acid deposition

Statement of the American Meteorological Society
As adopted by the Council from June 1, 1989 Mail Ballot

Acid deposition (familiarly "acid rain") is an important issue of public policy in which atmospheric processes play a key role. This statement from the American Meteorological Society addresses the present state of knowledge and uncertainty about atmospheric aspects of the acid deposition phenomenon in the context of prospective legislation and regulatory action to decrease acid deposition.

Definition: Acid deposition consists of delivery of acidic substances, mainly sulfur and nitrogen oxides, acids and salts, through the atmosphere to the earth's surface. These compounds (principally the oxides) are introduced into the atmosphere as by-products of combustion and industrial activity, at rates which greatly exceed natural emission rates in industrialized areas such as eastern North America. Acid deposition also includes contributions from natural sources and deposition of other acidic compounds, but these contributions are relatively minor. Deposition processes include delivery of material to the Earth's surface by precipitation processes ("wet deposition") and by direct uptake processes at the Earth's surface involving turbulent mixing or settling of gases and particles followed by absorption, adsorption, adhesion, or impaction ("dry deposition"). The direct impact of acidic cloud or fog droplets on vegetation or other surfaces also contributes to acid deposition.

Causes for Concern: Acid deposition is widely held to be responsible for substantial deleterious effects on aquatic ecosystems and, perhaps in conjunction with other factors such as surface level ozone, on forests. Acid deposition along with other pollutants may also influence yields of certain cultivated crops and contribute to deterioration of structural and ornamental materials. Human health in some instances may be affected. In view of its possible economic, ecological, and aesthetic consequences, acid deposition is a phenomenon of widespread concern. This concern is reflected in pending legislation and regulation to reduce acid deposition by controlling emissions of sulfur and/or nitrogen oxides.

Acid Deposition Monitoring: Extensive information is available from networks that have monitored wet acid deposition for several years, in some cases up to a decade or more. In eastern North America, wet acid deposition is 3 to 10 times greater than values measured in remote locations.

On the other hand, dry deposition of gases or particles to surfaces such as vegetation or soil cannot be directly monitored by existing techniques, and must be inferred from concentrations of the airborne species together with measurements of pertinent meteorological variables and knowledge of surface properties. Because of the difficulties of these air–surface exchange measurements, they have been made only recently at a few stations, the size of the data base is not comparable to that for wet deposition. However, it can be stated that annual dry deposition of SO_2 and NO_2 is substantial and tends to increase in importance relative to wet deposition near source regions.

Meteorological Issues: The atmosphere is both the pathway by which acid deposition materials travel from sources to places where they are deposited, and the medium in which combustion products are transformed into acidic compounds. Meteorological concerns include:

a) processes of transport and diffusion of surface-derived materials of all kinds,

b) chemical reactions among airborne substances, and

c) processes whereby materials are transferred from the atmosphere to surface elements, including vegetation, soils, water bodies, and structures.

A goal of meteorological research is to provide knowledge which can be used to help shape emission control scenarios that will maximize reduction in acid deposition at a minimum cost to society.

The acid deposition issue is one of several interconnected impacts of man's activities upon the atmospheric/oceanic/biospheric environment. Research directed at acid deposition mechanisms and related control strategies should, when possible, also consider interactions with such other issues as control of tropospheric ozone, reduction of greenhouse gas emissions and mitigation of climatic change stresses.

Acid Deposition Modeling: In order to organize knowledge in a more logical way, scientists have constructed atmospheric transport models which can be applied to the development of strategies to reduce acid deposition in a particular geographical region through a two-step process:

1. Describe how acid deposition at a given location is derived from contributions of nearby and distant emission sources; i.e., the source-receptor relationship.

2. Use this information to predict deposition at this location when emission strengths are changed.

However, the source–receptor relations are difficult to establish because acid deposition at any given location is the summation of pollution from numerous upwind sources. Mixing within the atmosphere makes it difficult to distinguish the relative impact of local versus distant sources.

Developing improved understanding of source–receptor relationships requires research into the pertinent meteorological, physical and chemical processes. This research includes laboratory studies of chemical and physical processes, field studies examining transport and transformation of acidic and related substances, and studies of long-range transport using tracer compounds. Then regional-scale numerical models (extending over 1,000 kilometers or more) can be constructed to describe the overall transport and deposition. A variety of regional scale models have been developed in recent years, and are currently undergoing

field evaluation. These models offer the promise of improved understanding of regional scale source-receptor relationships in the near future.

Although current information on source–receptor relations for acid deposition is uncertain, much pertinent descriptive and qualitative information is known. The currently available information is adequate for interpretive evaluation of the changes in deposition patterns expected to result from regional changes in the patterns of the primary emissions. Principles of atmospheric transport and diffusion are well established. Knowledge of atmospheric chemistry is expanding very rapidly; however, it is possible that some reactions important in acid deposition are yet to be identified. Sulfur and nitrogen compounds of concern are inevitably removed from the atmosphere by deposition to the earth's surface. Consequently, reductions in primary emissions will generally result in similar reductions in acid deposition taken as a whole over all receptor locations. However, this is complicated by seasonal and shorter term differences in the transport ability of the atmosphere; the scales of transport range from hundreds to thousands of kilometers. Studies involving elemental tracers characteristic of particular regions or of unique events have established this transport on the thousand kilometer scale. Consideration of material budgets is also useful in understanding the gross picture. Comparison of annual wet deposition of sulfur and nitrogen in eastern North America with emissions indicate that about one-third of the emitted material is deposited in precipitation. Comparable amounts are thought to be dry deposited; and the remaining third is thought to be deposited in the western Atlantic Ocean. This information can assist in formulation of policy and development of strategies for control of acid deposition. In particular, the large distance scales require that any approach to the control of acid deposition be regional in scope and not merely local.

Conclusions and Recommendations: Qualitatively, the processes of atmospheric transport, transformation, and deposition are well understood. In view of the difficulties in constructing, executing, and evaluating numerical models that emulate these processes in a quantitative manner, it is likely that considerable uncertainties in source-receptor relations for acid deposition will remain for some time. However, currently available analysis methods are adequate for interpretive evaluation of the broad changes in deposition expected to result from regional changes in emission patterns.

The AMS recommends that atmospheric research and monitoring activities be intensified during those periods when emission changes are expected (as may result from legislative requirements, for example) to allow improvement of regional scale analysis methods and models needed to evaluate future regional scale control issues, and to improve descriptions of source-receptor relations.

Summary: Acid deposition is attributable primarily to emissions of sulfur and nitrogen oxides produced during combustion processes. This deposition extends hundreds to thousands of kilometers from emission sources. It is thus very difficult to identify and quantify the specific source of acid deposition at a given receptor. Gaining a better knowledge of source-receptor relations for acid deposition is the objective of much ongoing research and monitoring. Although policy decisions regarding acid deposition will for some time to come be made on the basis of incomplete knowledge of source-receptor relations, such decisions can be made based on our present understanding. Irrespective of near-term policy decisions, it is essential that research and monitoring continue at a high level. The American Meteorological Society emphasizes the seriousness with which it views both the importance and the scientific uncertainties associated with this environmental issue. ●