MASTER

TEMPORAL PERSPECTIVE ON ACID DEPOSITION RESEARCH

by

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presented to

Subcommittee on Natural Resources
Committee on Science and Technology
U.S. House of Representatives

February 20, 1980

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The phenomenon of acidic precipitation is widely recognized as a major environmental problem in northern Europe and North America. This committee has previously obtained information on the sources of acidic precipitation, its chemical nature and geographic distribution, so it is not necessary to review these topics in toto. I will, however, give my definition of "acid rain," present some new data on the regional and temporal nature of the problem, and then discuss research needs.

There is some confusion as to what is meant by the popular generic term "acid rain." "Acid rain" includes rain, fog, dew and snow with strong acid concentrations in excess of 2.5 micro equivalents per liter ($\mu\text{eq}/\ell$), which is a pH of 5.6. "Acid

rain" also includes the deposition of particulate matter, such as ammonium sulfate aerosols, and other aerosols which may contain toxic metals or organic substances, and the deposition of SO_2 and NO_2 gases. "Acid rain" is differentiated from other forms of air pollution, primarily by distance from identifiable sources and by having sulfuric and nitric acids as the principal contaminants impacting regions remote from emission sources. Rain and snow in the United States east of the Mississippi River have average acid concentrations of from 10 to 80 $\mu\text{eq}/\ell$ (pH 5.0 to 4.1) (Likens et al. 1979).

New findings on regional acidification

Acidification of lakes is reported in the Adirondack Mountains (Schofield 1976), Maine (Davis et al. 1978), Florida (Brezonik, pers. comm.), and Washington State (Gillion and Horner 1977). Recent observations (Hendrey et al. 1980) demonstrate that streams in the Blue Ridge Mountains of North Carolina have become acidified as well. Data on stream alkalinity and pH, collected in the period 1960-1964 are compared to data collected in 1979 in Figures 1 and 2. If no change in pH were observed, the values would fall on the solid diagonal line in Figure 2. An obvious pH decrease was observed.

Methods used for measuring alkalinity in the earlier data result in an overestimation of about 40 $\mu\text{eq}/\ell$. The dashed line in Figure 1 is the line of equal value for alkalinity with the older data reduced by 40 $\mu\text{eq}/\ell$. Eighty percent of the streams

have been acidified (lost alkalinity). We observed similar acidification of waters in New Hampshire and we suspect that an examination of existing data would reveal a pattern of acidification in many other areas of the eastern United States.

The impact of acidic precipitation on the productivity of forests, if there is any impact, is either so slight that it cannot be measured by existing techniques, or has a long period of latent injury before measurable impacts are detected. One latent impact is decreased nutrient availability due to accelerated leaching by acid inputs to the soil system. One set of evidence that long-term nutrient depletion is occurring in acid impacted areas has been obtained in Nova Scotia. Between 1954-1955 and 1969-1977, the observed pH values and calcium concentrations of eleven rivers dropped considerably (Figure 3). Watershed acidification causes an acceleration in mineral weathering rates and the concentrations of calcium, magnesium and aluminum in stream waters are observed to increase (Gjessing et al. 1976). The implication of the reduced calcium concentrations observed in the Nova Scotia rivers, while acidity increases, is that the watersheds have already lost their most available calcium and that permanent depletion of plant nutrients is occurring.

Studies like these demonstrate the insidious long-term effects of chronic acid deposition. Other changes may be occurring which are as yet completely unnoticed and which may have deleterious impacts on ecosystems and other aspects of "welfare."

Research Needs

The overriding objective of acid deposition research is to obtain information for regulatory purposes. Currently, regulatory decisions concerning emissions of atmospheric pollutants to control "acid rain" must be made without the benefit of knowledge as to whether or not crops and forests are seriously impacted by "acid rain"; whether or not experimental evidence of injury can be used to calculate actual agronomic and forestry losses; whether or not reductions of emissions from several regional sources will produce a desired level of abatement of acid conditions in the surface waters of a receptor region; or even whether or not the effects of soil acidification are reversible within the span of a human generation or on a scale of geologic time.

Several reports have been presented in the past two years which make recommendations concerning specific research needs. These reports are described in Table 1* and the reports have been submitted separately to this committee. Rather than provide a new listing of specific recommendations, I will discuss management considerations for the six general types of research on acid deposition and its environmental impacts listed in Table 2.

*A new listing of research priority will also appear next month in a report by the Interagency Acid Rain Coordinating Committee (co-chaired by EPA and DOA) under the title Federal Acid Rain Assessment Plan.

These six study areas will require different research management approaches. The long-term monitoring of precipitation chemistry will require an initial intensive effort for several years to establish and calibrate the monitoring and analytical system, and to analyze the initial rush of data. The National Atmospheric Deposition Program, now underway, is establishing such a system. It will eventually require an open-ended commitment to a stable monitoring program, much as weather data are collected. The key management words are long-term stability (more than ten years).

Defining areas of impact is currently underway, based on the available deposition chemistry data (e.g. Likens et al. 1979). Several studies have identified sensitive areas and areas at risk (sensitive and exposed to acidic deposition) with various scales of resolution, from continental (Galloway and Cowling 1978; Likens et al. 1979) to the county level (Hendrey et al. 1980). This type of work is of a short-term nature, with projects lasting a few months to a year or two. Economic assessments are based primarily on existing data, so they can be performed rather quickly. For management purposes these are seen as short-term or quick response studies (less than two years). Long-term stability is not required.

Dose-response studies may at first also appear amenable to quick response, short-term management, and in some cases this may be possible (e.g. acute LD₅₀ studies on aquatic organisms). But

many plants which are suspected of being sensitive, and aquatic animals which are sensitive to acid-stress may have life cycles lasting several years. Chronic exposures to low pollutant levels may not produce immediate mortalities. Stress induced by acid or other toxic substances may impact at an unknown point in the life cycle or even by failure to produce a following generation (e.g. Beamish 1974). Systematic dose-response studies, such as a plan for experiments dealing with crops, following standard agronomic practices and producing statistically valid results, require a perspective of several years. The management strategy required is intermediate-term stability (2 to 5 years).

Systems studies are those dealing with assemblages of components. For example, plant physiology, aquatic ecosystems, soil microbial ecosystems, or forest ecosystems, all contain numerous components. The acid deposited into a watershed reacts with many components of the terrestrial ecosystem and then with those of the aquatic ecosystem. We do not yet understand the relationship between acid loading and chemical response, let alone biotic response. These studies cannot be accomplished in a short-term management atmosphere. An intermediate-term perspective is sufficient in some cases. However, long-term (5-10 years) studies of lakes in calibrated watersheds are given high priority for research. These may be initiated and produce useful information with an intermediate-term perspective, but their real value will appear after many years of study (e.g. as in the Hubbard Brook Experimental Forest, Bormann

and Likens 1979). If a regulatory goal is to obtain a balance between the losses due to watershed acidification and the costs associated with reduced emissions of acid-forming materials, then one must have an understanding of the interaction between the pollutants and the receptor ecosystems; knowledge of the response and consequent interaction among ecosystem components is essential.

Both Ecologists and managers of large corporations have noted that there is strength in diversity. If there is to be a multimillion dollar program of research on acid deposition, then diversify its management. Match the management needs of the various types of research with management agencies best suited for each task. Concentrating all of the research effort under a single agency or directorate may stifle a desirable diversity in management approaches, hence in research effort. Provide for the long-term stability required for ecosystem research as well as for the quick-response appropriate to state-of-knowledge questions.

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Table 1. Four recent reports providing recommendations for research on "Acid Rain."

Ecological Effects of Acid Precipitation.

Report of a workshop held at Galloway, U.K., 4-7 September 1978. EPRI SOA77-403. M. J. Wood, ed. Prepared by Central Electricity Research Laboratories (Kelvin Avenue, Leatherhead, Surrey, KT22 7SE, U.K.) for Electric Power Research Institute (3412 Hillview Ave., Palo Alto, CA 94303).

Comment: Workshop of 45 scientists organized to review existing knowledge and identify major areas of uncertainty.

Principal topics: rain, snow and dry deposition; interactions between deposition, vegetation and soils; soil chemistry; effects on surface waters and aquatic ecology; effects of acid waters on fish; land-water interactions; modeling and synthesis.

Limnological Aspects of Acid Precipitation.

Report of the international workshop at Sagamore Lake, New York, September 25-28, 1978. BNL 51074. G. R. Hendrey, ed. Sponsored by Corvallis Environmental Research Laboratory, US-EPA, and Brookhaven National Laboratory, US-DOE.

Comment: Workshop of 20 scientists expert in the topic area. The goals were to take stock of limnological projects in progress, to identify and prioritize research topics needing further investigation, and to discuss chemical and biological methods and methodological problems.

Principal topics: pH and acidity measurement; regional lake surveys; aluminum chemistry in dilute waters; chemical budgets, and watershed acidification; benthic organisms; biological processes, toxicity of metals; liming.

A National Plan for Assessing the Problem of Atmospheric Deposition (Acid Rain).

A report to the Council on Environmental Quality. National Atmospheric Deposition Program NC-141. J. N. Galloway, E. B. Cowling, E. Gorham, and W. W. McFee.

Comment: Report prepared at the request of CEQ, has two objectives, (1) to assess the scope of available knowledge about atmospheric deposition and its effects on agricultural lands, forests, ranges, parks surface waters and aquatic life in the U.S. and (2) to recommend a coordinated program of research and monitoring necessary to serve as a basis for management of atmospheric emissions and amelioration of adverse effects on plant and animal life.

Principal topics: Atmospheric deposition; aquatic and wetland ecosystems; terrestrial vegetation; soils; outputs from terrestrial and aquatic ecosystems.

Effects of Acid Precipitation on Vegetation, Soils and Terrestrial Ecosystems.

Report from the International Workshop at Brookhaven National Laboratory June 12-14, 1979. BNL (in press). L. S. Evans and G. R. Hendrey, eds. sponsored by Corvallis Environmental Research Laboratory, US-EPA, and Brookhaven National Laboratory, US-DOE.

Comment: Workshop of 27 scientists expert in the topic area. The objectives were to determine (1) current knowledge of the effects of acid precipitation on vegetation, soils and terrestrial ecosystems, (2) research needed to understand environmental impacts, and (3) to help coordinate research groups to avoid excessive duplication of effort.

Principal topics: Mechanisms of foliar injury; characterization of foliar injury; metabolic effects of acid rain on foliage; chemical effects on soils; biological effects on soils; impacts on crops; impacts on forest ecosystems; state of knowledge and research priorities.

Table 2. Research topics recognized as essential to providing information needed for the intelligent regulation of "acid rain" problems.

1. Long-term monitoring of precipitation chemistry
 - temporal changes
 - geographic changes
2. Defining areas of impact
 - deposition monitoring
 - identification of sensitive areas
 - identification of areas at risk
3. Broadening of impact data bases
 - collation of existing data on water and soil chemistry
 - temporal trend analysis
4. Dose-response functions
 - soils
 - aquatic organisms
 - crop plants
 - forest plants
5. System studies
 - plant physiology
 - aquatic ecosystems
 - soil chemical systems
 - soil microbial systems
 - forest ecosystems
6. Economic assessments
 - crops, forests, fisheries
 - recreation, aesthetics
 - structural corrosion
 - waste management alternatives for SOX, ROX and NOX

ALKALINITY vs. ALKALINITY FOR NORTH CAROLINA STREAMS

Figure 1. Comparison of alkalinity data collected in the period 1960-1964 to data collected in 1979. The solid diagonal line represents equal values. The dashed line represents equal values when the old data is corrected by subtracting 40 $\mu\text{eq./l}$ (from Hendrey et al., 1980).

pH vs. pH FOR NORTH CAROLINA STREAMS

Figure 2. Comparison of pH data collected in the period 1960-1964 to data collected in 1979. The diagonal line represents equal values (from Hendrey et al. 1980).

Figure 3. Changes in the pH and calcium concentration observed in several Nova Scotia rivers between 1954 and 1977. (Data for 1954-55 from Thomas, J. F. J. 1960: The Atlantic Provinces and the St. John River drainage basins in Canada, 1954-56. Water Survey Report No. 11, Industrial Water Resources of Canada, Dept. of Mines and Technical Surveys, Ottawa and 1969-77 data from National Water Quality Data Bank, Department of Environment, Water Quality Branch, Ottawa. The figure was produced by Dr. M. E. Thompson, Canada Centre for Inland Waters.)