschung, Potsdam, Germany
5) Russia --Vassily Sokolov, Russian Academy of Sciences, Moscow, Russia
6) Japan -- iranda Schreurs, University of Maryland, College Park, MD
7) Canada --Rod Dobell, University of Victoria, British Columbia, Canada
8) Mexico --Diana Liverman, Pennsylvania State University, University Park, PA
9) United States -- William Clark and Nancy Dickson, Kennedy School of Government, Harvard University, Cambridge, MA

The roles played by seven actor groups were examined within each nation:
1) Expert communities -- mainly scientists and engineers with special knowledge about each environmental risk;
2) Business and industry groups -- mainly the electric utility, coal, automobile, and other industries;
3) Other non-governmental groups -- mainly environmental groups, trade associations, and private foundations;
4) Executive branches of government -- mainly federal government agencies, but including some state and provincial organizations as well;
5) Legislative branches of government such as Congress in the USA or Parliament in Canada;
6) Judicial branches of government; and
7) The media -- including both print and electronic media.

Studies were then made of the risk-assessment and risk-management functions performed by each actor group within each nation with respect to each environmental risk. The definitions listed below are those used for the case study of acidification and long-range transport of air pollutants:
1) Issue Framing -- framing the issue of acidification and associated long-range transport of air pollutants (LRTAP);
2) Risk Assessment -- assessing the nature and magnitude of the risks imposed by acidification and LRTAP;
3) Response Assessment -- assessing alternative strategies by which the risk of acidification and LRTAP could be managed;
4) Goal and Strategy Formulation -- formulating specific goals and strategies by which the risks of acidification and LRTAP could be managed;

5) Implementation -- actions taken by one or more actor groups in an effort to manage the risk of acidification and LRTAP;
6) Monitoring -- measuring the amount and intensity of risk and the nature and magnitude of damage or injury caused by acidification and LRTAP; and
7) Evaluation -- self-conscious efforts by different actor groups to determine the effectiveness of their own efforts, or the efforts of other actor groups, in fulfilling one or more of the preceding six risk-assessment and/or risk-management functions.

2. EVALUATION OF AMERICAN ACIDIFICATION RESEARCH

From a broad array of evaluation documents produced by the seven actor groups listed above, 16 were selected for detailed analysis:
--Eight documents from four different **expert communities** -- one by a group of four scientists which led to establishment of the National Acid Precipitation Assessment Program (NAPAP) (Galloway et al, 1978), one by a professional society dealing with the NAPAP Interim Assessment (LeFohn and Krupa, 1988a, 1988b), five documents by scientists selected by the Ecological Society of America (Levine, 1992; Russell, 1992; Cowling, 1992; Loucks, 1992; Schindler, 1992), and another noted scientist (Likens, 1992);
--Two documents from **business and industry** -- both by a former Director of Environmental Research at the Electric Power Research Institute (Perhac, 1991a, 1991b);
--Four documents from **executive branch organizations** -- two by Ad Hoc evaluation committees (EPA, 1983; OSTP, 1984) (the latter by Presidential appointment), the NAPAP Oversight Review Board report (NAPAP, 1991a), and one by a former director of NAPAP (Mahoney, 1990);
--Two documents from **Congress** -- a report by the Congress' Office of Technology Assessment (OTA, 1984), and an oversight hearing on plans for NAPAP's 1990 Integrated Assessment (House of Representatives, 1988).

The principal foci of these documents were successes and shortcomings of two North American research and assessment programs or activities:
1) **Memorandum of Intent Work Group Reports** (MOI, 1982-83) which were developed in response to a Congressional resolution calling for negotiation of an air-quality treaty between Canada and the United States, and
2) The **National Acid Precipitation Assessment Program (NAPAP)** -- the 10-year-federal research and assessment program in the United States (NAPAP, 1991b, 1991c).

3. INSIGHTS FROM THESE SIXTEEN EVALUATION DOCUMENTS

Preparation of the Evaluation Chapter for the United States Case Study on Acidification (Cowling, 1994) revealed five major types of insights:

1) Many incremental changes in understanding of the phenomena and effects of air pollution and acidification have occurred in the United States since 1960.

2) Despite many gaps in scientific understanding, adequate information about the phenomenon and effects of acidification were available in 1984 for the United States and Canada to take initial steps to decrease emissions of sulfur and nitrogen oxides on both sides of the border and to reconvene negotiations to set a preliminary target load for acid deposition in aquatic ecosystems of the northeastern United States and southeastern Canada. This is the judgment of the Nierenberg Committee (OSTP, 1984). On the basis of an entirely separate evaluation process, substantially the same conclusion was reached by the Office of Technology Assessment in its Report to Congress -- *Final Report on Acid Rain and Transported Air Pollutants: Implications for Public Policy* (OTA, 1984).

3) Significant innovations took place during the 1980's and 1990's in institutional arrangements by which the United States sought to assess and manage the risks of acidification and long range transport of air pollutants.

4) A total of 8 general lessons and 19 more specific lessons are available to be learned from the United States' experience with acid deposition research. Some of these general and specific lessons may be of value in improving the policy performance of the United States and other countries as they seek solutions to the acidification and other global, national, and regional environmental problems.

5) The NAPAP Oversight Review Board provided a series of guidelines for formulation of research program findings to be used for policy purposes.

Several of these incremental changes, institutional and process innovations, lessons available to be learned, and guidelines for formulation of statements of findings are summarized below.

3.1 Incremental Changes in Understanding Air Pollution and Acidification

1) During the 1960s, air pollution was regarded as a local, mostly urban problem mainly affecting human health. In contrast, by the early 1990s, air pollution has come to be regarded as both a local *and* a regional problem in urban, rural, and even some remote areas of the United States, where it has been having significant influences on the stability of ecosystems, engineering materials, historical monuments, visibility, etc.

2) During the 1960s, "dilution" was confidently believed to be "a solution to pollution". In recent years, we have come to realize that "what goes up comes down somewhere and probably has some kind of effect when it gets there".

3) During the 1960s, we thought of pollutant exposure in terms of air concentrations and/or annual amounts of deposition. Now we realize that cumulative (multi-decade) exposures also are important and that we must understand that soils, have a finite "sulfate absorption capacity" or "assimilative capacity" for acidifying substances and other airborne pollutant chemicals.

4) During the 1960s, we thought that most pollutants of concern were primary pollutants, that is, the substances that caused a pollution problem were emitted directly by a pollution source. In recent years we have come to recognize that secondary pollutants also are important. Secondary pollutants are injurious substances formed in the atmosphere from primary pollutants. Acid deposition and ozone near the ground are examples of secondary pollutants.

5) During the 1970s, we thought acid deposition was largely a problem of long distance transport. Now we recognize that acid deposition is both a long-distance and a short-distance problem and that areas of high chemical loading in the United States are substantially coincident with areas of high emission. This is not true in some (mostly remote) parts of eastern Canada, however. Here, distant sources of pollutants are more important than local sources.

6) During the early 1970's, we thought that sulfur dioxide was the principal cause of airborne acids and acidifying substances. Now we recognize that a wide variety of both sulfur and nitrogen compounds are important causes of acidifying deposition from the atmosphere in North America and Europe.

7) During the early 1970's, we thought of acid deposition mostly as a wet-deposition phenomenon, hence the terms *"acid rain"* or *"acid precipitation"*. Now we think of acid deposition as both a wet, and a dry, and a cloud-water deposition phenomenon involving acid rain, acid snow, acid fog, acid dew, acid aerosols, acid particles, acidic gases, and other acidifying substances.

8) During the 1980's, we used the terms *"acidic rain"* or *"acidic deposition"*. Increasingly now we use the terms *"acidifying deposition"* and *"acidification"* because not all acidifying substances are acidic, and not all substances that cause acidification are acidic either.

9) During the 1980's, a major convergence of extreme views about acidification took place both in scientific and in public opinion. In 1980, some scientists, and many in the public, believed that air pollution in general and acid deposition in particular posed serious and immediate threats to the health and productivity of aquatic and terrestrial ecosystems. By contrast, another group of scientists, and some in the public, believed that air pollution was mainly an urban problem, the acids present in precipitation were too dilute to have significant effects on any but the most sensitive lakes and streams, and acid deposition was unlikely to affect crops or forests. By the end of this decade, these extreme views converged into a more moderate middle ground:

--There are important effects of acidification on aquatic ecosystems in some regions of North America where sulfate absorption capacity of soils have been exhausted;
--Nitrogen saturation of some forest soils is occurring in the Untied States;
--High-mountain red spruce forests exposed to acid cloud water in the northeastern United States are predisposed to damage by winter frost;
--Agricultural crops are not seriously threatened by acid deposition, but are being impacted by ozone near the ground in large parts of eastern North America;
--Continuing deposition of large amounts of sulfur and nitrogen oxides over decades of time leads to continuous alteration of terrestrial and aquatic ecosystems;
--Decreased loading of the atmosphere with sulfur and nitrogen oxides will ameliorate these ecological effects, improve visibility, and decrease harm to engineering materials and historical monuments.

10) In the Clear Air Act Amendments of 1990, the United States initiated a system of marketable pollution-trading permits, continuous emissions monitoring, requirements for decreases in emission of VOC, etc.

11) During the 1980's, the United States found it difficult to consider specific critical or even target loads of acidifying substances. Recently, as the concept of critical loads and associated target loads has gained wider acceptance among our own citizens and in many European countries, some rethinking of our earlier national reluctance to consider such approaches appears to be developing.

3.2 Innovations in Scientific Research and Assessment Processes

The most important institutional and process innovations deriving from the NAPAP experience were the following:

1) Development of a unique mechanism for federal interagency coordination. NAPAP was governed by a federal interagency coordinating committee with six "leading agencies", each with different specific roles in research and assessment, and six other "contributing agencies". This organizational construct had no true "lead agency" with both administrative authority and budgetary control over most of the NAPAP program. Such an approach had not been used before in the United States. NAPAP's federal interagency coordinating committee was called the Acid Precipitation Task Force. It served from the time of NAPAP's establishment in 1981 through 1990 when NAPAP produced its 1990 Integrated Assessment. This mode of organization had the constructive effect of bringing together in a single coordinated program a total of 12 different federal agencies. Many of these agencies had widely different agency missions. After 10 years of working together, many agency representatives felt that they were in a better position to help the country make policy decisions that transcend different agency jurisdictions, regions, industrial sectors, and value systems within both Canadian and United States society.

2) Apparently in deference to this organizational innovation, however, NAPAP developed a tradition that all six "leading agencies" in the program would have to approve, prior to publication: all state of science reports, state of technology reports, annual reports, interim and final assessment documents, scientific findings, testimony for congressional hearings, and other public documents. This requirement for unanimous approval by six different agencies of government in light of advice received from both an Interagency Science Committee and an Interagency Policy Committee, frequently led to compromise, "watering down", and, almost always, to substantial delay in release of research and assessment findings.

3) The most significant process innovation deriving from the NAPAP experience was development of a new paradigm for "integrated assessment" (House of Representatives, 1988; Mahoney, 1990; NAPAP, 1989)which should:

a) Be based on credible scientific information which is well documented and available to all users;
b) Be developed according to a structured plan which includes i) definition of all effects studied, and ii) specific policy and scientific questions to be addressed;
c) Be developed with its plan and specific questions open for review by all potential users in the United States and Canada and modified to include consideration of user comments;
d) Document all data, quality assurance methods, computational analysis methods, and computer software used, to facilitate subsequent analyses by user groups;
e) Define uncertainties, to allow users to evaluate confidence in reported findings;
f) Be structured to facilitate incorporation of new information on trends, dose-response models, emissions estimates, etc.; and
g) Include illustrative management scenarios that consider the benefits, costs, and timing of alternative control measures and technologies.

3.3 General and Specific Lessons That are Available to be Learned from the Acid Deposition Experience in the United States

1) *"Integrated Assessment"* is very different from "scientific research and reporting" (see items 3a-3g in Section 3.2 above). So also are *"Guidelines for Formulation of Research Program Findings To Be Used for Policy Purposes"* different from those for preparation of scientific findings not planned for use for policy purposes. The guidelines developed by the NAPAP Oversight Review Board (NAPAP, 1991a) are of sufficient value for other policy-focused purposes that they are reproduced in their entirety in Section 3.4 of this paper.

2) The key actors in developing a science-based integrated assessment are not two in number -- scientists and government decision makers -- as many had assumed before the acidification research and assessment experience, but rather at least four in number -- scientists; policy analysts; communicators; and decision

makers -- including decision makers in industry, governments, and public interest groups (NAPAP, 1991a; Cowling, 1992, Russell, 1992).

3) It is desirable to include very highly skilled and experienced representatives from each of these actor groups in developing peer review panels, arranging oversight hearings, and establishing *Ad Hoc* evaluation committees. In NAPAP, scientists were selected disproportionately for service on such evaluation panels and committees. Policy analysts, representatives of states, other user groups, and experienced decision makers were conspicuous by their almost complete absence from such panels and committees. Partly as a result of this bias, NAPAP science was generally regarded as more satisfactory than NAPAP assessments.

4) The United States is just beginning to learn how to develop, maintain, and police the necessary "series of highly selective semi-permeable barriers that allow or block influence of different types from one set of players to another [see list of key actor groups in item 2 above]. For example, scientist doing and reporting their research must be isolated from influence over what they *find and report*, but be subject to direction over the questions that are of importance to the decision. Policy-makers must be protected from policy-analysts or scientists telling them what they should *decide*, but open to information about what the consequences of alternative decisions are likely to be" (For further information on this topic see Russell, 1992).

5) In a policy-focused scientific research and assessment process, success will be enhanced if the program will consider and apply the following 19 specific lessons and/or recommendations:

--Give assessment primacy.
--Understand the role of science and how to use it effectively to answer critical policy questions and associated scientific questions identified within an integrated assessment framework (Mahoney, 1990; NAPAP, 1989, 1991a).
--Develop and maintain liaison with relevant research and assessment groups in other countries, especially those in which scientific and policy understanding may be more advanced than in the United States, and also in those countries whose interests also may be affected by the policy decisions contemplated in this country.
--Provide adequate financial and human resources to get the research and assessment jobs done well and on time.
--Maintain continuous and open communication between the assessment preparing and user/decision maker communities in this country and abroad.
--Provide an appropriate fraction of the total funds for the program (10 to 20% has been suggested) to explore unexpected research leads, novel research approaches, and, especially, for individual-investigator-initiated fundamental research on promising new hypotheses.
--Configure organization and authority to match responsibility.
--Obtain and maintain political commitment.
--Develop effective methodologies for estimating benefits as well as costs.
--Report scientific uncertainties explicitly.

--Maintain scientific credibility through extensive and repeated interdisciplinary peer reviews with peer reviewers selected from user communities, both in this country and abroad.
--Provide for independent external scientific oversight.
--Take special care with the timeliness, quality, and completeness of communications.
--Refuse to publish in the name of the program, any assessment report that does not meet appropriately high scientific and technical standards.
--Identify authors of all assessment documents by name, institutional affiliation, and other potential sources of bias.
--Describe accurately the peer review and other quality assurance processes actually used in preparing all parts of all assessment documents.
--Beware of large data sets and large models. Also beware of advocates for use of such resources who, in the interest of protecting their favorite data set or model, inhibit their early use to give approximate findings that could guide further research and data gathering activities.
--In large-scale field programs of research and assessment, be sure that the time, financial, and human resources needed for advance planning, scientific quality assurance, data quality assurance, data archiving, and data analysis and interpretation are adequate.
--Take steps to ensure continuity. Especially, beware of the (conscious or unconscious) tendency to cut monitoring programs as soon as policy decisions have been made. Monitoring programs are essential to verify if expected benefits are achieved at something close to expected costs of implementation.

6) The electric utility and coal industries in the United States should learn several important lessons including the following (Perhac, 1991a, 1991b):
--"Most environmental issues end up as legislation or regulation. Therefore, the industry should prepare early to meet issues and to work with legislators (and their staffs) and environmental groups to arrive at a solution."
--"Industry should coordinate its efforts better and strive for a consensus approach to environmental issues."
--Industry must "overcome the common perception that it holds a rigid three-fold approach to environmental issues:
  a) The problem is not serious,
  b) If it is serious, industry isn't part of it, and
  c) If industry is part of it, nothing can be done about it."
--"Presenting scientific or technological uncertainty as a rationale for inaction simply won't stand up. The environmental community won't be swayed and Congress won't be impressed".
--"More emphasis should be placed on policy-related research". In this connection, integrated assessment and benefit/cost analyses are especially important".
--"Industry should put more effort into providing cost/benefit information, especially that related to technological options."

7) There appeared to be no significant correlation between the amount of financial and human resources devoted to an evaluation document, or the scientific prestige of a review panel or oversight committee, and its impact on either social learning or policy improvement. Among the 16 documents selected for analysis, the least costly were those prepared by Director Mahoney ($500-$2,000) in 1990, by four NADP scientists in 1978 ($10,000), and by the Ecological Society of America in 1992 ($50,000). The most costly evaluation documents were the Deutch Committee ($100,000-200,000) and Nierenberg Committee Reports ($150,000-200,000), the APCA Technical Amplification of the NAPAP Interim Assessment ($200,000-300,000), and the OTA Report ($400,000-500,000). In fact, if there is a correlation between the value and the cost of the documents, the correlation is probably inverse. The criteria for this evaluation of relative value are entirely subjective, however (Cowling, 1994)!

8) The nearly 10-year-long delay that took place in the United States about the timing of passage of the Clean Air Act Amendments of 1990 -- in 1990 instead of 1981, 1982, 1983, 1984, ... 1989 (as they were originally scheduled or attempted by other persons than the President) bears out Ralph Perhac's conclusion that the power of the President of the United States in dealing with contentious environmental issues is extraordinary (Perhac, 1991a, 1991b)!

3.4 Guidelines for Formulation of Research Program Findings To Be Used for Policy Purposes:

The NAPAP Oversight Review Board developed the following set of guidelines for formulation of statements of scientific findings to be used for policy purposes. These guidelines are reproduced here in the form of checklist questions to illustrate the care that needs to be taken by scientists and policy analysts in research and assessment programs at the interface between science and public policy (NAPAP, 1991a).

1) Is the statement sound? Have the central issues been clearly identified? Does each statement contain the distilled essence of present scientific and technical understanding of the phenomenon or process to which it applies? Is the statement consistent with all relevant evidence -- evidence developed either through this research program or through analysis of research conducted outside of this program? Is the statement contradicted by any important evidence developed through research inside or outside of the program? Have apparent contradictions or interpretations of available evidence been considered in formulating the statement of principal findings?

2) Is the statement directional and, where appropriate, quantitative? Does the statement correctly quantify both the direction and magnitude of trends and relationships in the phenomenon or process to which the statement is relevant? When possible, is a range of uncertainty given for each quantitative result? Have various sources of uncertainty been identified and quantified, for example, does the statement include or acknowledge errors in actual measurements, standard

errors of estimate, possible biases in the availability of data, extrapolation of results beyond the mathematical, geographical, or temporal relevancy of available information, etc.? In short, are there numbers in the statement? Are the numbers correct? Are the numbers relevant to the general meaning of the statement?

3) Is the degree of certainty or uncertainty of the statement indicated clearly? Have appropriate statistical tests been applied to the data used in drawing the conclusion set forth in the statement? If the statement is based on a mathematical or novel conceptual model, has the model or concept been validated? Does the statement describe the model or concept on which it is based and the degree of validity of that model or concept?

4) Is the statement correct without qualification? Are there limitations of time, space, or other special circumstances in which the statement is true? If the statement is true only in some circumstances, are these limitations described adequately and briefly?

5) Is the statement clear and unambiguous? Are the words and phrases used in the statement understandable by the decision makers of our society? Is the statement free of specialized jargon? Will too many people misunderstand its meaning?

6) Is the statement as concise as it can be made without risk of misunderstanding? Are there any excess words, phrases, or ideas in the statement which are not necessary to communicate the meaning of the statement? Are there so many caveats in the statement that the statement itself is trivial, confusing, or ambiguous?

7) Is the statement free of scientific or other biases or implications of societal value judgments? Is the statement free of influence by specific schools of scientific thought? Is the statement also free of words, phrases, or concepts which have political, economic, ideological, religious, moral, or other personal-, agency-, or organization-specific values, overtones, or implications? Does the choice of how the statement is expressed rather than its specific words suggest underlying biases or value judgments? Is the tone impartial and free of special pleading? If societal value judgments have been discussed, have these judgments been identified as such and described both clearly and objectively?

8) Have societal implications been described objectively? Consideration of alternative courses of action and their consequences inherently involves judgments of their feasibility and the importance of effects. For this reason, it is important to ask if a reasonable range of alternative policies or courses of action have been evaluated? Have societal implications of alternative courses of action been stated in the following general form?:

"If this [particular option] were adopted then that [particular outcome] would be expected."

9) Have the professional biases of authors and reviewers been described openly? Acknowledgment of potential sources of bias is important so that readers can judge for themselves the credibility of reports and assessments.

4. CONTRASTS BETWEEN EUROPEAN AND AMERICAN ATTITUDES ABOUT ACIDIFICATION AND LONG-RANGE TRANSPORT OF AIR POLLUTANTS

As discussed further by Nilsson and Cowling (1992), there are a number of important differences between European and American attitudes about research and management of acidification and long-range transport of air pollutants. Among the more intriguing of these differences are the following:

--Greater acceptance of the concepts of critical loads and target loads in Europe,
--Greater concern about visibility degradation in North America,
--Greater concern about pollution-induced changes in water quality and aquatic ecosystems in Canada and northern Europe than in the USA or central Europe,
--Greater trust of Europeans generally in their governments,
--Greater acceptance of the concept of tradeable pollution permits in the USA,
--Greater acceptance of the idea of carbon taxes in Europe, and
--Differences in the roles that scientists and policy analysts play in public decision making in large and small democratic nations.

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