Acid Rain: Science and Policy Making

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Citation: Winstanley, Derek, Robert T. Lackey, Walter L. Warnick, and John Malanchuk. 1998. Acid rain: science and policy making. *Environmental Science and Policy*. 1(1): 51-57.

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ELSEVIER

Environmental Science & Policy 1 (1998) 51–57

Environmental Science & Policy

Acid rain: science and policy making☆

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Abstract

Science plays an important role in the resolution of environment and energy issues. Based on more than 40 years of experience as agency representatives, analysts and science program managers during the 1980s and 1990s, the authors provide their perspectives on some aspects of the interplay between science and policy in the acid rain assessment process. The topics addressed include the setting of science-based policy questions, the establishment of 'semipermeable barriers' between science and policy, oversight and governance, baseline scenarios, assessments, funding, and scientific products and peer review. Lessons to be learned from NAPAP have relevance to conducting other major environmental assessments.

Keywords: Acid rain; Assessments; Environment; Science; Policy making; Management; Funding; Peer review

1. Introduction

The interplay between science and policy in addressing environment and energy issues is an important topic that has not been examined thoroughly. The scientific assessment of the acid rain policy 'problem' in the United States by the federal government serves an excellent example to illustrate the proper, and sometime improper, roles of science, assessment, and policy making. Our purpose is not to argue for any particular policy position, but rather to present our perspectives on the proper role of science, scientists, assessors, and policy makers. Other scientists and managers involved in acid rain and other assessments may have different perspectives on the interplay between science and policy.

In the 1970s, there was heated scientific and policy debate about the effects of sulfur deposition (popularly referred to as 'acid rain') on ecological resources in the United States. Politically, there were strong advocates for a wide diversity of policy positions. These positions ranged from not requiring more stringent and costly controls of sulfur dioxide emissions in the absence of compelling evidence of adverse effects, to requiring additional sulfur emission reductions costing billions of dollars in the presence of a weight of evidence of widespread adverse effects (for a summary of some of the early debates see Rubin, 1991; Rubin et al., 1991).

To provide a scientifically sound assessment of the acid rain 'problem', Congress passed and President Carter signed, the Acid Precipitation Act of 1980 (Public Law 96-294). The Act directed the United States Government to undertake a 10 year research and assessment program to determine the causes and consequences of acid precipitation and develop options for controlling and/or mitigating the problem.

The National Acid Precipitation Assessment Program (NAPAP) was the interagency organization created in response to the act. NAPAP involved 12 Federal agencies, hundreds of scientists within and outside of the federal government, and cost more than

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a half billion dollars over 10 years. Congress directed that NAPAP be policy-relevant; research or other scientific activities undertaken by NAPAP were to help answer public policy questions relating to the causes and effects of acid rain and the costs and benefits of mitigation and control options. The agencies responsible for NAPAP interpreted the law as a Congressional directive not to develop a *recommendation(s)* of a preferred policy option(s), but rather to produce a credible scientific and technical *evaluation* of the consequences of various policy options. It would be left to the public and their elected representatives to pass judgement on the appropriateness of specific actions to address the issue of acid rain. It was anticipated that, in part, such decisions would be based on the scientific and technical information provided by NAPAP. It was also recognized that, in addition to considering the scientific and technical information, decision makers would also take into account nonscientific and nontechnical information relating to equity, distribution, public opinion, and a range of human values. The extent to which scientific and technical information should weigh in the decision-making process was always a subject of lively debate in interagency meetings, especially at meetings where scientists and representatives from the policy offices were engaged.

NAPAP was not to be a fundamental research program as such, although it was anticipated that research would be required to help answer some of the policy-relevant questions. In hindsight, the assessment required by Congress would be much more difficult than most individuals realized at the start of the exercise.

NAPAP was originally designed for completion in a decade, but was reauthorized by the 1990 Clean Air Act Amendments (CAAA) under Public Law 101-549 to evaluate the efficacy and adequacy of the additional air pollution regulations authorized in the amendments. Title IV of the CAAA imposes a 10 million ton reduction in sulfur dioxide emissions measured against 1980 emissions. About 8.5 million tons of this reduction will come from electric utilities. The utility reduction will occur in two phases. In Phase I (January 1, 1995 through December 31, 1999) each of about 260 generating units at 110 plants will receive an annual allocation of sulfur dioxide allowances, with an allowance being the right to emit one ton of sulfur dioxide. A generating unit can take advantage of Title IV's allowance trading and banking system. In Phase II, effective January 1, 2000, the affected population consists of the Phase I units plus about 700 more plants (roughly 2000 more units). The utility industry will be allocated 8.95 million sulfur dioxide allowances in 2010 and will be capped at that level thereafter.

To make sure that the required emissions reductions are actually taking place, power plants will have continuous emissions monitoring systems. In 1995, the first year of phase I, total utility emissions of sulfur dioxide were reduced by about 19% from 1994 emission levels (USEPA, 1996).

Title IV also establishes that, "a coal-fired utility unit [that] must meet... sulfur dioxide reduction requirements... shall be subject to the emission limitations for nitrogen oxides...". The United States Environmental Protection Agency has established these 'emissions limitations' in two phases, through emissions rate standards for different types of boilers. Title IV reductions in the emission of nitrogen oxides will reduce utility industry emissions of nitrogen oxides by two million tons, with this reduction supplemented by ozone-related utility controls of nitrogen oxides. Unlike sulfur dioxide, the CAAA make no provisions for a cap on the emissions of nitrogen oxides.

Our insights, conclusions and recommendations presented in this paper are based on our 40 years of experience as agency representatives, analysts and science program managers with NAPAP during the 1980s and 1990s, and as managers of NAPAP itself. Our perspectives complement those of other authors (e.g. Roberts, 1991; Russell, 1992; Herrick and Jamieson, 1995).

2. Oversight and governance

An important aspect of NAPAP is the organizational structure. Congress mandated that the principals of 3 federal agencies serve as joint chairmen of a governing Task Force, with four Presidential appointees, the representatives of 9 federal agencies and the directors of 4 national laboratories of the US Department of Energy as additional members. Thus, NAPAP is governed to a large extent by political appointees, who may be expected to factor political interests into their decisions. Also, only federal employees served on the Interagency Science and Policy Committees and the technical working groups. NAPAP has reached out to include the research results from nonfederal organizations, but it is primarily a federal program.

Program review and oversight by an external panel of experts is a necessary ingredient of any successful research and assessment program. Such a panel, composed of technical and policy experts from government, academia and industry, should provide guidance on the scope, content, process and products of the program and should provide advice and recommendations to a governing board. NAPAP had the benefit of an external oversight review board only towards the end of the first ten years (Oversight Review Board, 1991). Some of the internal debates on the scope of the program might have been resolved more efficiently had NAPAP benefited from an external oversight review board at an early stage. The Oversight Review Board did add to the credibility of NAPAP's products, but was unable to overcome the political desire for NAPAP to delay its final assessment findings until after the 1990 Clean Air Act Amendments were passed. The delays in preparing and releasing the 1990 assessment findings have often been attributed to shortcomings in the NAPAP process. In reality, it was firm pressure from some participating agencies that prevented the release of the assessment findings until after the acid rain controls were enacted.

Today, NAPAP does not have an external oversight review board. The resources now allocated to NAPAP appear insufficient to allow a thorough and credible evaluation of the efficacy and adequacy of the CAA acid rain controls, as mandated by Congress in 1990.

Governance of major assessments should not be solely in the hands of political appointees. A national assessment is best governed by a consortium of stakeholders.

3. Assessment

Among other things, an assessment examines critically each link of the causal chain connecting human activity to health or environmental effects. An assessment thus identifies weak links which need to be addressed by research. Conducting an initial assessment is necessary to identify the critical research gaps and define the research agenda. Updating the assessment regularly provides current technical information to analysts and decision makers and a basis for refining research priorities (Bolin, 1994).

The scientific credibility of the assessment process will be questioned at every conceivable opportunity, so managers need to be prepared to defend the assessment. Structuring and conducting assessments requires strong leadership by scientists who have broad technical expertise and good communication and management skills. Assessment leaders must be able to maintain what Milton Russell, Chair of the NAPAP Oversight Review Board, described as a 'semipermeable barrier' between science and policy.

The process of addressing environmental issues brings with it a little-appreciated inherent bias. Many successful researchers, especially those operating in the American 'free market approach' to deciding what research to fund, are great opportunists when seeking funding: 'good news' or 'old news' seldom results in financial support for research, but identifying potentially large ecological or health impacts does. Researchers, especially soft money academic and government scientists, will tend to continue their priorities and frequently hang their research hat on whatever funding hook is there. Pressure will be exerted by scientists who exploit a crisis atmosphere to lobby for funding their area of research; such behavior in the research enterprise should not be underestimated. Elected officials and political appointees are also particularly susceptible to responding to the crisis of the moment. A strong management structure and budget stability can help avoid constantly lurching from one crisis of the month to the next. One method of tempering the impacts of alarmism on the scientific agenda is to have an effective governing board comprised of a consortium of stakeholders.

Differences in missions and organizational structure within and among agencies can impede the assessment process. Research organizations can be expected to protect their long-term interests and resist what they may view as a diversion of resources from 'true science' to the 'assessment' process. Policy offices, on the other hand, can be expected to protect their policy interests, rather than support open-ended research and assessments whose outcomes may run counter to preconceived policy positions. A commitment to an open and comprehensive assessment process by agency heads is necessary, if agency cooperation is to be sustained and the results of scientific investigation are to be useful. Essential elements of an open assessment process include the involvement of nonfederal policy makers and resource managers in setting the policy questions and identifying policy options to be evaluated, the involvement of a diversity of nonfederal scientists in conducting the research and assessment activities, and external peer review.

4. Policy questions and the roles of key players

Many of the disagreements among scientists, science managers, and policy analysts in NAPAP and the acid rain community were fundamentally over different opinions of what the key policy questions were (or should be). The purpose of a research and assessment program such as NAPAP is to provide technical data and information that is needed by policy analysts and decision makers, including the public. Therefore, it is important at the outset to specify the data and information needs of policy analysts and decision makers as the basis for setting research priorities, structuring assessments and establishing reporting formats.

Research and assessments are shaped by the definition of the issue and, hence, it is important to obtain consensus on the scope and bounds of the issue and the policy questions at the start of a research and assessment program. In scoping and bounding the problem and identifying specific policy questions, it is important and necessary for technical experts, policy analysts and decision makers to engage in dialogue. Such dialogue should ensure that policy-relevant questions are set that can be answered objectively by technical experts. Having defined the policy questions at the outset, any changes must be communicated to everyone in the program.

When issues are scientifically complex and politically sensitive, it is perhaps inevitable that it will be difficult and controversial to delineate at the start of the program a precise scope of study (Allen and Gould, 1986). Particularly with a 10 year program, it can be expected that the scientific understanding will evolve and policy interests will change. In order to deal effectively with evolving science and information needs and to ensure a focused program, program managers need both flexibility and a strong management structure.

Great care should be exercised in specifying the policy questions to be addressed by technical experts. Policy questions are often posed in highly value-laden terminology, which may be unnecessarily divisive and unsuitable for scientists to answer objectively. Words like degradation, adverse, impact dangerously, critical loads, targets, acceptable and safe often appear in policy-relevant questions, but these are value-laden and require nontechnical input to answer. Questions that merely ask about a direction of change may also be value-loaded, since they can overlook questions about the magnitude and significance of any change. To the extent possible, policy-relevant questions should be posed so as to evoke quantitative answers and not be value-laden.

In NAPAP, there was, not unexpectedly, often a lack of agreement among representatives of different agencies, even among the representatives of the science and policy offices within the same agency, as to the scope of the assessment. One constant uncertainty dealt with was whether the policy questions should be limited to sulfur alone (e.g. the policy question of whether there ought to be additional controls on sulfur emissions), or whether scientists and policy analysts should look in depth at a broader suite of air pollutants (particularly nitrogen). In the 1970s and early 1980s, the acid rain debate focused on the effects of sulfur deposition on aquatic and terrestrial systems. Nitrogen deposition was generally considered not to be a major problem, largely because nitrogen is a nutrient and is often in short supply in the environment. With the electric utilities contributing about two thirds of the sulfur dioxide emissions, they presented a clear focus for emissions reductions, compared to the much more diffuse sources of nitrogen oxide emissions.

Sulfate aerosols are also a major cause of visibility impairment, especially in the east, and controlling sulfur dioxide emissions to address the acid rain issue would also result in improved visibility. It was also well recognized by scientists that sulfate aerosols are a major cause of a reduction in radiative forcing, which tends to cool the climate. The policy offices, however, were quite reluctant to emphasize the cooling effect of sulfur dioxide emissions, when an emerging policy topic was global warming. Today, there is renewed emphasis on sulfur dioxide emissions as they contribute to the formation of fine particulate matter and are implicated in human health effects. The important role of sulfate aerosols in radiative forcing and climate change is well recognized by international scientists (Houghton et al., 1995), but is not addressed domestically or internationally by policymakers; the United Nations' Framework Convention on Climate Change addresses only greenhouse gases.

One effect of compartmentalizing in the policy arena the effects of pollutants is that laws and regulations are compartmentalized; the emissions of sulfur dioxide, for example, have been reduced over the last few decades by largely separate foci on human health, acid deposition, and visibility impairment — with still no focus on sulfur dioxide as it effects the climate system. Technically, it would make sense to have a sulfur dioxide control program that recognizes all the multiple effects of the emissions and, hence, the multiple benefits of emissions controls. It remains a challenge to decision makers to draw on the scientific understanding and address related issues in a more integrated manner.

A second example involved protracted debate over the appropriateness and necessity of NAPAP engaging in social and economic analysis, as well as physical, biological and chemical research. Our experience indicates that the political process considers questions of equity and distribution to be crucial (i.e. who is causing the problem, if there is one, and who will pay for its solution). Congress actually required NAPAP to conduct economic analysis, but it was only late in the 1980s that NAPAP began to embrace this topic. However, benefit–cost analysis was and remains controversial, as well as threatening to some policy interests and, hence, benefit–cost analysis has been afforded low priority by NAPAP. The main policy debate was, and remains, the extent to which the benefits of emissions controls can be demonstrated to equal or exceed the costs of emissions control. At the heart of this issue are two factors: (i) benefit–cost analysis conducted prior to having a sound scientific understanding of impacts is likely to be misleading, the total economic benefits of acid rain control can be quantified in a meaningful manner only when the total damage caused by acid rain is known and (ii) the extent to which nonmonetary values can be quantified and incorporated in benefit–cost analysis is controversial.

Given that the political process places high priority on questions of equity and distribution, and that most scientists tend not to view technical problems in this way, the onus rests on program managers to ensure that the data and information needed to answer these important policy-relevant questions are provided. For example, the fact that there might be effects of acid rain on materials in the northeast is relevant, but the divisive question is *who* is causing the problem and *who* should pay for the solution. Science can potentially answer the cause and effect part of the question, but not the part of who should pay.

Another issue is the fact that policy makers often want answers to questions which are inappropriate for scientists to provide. For example, science cannot and should not answer policy questions such as, "Is an x ton reduction in sulfur emissions sufficient to prevent adverse effects?" Scientists can predict, at least within some error band, the likely *consequences* of such an emissions reduction, but should not proffer normative solutions, as they typically require nontechnical as well as technical valuations. It is the decision makers who should determine what is sufficient and what is adverse. It is deceptively tempting for scientists to cross the line between reporting what 'is' and recommending what 'ought' to be done, especially when interpreting science for nontechnical persons. When scientists interject their personal values, they necessarily compromise scientific objectivity. While scientists are also members of a democratic society and have every right to recommend political actions, it is inevitable that the audience will not be able to separate their technical and nontechnical conclusions. The challenge is to stimulate open scientific investigation and reporting and to separate these from advocacy. We recognize that this is not an easy task and we do not see much evidence that it has been accomplished.

Policy analysts tend to use whatever scientific models and other tools that are available without fully understanding the scientific uncertainties embodied. Therefore, it is important for scientists to state clearly the strengths and limitations of the models, including identification of the assumptions built into their models, to encourage sensitivity analyses using different assumptions, and to provide uncertainty bands on the results of model runs. These requirements could be enforced through the peer-review process. Ultimately, the only effective way to discourage the use of a flawed model is to replace it with a better model.

Scientists, policy analysts and decision makers need to work interactively, but each has a very clear and separate role. Policy analysts and decision makers should play central roles in scoping and bounding the problem and identifying policy options to be evaluated. Once scientists, policy analysts and decision makers have engaged in this dialogue, policy analysts and decision makers should not participate in conducting the assessment.

Assessment specialists should report technical (scientific, technological and socio-economic) information from all sources to policy analysts for their use. Policy analysts and resource managers will then combine technical with nontechnical information in identifying and analyzing a range of policy options. The nontechnical information may include, for example, consideration of political and social factors and equity. To the extent possible, policy-relevant questions should be posed so as to evoke quantitative answers and not be value-loaded. Questions that seek both direction and magnitude of change, are less value-laden and more appropriate for scientific analysis.

5. The baseline scenario

Assessments of environmental issues typically necessitate some degree of 'crystal ball gazing', for a number of reasons. Policy analysts and decision makers need to know, for example, the likely impacts of continuing emissions on human health and the environment in the absence of further regulation and control. The establishment of such a baseline scenario is dependent upon the setting of assumptions about demographic and economic growth, compliance with existing laws and regulations, and the likely adoption of new technologies.

Such a scenario(s) provides policy analysts and decision makers a view(s) of the future in the absence of new laws and regulations and, hence, provides a basis for evaluating the need for new laws, regulations and incentives. A baseline scenario also provides a foundation against which to evaluate the costs and benefits of alternative control and mitigation strategies. Baseline scenarios should also include changes in social and economic conditions and technology substitutions, which might influence the future levels and effects of pollution and the need for new laws and regulations. For example, continued economic growth of $x\%$ per year may result in a few decades not only in more pollution, but also in a generally more wealthy society, more able to substitute new, energy-efficient and environmentally-friendly technologies. These substitutions should also be captured in the baseline scenario(s) policies.

A major omission in the assessments and policy analyses performed by NAPAP and others was consideration of the consequences of railroad deregulation on acid rain control. Deregulation of the transport industry in the early 1980s eventually provided economic incentives for the shipment of low-sulfur, low-cost coal from the west to major markets in the east. The use of this low sulfur coal has been a major and largely unexpected method of reducing acid rain in the east. Although the use of these coal reserves has probably been stimulated by the passage of the 1990 acid rain control laws, it is possible that their use in the east would have been expanded greatly on purely economic grounds, even in the absence of acid rain control legislation. It is not apparent that anybody foresaw the consequences of railroad deregulation in the resolution of the acid rain issue, but the message here is to ensure that macro-policy changes are factored into the construction of baselines. These type of macro-changes can best be foreseen and analyzed by having far-sighted macro-economists engaged in the assessment team.

The construction of a comprehensive baseline scenario(s) provides a foundation for a meaningful environmental assessment to be conducted and cost-effective policy options to be identified.

6. Communications

Clients fund research and assessment activities because the output and outcomes are, or could be, important to them. It is essential, therefore, for scientists to provide regular, scheduled updates on the policy-relevant results of evolving research and assessment activities to government, academia, industry, and the public. Key scientists should be involved in these briefings and should be prepared to handle the inevitable pressure to speculate on the significance of interim results. Interim briefings are a critical element of the assessment process and they will require more careful attention than most scientists want to devote.

Scientists and assessment managers should look for appropriate conclusions as quickly as possible, but always bound them with confidence estimates. Not every piece of scientific information is of equal value in policy analysis: an 'educated guess' might be acceptable in answering some questions; 'near certainty' is required for others. For critical elements of policy analysis, a statistical confidence interval might be necessary.

The mechanism by which decisions are made in a democracy is not via wise scientists advising independent leaders. Rather, decisions are more the product of public opinion than scientific opinion, as the decision makers are representatives of that broader public. The findings of a program like NAPAP will have minimal impact on policy formulation unless there is purposeful communication with the public, so that there is an opportunity for public opinion to evolve as scientific opinion advances. That NAPAP largely eschewed communication with the public prevented it from having more of an impact on public policy.

Effective public communication in a meaningful, accurate, unbiased, timely and yet understandable manner requires very special attention. It requires dedicated resources and trained and experienced personnel.

7. Research and funding

In addition to the influence of public opinion, major decisions in a democratic society are also shaped by interest groups. It is prudent, therefore, for research and assessment managers to beware of political efforts to use the scientific enterprise to focus on questions and answers that tend to support a particular policy position. This is not usually a covert endeavor, but rather a reflection of the missions and goals of organizations that fund research and assessments. The result is that research direction can be fundamentally determined by the sources of available funding. NAPAP, by simultaneously fostering the participation of multiple agencies, each with its own mission, while forcing those agencies to deal with one another, had an effect of tempering the influence of any single agency. It would have been even more desirable for NAPAP to have engaged states, industry and other groups more actively in the assessment process.

8. Scientific achievements and peer review

Fostering scientific debate and peer review are essential ingredients in setting research priorities and advancing science. NAPAP provided a platform for vigorous, healthy debates among agencies having diverse missions and perspectives. Like most other scientific endeavors, the results of NAPAP research were published in the peer-reviewed literature. NAPAP also benefitted from periodic external review of major program elements to evaluate the relevance and quality of the research. The research activities conducted and supported by state governments, industry and scientists in other countries contributed substantially to the research and assessment activities funded by NAPAP. A thorough scientific evaluation of NAPAP's findings are presented in Lefohn and Krupa (1991).

And science most certainly did advance. A dozen assertions, commonly presented as reality in the 1970s or early 1980s, have been proved to be wrong in light of the understanding that was gained by NAPAP. For example, significant improvements in modeling aquatic ecosystems were affected by new information on key variables in different ways; the cumulative result has been that the revised, more complete NAPAP aquatic effects model, MAGIC, now predicts smaller acidification responses in high-deposition regions such as the Adirondacks (Sullivan and Cosby, 1995). Sulfate in Adirondack lakes and streams now appears much less an acidifying agent often than previously believed. As a corollary, the reduction in acid deposition resulting from the implementation of the acid rain control program is not expected to measurably reduce the number of acid lakes and streams in the Adirondacks. This extends the NAPAP finding that "it now appears that even in the most sensitive watersheds, 60%–90% of acid impacts are neutralized, and in lakes with preindustrial pH values greater than 6.0, this can approach or exceed 100%" (NAPAP, 1991).

9. Conclusion

The science–policy interplay is complex and involves two way interactions. In an ideal world, many scientists would perhaps like to believe that sound, objective science provides the foundation for decision making. In reality, policy and politics influence science and science is only one ingredient in decision making. What should be of greatest interest to scientists is to ensure that the integrity of the scientific process is upheld in the assessment process. The scientific process includes the freedom and resources to test multiple hypotheses and to present alternative interpretations of data, freedom to conduct benefit–cost and other economic analyses, and freedom to report in a timely manner. Mechanisms necessary for ensuring scientific integrity include a governing board comprised of a consortium of stakeholders, external advice and peer review, strong program management, program flexibility, and the establishment of a 'semipermeable barrier' between science and policy.

A real and long lasting benefit of the program might be in transferring lessons learned in the assessment process and in environmental research management to a relatively large group of scientists, program managers and the public. We believe that the lessons to be learned from NAPAP have relevance in conducting other major environmental assessments relating to, for example, global change and the national assessment of Gulf of Mexico hypoxia.

It is hoped that this paper might encourage discussion and debate by others on the interplay between science and policy.

Acknowledgements

We are grateful for the constructive comments and suggestions received from external peer reviewers.

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