ACID PRECIPITATION—

AN ANNOTATED BIBLIOGRAPHY

U.S. Geological Survey Circular 923

ACID PRECIPITATION—
AN ANNOTATED BIBLIOGRAPHY

Compiled by Denise A. Wiltshire and Margaret L. Evans

GEOLOGICAL SURVEY CIRCULAR 923

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

1984

Department of the Interior
WILLIAM P. CLARK, *Secretary*

March 3, 1849

U.S. Geological Survey
Dallas L. Peck, *Director*

Library of Congress Catalog-card No. 84-601039

Free on application to Distribution Branch, Text Products Section,
U. S. Geological Survey, 604 South Pickett Street, Alexandria, VA 22304

CONTENTS

TABLE

Acid Precipitation--An Annotated Bibliography

By

Denise A. Wiltshire and Margaret L. Evans

ABSTRACT

This collection of 1660 bibliographic references on the causes and environmental effects of acidic atmospheric deposition was compiled from computerized literature searches of earth-science and chemistry data bases. Categories of information are (1) atmospheric chemistry (gases and aerosols), (2) precipitation chemistry, (3) transport and deposition (wet and dry), (4) aquatic environments (biological and hydrological), (5) terrestrial environments, (6) effects on materials and structures, (7) air and precipitation monitoring and data collection, and (8) modeling studies. References date from the late 1800's through December 1981. The bibliography includes short summaries of most documents. Omitted are unpublished manuscripts, publications in press, master's theses and doctoral dissertations, newspaper articles, and book reviews. Coauthor and subject indexes are included.

INTRODUCTION

Scientists throughout the world are conducting research on the causes and ecological impacts of acidic atmospheric deposition. Although public awareness of the environmental problems caused by acid precipitation has become widespread only recently, scientists have been investigating the problem for decades. The term "acid rain" was first used in 1872 by Robert Angus Smith, an English chemist who studied regional variations of precipitation chemistry in western Europe (Cowling, 1982). Smith's investigations of the chemistry of precipitation remained obscure among the scientific community for years, however, and it was not until 1948 in Sweden that the first large-scale precipitation-monitoring network was established (Cowling, 1982). The network was expanded in the early 1950's to Norway, Denmark, and Finland, and soon included most of western and central Europe. During this time, Barrett and Brodin (1955) and Gorham (1955) began to systematically study the causes of acid precipitation and its effects on aquatic ecosystems based on data collected in Sweden, England, and Canada. Results of their studies provided the scientific community with a foundation for further investigation of the complex natural systems and processes that are affected by acid precipitation.

Research on acid precipitation today is multidisciplinary and diverse. Scientists are studying the sources, transport, and deposition patterns of acid precipitation and are conducting extensive research on its effects on aquatic and terrestrial ecosystems and on building materials. The literature resulting from these investigations is vast and is published in a multitude of sources. Thus, a need has arisen for a comprehensive guide to the published literature on acid precipitation.

Purpose and Scope

Most of the recent bibliographies on acid precipitation address only a few specific aspects of research, and few include subject indexes.

The purpose of this bibliography is to provide a collection of references to published literature on the causes and environmental effects of acidic atmospheric deposition throughout the world, the following categories are represented:

Atmospheric chemistry (gases and aerosols)
Precipitation chemistry (wet and dry)
Aquatic environments (biological and hydrological)
Terrestrial environments
Effects on materials and structures
Air and precipitation monitoring and data collection
Modeling studies

Most of the documents were published after 1960, but some were published as early as the late 1800's. This collection cites books, journal articles, conference proceedings, technical reports, published notes, and published commentaries.

Omitted are documents of the following types: unpublished manuscripts, publications in press, master's theses and doctoral dissertations, newspaper articles, and book reviews. Also omitted are research reports published by the Norwegian Institute for Water Research (NIWR) for the SNSF Project, Acid Precipitation-Effects on Forest and Fish. Many of these reports have been published in other journals, however, and are cited herein. Papers from the proceedings of the International Conference on Ecological Impact of Acid Precipitation, held in Sandefjord, Norway, 1980, which was published by the NIWR, are also included.

Sources of Related Information

The researcher may wish to consult other related bibliographies to supplement the references listed in this bibliography. Some of these are described below.

A bibliography of reports resulting from investigations by the Norwegian Interdiciplinary Research Programme (SNSF project), titled "Acid Precipitation--effects on Forests and Fish" was published in 1981 (Tollan). A bibliography on the long-range transport of air pollutants (Canada Atmospheric Environment Service,. 1980) was compiled jointly by the Ontario Ministry of the Environment and the Federal Atmospheric Environment Service of Canada. A bibliography on health effects of acid precipitation was compiled by Dailey and Winslow (1980) of the National Library of Medicine.

A computerized data base of bibliographic references on acid precipitation and related topics has been developed by the Corvallis Environmental Research Laboratory, U.S. Environmental Protection Agency. The file contained 4,000 titles in March 1982.

Approach

Computerized bibliographic searches of chemical, engineering, biological, and physical sciences data bases were conducted. A list of data bases that were searched and their time coverage are given in table 1.

In addition, data bases maintained by the U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, and the U.S. National Park Service were searched.

A request was sent to 300 researchers in the U.S., Canada, Norway, and Sweden for lists of their publications and for reprints; most responded, and many provided extensive bibliographic information.

The criteria for selection of documents were (1) relevance to the categories listed in the "Purpose and Scope" section, and (2) availablility of the documents.

Table 1.--List of data bases searched

Name of data base	Time coverage	Description
Agricola	1970 to present	Indexing data base of the National Agricultural Library, Beltsville, Md.
Aqualine	1974 to present	Indexing data base of the Water Research Center, Buckinghamshire, England
Aquatic Sciences and Fisheries Abstracts	1978 to present	Online version of Aquatic Sciences and Fisheries Abstracts
Biosis Previews	1969 to present	Online version of Biological Abstracts
CA Search	1967 to present	Online version of Chemical Abstracts
Compendex	1970 to present	Online version of Engineering Index
DOE Energy	1974 to present	Indexing data base of the U.S. Department of Energy
Enviroline	1970 to present	Bibliographic data base for environmental energy information produced by Environment Information Center, N.Y.
GEOREF	1961 to present	Earth-sciences data base produced by American Geologial Institute, Falls Church, Va.
NTIS	1964 to present	National Technical Information Service, data base of government-sponsored research reports
Pollution Abstracts	1970 to present	Online version of Pollution Abstracts
Selected Water Resources Abstracts	1968 to present	Online version of Selected Water Resources Abstracts

Most of the documents cited in this bibliography are annotated, and most annotations were written by the compilers. The annotations are brief summaries of what is contained in the cited reference; they are not intended as abstracts. Some annotations give more detailed information than others, particularly annotations of complex journal articles and lengthy reports. Some abstracts were reprinted from the original publication with permission from the author and publisher. Three types of documents are cited but not annotated: (1) conference proceedings that contain only abstracts, (2) chapters in textbooks, and (3) collected works that do not contain abstracts.

Terms used in the subject index were selected from the "Water Resources Thesaurus" (U.S. Office of Water Research and Technology, 1980). Some additional terms selected were from "GEOREF Thesaurus and Guide to Indexing" (Riley, 1980).

Arrangement of References

References are arranged alphabetically by principal author (personal or corporate); where more than one publication by the same author is listed, the references are in chronological order.

References are numbered consecutively; a coauthor index and a subject index at the back refer to these numbers.

Acknowledgments

The compilers thank the researchers in the U.S., Norway, Sweden, and Canada who sent copies of their reports, reprints, and lists of their publications. We also appreciate the cooperation and assistance from the New York State Library and the U.S. Geological Survey Library who provided interlibrary loan and reference services. Special thanks are extended to Danny Rambo of the U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, and Erik R. Hauge of the U.S. National Park Agency, for providing access to the data bases of acid-precipitation literature maintained by their agencies.

Acknowledgement is also made to the following publishers for permission to reprint copyrighted abstracts:

Ann Arbor Science Publishers

Pergamon Press

Plenum Press

D. Riedel Publishing Company

U.S. Forest Service

REFERENCES CITED IN INTRODUCTION

Barrett, Earl, and Brodin, Gunnar, 1955, The acidity of Scandinavian precipitation: Tellus, v. 7, no. 2, p. 251-257.

Canada Atmospheric Environment Service, 1980, A bibliography--long-range transport of air pollutants and acidic precipitation: Downsview, Ontario, LRTAP Program Office, Environment Canada, 95 p.

Cowling, E. B., 1982, Acid precipitation in historical perspective: Environmental Science and Technology, v. 16, no. 2, p. 110A-123A.

Daily, N. S., and Winslow, S. G., 1980, Health and environmental effects of acid rain--an abstracted literature collection, 1966-1979: Bethesda, Md., Federation of American Societies for the Experimental Biology, 202 p.

Gorham, Eville, 1955, On the acidity and salinity of rain: Geochemica et Cosmochimica Acta, v. 7, p. 231-239.

Riley, S. J., ed., 1981, GEOREF thesaurus and guide to indexing (3d ed.): Falls Church, Va., American Geological Institute, 431 p.

Tollan, Arne, 1981, Annotated bibliography, 1974-1980, SNSF project; Acid precipitation--effects on forest and fish: Oslo-As, Norway, Norwegian Institute for Water Research, 42 p.

U.S. Office of Water Research and Technology, 1980, Water resources thesaurus (3d ed.): Washington, D.C., U.S. Department of the Interior, Office of Water Research and Technology, OWRT IT-80/1, 1 v.

BIBLIOGRAPHY

A

1

ABER, J. D., HENDREY, G. R., BOTKIN, D. B., FRANCIS, A. J., and MELILLO, J. M., 1980, Simulation of acid precipitation effects on soil nitrogen and productivity in forest ecosystems: Upton, N.Y., Brookhaven National Laboratory, BNL-28658, 30 p.

This article describes two numerical simulation models of the influence of acid rain in inducing changes in the decomposition of organic matter and the effect of nitrogen availability on productivity in northern hardwood forests. One set of simulations indicates that small changes in nitrogen availability due to acid precipitation result in calculable short-term changes in production in nitrogen-limited forests. When further effects on productivity are included in the second set of simulations, the results are complicated by temporal changes in the balance between production and decomposition; this balance determines nitrogen mineralization. Small increases or large decreases in decomposition rates may significantly reduce harvestable yields.

2

ABRAHAMSEN, Gunnar, 1980, Acid precipitation, plant nutrients and forest growth, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 58-63.

3

ABRAHAMSEN, Gunnar, 1980, Effects of acid precipitation on soil and forest, 1. Methods of the field experiments, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 190-191.

4

ABRAHAMSEN, Gunnar, 1980, Effects of acid precipitation on soil and forest, 4. Leaching of plant nutrients, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 196-197.

5

ABRAHAMSEN, Gunnar, 1980, Impact of atmospheric sulphur deposition on forest ecosystems, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 397-415.

5 (continued)

Results from experiments in coniferous forests supplied with artificial rain of varying acidity are discussed. The acidity of the "rain" was adjusted using H_2SO_4.

The enrichment of K, Ca, and Mg in throughfall beneath spruce crowns is increased by decreased pH of the artificial rain. This has not significantly influenced the nutrient concentrations in the needles. The content of NH_4 and NO_3 in throughfall is less than that of incident rain, and it is not influenced by rain acidity.

The soil chemical properties have been studied in field plots and with lysimeters. Artificial rain with pH at 3 and below has significantly increased the net leaching of K, Ca, and Mg. As a consequence, the base saturation and soil pH have decreased. These are strong indications that the present acidity of precipitation has also reduced the concentration of exchangeable metal cations in the soil. A significant net leaching of NH_4 and NO_3 has been found in the most acidified plots.

Variations in soil chemical properties have not signficantly influenced the concentrations of most nutrient elements in the needles. In one experiment, the foliar concentration of N was temporarily enhanced. This was most likely the reason for a slight increase in the tree growth. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

6

ABRAHAMSEN, Gunnar, HORNTVEDT, Richard, and TVEITE, Bjorn, 1977, Impacts of acid precipitation on coniferous forest ecosystems: Water, Air, and Soil Pollution, v. 8, no. 1, p. 57-73.

This paper summarizes the results from current studies in Norway. One main approach is the application of artificial acid "rain" and of lime to field plots and lysimeters.

Application during two growth seasons of 50 mm/month of "rain water" of pH 3 to a podzol soil increased the acidity of the humus and decreased the base saturation. The reduction in base saturation was mainly due to leaching of Ca and Mg.

Laboratory experiments revealed that decomposition of pine needles was not affected by any acid "rain" treatment of the field plots. Liming slightly retarded the decomposition.

No nitrification occurred in unlimed soils (pH 4.4-4.1). Liming increased nitrification.

6. (continued)
The soil enchytraeid (Oligochaeta) fauna was not much affected by the acidification.

Germination of spruce seeds in acidified mineral soil was negatively affected when soil pH was 4.0 or lower. Seedling establishment was even more sensitive to increasing soil acidity.

Analysis of throughfall and stemflow water in southernmost Norway reveals that the total deposition of H_2SO_4 beneath spruce and pine is approximately two times the deposition in open terrain. A large part of this increase is probably due to dry deposition. Increased acidity of the rain seems to increase the leaching of cations from the tree crowns.

Tree-ring analysis of spruce (*Picae abies* (L.) Karst.) and pine (*Pinus sylvestris* L.) has been based on comparisons between regions differently stressed by acid precipitation and also between sites presumed to differ in sensitivity to acidification. No effect that can be related to acid precipitation has yet been detected on diameter growth. [Abstract reprinted by permission of D. Riedel Publishing Company.]

7
ABRAHAMSEN, Gunnar, HOVLAND, Jon, and HAGVAR, Sigmund, 1980, Effects of artificial acid rain and liming on soil organisms and the decomposition of organic matter, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 341-362.

8
ABRAHAMSEN, Gunnar, and STUANES, A. O., 1980, Effects of simulated rain on the effluent from lysimeters with acid, shallow soil, rich in organic matter, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 152-153.

9
ABRAHAMSEN, Gunnar, STUANES, A. O., and BJOR, Kristian, 1979, Interaction between simulated rain and barren rock surface: Water, Air, and Soil Pollution, v. 11, p. 191-200.

Increased acidity of rivers has caused extensive fishkills in the mountainous regions of southern Norway. The increase in acidity is generally attributed to acid precipitation. This article discusses the relationship between chemical composition of simulated rain and runoff from bare granitic rock that is partially covered by lichens. The authors conclude that the pH of the runoff was affected by the acidity of the rain and its content of neutral salts.

10
ACKERMAN, W. C., HARMESON, R. H., and SINCLAIR, R. A., 1970, Some long-term trends in water quality of rivers and lakes: American Geophysical Union Transactions, v. 51, p. 516-522.

This article describes temporal trends in the water quality of Lake Michigan and three river watersheds in Illinois (Illinois River at Peoria, Mississippi River at Alton, and Ohio River at Cairo). Long-term records of chloride, sulfate, and nitrate concentrations; total dissolved solids (tds); and alkalinity at four sites were analyzed. Results indicate that Lake Michigan and the three rivers carry a substantially higher amount of dissolved solid materials than at the turn of the century. The increase in chloride concentrations varied from 100 percent in 52 years to 300 percent in 70 years and increases in sulfate concentrations varied from 80 percent in 43 years to 155 percent in 62 years. Long-term changes in alkalinity were not significant at any of the four stations. Increases in tds were smaller than the rest because of naturally occurring high levels of calcium, magnesium, and carbonates.

11
ADAMS, D. F., FARWELL, S. O., PACK, M. R., and BAMESBERGER, W. L., 1979, Preliminary measurements of biogenic sulfur-containing gas emissions from soils: Journal of the Air Pollution Control Association, v. 29, no. 4, p. 380-383.

This article presents preliminary data from a 1977 project to determine the composition and flux of sulfur gases from soils in the Sulfate Regional Experiment (SURE) area in eastern United States. The dynamic-emission-chamber technique was used to determine sulfur flux at six to eight sampling sites with soils ranging from coastal saline marsh to poorly drained inland organic soils to mineral soils. Average annual sulfur flux from the sampling sites ranged from 0.002 to 152 $(g/m^2)/yr$. Results of the study suggest that several biogenic sulfur-containing compounds besides hydrogen sulfide should be considered in evaluations of the global sulfur cycle.

12
ADAMS, D. F., FARWELL, S. O., PACK, M. R., and ROBINSON, E., 1980, Estimates of natural sulfur source strengths, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 35-45.

12 (continued)
Data are presented for the first systematic measurements of biogenic sulfur gas flux from nine major soil orders within the northeastern United States Sulfate Regional Experiment (SURE) area.

Sulfur gas enhancment of sulfur-free sweep air passing through dynamic emission flux chambers placed over selected sampling areas was determined by wall-coated open-tubular capillary-column cryogenic gas chromatography (WCOT/GC) using a sulfur-selective flame photometric detector (FPD).

Sulfur gas mixtures varied with soil order, ambient temperature, insolation, soil moisture, cultivation, and vegetative cover. Statistical analyses indicated strong temperature and soil order relationships for sulfur emissions from soils.

Fluxes ranged from 0.001 g to 1940 g of total sulfur per square meter per year. The calculated mean annual land sulfur flux, weighted by soil order, was 0.02 g of S per square meter per year for the SURE area, or 43,660 metric tons total. The estimated annual average sulfur flux increased from 65 metric tons per 6400 km^2 for the land grids in the northern tier to an average of 165 metric tons for the land grids in the southernmost SURE tier.

This systematic sampling of major soils provides a much broader data base for estimating biogenic sulfur flux than previously reported for three Atlantic coast intertidal sites. Thus, this study provided the first sulfur flux estimates for inland soil representing approximately 95% of the land of the northeastern United States. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

13
AHLBERG, M. S., LESLIE, A. C. D., and WINCHESTER, J. W., 1978, Characteristics of sulfur aerosol in Florida as determined by pixe analysis, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 773-777.

The particle size distribution of sulfur has been determined in Florida during two seasons, July-August and December 1976. Approximately 120 cascade impactor samples from 10 widely distributed urban and nonurban sites in the state, each sample consisting of 6 separate particle size fractions from <0.25 μm to >4 μm aerodynamic diameter, were analyzed by proton induced X-ray emission for elemental constituents in over 800 individual specimens, including blanks. Most of the sulfur occurred in a fine particle mode <2 μm diameter, with lesser amounts in a coarse mode, >2 μm. The mass median aerodynamic diameter, MMAD, of sulfur in the fine mode was found to be greater for samples collected under higher average relative humidity, r.h., conditions than samples from lower humidities. The trend of MMAD with r.h. indicates that ammonium sulfate, rather than sulfuric acid, is more likely to be the principal chemical form of sulfur in the fine mode. [Abstract reprinted by permission of Pergamon Press.]

14
AHLBERG, M. S., and WINCHESTER, J. W., 1978, Dependence of aerosol sulfur particle size on relative humidity: Atmospheric Environment, v. 12, p. 1631-1632.

Cascade impactors were used to sample ambient aerosol particle size fractions in laboratory experiments before and after increasing humidity by air flow over a water surface. Mass median aerodynamic diameters (MMAD) of sulfur particles were measured by proton-induced X-ray emission. Results from 12 experiments indicate that the increase in MMAD with increasing relative humidity, ranging from 10 to 97 percent, corresponds closer to the theoretical curve for $(NH_4)_2SO_4$ than for H_2SO_4. This suggests that $(NH_4)SO_4$ is the principal sulfur species in particles in the 2-μm diameter range.

15
ALEXANDER, Martin, 1980, Effects of acid precipitation on biochemical activities in soil, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 47-52.

16
ALEXANDER, Martin, 1980, Effects of acidity on microorganisms and microbial processes in soil, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 363-374.

17
ALFHEIM, I., STOBET, M. B., GJOS, N., BJORSETH, A., and WILHELMSEN, S., 1980, Analysis of organic micropollutants in aerosols, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 100-101.

18
ALKEZWEENY, A. J., and HALES, J. M., 1981, The impact of non-recipitating clouds on the transport and formation of acid aerosols, in American Chemical Society, Division of Environmental Chemistry, 182nd National Meeting, New York, N.Y., Preprints, v. 21, no. 2: Washington, D.C., American Chemical Society, p. 25-27.

19
ALLAN, J. D., 1980, Laboratory simulation of acid rain effects on freshwater microcrustaceans: College Park, Md., Maryland University, Water Resources Research Center Technical Report no. 60, 5 p.

The sensitivity of freshwater microcrustaceans to stress from acid precipitation was investigated in 1980. *Daphnia pulex* were subjected for 10 days to exposures for 1, 12, 24, 48, and 96 hours at pH values of 4.0 to 6.6. A satisfactory test system is developed for acid stress in laboratory populations of freshwater crustaceans. *D. pulex* seem to be severely affected by pH stress at values of 4 to 4.5.

20
ALLAN, R. J., and JONASSON, I. R., 1978, Alkaline snowfalls in Ottawa and Winnipeg, Canada: Atmospheric Environment, v. 12, p. 1169-1173.

The influence of a cement plant on the occurrence of alkaline snowfall in the Ottawa-Hull National Capital Region of Canada is documented. During the winter of 1974-75, snow samples collected at sites in the center of Ottawa had pH values greater than 9, whereas snow samples collected outside the city limits had pH values less than 6. Snow samples were collected again during the winter of 1975-76 after the cement plant had ceased operation. Samples from the most alkaline area in 1974-75 has pH values of 6 or less during the 1975-76 period. Snow samples collected in Winnipeg, Manitoba near cement plants during the winters of 1975-76 and 1976-77 were also alkaline; results from the analyses support the hypothesis that alkaline snowfall in Ottawa was related to the city's cement industry.

21
ALLARD, D. J., and ALLEN, E. R., 1979, The chemistry and precipitation over Albany, New York, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 41-53.

22
ALLEN, R. O., and STEINNES, E., 1980, Contribution from long-range atmospheric transport to the heavy metal pollution of surface soil, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 102-103.

23
ALLEN, S. E., CARLISLE, A., WHITE, E. J., and EVANS, C. C., 1968, The plant nutrient content of rainwater: Journal of Ecology, v. 56, p. 497-504.

Seasonal variation in total quantities of plant macronutrients (suspended and soluble constituents) in rainfall were monitored at five sites in Great Britain from 1962-66. Nutrient quantities correlated closely with rainfall volumes; periods of very high rainfall were associated with greater quantities of macronutrients, and periods of very low rainfall were associated with lesser quantities. The relationships between high and low rainfall and macro-nutrient quantities applied only at some stations and for some elements, especially phosphorus. Maritime influences and agriculture also affected macro-nutrient quantities, but the distance of sites from the influence did not seem to affect the quantities. Local topography greatly affected the extent of maritime influences on macronutrient quantities.

24
ALMER, Brodde, DICKSON, W. T., EKSTROM, Christina, and HORNSTROM, Einar, 1978, Sulfur pollution and the aquatic ecosystem, in Nriagu, J. O., ed., Sulfur in the environment, part II--Ecological impacts: New York, John Wiley, p. 271-311.

25
ALMER, Brodde, DICKSON, W. T., EKSTROM, Christina, HORNSTROM, Einar, and MILLER, U., 1974, Effects of acidification on Swedish lakes: Ambio, v. 3, no. 1, p. 30-36.

The acidification of about 3,000 lakes in the west-coast region of Sweden was investigated from 1970-72. Half the lakes had pH values less than 6.0. In autumn, 36 percent of the lakes has pH values less than 5.0, and in the spring 22 percent had pH values less than 5.0. The results indicate that the acidification process has accelerated in the last 30 years. The report also includes a discussion of effects of acidification on phytoplankton, diatoms, and fish.

26
ALTSHULLER, A. P., 1973, Atmospheric sulfur dioxide and sulfate--distribution of concentration at urban and nonurban sites in United States: Environmental Science and Technology, v. 7, no. 8, p. 709-719.

Relationships between urban sulfate and urban sulfur dioxide, and the ratio of sulfur dioxide to sulfate at 20 sites at 20 cities, computed through statistical analyses are tabulated and discussed. Sulfates constitute

26 (continued)
a greater percentage of the sulfur compounds at western urban sites, and background levels of water-soluble sulfate are considerably greater at eastern nonurban sites. At urban sites the relationship between sulfur dioxide and sulfate is nonlinear. At eastern nonurban sites a large residue sulfate level of at least 5 $\mu g/m^3$ exists because of long-distance transport of sulfur dioxide.

27
ALTSHULLER, A. P., 1980, Seasonal and episodic trends in sulfate concentrations (1963-1978) in the eastern United States: Environmental Science and Technology, v. 14, no. 11, p. 1337-1349.

This article presents statistical trends and episodic characteristics of sulfates and sulfur dioxide in the eastern states. Sulfate concentrations decreased during winters from 1963-78, particularly at urban sites in the Northeast. Local primary sulfate emissions accounted for most of the excess sulfate above regional background levels in the Northeastern urban sites. During summer, sulfate concentrations were strongly influenced by the frequency of regional high-sulfate episodes and correlated well with visibility trends.

28
AMDUR, M. O., 1978, Effects of sulfur oxides on animals, in Nriagu, J. O., ed., Sulfur in the environment, part II--ecological impacts: New York, John Wiley, p. 61-74.

29
AMUNDSON, R. G., and WEINSTEIN, L. W., 1980, Effects of airborne F on forest ecosystems, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 63-78.

Although fluoride (F) injury to forests has been documented frequently, no systematic studies of F within the forest ecosystem have been made to date. This paper reviews the present state of knowledge on F pollution and its effects in terms of tree growth, plant injury, forest community structure, interaction with pathogens and insects, and distribution within the environment. The preparation of this review indicated the many areas of the fluoride and plant interaction is poorly understood. [Abstract reprinted by permission of U.S. Forest Service.]

30
ANDERRSON, Folke, FAGERSTROM, Torbjorn, and NILSSON, S. I., 1980, Forest ecosystem responses to acid deposition-hydrogen ion budget and nitrogen/tree growth model approaches, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects of Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 319-334.

31
ANDERSON, D. E., and LANDSBERG, H. E., 1979, Detailed structure of pH in hydrometers: Environmental Science and Technology, v. 13, no. 8, p. 992-994.

Data on pH of atmospheric precipitation, dew, frost, and fog were collected under a variety of weather conditions at three sites--one in an urban area, one near a large fossil-fuel powerplant, and one in a wooded area without nearby sources of pollution. Mean precipitation of pH 4.7 was not normally distributed when measured per millimeter of precipitation. Strong changes in pH occurred during many climatic events; pH values ranged from 2.7 to 6.9. Concentrations of nitrate, sulfur, trace metals (Na, Pb, V), and hydrogen ion were higher in samples collected downwind of the powerplant. The mean pH of dew and frost samples at the three sites was about 5.7.

32
ANDERSON, Steven, 1974, The effects of acid rain on nitrogen fixation in western Washington coniferous forests: Olympia, Wash., Evergreen State College, 38 p.

Acid precipitation is indicated to have little effect on nitrogen fixation in western Washington coniferous forest soils because of the pH buffering capacity of the canopy. Nitrogen-fixing lichens and bacteria in the canopy are more directly exposed to acid precipitation and hence are more adversely affected.

33
ANDERSSON, Gunnar, FLEISCHER, Siegfried, and GRANELI, Wilhelm, 1978, Influence of acidification on decomposition processes in lake sediment: International Association of Theoretical and Applied Limnology, Proceedings, v. 20, p. 802-807.

The effects of pH on chemical processes in lakes were investigated to determine (1) transformation of sugar (glucose) in sediments, (2) sediment-oxygen uptake and production of carbon dioxide, and (3) exchange of dissolved substances between sediments and water. Results suggest that most sediment material, even in highly acidified lakes, are unaffected by acidic water, but decomposition of material lying on the sediment surface is retarded by low pH.

34
ANDERSSON, Tage, 1969, Small-scale variations of the contamination of rain caused by washout from the low layers of the atmosphere: Tellus, v. 21, no. 5, p. 685-692.

Rainfall data were collected from 24 stations in an area of about 400 km^2 surrounding Uppsala, Sweden, and samples were analyzed for pH, conductance, Cl, Na, K, Ca, and S. Concentrations of Cl, K, Ca, and S were highest in and near Uppsala because of washout in the subcloud layer, which is most heavily polluted near the town.

35
ANDREN, A. W., and STRAND, J. W., 1981, Atmospheric deposition of particulate organic carbon and polyaromatic hydrocarbons to Lake Michigan, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 459-479.

36
ANDRYUKOV, V. P., and NAZAROV, I. M., 1979, Petroleum hydrocarbon atmospheric transport, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 109-116.

37
ANEJA, V. P., 1980, Direct measurement of emission rates of some atmospheric biogenic sulfur compounds and their possible importance to the stratospheric aerosol layer, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 48-54.

Atmospheric sulfur compounds of biogenic origin are thought to constitute a significant fraction of the atmospheric sulfur burden. A determination of fluxes of these compounds into the atmosphere is desirable in order to permit accurate assessment of the relative roles of anthropogenic and biogenic sources in contributing to such phenomena as the atmospheric sulfate burden and acidity in precipitation.

Direct measurements of sulfur emission rates were made in salt marshes on the coast of North Carolina during the summers of 1977 and 1978. An emission flux reactor (chamber) technique was used to determine the emission rates of sulfur compounds into the atmosphere. The sulfur gases were identified and their concentrations in the flux reactor measured with a gas chromatograph (GC) equipped with a flame photometric detector specific for sulfur (S). Hydrogen sulfide (H_2S, average flux 0.5 g of S per square meter per year), dimethyl sulfide [$(CH_3)_2S$, average flux 0.4 g of S per square meter per year], carbonyl sulfide (COS, average flux 0.3 g of S per square meter per year) were measured. In general, the emission rates of these gases varied over a wide range of concentrations under varying conditions of soils, soil moisture, temperature, and insolation. Based upon the measured fluxes, the emissions from marshes are important to the sulfate aerosol burden (19% or less) of the stratosphere but unimportant for the tropospheric sulfur burden. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

38
ANONYMOUS, 1975, Scientists puzzle over acid rain: Chemical and Engineering News, v. 53, no. 23, p. 19-20.

This commentary gives an overview of the causes, sources, and long-term effects of acidic atmospheric deposition and summarizes topics discussed at the First International Symposium on Acid Precipitation at Columbus, Ohio, in 1975.

39
ANONYMOUS, 1979, EPA projects worsening acid rain problem in United States through century's end: Journal of the Air Pollution Control Association, v. 29, no. 12, p. 1250-1251.

Air-pollution projections by the U.S. Environmental Protection Agency (EPA) indicate continuing high SO_2 emissions and a 50-percent increase in NO_x emission to the year 2000. This commentary outlines acid-precipitation research programs of the EPA and the Electric Power Research Institute.

40
APPEL, B. R., TOKIWA, Y., and HAIK, M., 1981, Sampling of nitrates in ambient air: Atmospheric Environment, v. 15, p. 283-289.

Methods for the measurement of nitric acid (HNO_3), particulate nitrate, and total inorganic nitrate (TIN) are compared among atmospheric samples from the Los Angeles basin. Sampling of particulate nitrate with an acid gas denuder, Teflon prefilter, and HNO_3 trap provided the greatest accuracy. HNO_3 values obtained by difference between TIN and particulate nitrate are too high because of dissociation of NH_4NO_3 to HNO_3 and NH_3. Formation of artifact particulate nitrate on glass fiber filter was due to HNO_3 rather than NO_2.

41
APPEL, B. R., WALL, S. M., HAIK, M., KOTHNY, E. L., and TOKIWA, Y., 1980, Evaluation of techniques for sulfuric acid and particulate strong acidity measurements in ambient air: Atmospheric Environment, v. 14, p. 559-563.

This article evaluates the selective extraction of sulfuric acid (H_2SO_4) from filter samples with benzaldehyde and compares results of the benzaldehyde extraction method with microtitration determination of strong acids. The procedure uses both laboratory-prepared filters with known H_2SO_4 aerosol levels and sample filters from a location near sources of SO_2 + H_2SO_4. In the presence of atmospheric particles, H_2SO_4 aerosol recovery was ≤ 30 percent by benzaldehyde, but >60 percent by strong acid titration. This difference is due to the reaction of H_2SO_4 aerosols with particulate matter to yield strong acid compounds of minimal solubility in benzaldehyde. Atmospheric H_2SO_4 may be present at higher levels than reported.

42
APPEL, B. R., WALL, S. M., TOKIWA, Y., and HAIK, M., 1980, Simultaneous nitric acid, particulate nitrate and acidity measurements in ambient air: Atmospheric Environment, v. 14, p. 549-554.

This article evaluates measurement methods for atmospheric nitric acid and the formation of artifact particulate nitrate on filter media. Ambient air samples were collected in winter at Pittsburg, Calif., which is near stationary emission sources of sulfuric and nitric acid. Nitric acid at ambient concentrations can be measured with >97 percent efficiency when nylon or NaCl-impregnated filters are used. Short-term sampling is recommended for minimizing errors because atmospheric particulate matter on Teflon prefilters retains HNO_3. A large positive error in HNO_3 measurements may be attributed to loss of NH_4NO_3 from the prefilter by volatilization.

43
ARKLEY, R. J., and GALUSER, Rudolph, 1980, Effects of oxidant air pollutants on pine litter-fall and the forest floor, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 225.

44
ARMENTANO, R. V., LOUCKS, O. L., and WILLIAMS, W. T., 1980, Regional air-pollution impacts on forest growth, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 226.

45
ARMSTRONG, F. A. J., and SCHINDLER, D. W., 1971, Preliminary chemical characterization of waters in the Experimental Lakes area, northwestern Ontario: Journal of the Fisheries Research Board of Canada, v. 28, p. 171-187.

Water samples were collected from 40 small lakes in the Canadian Shield of northwestern Ontario from 1968-69. Total dissolved nitrogen and phosphorus data were compiled for five lakes at intervals of several weeks during summer stagnation. The three deeper lakes showed little change, but the two shallower lakes showed nitrogen increases of 0.22 and 0.6 g m^2 and phosphorus increases of 0.03 and 0.13 g m^2. Input and outflow of nutrients were calculated for four lakes; all four retained nutrients. Nurients were lost to sediments in the two deeper lakes, and increases in dissolved nutrients were derived from the sediments in the two shallower lakes. Analyses of 33 other Canadian Shield lakes in the Experimental Lakes area indicate that these lakes are more dilute than any in the Canadian Shield except for some in the Northwest Territories. The lakes of the Experimental Lakes area are also more dilute than any other lakes in the world except for some alpine lakes in California.

46
ARNOLD, D. E., LIGHT, R. W., and DYMOND, V. J., 1980, Probable effects of acid precipitation on Pennyslvanian waters: Corvallis, Oregon, U.S. Environmental Protection Agency, EPA-600/3-80-012, 20 p.

The effects of acid precipitation on water chemistry and fish communities in Pennsylvania freshwaters were investigated from available data. About 34 percent of the cases showed decreases in pH, alkalinity, or both. Average decrease in alkalinity was 15.1 mg/L as $CaCO_3$; the maximum decrease was 105 mg/L. Most decreases in alkalinity occurred in streams underlain by the relatively insoluble rocks of the Allegheny Plateau. Fifty-eight percent of the waters with decreased alkalinity or pH showed a decrease in the number of fish species.

47
ASKNE, C., and BROSSET, Cyrill, 1972, Determination of strong acid in precipitation, lake-water and air-borne matter: Atmospheric Environment, v. 6, p. 695-696.

Methods for determining strong acid in precipitation, lake water, and airborne matter were studied. Results show that strong acid can be determined in rainwater by eliminating

47 (continued)
CO_2 in the sample followed by titration with NaOH using Gran's plot. A more detailed paper on this method, titled "Method for Determining Strong Acid in Precipitation Based on Coulometric Titration with Application of Gran's Plot," was published by the SNSF Project in 1973.

48
ASMAN, W. A. H., 1980, Draft, construction and operation of a sequential rain sampler: Water, Air, and Soil Pollution, v. 13, p. 235-245.

A description of the construction and operation of a sequential rain sampler used for collecting data during all types of precipitation events is given. The authors conclude that (1) the collector opening can be made smaller than 0.64 m^2 (by 0.20 m^2), (2) the measured rainfall rate depends on the recording rate of the rain gauge, and (3) all surfaces of the sampling paraphernalia should be covered with inert material.

49
ASMAN, W. A. H., and SLANINA, Jakob, 1980, Meteorological interpretation of the chemical composition of precipitation and some results of sequential rain sampling, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 140-141.

50
ASMAN, W. A. H., SLANINA, Jakob, and BAARD, J. H., 1981, Meteorological interpretation of the chemical composition of rain-water at one measuring site: Water, Air, and Soil Pollution, v. 16, p. 159-175.

Rainwater was sampled at a coastal site at Den Helder, the Netherlands, during 42 periods of 2 or 3 days and analyzed for concentrations of 16 components. Coefficients of variation in the amounts of rainfall did not show a definite relationship between wind speed and amount of rainfall. The same observation was made for the coefficients of variation of the concentrations of the 16 components that were analyzed. With the exception of wind direction, all other meteorological factors have only a minor effect in determinating the chemical composition of rainwater. Nitrogen oxide is responsible for generating 36 percent of the hydrogen ions in rainwater, and ammonia is the most neutralizing substance.

51
ATKINS, W. R. C., 1947, Electrical conductivity of river, rain, and snow water: Nature, v. 159, p. 674.

Electrical conductivity was measured in rainwater and snow samples collected at five sites in Great Britain and India. Riverwater samples from a site in Ceylon were relatively pure and had conductivities of 10-20 µmho/cm at 25°C. Snow and rainwater samples collected at Plymouth, Great Britain had greater conductivity than those collected at a rural site in Dartmoor, Great Britain.

52
ATTIWELL, P. M., 1966, The chemical composition of rainwater in relation to cycling of nutrients in mature Eucalyptus forest: Plant and Soil, v. 24, no. 3, p. 390-406.

The effect of foliar leaching in a mature forest of *Eucalyptus obliqua* on the Great Dividing Range of southeastern Australia was investigated. Rainwater samples were collected for 2 years at a site in a forest and in an open plot of land. Samples were analyzed for sodium, potassium, calcium, magnesium, and phosphorus. The ionic composition of rainwater from the open plot correlates well with the expected pattern of geographic distribution; the source of the ions was mostly oceanic but partly terrestrial. Ion concentration in rainwater collected from both the forested and open area is inversely and exponentially related to the intensity of rainfall during a collection period. The author concludes that ionic concentrations of throughfall beneath a forest canopy are greater than the concentration of rainwater in the open area because of foliar leaching.

53
AUBERTIN, G. M., THORNER, B. C., and CAMBELL, John, 1976, A precipitation collector and automated pH-monitoring system: U.S. Department of Agriculture, Forest Service Research Note NE-220, 8 p.

This article describes a continuous precipitation collector and automated pH-monitoring system. The system automatically monitors the pH of precipitation and records values on a strip chart. Composite rainwater samples can be obtained manually for chemical analyses over any period of a storm. The system can be adapted to accomodate a flow-through specific conductance probe, meter, and recorder, or it can be modified and connected directly to an autoanalyzer-recording system for complete automation.

54
AXELROD, M. C., COYNE, P. I., BINGHAM, G. E., KERCHER, J. R., MILLER, P. R., and HUNG, R. C., 1980, Canopy analysis of pollutant injured Ponderosa pine in the San Bernardino National Forest, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 227.

55
AYERS, G. P., 1978, Quantitative determination of sulphate in individual aerosol particles: Atmospheric Environment, v. 12, p. 1613-1621.

Quantitative determination of sulfate (SO_4) for individual aerosol particles can be done by a vapor-deposited thin-film method. The particles may range from 0.01 µm to a few µm in diameter. The method uses a calibration curve that relates the mass of SO_4 in a particle to the diameter of the reaction ring it produces with a thin layer of barium chloride. The calibration curve is identical, within experimental error, for ammonium sulfate, sulfuric acid, and mixed $(NH_4)_2\ SO_4/NaCl$ particles, the latter at sulfate levels down to 5 percent molar. From these results, the author concludes that the calibration curve is useful for determining soluble sulfate in aerosol particles.

B

56
BAATH, Erland, BERG, Bjorn, LOHM, Ulrik, LUNDGREN, Bjorn, LUNDKVIST, Helene, ROSSWALL, Thomas, SODERSTROM, Bengt, and WIREN, Anders, 1980, Soil organisms and litter decomposition in a scots pine forest--effects of experimental acidification, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 375-380.

57
BAATH, Erland, LUNDGREN, Bjorn, and SODERSTROM, Bengt, 1979, Effects of artificial acid rain on microbial activity and biomass: Bulletin of Environmental Contamination and Toxicology, v. 23, p. 737-740.

Norwegian forest soils were treated with simulated acidic rain containing sulfuric acid (pH 3.0 and pH 2.0) for 5 years. Results suggest that the long-term effect of acidic precipitation on coniferous forests could be a decrease in microbial activity, followed by a decrease in microbial immobilization of nitrogen.

58
BABCOCK, L. R., Jr., 1978, Sulfur dioxide-emission control--costs and benefits, in Nriagu, J. O., ed., Sulfur in the environment, part 1--The atmospheric cycle: New York, John Wiley, p. 85-122.

59
BABICH, Harvey, DAVIS, D. L., and STOTZKY, Guenther, 1980, Acid precipitation, causes and consequences: Environment, v. 22, no. 4, p. 7-13.

This paper reviews the causes and sources, long-distance transport, and environmental impact of acidic precipitation. It discusses the effects of acidic precipitation on abiotic and biotic components of terrestrial and aquatic ecosystems and on structures and materials such as marble buildings and metals.

60
BABICH, Harvey, and STOTZKY, Guenther, 1978, Influence of pH on inhibition of bacteria, fungi, and coliphages by bisulfite and sulfite: Environmental Research, v. 15, p. 405-417.

This article investigates the effects of bisulfite (HSO_3^-) and sulfite (SO_3^{2-}) on the growth of bacteria and fungi and on the survival of coliphages. HSO_3^- was more inhibitory to growth than SO_3^{2-} and the effects of both were directly correlated with pH values, that is, the lower the pH, the greater the toxicity of the anions. The article asserts that researchers should consider adverse effects of the anionic solubility products of SO_2 when determining the impact of SO_2 on the biosphere.

61
BACHE, B. W., 1980, The acidification of soils, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 183-202.

62
BACHE, B. W., 1980, The sensitivity of soils to acidification, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 569-572.

63
BACKLIN, L., SODERLUND, Rolf, and GRANAT, Lennart, 1977, An improved precipitation collector system for subsequent chemical analysis, in World Meteorological Organization, Air pollution measurement techniques: Geneva, Switzerland, World Meteorological Organization, Special Environmental Report no. 10, WMO-no. 460, p. 58-62.

64
BAIER, J. H., and FRIZZOLA, J. A., 1975, Contaminants in rain water and their relationship to water quality, part I: Water and Sewage Works, v. 122, no. 8. p. 72-75.

This article discusses the effect of contaminants in precipitation on ground-water quality. Rainwater samples have been collected at several sites in Suffolk County, Long Island, N.Y. and analyzed for pH, sulfate, chloride, sodium, and nitrogen compounds. (See also Frizzola, J. A., 1975, herein.)

65
BAKER, J., HOCKING, Drake, and NYBORG, Marvin, 1977, Acidity of open and intercepted precipitation in forests and effects on forest soils in Alberta, Canada: Water, Air, and Soil Pollution, v. 7, no. 4, p. 449-460.

Emissions of SO_2 appear to have an acidifying effect on grossfall (open rainfall), throughfall, stemflow, and soil solution at sites near major sources. Resulting effects on soil chemistry include elevated extractable acidity and aluminum and depressed exchangeable bases, especially Ca and Mg. These changes are mostly in the incipient phases in the study area. [Abstract reprinted by permission of D. Riedel Publishing Company.]

66
BAKER, J. P., and SCHOFIELD, C. L., 1980, Aluminum toxicity to fish as related to acid precipitation and Adirondack surface water quality, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 290-291.

67
BAKER, M. B., 1981, An analysis of the first year of MAP3S rain chemistry measurements: Atmospheric Environment, v. 15, no. 1, p. 43-55.

This article presents preliminary data from the Multistate Atmospheric Power Production Pollution Study (MAP3S) and discusses a theoretical model of pollutant scavenging, namely sulfates. Chemical analysis of rain data from the MAP3S network gives numerical values for parameters of theoretical models of wet deposition of sulfur that are similar to values estimated for western Europe. According to the model the probability of rain is about equal to 0.12, the characteristic rainout scavenging rate of sulfates is about 0.3/hr, and residence time for atmospheric sulfur species is about 100 hr. Sulfate and nitrate affect pH at all stations in the network. Meteorological analysis of selected high-deposition events indicates inadequacies in present reporting and collecting procedures.

68
BAKSI, W. F., CRAIG, G. R., RICHARDS, J., and REINKE, J., 1977, The effects of copper and depressed pH on flagfish reproduction: Rexdale, Ontario Ministry of the Environment, 12 p.

This article investigates the effect of reduced pH and increased copper concentrations on flagfish reproduction. Flagfish egg production was inhibited within 3 days of exposure to pH values between 5.5 and 6.8. Copper impaired reproduction at concentrations of 7 ppm above a background level of 7.3 ppb. Results indicate that sublethal quantities of metals and acidity have adverse affects on aquatic life.

69
BALDWIN, A. D., 1971, Contribution of atmospheric chloride in water from selected coastal streams of central California: Water Resources Research, v. 7, no. 4, p. 1007-1012.

Water-quality and streamflow data were collected at five streams draining coastal watersheds between Half Moon Bay and Santa Cruz, Calif., from April 1965 through June 1966 to evaluate the contributions of atmospheric chloride to these basins. Geologic rock units affect the water quality in four of the basins. About 59 percent of the dissolved chloride discharging from basins underlain by Tertiary sedimentary rocks originates from the atmosphere. Nineteen percent of the dissolved chloride contributed by the atmosphere is dissolved in rainfall, and 40 percent is contributed to the basins as fine particulate dust, fallout from fog, or as an aerosol.

70
BALLANTINE, D. S., BEADLE, R. W., and JACOBSON, J. S., 1979, Research on the chemistry and ecological effects of atmospheric pollutants initiated by the Department of Energy, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 1-4.

71
BANASZAK, K. J., 1975, Relative throughfall enrichment by biologic and by aerosol-derived materials in loblolly pines: University, Miss., Mississippi State University, Water Resources Research Institute, 28 p.

This article describes the enrichment of throughfall by solution of biological and aerosol materials in loblolly pines (*Pinus taeda* L.) in north-central Mississippi. Rainfall and water from throughfall and stemflow of the trees were analyzed for

71 (continued)
silica, phosphate, ammonium, sulfate, nitrate, pH, alkalinity, potassium, sodium, and calcium. The contribution of aerosol material to the dissolved load of throughfall was minimal, and no net loss of constituents except potassium was evident from the canopy of young, growing loblolly pines in dense stands.

72
BANDY, A. R., and MAROULIS, P. J., 1980, Impact of recent measurements on OCS, CS_2, and SO_2 in background air on the global sulfur cycle, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 55-68.

Background measurements of sulfur dioxide, carbon disulfide, and carbonyl sulfide are reported with emphasis on the marine atmosphere. The SO_2 and OCS data were collected during aircraft flights extending from 57°S to 70°N latitude. The CS_2 data were collected at Philadelphia, Penn., and Wallops Island, Va. Atmospheric oxidation of CS_2 was estimated to contribute no more than 20 percent of the OCS and no more than 33 percent of the SO_2 measured in the marine atmosphere. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

73
BARNES, C. R., and SCHROEDER, R. A., 1981, Trends in acid precipitation in New York--1965-78, in American Chemical Society, Division of Environmental Chemistry, 182nd National Meeting, New York, N.Y., Preprints, v. 21, no. 2: Washington, D.C., American Chemical Society, p. 68-71.

74
BARNES, R. A., 1979, The long range transport of air pollution, a review of European experience: Journal of the Air Pollution Control Association, v. 29, no. 12, p. 1219-1235.

A summary is given on the climatology, health and environmental effects, cost of damages, and abatement of the long-range transport of air pollutants (LRTAP). Emissions of sulfur and nitrogen oxides are expected to increase in the next 20 years. Two apparent effects of LRTAP (particularly sulfates and nitrates) are the localized increase of acidity of freshwaters and the reduction of visibility during summer.

75
BARNES, R. A., and LEE, D. O., 1978, Visibility in London and the long distance transport of atmospheric sulphur, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 791-794.

75 (continued)
The long distance transport of air pollutants and summer visibility in London is related to sulfate concentration and wind direction. The results suggest that a non-linear, approximately inverse relationship exists between visibility and aerosol sulfate concentration. The worst mean visibility (6.4 km) and the highest daily mean sulfate concentration (1610 μg m^{-3}) both occur in airflows between east and south. The most likely source of the sulfate on these occasions would be emissions on the continental mainland. [Abstract reprinted by permission of Pergamon Press.]

76
BARRETT, Earl, and BRODIN, Gunnar, 1955, The acidity of Scandinavian precipitation: Tellus, v. 7, no. 2, p. 251-257.

Precipitation data were collected monthly at stations in Sweden from June 1953 through June 1954 and analyzed for pH. Regions of acidity and alkalinity can be defined in relation to pH of water in equilibrium with atmospheric carbon dioxide. Greatest acidity was found in samples collected in winter, and greatest alkalinity in samples collected in spring. Coastal stations unaffected by local pollution show persistently high acidity, and inland northern stations show equally persistent alkalinity.

77
BARRIE, L. A., 1978, An improved model of reversible SO_2-washout by rain, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 407-412.

Removal of sulphur dioxide from the atmosphere by rain is an important feature of atmospheric sulphur budgets. The exchange of sulphur dioxide between a falling rain drop and air is complicated not only by the complex circulation inside the drop but also by the chemical reactivity of the gas with water. The latter characteristic results in a non-linear relationship between the liquid and gas phase SO_2 concentrations. This relationship is derived.

An improved method of modelling reversible SO_2 exchange between a falling rain drop and air is presented, which takes into account phenomena associated with the solution chemistry of SO_2 (e.g. ion-enhanced diffusion) as well as the microphysical effects of internal circulation.

The model is used to calculate the redistribution and washout of an SO_2 plume by raindrop spectra characteristic of drizzle and heavy rain. The fractional plume washout rate (% mm^{-1} rain) is inversely related to plume concentration and thickness. In heavy

77 (continued)
rain (25 mm h^{-1}) washout from a 1000 ppb(v) SO_2 plume of 20 m thickness occurs at a rate of 56% h^{-1}. The relative importance of gas phase and liquid phase mass transfer is dependent on SO_2 atmospheric concentrations. At plume concentrations lower than 300 ppb(v) gas phase control dominates. Beneath a plume, harmful ground level SO_2 concentrations are unlikely to occur as a result of reversible washout by rain. [Abstract reprinted by permission of Pergamon Press.]

78
BARRIE, L. A., 1981, The prediction of rain acidity and SO_2 scavenging in eastern North America: Atmospheric Environment, v. 15, no. 1, p. 31-41.

This article presents a method for predicting acidic rainfall from sulfur dioxide emission rates and meteorological data. A quantitative relationship between the S^{4-} concentration, pH, and temperature of rain is derived and used in long-range transport models to mathematically simulate the SO_2 scavenging process. The article also discusses incorporating SO_2 washout into sulfur cycle models.

79
BARRIE, L. A., and GEORGII, H. W., 1976, An experimental investigation of the absorption of sulphur dioxide by water drops containing heavy metal ions: Atmospheric Environment, v. 10, p. 743-749.

The absorption of sulfur dioxide (SO_2) by 2-mm diameter droplets of solutions of dilute heavy metal solutions exposed to trace concentrations of SO_2 in air was measured at 25°C and 8°C. When pH was decreased, the rate of SO_2 adsorption by a droplet of catalyst solution decreased. When the temperature of manganese solution was decreased from 25°C to 8°C, the SO_2 adsorption rate decreased 5 to 10 times.

80
BARRIE, L. A., and WALMSLEY, J. L., 1978, A study of sulphur dioxide deposition velocities to snow in northern Canada: Atmospheric Environment, v. 12, p. 2321-2332.

Snow samples were collected from 55 sites near an isolated point source in northeastern Alberta, Canada, to study deposition velocities of sulfur dioxide to snow. Only 0.14 percent of the emitted sulfur was deposited within a radius of 25 km. Ambient sulfur concentrations and sulfur deposition measured at one site yielded a SO_2 deposition velocity of 0.25 cm/s, which compared favorably to the mean deposition velocity 0.03-0.4 cm/s calculated from a Gaussian dispersion model.

81
BARTNICKI, J., PRUCHNICKI, J., and PUDYKIEWICZ, J., 1979, Sensitivity of unilevel trajectory model to random errors in initial fields, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 265-270.

82
BARTON, Paul, and VATANATHAM, Terathai, 1976, Kinetics of limestone neutralization of acid waters: Environmental Science and Technology, v. 10, no. 3, p. 262-266.

A discussion is presented on the kinetics and equilibria of limestone treatment of metal acid wastewaters and a kinetic expression for designing neutralization reactors. The rate of neutralization of sulfuric acid was controlled by hydrogen diffusion in the pH range of 2.5-6.0.

83
BEAMISH, R. J., 1972, Lethal pH for the white sucker *Catostomus commersoni*, (Lacepede): Transactions of the American Fisheries Society, v. 2, p. 355-359.

Described are lethal levels of pH for white suckers and behavior of young white suckers in water acidified by hydrochloric and sulfuric acids. When pH was lowered below 4.5, fish stopped feeding. The behavior of the fish varied with pH; fish initially became extremely active for a short period followed by prolonged periods of inactivity.

84
BEAMISH, R. J., 1974, Growth and survival of white suckers (*Catostomus commersoni*) in an acidified lake: Journal of the Fisheries Research Board of Canada, v. 31, p. 49-54.

The growth, population, and food of white suckers (*Catostomus commersoni*) from two lakes in the La Cloche Mountain region of Ontario, Canada, were examined to determine the effect of low pH on the white sucker population. Reduced growth and death of white suckers appreared directly related to low pH, not to a shortage of food caused by decreasing pH.

85
BEAMISH, R. J., 1974, Loss of fish populations from unexploited remote lakes in Ontario, Canada, as a consequence of atmospheric fallout of acid: Water Research, v. 8, no. 1, p. 85-95.

Fish populations were examined at Ontario Society of Artists (OSA) and Muriel Lakes in the La Cloche Mountain region, Ontario,

85 (continued)
Canada to determine long-term lethal effects of low pH on fish stocks. Emissions from nickel smelters in Sudbury, Ontario contribute significantly to the contamination of lakes in the La Cloche region. Lake contamination has resulted in the loss of fish stocks. High concentrations of nickel in lakes, precipitation, and stack emissions, and abnormally high concentrations of hydrogen and sulfate ions in the lakes studied, are the principal causes of reduced fish populations.

86
BEAMISH, R. J., 1975, Long-term acidification of a lake and resulting effects on fish: Ambio, v. 4, no. 2, p. 98-102.

The effect of acid precipitation on fishes from George Lake, Ontario, Canada, was studied from 1966 to 1973. The size and population of white suckers declined during the study as did the pH of the lake. An increase in the percentage of spinal deformities found in the white sucker population seems related to a decrease in pH below 5.0. The study concludes that a change in normal calcium metabolism by white suckers was induced by low pH and that abnormally low serum calcium levels may be related to the failure of fish to spawn.

87
BEAMISH, R. J., 1976, Acidification of lakes in Canada by acid precipitation and the resulting effects on fishes: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 501-514.

In the Sudbury region of Ontario, Canada, fallout of sulfur oxides has been shown to be responsible for damage to vegetation, lakes, and fishes.

The acidic fallout has been shown to effect a rate of acidification in many lakes that over several decades has resulted in the extinction of many species of fishes. Fish exhibit profound differences in acid tolerance but show some similarities in their physiological response to levels within the range of their individual susceptibilties. Prior to extinction most females of a particular species did not release their ova to be fertilized. The failure of females to spawn was coincident with an inability to maintain normal serum Ca levels. In some species growth was reduced despite an adequate supply of preferred food items. High concentrations of acid were considered to be the principal factor stressing the fish populations. Elevated concentrations of some heavy metals may add to the stress caused by high concentrations of acid. [Abstract reprinted by permission of D. Riedel Publishing Company.]

88
BEAMISH, R. J., BLOUW, L. W., and McFARLANE, G. A., 1976, A fish and chemical study of 109 lakes in the Experimental Lakes Area (ELA), northwestern Ontario, with appended reports on lake whitefish ageing errors and the northwestern Ontario baitfish industry: Environment Canada, Fisheries and Marine Service Technical Report no. 607, 116 p.

A survey of 109 lakes found lake trout in 20 and whitefish in 10 of the larger, deeper lakes. Both species are slow growing. Analyses of lake-water samples for 29 chemical constituents indicate that all lakes are generally similar in chemical composition. Concentrations of heavy metals are low. Average pH is 6.5; pH ranges from 4.8 to 7.4. The relationship between several fish species and selected lake characteristics (area, maximum depth, conductivity, sulfate, pH, and hardness) is plotted through regression analysis. The large lakes contain more species of fish and a significant relationship exists between the number of species and the chemistry and size of the lake.

89
BEAMISH, R. J., and HARVEY, H. H., 1972, Acidification of the La Cloche Mountain Lakes, Ontario, and resulting fish mortalities: Journal of the Fisheries Research Board of Canada, v. 29, no. 8, p. 1131-1143.

Described are the acidification of lakes in the La Cloche Mountain region, Ontario, Canada, and the loss of fish populations. Of 150 lakes analyzed for pH, 33 had values of less than 4.5 and 37 ranged from 4.5 to 5.5. This article presents tables of data on the loss of populations of lake trout (*Salvelinus namaycush*), lake herring (*Coregonus artedii*), white suckers (*Catostomus commersoni*), and other fishes from Lumsden Lake. The pH of Lumsden Lake decreased from 6.8 in 1961 to 4.4 in August 1971 at which time a drastic decline occurred in the abundance of fishes.

90
BEAMISH, R. J., and VAN LOON, J. C., 1977, Precipitation loading of acid and heavy metals to a small acid lake near Sudbury, Ontario: Journal of the Fisheries Research Board of Canada, v. 34, p. 649-658.

Precipitation-induced changes in acid and heavy-metal concentration in Lumsden Lake, a small acidic lake in the La Cloche Mountains, Ontario, Canada, were monitored from 1972 through 1973. Atmospheric deposition added an excess of 2135 Kg of sulfuric acid and lake pH decreased from 5.2 to 4.7 in 1972. The excess of sulfuric acid was 1271 kg in 1973. Predicted annual pH, computed from the deposition of atmospheric sulfate, in 1973

90 (continued)
ranged from 4.8 to 4.7; however, there was no net change in lake pH. The lake contained high concentrations of sulfate, manganese, zinc, and nickel. The high concentrations of manganese and possibly zinc seem to result from increased mobilization of these metals from lake sediments and(or) watersheds as pH decreased. Atmospheric fallout also contributed high quantities of nickel and copper to the watershed. The lake retained some of the nickel and copper but little or no lead.

91
BEHNKE, J. A., ed., 1978, Aluminum pollution caused by acid rain killing fish in Adirondack lakes: BioScience, v. 28, no. 7, p. 472.

Acid rain in the Adirondack Mountains, N.Y., has caused widespread aluminum poisoning in fish. Nitric and sulfur oxides emitted from industrial centers are transported and washed from the atmosphere by rain and snow over the Adirondacks. Acids build up in the snowpack throughout the winter and are released in runoff during spring snowmelt. The chemical reaction between nitric acid and soils results in the release of aluminum into lake waters.

92
BEILKE, Siegfried, and GEORGII, H. W., 1967, Investigation on the incorporation of sulfur-dioxide into fog- and rain-droplets: Tellus, v. 20, no. 3, p. 435-441.

This article examines washout and rainout of atmospheric trace gases and aerosols by raindrops and fog droplets. A mathematical model was developed to calculate the sulfate concentration in rainwater caused by washout and rainout of sulfur dioxide (SO_2) and sulfate aerosols. SO_2 contribution to sulfate concentration in rainwater was 5 percent by rainout and 70 percent by washout. Sulfate aerosols contributed 20 percent by rainout and 5 percent by washout.

93
BEILKE, Siegfried, and GRAVENHORST, Gode, 1978, Heterogeneous SO_2-oxidation in the droplet phase, <u>in</u> Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 231-239.

In order to determine the rate controlling step for sulfate formation in a heterogeneous droplet system, SO^2-transfer within the gas phase towards and within droplets are calculated, equilibrium between SO_2 in the gas phase and sulfur (IV) in cloud and fog droplets is reached within less than 1 second. Oxidation of sulfur (IV) to sulfate in the droplet phase proceeds slower by orders of magnitude. Three mechanisms of SO_2-oxidation are discussed: (a) SO_2-oxidation by O_2 in the absence of catalysts; (b) SO_2-oxidation by O_2 in the presence of catalysts, and (c) SO_2-oxidation by strongly oxidizing agents. Mechanism (a) contributes only to a negligible extent to sulfate formation in droplets even in the presence of typical concentrations of ammonia. Indications are strong that the major function of the SO_2-NH_3-H_2O-system is not the oxidation of SO_2 to sulfate. Oxidation mechanism (b) may contribute to a significant extent to sulfate formation in urban fogs in which case the concentrations of catalysts can be sufficiently high. For clouds in remote areas with much lower catalyst concentrations SO_2-oxidation by mechanism (b) seems to be of little importance. The oxidation by strongly oxidizing agents (mechanism [c]) appears to be the dominant mechanism although some experimental discrepancies have to be resolved. [Abstract reprinted by permission of Pergamon Press.]

94
BEILKE, Siegfried, LAMB, D., and MULLER, J., 1975, On the uncatalyzed oxidation of atmospheric SO_2 by oxygen in aqueous systems: Atmospheric Environment, v. 9, p. 1083-1090.

This work discusses possible causes for discrepancies in uncatalyzed heterogeneous transformation of SO_2 to SO_4 by O_2 in aqueous solutions. Measured rates of sulfate formation were normalized to a common gas phase concentration. The conversion rate of SO_2 to sulfate is not dependent on temperature and is nearly proportional to $[H^+]^{-2}$ in the pH range of 3 to 6. Large amounts of sulfate in atmosphere may be due to catalyzed reactions or stronger oxidizing agents.

95
BELL, H. L., 1971, Effect of low pH on the survival and emergence of aquatic insects: Water Research, v. 5, no. 6, p. 313-319.

Nine species of aquatic insects (dragonflies, stoneflies, caddisflies, and mayflies) were subjected to laboratory tests to determine long-term tolerance and effects of pH on emergence. The insects were placed in stainless steel tanks containing water with pH values ranging from 1.0 to 7.0. Long-term tolerance values (pH at which 50 percent of the organisms died) ranged from pH 2.45 (caddisflies) to pH 5.38 (mayflies). Fifty percent of the insects emerged at pH between 4.0 and 5.9, and all species were more sensitive to low pH during the period of emergence.

96
BELL, H. L., and NEBEKER, A. V., 1969, Preliminary studies of the tolerance of aquatic insects to low pH: Journal of the Kansas Entomological Society, v. 42, no. 2, p. 230-236.

96 (continued)
Mature larvae and nymphs of 10 species of aquatic insects were tested in a laboratory for their relative tolerance to low pH during a 96-hour period. The lethal pH rate was established as the pH at which 50 percent of the larvae died. Larvae and nymphs had marked differences in tolerance to low pH, but in general, all test species, were fairly tolerant. Lethal pH values ranged from 4.65 for mayflies (*Ephemerella subvaria*) to 1.50 for caddisflies (*Brachycentrus americanus*).

97
BELL, J. N. B., 1981, Acid precipitation--a new study from Norway: Nature, v. 292, no. 5820, p. 199-200.

This article summarizes the final report for the Norwegian research program "Acid Precipitation--Effects on Forest and Fish" (SNSF project, 1972-1980). The report suggests that precipitation in southern Scandinavia has become more acidic as a result of long-range transport of air pollutants. An increasing proportion of the acidity is contributed by nitrogen oxides. Yet to be determined is the importance of dry deposition of gaseous and particulate sulfur and nitrogen compounds directly onto vegetation and soils. Acid precipitation seems to mobilize aluminum in soils, which is a significant factor contributing to the destruction of fish populations. Severe problems result from the flush of acid water into lakes during spring snowmelt. No consistent findings on the effects of acid precipitation on forest productivity have been reported.

98
BELL, P. R., 1958, The ability of *Sphagnum* to absorb cations preferentially from dilute solutions resembling natural waters: Journal of Ecology, v. 47, p. 351-355.

Water samples were collected from a bog in a pine forest west of Rhua Noa, Scotland and analyzed for electrical conductivity. The total concentration of metallic ions was considerably lower in a sample from the center of the bog than in the sample from a small stream entering the bog. The conductivity of the bog water, despite the lower concentration of hydrogen ion, was more than double that of the stream entering the bog. The author suggests that the high concentration of electrolytes other than calcium, magnesium, and iron in the water of the bog pool was caused by the absorption of ions of higher valencies by *Sphagna* from the inflowing water and evaporation from the surface of the bog.

99
BENARIE, Michel, 1976, Transport of pollutants considered from the point of view of a short and medium-range material balance: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 329-338.

99 (continued)
Episodical long range transport is the quasi-instantaneous peak event. It does not express the total dosage of pollutant carried over from the source area to some distant place. The purpose of the present paper is to obtain an average material balance of a pollutant leaving a given area. Available information from the OECD "Long Range Transport of Air Pollutants" is being used for this purpose. The IRCHA is one of the laboratories participating in this project.

Our main sampling station is 37 km from the center of the Paris district. This position allows us to compute, based on emission data from the area and air pollution survey records, the amount of pollutant (total S) leaving the region. We worked out this specific example because we had the first-hand, verified data.

Out of a total emission of about 300 kT SO_2 yr^{-1} (1972 figure), over 50% may be accounted for as remaining inside the 37 km-radius circle. Gaseous and particulate dry deposition mechanisms are considered mainly responsible for this fact. Less than half of the total S emission seems to be transported beyond the 37 km radius limit. The exact aspect of the deposition function within the national territory is currently being researched. [Abstract reprinted by permission of D. Riedel Publishing Company.]

100
BENGTSON, Curt, BOSTROM, C. A., GRENNFELT, Peringe, SKARBY, L., and TROENG, E., 1980, Deposition of nitrogen oxides to scots pine (*Pinus sylvestris* L.), in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 154-155.

101
BENGTSSON, Bo, DICKSON, W. T., and NYBERG, Per, 1980, Liming acid lakes in Sweden: Ambio, v. 9, no. 1, p. 34-36.

This article presents application and costs of liming lakes to remedy low pH caused by acidic atmospheric deposition. Although liming is a possible method of keeping acidified waters alive, the best way to improve water quality is to decrease sulfur emissions and the acid load.

102
BENNETT, D. A., 1980, Acid rain research inventory FY 79-80: Washington, D.C., U.S. Environmental Protection Agency, Office of Research and Development, EPA-600/9-80-038, 63 p.

This booklet lists and describes the 1979-80 EPA funded research projects on acid precipitation.

103
BERKOWICZ, Ruwim, and PRAHM, L. P., 1978, Pseudospectral simulation of dry deposition from a point source, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 379-387.

A pseudospectral, two-dimensional model for dispersion and dry deposition of atmospheric pollutants is developed on the basis of gradient-transfer theory (K-theory). A symmetrical transform is developed for the vertical direction satisfying the condition of mass conservation. The deposition to the ground is represented by a sink term at the surface, and according to this the model is called the surface depletion model. Comparison with analytical solutions is performed in the case of constant wind and diffusivity profiles. Agreement between numerical and analytical results is within 2-5% even with only 17 grid points. The pseudospectral method is more accurate than finite difference methods, especially with respect to advection. Multiple sources and time-dependent physically realistic, e.g. measured wind and diffusivity profiles can easily be treated. Sources between grid-points can be accurately represented.

The pseudospectral model is used for calculation of deposition rates with diffusivity and wind profiles for different atmospheric stability conditions. Comparison is made with the conventional, Gaussian source depletion method for estimates of dry deposition from a point source. The discrepancy between the two models increases with increasing atmospheric stability. In the stable case with a deposition velocity of 1 cm s^{-1} and a point source at a height of 25 m, the Gaussian source depletion model underestimates the suspension ratio by a factor of 1.5 at a downwind distance of 22 km from the source. The surface concentration is overestimated by nearly a factor of 2 at the same distance. Contrary to other, more simple surface depletion models which do not take wind and diffusivity profiles into account, it is found that the suspension ratio is smaller for the surface depletion than the source depletion model at short distances, while the opposite relation occurs only a larger distances. This effect is ascribed to the low wind veolcity at the surface which results in stronger depositon close to the source, while at larger distances the vertical diffusive transport becomes more important for the rate of dry deposition. The present results are especially relevant for dispersion and deposition in cases of low diffusivities, where the difference between the two-dimensional pseudospectral surface depletion model and other less sophisticated deposition models is most pronounced. [Abstract reprinted by permission of Pergamon Press.]

104
BERKOWICZ, Ruwim, PRAHM, L. P., and LOUIS, Jean-Francois, 1979, Global 2-D spectral dispersion model, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 359-366.

105
BERNER, R. A., 1971, Worldwide sulfur pollution of rivers: Journal of Geophysical Research, v. 76, no. 27, p. 6597-6600.

This article gives estimates of the amount of airborne sulfur contributed from major sources to the world average for river water. Pollution from manmade sources contribute 28 percent (probable minimum value). Weathering of sedimentary rocks contributes 35 percent; volcanic emanations and hot springs contribute 7 percent; and sulfur carried inland from oceans contributes 30 percent.

106
BERRY, M. A., and BACHMANN, J. D., 1977, Developing regulatory programs for the control of acid preciptation: Water, Air, and Soil Pollution, v. 8, no. 1, p. 95-103.

The U.S. Clean Air Act provides mechanisms by which the public welfare may be protected from "any known or anticipated adverse effects associated with the presence of (an) air pollutant in the ambient air". The history of the U.S. Environment Protection Agency's (EPA) efforts to establish and defend a secondary ambient air quality standard for S oxides is reviewed. The role of acid rain in producing "welfare effects" is described. Emphasis is given to the fact that a wide range of effects not simply limited to forest vegetation must be considered when designing pollution control programs.

The possible effects of ignoring acid rain in developing control strategies to meet health related standards for S oxides, N oxides and particulates are mentioned. Researchers need to be aware of the kinds of information which are needed by regulatory agencies before a regulatory program can be designed for alleviating the threat. Concern and speculation are not adequate. Accurate dose-response information and cumulative damage estimates are needed to quantify the effects of acid rain. Of vital importance are: (1) discovery of pollutant concentrations, mechanisms, and atmospheric conditions which lead to harmful effects; and (2) identification of major sources of the pollutant. The effect such information could have on techniques for meeting ground-level air-quality standards such as tall stacks and Intermittant Control Systems (ICS) is discussed. The desirability of an integrated research effort in this area

106 (continued)
to answer these needs is stressed. EPA efforts in this regard are mentioned. [Abstract reprinted permission of D. Riedel Publishing Company.]

107
BERTIN, Leonard, 1980, Acid rain: Ascent; Journal of Atomic Energy of Canada Limited, v. 2, no. 1, p. 7-13.

This article presents data on the impact on air quality in Canada of converting 80 electric generating stations in northeastern U.S. from oil to coal fuel. Additional generating stations that are needed to meet future energy demands will also affect air quality. An amendment to the Clean Air Act could relieve U.S. utilities of the obligation to install effective antipollution equipment in coal-burning stations scheduled for construction in 1995.

108
BERTRAND, J., CERF, A., and DOMERGUE, J. L., 1979, Repartition in space and time of dust haze south of the Sahara, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 409-415.

109
BESS, F. D., 1980, Acid rain: Ecolibrium, v. 9, no. 4, p. 1-4.

The problem of acid precipitation in northeastern United States is growing in severity in the geographical areas affected. The environmental damages caused by acid precipitation include loss of fish populations from acidic lakes and streams, damage to physical structures and materials, and leaching of nutrients from soils. The principal causes of acid precipitation in the Northeast are emissions of sulfur and nitrogen oxide from large power plants and smelters located in the Ohio Valley.

110
BEVERIDGE, A., and PICKERING, W. F., 1980, Influence of humate-solute interactions on aqueous heavy metal ion levels: Water, Air, and Soil Pollution, v. 14, p. 171-185.

The degree of removal of heavy-metal ions (Cu, Pb, Zn, Cd) from aqueous solution by humic acid suspensions varies with solution pH, concentration of competing cations, nature of organic material, and the complexing power of any ligands present. As pH increases, the amount of ions absorbed in acid media increases until the threshold value required for partial dissolution of the solid and formation of the soluble metal humates is exceeded. Metal ion retention by

110 (continued)
the solid occurs in the presence of ligands, and zero uptake occurs when the soluble complexes formed have a greater effective stability than those resulting from the interaction of humic acid metals.

111
BEWERS, J. M., 1980, Trace metals in the ocean, in, Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 64-65.

112
BHATIA, S. P., 1978, Organosulfur emissions from industrial sources, in Nriagu, J. O., ed., Sulfur in the environment, part 1--The atmospheric cycle: New York, John Wiley, p. 51-83.

113
BIALOBOK, Stefan, 1980, Forest genetics and air pollutant stress, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 100-102.

The breeding of trees, particularly conifers, for cultivation in regions under the influence of industry is of considerable economic importance. This article discusses the role of genetic polymorphism in the process of adaptation to such environments and presents results of research on the genetic variability in Scots pine populations in industrial areas and in regions without gaseous pollution. It also discusses methods of selecting tree populations tolerant to industrial emissions and identifies genetic markers of tolerance. [Abstract reprinted by permission of U.S. Forest Service.]

114
BICK, G. H., HORNUFF, L. E., and LAMBREMONT, E. N., 1953, An ecological reconnaissance of a naturally acid stream in southern Louisiana: Journal of the Tennessee Academy of Science, v. 28, no. 3, p. 221-231.

This paper gives zonation of biota and physical and chemical data collected during 1951 at six sites on a small acid stream. These data are compared to data collected one year later, after the stream was widened, deepened, and the natural obstructions had been removed. The most striking difference in the chemical quality of stream was reduced dissolved oxygen and lower pH. Three of the stations were nearly devoid of macroscopic life after the stream alteration.

115
BICK, Hartmut, and DREWS, E. F., 1973, Selbstreinigung und Ciliatenbesiedlung in saurem Milieu (Modellversuche): Hydrobiologia, v. 24, no. 4, p. 393-402 [in German].

This article describes a laboratory study of the effect of acidification on the bacterial decomposition of peptone and ciliated protozoa. Increased acidification caused reduced rate of decomposition and nitrification; no oxidation of ammonia occurred below pH 5. Total counts of bacteria and ciliates and the number of ciliated protozoa decreased rapidly at pH 5 and below.

116
BIDLEMAN, T. F., CHRISTENSEN, E. J., and HARDER, H. W., 1981, Aerial deposition of organochlorines in urban and coastal South Carolina, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 481-508.

117
BIGGS, R. B., MILLER, J. C., OTLEY, M. J., and SHIELDS, C. L., 1973, A mass balance model of trace metals in several Delaware watersheds: Newark, University of Delaware, Technical Research Project Completion Report, 47 p.

Rain and river-water samples were collected at four sites in northern and southern Delaware and analyzed for copper, cadmium, and mercury. Results were used to calculate the concentration of metals in rainfall at the sites and the outflow of dissolved metals in the streams.

118
BINGHAM, G. E., and COYNE, P. I., 1980, Photosynthesis and stomatal behavior in Ponderosa pine subjected to oxidant stress--water stress response, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 228.

119
BISOGNI, J. J., Jr., 1980, Evaluation of limestone neutralization of acidic Adirondack surface waters: Washington, D.C., U.S. Department of the Interior, Office of Water Research and Technology, Project Technical Completion Report, 21 p.

This article evaluates the effectiveness of limestone in packed-bed reactors in neutralizing acidic surface waters in the Adirondack Mountains of New York in terms of sediment-water interactions and kinetics of acid neutralization by limestone. Little hydrogen-ion interaction occurs between sediment in the lakes and streams studied. Neutralization by limestone in packed-bed reactors appears economically feasible.

120
BISOGNI, J. J., Jr., and DRISCOLL, C. T., Jr., 1979, Characterization of the pH buffering systems in dilute Adirondack surface waters: Washington, D.C., U.S. Department of the Interior, Office of Water Research and Technology, Project Technical Completion Report, 134 p.

This paper discusses aquatic chemistry of dilute surface waters in the Adirondack Mountain region of New York. Water-quality and sediment analyses were conducted for 1 year at three undisturbed lakes and their tributaries. Analytical methods were developed for estimating speciation of aluminum and components of acid neutralization. It is concluded that hydrogen and aluminum cations are significant in the acidification process. Natural organic acids and inorganic aluminum are important pH buffering components in the watersheds studied.

121
BJOR, K., and TEIGEN, O., 1980, Effects of acid precipitation on soil and forest, 6. Lysimeter experiment in greenhouse, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 200-201.

122
BLAKE, L. M., 1981, Liming acid ponds: New York Fish and Game Journal, v. 28, p. 208-214.

The application of lime to neutralize acidic ponds in New York has been practiced for more than 20 years. This article describes the common lime treatments and resulting changes in pH, alkalinity, and fish populations and presents data on cost-benefit ratios. Results of the study indicate that liming is effective and economically feasible for both accessible and remote ponds.

123
BLOOMFIELD, J. A., QUINN, S. O., SCRUDATO, R. J., LONG, Dean, RICHARDS, Arthur, and RYAN, Frank, 1980, Atmospheric and watershed inputs of mercury to Cranberry Lake, St. Lawrence County, New York, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 175-210.

Cranberry Lake is a large (28.2 km^2) reservoir located in the northwestern Adirondack Mountains in New York State. The area surrounding the lake is primarily wilderness

123 (continued)
with no major industry. In 1969, fish collected from Cranberry Lake and nearby Stillwater Reservoir as part of a Statewide sample collection program yielded anomalously elevated mercury levels when compared to similar sized and aged fish of the same species from other lakes in the State. This paper documents studies conducted by New York State over the last ten years concerning the Cranberry Lake situation.

Results to date indicate that levels of mercury in atmospheric fallout at Cranberry Lake are low; rainfall and snowpack levels are usually less than 25 ng HG/l of liquid sample. The Cranberry Lake watershed contributes more mercury to the lake than it receives from the atmosphere as stream inputs to the lake exceed atmospheric inputs to the watershed by a ratio of 1.4:1. Although the pH of Cranberry Lake is generally above 6, measurements taken of streams and lake water during spring runoff yielded pH values of less than 4.5. It is hypothesized that the acidity of the Cranberry Lake system is causing an increase in the availability of mercury to the biota, rather than an absolute increase in water mercury concentrations due to atmospheric or other inputs. [Abstract reprinted by permission of Plenum Press.]

124
BLUMENTHAL, D. L., OGREN, J. A., and ANDERSON, J. A., 1978, Airborne sampling system for plume monitoring, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 613-620.

A single-engine Cessna 206 was modified and instrumented for plume sampling. This aircraft was used as one of the primary sampling platforms for Project MISTT (Midwest Interstate Sulfur Transformation and Transport) as well as other studies. On board aerosol instrumentation included a condensation nuclei monitor, aerosol charge acceptance monitor, integrating nephelometer, electrical aerosol analyser, optical particle counter, size-segregated filter sampler, and a wing-mounted impactor system. The efficiency of the size distribution sample inlet system was greater than 90% for aerosols between 0.009 and 2.5 μm dia. Ozone, sulfur dioxide, nitric oxide and total oxides of nitrogen were monitored continuously. Hydrocarbon concentrations and composition were obtained by gas chromatographic anlysis of air samples collected in stainless steel canisters. Temperature, dewpoint, turbulence, pressure (altitude), and bearing and distance from an aircraft navigation station were also measured. Data from the aircraft system were processed in a preliminary fashion in the field within a few hours of a flight. Final data processing was performed at the various laboratories involved and included application of instrument response time corrections when necessary. The large number of simultaneous measurements possible with the system and the operational procedures which allow rapid feedback of sampling results to the investigators have greatly facilitated the study of pollutant transformation and transport in plumes. [Abstract reprinted by permission of Pergamon Press.]

125
BOGDANOV, S., VIDENOV, P., and SAVOV, E., 1979, Fluctuations of the abundance of carbon monoxide, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 135-140.

126
BOGEN, D. C., NAGOURNEY, S. J., and TORQUATO, C. C., 1981, Major ion composition of atmospheric deposition and particulates at American Samoa, in American Chemical Society, Division of Environmental Chemistry, 182nd National Meeting, New York, N.Y., Preprints, v. 21, no. 2: Washington, D.C., American Chemical Society, p. 34-37.

127
BOLGER, P., LAPORTE, G., BRUHMULLER, F., 1979, Precipitation monitoring during Inco's strike shutdown period (Sept. 15, 1978-June 4, 1979): Copper Cliff, Ontario, Inco Metals Company, 1 v.

No significant reduction in precipitation acidity was observed near Sudbury, Ontario during a strike shutdown of Inco Metals Company from 1978-79. During the shutdown, 59 precipitation events were monitored at a site 10 km west of Sudbury. The pH of precipitation ranged from 3.70 to 4.82; the mean pH was 4.13. Hydrogen ion concentration was high (49.63 mg/M^2 per 38 weeks), and the greatest acidic deposition occurred during spring as a result of the increase in precipitation quantity. Elevated acidity of precipitation appeared to be related to emissions from the United States.

128
BOLIN, Bert, and GRANAT, Lennart, 1973, Local fallout and long-distance transport of sulfur: Ambio, v. 2, no. 3, p. 87-91.

This article presents data on the rate of oxidation of sulfur dioxide (SO_2) into sulfuric acid (H_2SO_4) and deposition of airborne SO_2 and compares the results with those from of a study conducted in 1973 (Hogstrom, Ulf, in Ambio, 1973, v. 2, p. 37-41). Also investigated is the role of dry deposition of SO_2 in the atmospheric sulfur budget.

129
BOLIN, Bert, and PERSSON, Christer, 1975, Regional dispersion and deposition of atmospheric pollutants with particular application to sulfur pollution over western Europe: Tellus, v. 27, no. 3, p. 281-310.

This article presents a series of equations relating sources and sinks for atmospheric pollutants resulting from turbulent atmospheric processes. Regional dispersion and deposition are computed from a combination of statistical characterizations for emissions, horizontal and vertical dispersion, and various sink mechanisms. The article presents a simplified study of the emission dispersion and deposition of sulfur.

130
BOMBERGER, D. C., and PHILLIPS, R. C., 1979, Technological options for mitigation of acid rain, in Gunnerson, C. G., and Willard, B. E., eds., Acid rain: ASCE National Convention, Boston, Mass., 1979, Proceedings: New York American Society of Civil Engineers, p. 132-166.

131
BORMANN, F. H., 1974, Acid rain and the environmental future: Environmental Conservation, v. 1, no. 4, p. 270.

Rainfall in a large area of northeastern United States has an average annual pH of 4.0, but pH values between 2 and 3 have been recorded. Precipitation-chemistry data of New York indicate that rainfall has become 200 to 1,000 times more acidic during the last two decades. Increased use of fossil fuels during the last 20 years seems the most likely explanation for the increased acidification of rain; however, the causes of acid precipitation are complex. Aquatic and terrestrial ecosystems are being adversely affected by acid precipitation. Cumulative effects over several decades could result in serious deterioration of these systems.

132
BORMANN, F. H., and LIKENS, G. E., 1977, The fresh air-clean water exchange: Natural History, v. 86, no. 9, p. 63-71.

This article describes the role of the forest ecosystem in removing acid and heavy metals. Studies conducted at small (30 to 100 acres), heavily forested watersheds in the mountains of central New Hampshire indicate that the forest ecosystem removes pollutants by filtering air and water that flow through the landscape. A forest regulates the chemical quality of water percolating through it into streams or underground. Forest soils act as filtation systems between polluted rain and water supplies for human consumption. Data collected over 10 years indicate that the amount of nitrate, a naturally occurring compound and byproduct of automobile exhaust, is increasing in rain; most of the nitrate is being held within the forest ecosystem. Rain in northeastern U.S. is becoming more acidic as a result of increasing use of fossil fuels, which contribute sulfur and nitrogen pollutants in the atmosphere.

133
BORNEMISZA, E., and LLANOS, R., 1967, Sulfate movement, adsorption, and deposition in three Costa Rican soils: Soil Science Society of America, Proceedings, v. 31, p. 356-360.

The movement, absorption, and desorption of sulfate and factors affecting it were studied in samples from the A and B horizons of three different soils from Costa Rica. Results indicate that little sulfate movement occurred. Very concentrate-dependent absorption of sulfate was observed in alluvial soils but not in latosols. Phosphate solutions, when used as desorbants, produced less variable sulfate desorption rates than water in the three soil types.

134
BOSTROM, K., 1967, Some pH-controlling redox reactions in natural waters, in Equilibrium Concepts in Natural Water Systems: Washington, D.C., American Chemical Society, Advances in Chemistry Series 67, p. 287-311.

Stoichiometric model systems are used to show that some naturally occurring redox processes have a distinct pH-controlling action, even in the presence of substances with a buffering capacity. High pH values can be found in systems where higher metal oxides act as oxidizers. An acid condition often develops when free oxygen is the oxidizer. Carbonates and silicates have a greater control over pH than redox processes.

135
BOSWELL, J. G., 1955, The microbiology of acid soils. IV. Selected sites in northern England and southern Scotland: New Phytologist, v. 54, p. 311-319.

Soil samples were collected from 1946-49 at sites in northern England and southern Scotland at altitudes above 225 m. Soil samples were studied for fungal and bacterial activity. Results indicate that fungi may sporulate less actively in acid soils. The heterotrophic bacteria isolated from the soils studied fermented a wide variety of sugars producing acid; acid production was partially dependent on the form in which nitrogen was supplied.

136
BOTKIN, D. B., and ABER, J. D., 1979, Some potential effects of acid rain on forest ecosystems--implications of a computer simulation: Upton, N.Y., Brookhaven National Lab., Report BNL-50889, 12 p.

The effects of acid precipitation on forest productivity and species composition were analyzed on a theoretical computer model that was originally designed for the Hubbard Brook Experimental Forest in the White Mountains of New Hampshire. The model successfully simulated the population dynamics of trees in a forest. Simulations indicate that a growth reduction of 10 to 25 percent per year for a species is needed to significantly change the role of the species or the total biomass of the forest.

137
BOUERES, L. C. S., and others, 1977, Sulfur and heavy metals in South American urban and nonurban atmospheres, in World Meteorological Organization, Air pollution measurement techniques: Geneva, Switzerland, World Meteorological Organization, Special Environmental Report no. 10, WMO-no. 460, p. 102-108.

138
BOULAUD, D., BRICARD, J., and MADELAINE, G., 1978, Aerosol growth kinetics during SO_2 oxidation, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 171-177.

Consideration is given to the water vapor/sulfuric acid mixture and, after discussing the theoretical results obtained by various authors, they are applied to the case of the atmospheric conditions after having introduced the notion of heteromolecular condensation. With consideration being given to the latter, it is shown that these results lead to orders of magnitude which are comparable to the results of simulation studies currently in progress.

Then the evolution of the aerosol formed in this manner is studied in the case of a continuous addition of sulfuric acid vapor and, at the end of a sufficient period of contact between the particles and the vapor, their subsequent growth through condensation is evaluated. [Abstract reprinted by permission of Pergamon Press.]

139
BOWERSOX, V. C. and De PENA, R. G., 1980, Analysis of precipitation chemistry at a central Pennsylvania site: Journal of Geophysical Research, v. 85, no. 10, p. 5614-5620.

139 (continued)
Precipitation samples were collected on an event basis at a rural site in central Pennsylvania and analyzed for sulfate, nitrate, ammonium, and hydronium ions. Results show that sulfate concentration varies with season, with high values in summer and low values in winter. Sulfate ion is the major determinant of acidity; however, sulfate alone does not account for total hydronium ion concentration.

140
BOYCE, S. D., and BUTCHER, S. S., 1976, The effect of a local source on the composition of precipitation in south-central Maine: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 375-384.

Bulk precipitation samples were collected from ten sites in south-central Maine during the period 18 June to 30 September, 1974. Data from the chemical analyses of the precipitation were used to determine regional deposition patterns of the ionic constituents. Acidic pH values ranging from 3.8 to 5.0 are characteristic of the region, but relatively alkaline pH values of 5.5 to 7.0 were observed in the precipitation from one collection site. Systematic increases in sulphate and Na deposition in the samples from this site suggest a local source.

The observations of the bulk precipitation analysis lead to a study of the chemical composition of precipitation near a kraft paper mill. Samples were collected during single precipitation events. The results indicate that this source can affect background levels of composition up to a distance of at least 20 km and that considerable care must be taken in the selection of sites for sampling background precipitation. [Abstract reprinted by permission of D. Riedel Publishing Company.]

141
BRADFORD, G. R., PAGE, A. L., and STRANGHAN, I. R., 1981, Are Sierra lakes becoming acid?: California Agriculture, v. 35, no. 516, p. 6-7.

Samples from 170 Sierra lakes were analyzed for pH in 1965 and compared with data from 114 lakes in October 1980. Results show no significant change in the acidity of lake waters in the Sierras during the past 15 years. Mean pH of lakes sampled was 6.0, 6.1, and 6.5 in September 1965, July 1980, and October 1980, respectively. Acid precipitation, as evidenced by low pH values in precipitation in coastal and interior valleys near urbanized areas, may be diluted and partly neutralized by the time it reaches the high Sierra.

142
BRADLEY, J. P., GOODMAN, P., CHAN, I. Y. T., and BUSECK, P. B., 1981, Structure and evolution of fugitive particles from a copper smelter: Environmental Science and Technology, v. 15, no. 10, p. 1208-1212.

Information on determining structure and evolution of fugitive particles is useful for assessing the environmental impact and possible abatement of particulate emissions from copper smelters and other industries. This article describes a method for tracing airborne particles back to a parent copper smelter and to the stage of the smelting process at which they were generated. The chemical and physical evolution of the particles under investigation are reconstructed.

143
BRAEKKE, F. H., 1980, Sulphate dynamics in natural environments--preliminary results from a case study, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 156-157.

144
BRAEKKE, F. H., 1981, Hydrochemistry of high Altitude catchments in south Norway, 1. Effects of summer droughts and soil-vegetation characteristics: As, Norway, Reports of the Norwegian Forest Research Institute, v. 36, no. 8, 26 p.

This is the first of three articles describing the hydrochemistry of two high-altitude catchments in southernmost Norway. Data were collected from July 1974 to December 1978. The watersheds were sinks for $H+$, NO_3, NH_4, and SO_4 and sources for Na, K, Ca, Mg, and Al. Greater evapotranspiration and $H+$ release occurred with increased peatland cover. Output of most other cations as well as SO_4, and Cl was reduced with peatland cover also. H^+- and SO_4-peaks occurred in fall stormflow after very dry summers, but when summers had normal rainfall, peaks for these components occurred in early spring. Data analyses indicate that SO_4 was the dominant anion in output water, which caused acidic conditions and set the leaching pattern for cations other than H^+.

145
BRAEKKE, F. H., 1981, Hydrochemistry of high altitude catchments in south Norway, 2. Water chemical gradients inside a catchment: As, Norway, Reports of the Norwegian Forest Research Institute, v. 36, no. 9, 39 p.

This is the second report in a series of three on the hydrology and hydrochemistry of catchments in southernmost Norway. These ecosystems have a significant impact on the water chemistry of outflows, particularly SO_4, H^+, Ca, Na, Al, and K. The low pH of water from barren bedrock and smaller bedrock openings seem to be due to sulfuric and nitric acid; the low pH of percolation and ground water seems to be due to peat sulfuric acid.

146
BRAEKKE, F. H., 1981, Hydrochemistry of high altitude catchments in south Norway, 3. Dynamics in waterflow and in release--fixation of sulphate, nitrate, and hydronium: As, Norway, Reports of the Norwegian Forest Research Institute, v. 36, no. 10, 21 p.

This report is the third in a three-part series on the hydrochemistry of two, high altitude catchments in southernmost Norway. Ground-water zones of mire ecosystems are strong sinks for nitrate and sulfate; mineral soil is the strongest sink for hydrogen ion. A mathematical model of water throughflow is developed; it shows that 62 percent of outflow from the catchment is chemically influenced by the peatlands.

147
BRAEKKE, F. H., 1981, Hydrochemistry in low-pH-soils of south Norway, 1. Peat and soil water quality: As, Norway, Reports of the Norwegian Forest Research Institute, v. 36, no. 11, 32 p.

This is the first of two articles examining the hydrochemical effects of acid precipitation on soligenous peatlands in southernmost Norway. Data were collected from five catchments from 1973-76. The peat layers that were studied had very low base satuation and high aluminum content. Strong acids significantly influenced pH in percolation and ground water of the peatlands; the average pH was 4.3. Water from barren bedrock plains had the highest aluminum concentration; percolation water in peat had the lowest. Aluminum leaching is increased by acidification of soils; however, the amount leached is not always indicative of the degree of acidification in a catchment.

148
BRAEKKE, F. H., 1981, Hydrochemistry in low-pH-soils of south Norway, 2. Seasonal variation in some peatland sites: As, Norway, Reports of the Norwegian Forest Research Institute, v. 36, no. 12, 22 p.

This article is the second of a two-part series summarizing hydrochemical data collected from five catchments in southernmost Norway from October 1973 through October 1976. Results of analyses show that hydrogen ion (H^+) of strong acids was a dominant cation in free water of all catchments, particularly in winter, spring and fall. H^+ concentration correlated well with sulfate

148 (continued)
(SO_4) concentration. It appears, therefore, that sulfuric acid is hydrochemically important to the ecosystems of these catchments. After very dry summers, when the water table was low, SO_4 was probably released from the ground water of the peatland as a result of oxidation. SO_4 was removed during the rest of the year by reduction processes. Peaks for the release of most cations occurred in September as noted for SO_4. Significant peaks in leaching for NH_4 and K from root zone in mires occurred in August. Channelled water flow through the catchment was about 1/3 of precipitation. This chemically unchanged water fraction could be important in the study of the effects of acid precipitation on terrestrial and limnic acidification.

149
BRAKKE, D. F., 1977, Rainwater--nutrient additions to a hypereutrophic lake: Hydrobiologia, v. 52, no. 2-3, p. 159-163.

Low pH values was observed in rainfall samples collected near Lake Sallie, Minn. Despite the low pH values, it contained less than 2 mg/L sulfate and had insignificant effects on the pH of well-buffered Lake Sallie. Increases and washout of dissolved nitrogen were observed in single rainfalls. Higher concentrations of ammonia than nitrate were found. Loading of atmospheric nitrogen may stimulate algal production.

150
BRAKKE, D. F., 1980, Atmospheric deposition in Norway during the last 300 years as recorded in SNSF lake sediments, U.S.A. and Norway. III. Cladoceran community structure and stratigraphy, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 272-273.

151
BRAUN, R. C., and WILSON, M. J. G., 1970, The removal of atmospheric sulfur by building stones: Atmospheric Environment, v. 4, p. 371-378.

The amount of sulfur (S) taken up by limestone from ambient air, and the amount taken up from mixtures of sulfur dioxide (SO_2) in a laboratory, were measured. The weathered surface of a limestone sample that had been exposed to the atmosphere for 5 centuries absorbed S as fast as a fresh surface cut from the same block. This finding, together with the low concentration of S near the surface of the stones, suggest that their surface reactivity was affected by removal of calcium sulfate in solution by rainwater.

152
BRESSAN, R. A., WILSON, L. G., and FILNER, Philip, 1978, Mechanisms of resistance to sulfur dioxide in the Cucurbitaceae: Plant Physiology, v. 61, p. 761-767.

This article examines the degree of injury caused by sulfur dioxide (SO_2) in four cultivars of *Cucurbita pepo* (squashes and pumpkins) and *Cucumis sativus* (cucumbers). The generic variation of plant resistance to SO_2 is attributed to differences in the rate of absorption of the gas. Whether the differences in rates of absorption are caused by differences in stomatal activity has not been determined.

153
BREZONIK, P. L., 1976, Nutrients and other biologically active substances in atmospheric precipitation: Journal of Great Lakes Research, v. 2, supplement no. 2, p. 166-186.

This article discusses sources and factors affecting concentrations of biologically active compounds in precipitation. Emphasis is on nitrogen and phosphorus. Rainfall concentrations of these constituents are variable, and estimating flux is difficult. Atmospheric sources of nutrients can contribute significant fractions to the total nutrient loadings to many lakes.

154
BREZONIK, P. L., EDGERTON, E. S., and HENDRY, C. D., 1980, Acid precipitation and sulfate deposition in Florida: Science, v. 208, p. 1027-1029.

Rainfall acidity in Florida has significantly increased in the past 25 years and average sulfate and nitrate concentrations have increased by factors of 1.6 and 4.5, respectively. Rainfall samples were collected at 24 sites in Florida from 1977-79 and analyzed for pH, conductivity, major ions, and other constituents. The northern three quarters of the State has annual average pH values below 4.7, and summer rainfall has average pH values 0.2 to 0.3 unit lower than winter rainfall. Sulfate concentrations are higher in summer.

155
BRICE, K. A., EGGLETON, A. E. J., and PENKETT, S. A., 1977, An important ground surface sink for atmospheric nitrous oxide: Nature, v. 268, p. 127-129.

Soil is considered a major source of atmospheric nitrous oxide (N_2O), and the ocean is considered both a source and a sink for this gas. The only sink that has been positively identified by atmospheric measurement is the stratosphere. This article presents evidence of an appreciable but unidentified ground-surface sink. Levels of N_2O in ambient air

155 (continued)
were measured, and a regular diurnal variation was observed. The authors suggest this variation is similar to that of gases such as sulfur dioxide, ozone, and peroxyacetyl nitrate, which are absorbed at ground-level surfaces. It is concluded that absorption of N_2O by vegetation or soil is the most likely explanation for the diurnal variation.

156
BRIGGS, R. T., 1972, SO_2--acid in the sky: The Ecologist, v. 2, no. 11, p. 18-23.

This article discusses the deleterious effects of sulfur dioxide (SO_2) emissions in Great Britain. The estimated quantity of sulfur dioxide discharged into the air is six million tons per year. SO_2 emissions are associated with visibility decreases during fog, corrosion of metal structures, and detrimental effects on chronic bronchitis patients.

157
BRIMBLECOMBE, P., and SPEDDING, D. J., 1974, The absorption of low concentrations of sulphur dioxide into aqueous solutions: Tellus, v. 26, no. 1-2, p. 272-276.

The deposition rate of gaseous sulfur dioxide to aqueous solutions representing a wide range of physical and chemical properties was measured. The deposition rate was unaffected by relative humidity. Some salts may cause a threefold decrease in deposition rate as the ionic strength increases from 0.1 M to 0.8 M.

158
BROCK, T. D., 1973, Lower pH limit for the existence of blue-green algae--evolutionary and ecological implications: Science, v. 179, p. 480-483.

Blue-green algae (*Cyanophyta*) were completely absent from habitats with pH values less than 4 or 5, whereas eukaryotic algae often proliferated. This article includes data on acidic, natural, and man-made habitats throughout the world. The data also include observations of algal distributions in natural pH gradients, and enrichment studies with media and inocula of various pH values.

159
BROMFIELD, A. R., 1974, The deposition of sulphur in the rainwater in northern Nigeria: Tellus, v. 26, no. 3, p. 408-411.

Sulfate concentrations as sulfur were measured at 11 sites at about 350 and 880 km from the sea in northern Nigeria during two rainy seasons. Concentrations at both sites were greatest at the beginning and end of the rains because of the presence of anthropogenic atmospheric sulfur, harmattan dust, and low precipitation. Concentrations were smallest at the peak of the rains because of dilution.

160
BRONIN, B. N., 1979, The principle of siting the control stations in long-range transport of air pollutants, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 79-84.

161
BROSSET, Cyrill, 1952, On the reactions of the aluminium ion with water: Acta Chemica Scandinavica, v. 6, p. 910-940.

Equilibrium conditions of the Al-OH system are studied through pH measurements. Observations of kinetic reaction conditions were used to determine reactions between aluminum ion and water.

162
BROSSET, Cyrill, 1973, Air-borne acid: Ambio, v. 2, no. 1-2, p. 2-9.

This article is a summary of the formation, occurrence, and atmospheric transport of airborne acid. It describes the conversion of sulfur dioxide to sulfuric acid and reports observations of the effects of acid particles from local and long-distance sources. It also discusses the effects of airborne acid on human health.

163
BROSSET, Cyrill, 1973, Danger of water pollution through air: Gothenburg, Swedish Water and Air Pollution, Report IVL-B-159, 1 v.

This book discusses the acidification of freshwater by airborne substances such as sulfur dioxide (SO_2). It presents models of the washout of SO_2 by precipitation and its oxidation to sulfuric acid (H_2SO_4) and includes data on deposition of strong acid by precipitation. Although extensive data on the acidity of airborne particulate matter are available, additional research is needed on the effects of airborne acid on water quality.

164
BROSSET, Cyrill, 1975, Acid particulate air pollutants in Sweden: Gothenburg, Swedish Water and Air Pollution Research Lab., Report IVL-B-222, 1 v.

Aerosols containing acid ammonium sulfate and generated by emissions from remote sources are affecting the air in Sweden. This report investigates the long-range transport of aerosols and mixing of these aerosols with particulates from local emissions.

165
BROSSET, Cyrill, 1975, The acidification of rain through the catalytic oxidation of sulfur dioxide: Gothenburg, Swedish Water and Air Pollution Research Lab., Report IVL-B-252, 32 p.

This article presentes a model of the oxidation of sulfur dioxide in aqueous solution based on the assumption that a catalytic ion and hydrogen sulfite ions form a sparingly soluble solid phase, which is oxidized by oxygen as soon as it is precipitated, resulting in the formation of sulfate ions and dissolution of the solid phase. The model is the basis of equilibrium calculations that explain some previous observations and may be used to make other similar calculations.

166
BROSSET, Cyrill, 1975, Determination of airborne acidity with some examples on the role of acid particles in acidification: Gothenburg, Swedish Water and Air Pollution Research Lab., IVL-B-226, 21 p.

Acidity of particles is determined by measuring the content of strong acids in leaching solutions of particle samples and in water draining from trees. A titration procedure based on Gran's plot is developed. The water soluble portion of particles sampled consists mainly of acid ammonium sulfates. It appears that acid particles become successively neutralized during transport over land by the uptake of ammonia.

167
BROSSET, Cyrill, 1976, Air-borne particles--black and white episodes: Ambio, v. 5, no. 4, p. 157-163.

"Black episodes" are defined periods of time when dark, airborne particles that contain ammonium sulfate and nitrate and are transported over Sweden from the European continent. Increased concentrations of sulfur dioxide (SO_2) and nitrogen may occur during "black episodes." Increased sulfate concentration of fine particles occurring during "black episodes" seems to be caused by catalytic oxidation of SO_2 with subsequent neutralization of the resulting sulfuric acid by ammonia. "White episodes" occur during dry, sunny weather when colorless, airborne particles that consist mainly of acid ammonium sulfate and are probably formed by a photochemical process are transported over the North Sea. Air flowing over Sweden that originates from the north contains low concentrations of particles and consists mainly of common salt and neutral ammonium sulfate.

168
BROSSET, Cyrill, 1976, A method of measuring airborne acidity--its application for the determining of acid content on long-distance transported particles and in drainage water from spruces: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 259-275.

The acid properties of particles have been investigated by means of measuring the content of mainly strong acid in leaching solutions of particle samples and in drain water from trees. The measurements are based on Gran's plot and on a study of its curvature. [Abstract reprinted by permission of D. Riedel Publishing Company.]

169
BROSSET, Cyrill, 1977, Determination of water soluble compounds produced by reactive gases in the atmosphere, in World Meteorological Organization, Air pollution measurement techniques: Geneva, Switzerland, World Meteorological Organization, Special Environmental Report no. 10, WMO-no. 460, p. 165-171.

170
BROSSET, Cyrill, 1977, Preliminary study of the possibility of a relationship between high acidity in lakes and high mercury content in their fish populations: Gothenburg, Swedish Water and Air Pollution Research Lab., IVL-B-378, 29 p.

Transport mechanisms of mercury to lakes in Sweden are investigated to determine similarities with the transport of acidic substances. Total concentration of mercury in the air on the west coast of Sweden does not seem to be related to the movement of high- or low-level winds. A positive correlation were found between mercury concentration in the air and the surface temperature of sea water. This article proposes a model of mercury deposition by the atmosphere to acid lakes.

171
BROSSET, Cyrill, 1978, Atmospheric formation, dispersion and deposition of acid substances: Gothenburg, Swedish Water and Air Pollution Research Institute, Report IVL-B-444, 14 p.

This article presents a qualitative analysis of the physical and chemical processes of atmospheric formation, dispersion, and deposition of acid substances based on results of a study conducted in Sweden. SO_2 and NO_x may oxidize in the atmosphere, and SO_2 may also oxidize after dry deposition. Oxidation of both may be photochemical or catalytic. Acid substances formed by these processes may be

171 (continued)
directly or indirectly introduced to a recipient in form of weak or strong acids. Dry deposition of SO_2 and probably HNO_3, and wet deposition of HSO_4 are the two forms of deposition responsible for acidification of waters observed in Sweden.

172
BROSSET, Cyrill, 1978, Investigation of the contributions of a point source to the acidification and to the content of sulfur dioxides in the surroundings: Gothenburg, Swedish Water and Air Pollution Research Lab., Report IVL-B-447, 94 p. [in Swedish]

The contribution of emissions from a glass-making factory in Halmstad, Sweden, to the total amount of sulfur dioxide in the surrounding area were measured in 1977. These data were used to calculate future emissions. Results of current emissions of sulfur dioxide were well below the maximum level established by Swedish public-health standards.

173
BROSSET, Cyrill, 1978, The role of ammonia in the chemistry of atmospheric aerosols: Gothenburg, Swedish Water and Air Pollution Research Institute, Report IVL-B-449, 33 p.

Concentrations of hydrogen ion (H^+) and ammonium ion (NH_4^+) in the water-soluble portion of airborne fine particles were determined. The concentration quotient, H^+/NH_4^+, varies systematically, which indicates that particles in air over agricultural areas take up ammonia. The particles seem to release this component in forested regions with the deposition of acidic precipitation.

174
BROSSET, Cyrill, 1978, Water-soluble sulphur compounds in aerosols, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 25-38.

Sampling of particles and analysis of their water-soluble part for H^+, NH_4+, SO_4^{2-} and NO_3^- were carried out in a remote and an urban area on the Swedish west coast. For the determination of H^+ a special procedure based on Gran's plot was used. High concentrations of sulphate were found in two types of particles of apparently different genetic origin. In fine particles the following solid sulphate phases were identified: $(NH_4)_2SO_4$, $(NH_4)_3H(SO_4)_2$ and NH_4HSO_4. Conditions for the formation and range of existence of these phases are discussed. The observed sulphate maxima are divided according to genetic and to some extent geographic origin of the particles into black and white episodes. Black episodes are associated with Continental air. They are accompanied by increased concentrations of nitrate, dark components and metals, e.g. Mn. Particles characteristic of white episodes seem to occur in air masses of varying origin. The sulphate maxima in this category are usually accompanied by hydrogen ion maxima, and minima for nitrate, dark components and metals. The formation of particle-borne ions in an urban area (Gothenburg, population 500,000) was also studied. For sulphate, this local contribution was found to be 16% of the mean concentration. Processes which might lead to black and white episodes are discussed. [Abstract reprinted by permission of Pergamon Press.]

175
BROSSET, Cyrill, 1979, Factors influencing pH in lake water: Water, Air, and Soil Pollution, v. 11, p. 57-61.

The reduction of pH in lake water containing no humic acid is calculated as a function of strong-acid deposition. Higher concentrations of an acid ($Ka = 3 \times 10^{-4}$), which seems to correspond to a functional group of humus, may under some conditions drastically contribute to lowering the pH of lake water.

176
BROSSET, Cyrill, 1980, The acid-base balance in lake water: Gothenburg, Swedish Water and Air Pollution Research Institute, Report IVL-B-540, 21 p.

The acid-base content of lake water is composed of strong base or acids, weak acids (mostly fluvic acid), and carbonic acid. Acidity may be determined through a simple titration method. Sometimes the concentration of undissociated carbonic acid is not in equilibrium with carbon dioxide concentration in air. Cases of observed supersaturation seem to be connected to the concentration of fluvic acid.

177
BROSSET, CYRILL, 1980, The fate of sulphuric acid aerosol in the atmosphere, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 145-152.

The phase diagram for $(NH_4)_2SO_4$-H_2SO_4-H_2O presented by Tang et al. (1978) was complemented with tie lines for the ammonia equilibrium concentration over the liquid phase (Lee and Brosset, 1979).

Such a complete diagram provides information essentially on the phase composition attained by a sulphuric acid droplet in equilibrium with the atmosphere. This composition can also be calculated if the relative humidity (r.h.) and the concentration of ammonia (pNH_3) of the atmosphere are known.

177 (continued)
Whether such calculations reflect real conditions or not depends on the equilibrium adjustment, i.e., if it is sufficiently fast relative to the variation in temperature (t), r.h., and $p\mathrm{NH}_3$ of the atmosphere.

Is was shown that the graphic correlation between r.h. and log $p\mathrm{NH}_3$ provides direct information on the phases present and their possible transformations. Such information, obtained through measurement of r.h. and $p\mathrm{NH}_3$, was in good agreement with particle composition established through chemical analysis. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

178
BROSSET, Cyrill, 1980, A method for evaluating the acid-base balance in natural waters: Water, Air, and Soil Pollution, v. 14, p. 251-265.

This article describes a method for evaluating total acid-base balance in lake-water samples. Calculations of the concentration of stong base or acid produced good results. The method of calculation may give somewhat less accurate results for carbonic acid in samples that are highly acidic.

179
BROSSET, Cyrill, and AKERSTROM, A., 1972, Long distance transport of air pollutants--measurements of black air-borne sulphur in Sweden during the period of September-December 1969: Atmospheric Environment, v. 6, p. 661-673.

Daily mean values of black, airborne particulate matter (soot) and particle-borne sulfur were calculated from data collected at 53 sites in Sweden to determine the long-distance transport of these pollutants. Daily variations in the occurrence of soot recorded at sites about 400 km apart followed a uniform pattern. A similar pattern was recorded for particle-borne sulfur at two sites about 500 km apart.

An appendix discusses a method developed in this study to determine sulfur in airborne particles through X-ray fluorescence.

180
BROSSET, Cyrill and FERM, Martin, 1976, Man-made airborne acidity and its determination: Gothenburg, Swedish Water and Air Pollution Research Lab., Report IVL-B-341A, 35 p.

Airborne acidity produced by man is defined as an unneutralized part of hydrogen ions that are introduced into precipitation or particulates as sulfuric acid and nitric acid. The unneutralized part of hydrogen ions can be determined from Gran's plot when the slope is the pseudolinear interval

180 (continued)
($C_{H+} \leq \cdot 10^{-4}$ eq/l). If the slope in the pseudolinear interval of the plot does not correspond to the sulfate concentration in the sample, other weak acids are interfering.

181
BROSSET, Cyrill, and FERM, Martin, 1978, Man-made airborne acidity and its determination: Atmospheric Environment, v. 12, p. 909-916.

Airborne acid from man-made sources primarily consists of sulfuric acid (H_2SO_4) and nitric acid (HNO_3), which are formed through the oxidation and hydrolization of sulfur dioxide (SO_2) and nitrogen dioxide (NO_2), respectively. The degree to which acids are neutralized depends on relative humidity and partial pressure of ammonia. The unneutralized part of the acids H_2SO_4 and HNO_3 can be determined through Gran's plot.

182
BROUZES, R. J. P., 1979, The use of high pH liming for primary treatment of municipal sewage--a summary statement, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 126-135.

183
BROWN, B. B., 1979, Protecting air quality in parks, in, Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 257-259.

184
BROWN, D. J. A., SADLER, K., HOWELLS, G. D., and KALLEND, A. S., 1980, Fish and freshwater chemistry, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 280-281.

185
BROWN, R. T., 1977, Snow as an accumulator of air pollutants: Water, Air, and Soil Pollution, v. 8, no. 1, p. 35-39.

Using simple analytical techniques, the amounts of air pollutants accumulated in winter snow were determined, and the results correlated with lichen survival on trees. Pollutants measured were particulate matter, sulfate, and chloride. An inverse relationship was found between amounts of each of these pollutants and the abundance of various lichens. [Abstract reprinted by permission of D. Riedel Publishing Company.]

186
BROWNSCOMBE, J. L., 1972, Sulphur in rainwater and air at some relatively clean sites in the British Isles from 1959 to 1970: Food and Agriculture Journal, v. 23, p. 1146-1147.

Air and rainwater samples were collected monthly from 1959-69 at three sites in Great Britain to monitor long term trends of sulfur concentrations. A maritime environment, an isolated rural area, and an area of rapid urban growth were selected as sampling sites. More than 70 percent of the total airborne sulfur at two sites was in the form of particulate matter. The median concentration of sulfur in rainwater ranged from 1.2 mg/L to 3.3 mg/L.

187
BRUBAKER, K. L., and ROTE, D. M., 1978, Dispersal models for sulfur oxides in urban environments, in Nriagu, J. O., ed., Sulfur in the environment, part 1--The atmospheric cycle: New York, John Wiley, p. 171-241.

188
BRUHN, J. N., PARMETER, J. R., Jr., and COBB, F. W., Jr., 1980, Oxidant impact on Ponderosa and Jeffrey pine foliage decomposition, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 229.

189
BRYANT, R. D., GORDY, E. A., and LAISHLEY, E. J., 1979, Effect of soil acidification on the soil microflora: Water, Air, and Soil Pollution, v. 11, p. 437-445.

Bacterial population and total soil respiration were determined for two Alberta soils to assess the short- and long-term effects of acidification. Bacterial population was significantly reduced in soil that had been acidified for long and short periods. Total soil respiration was significantly reduced in an acidified soil with a pH of 3.0 (long term) adjacent to a stockpile of elemental sulfur; however, a garden soil (pH 7.7) acidified to pH 3.2 showed no significant reduction in total soil respiration compared to its unacidified control soil.

190
BUCHAUER, M. J., 1973, Contamination of soil and vegetation near a zinc smelter by zinc, cadmium, copper, and lead: Environmental Science and Technology, v. 7, no. 2, p. 131-137.

190 (continued)
Soil and vegetation near a zinc smelter in Palmerton, Pa., have been contaminated with zinc, cadmium, copper, and lead because of metal oxide fumes emitted by the smelter. About 90 percent of metals deposited on the soil surface are retained in the top 15 cm of the soil profile. Metal aerosols may be entering leaves of depauperate trees directly, possibly through open stomates.

191
BUCKLEY, D. E., 1980, Rapporteur summary of panel discussion on terrestrial effects, in, Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 54-56.

192
BUDD, W. W., JOHNSON, A. H., HUSS, J. B., and TURNER, R. S., 1981, Aluminum in precipitation, streams, and shallow groundwater in the New Jersey Pine Barrens: Water Resources Research, v. 17, no. 4, p. 1179-1183.

Total aluminum (acid reactive) deposited in bulk precipitation at the McDonalds Branch basin, N.J. from May 1978 to May 1980 was 140 $(mg/m^{-2})/yr$. Outputs from streams and groundwater were 149 and 110 $(mg/m^{-2})/yr$. The input and output of aluminum were highest during summer because of elevated concentrations and increased precipitation and streamflow. Acid-reactive Al concentration in streams is correlated with concentration of dissolved organic matter, which suggests that Al is an organometallic complex. Al concentration in shallow ground water is controlled by gibbsite solubility in mineral soils and is therefore pH dependent. The relatively high aluminum concentrations in samples are attributed to acid conditions and mobile organic matter.

193
BUDIANSKY, Stephen, 1980, Acid rain and the missing link: Environmental Science and Technology, v. 14, no. 10, p. 1172-1173.

Little is known about the chemical pathways in the atmosphere that convert sulfur dioxide to nitrogen dioxide to the acids that are in rain. Observations of atmospheric sulfate show that the gas-phase of the photochemical oxidation process cannot account for total sulfate production. If photochemistry were the sole oxidation process that converts SO_2 to sulfate, then sulfate levels would diminish dramatically in winter. Some other processes such as heterogeneous reactions are a part of the sulfate production process.

194
BUDIANSKY, Stephen, 1981, Understanding acid rain: Environmental Science and Technology, v. 15, no. 6, p. 623-624.

This article discusses the complexity of acid precipitation. Varying weather conditions, soils, the presence of other pollutants, and species differences all affect the occurrence and effects of acid precipitation. The effects of acid precipitation on the forest ecosystem are difficult to evaluate because of the complexity of the system and difficulty in isolating the effects of individual pollutants.

195
BURNS, D. A., GALLOWAY, J. N., and HENDREY, G. R., 1981, Acidification of surface waters in two areas of the eastern United States: Water, Air, and Soil Pollution, v. 16, p. 277-285.

This article compares the acidification of surface waters in the White Mountains of New Hampshire and the Blue Ridge Mountains of North Carolina. Water samples from each region were collected during the summer of 1979 and analyzed for pH and alkalinity. Comparison of the results of these analyses with data from the early 1960's for North Carolina and data from the early 1930's for New Hampshire confirm that some acidification has occurred in both areas and that acidification of surface waters is more pronounced in New Hampshire.

196
BURROWS, W. D., 1977, Aquatic aluminum--chemistry, toxicology, and environmental prevalence: CRC Critical Reviews in Environmental Control, v. 7, no. 2, p. 167-216.

This article is a review of significant research on aluminum (Al) in the aquatic environment. It consists of three sections--toxicity, pollution of natural waters, and environmental prevalence. The section on toxicity includes aquatic animals, microorganisms, and higher plants, and omits discussions of toxicity effects on human health. The section on Al pollution in waters is of particular interest to acid precipitation researchers because it reviews the chemistry of Al in water and methods for determining its concentrations in water. The section on environmental prevalence gives extensive data on the Al concentration of world lakes, rivers, and subsurface waters. The article cites 225 bibliographic references.

197
BUSLER, I. V., MAKSIMOV, V. V., and MATVEYEV, A. A., 1973, Collector-analyzer for continuous automatic recording of the temperature, pH and electric conductivity of atmospheric precipitation: Soviet Hydrology--Selected Papers, no. 4, p. 381-387.

197 (continued)
An automatic analyzer for temperature, hydrogen ion concentration, and electric conductivity was tested on a precipitation collector. The automatic analyzer measures and records these values during the entire precipitation event and, at the end of the event, it automatically prepares for the next operating cycle. Use of this instrument does not preclude chemical analysis for other components.

C

198
CADLE, R. D., and LEDFORD, Margaret, 1966, The reaction of ozone with hydrogen sulfide: Air and Water Pollution--An International Journal, v. 10, p. 25-30.

This article describes the kinetics and products of the gas-phase reaction of ozone with hydrogen sulfide in a carrier gas consisting of a mixture of oxygen and nitrogen. Sulfur dioxide and water were the only products found. Reaction kinetics were evaluated with a flow system, and a method was developed for titrating with nitric oxide the ozone remaining after reaction with hydrogen sulfide. The reaction had orders near zero and 1.5 in hydrogen sulfide and ozone, respectively. The reaction seems at least partially heterogeneous.

199
CALIFORNIA AIR RESOURCES BOARD, 1981, Acid precipitation and its occurrence in California: Sacramento, California Air Resources Board, 14 p.

This report documents the occurrence of acid precipitation in California. Acid precipitation in California is produced locally, and long-distance transport of sulfuric and nitric acids is as significant as in the northeastern United States. Furthermore, nitric acid is a major contributor to the acidity of precipitation, in contrast to conditions in the northeast. Soils and lakes in the Sierra Nevada region of the State are particularly sensitive to acid precipitation. Additional research on the magnitude of the effects of dry deposition on freshwater and soil chemistry is needed.

200
CALLAHAN, C. J., 1979, Persistent elevated pollution episodes, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 15-18.

201
CALVERT, J. G., BOTTENHEIM, J. W., and STRAUSZ, O. P., 1978, Mechanism of the homogeneous oxidation of sulfur dioxide in the troposphere, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 197-226.

An evaluation has been made of the existing kinetic data related to the elementary, homogeneous reactions of SO_2 within the troposphere. A set of preferred values of the rate constants for these reactions is presented. Simulations using these data provide significant new evidence that the oxidation of SO_2 can occur at substantial rates through these homogenous reaction paths. The direct photo-oxidation of SO_2 by way of the electronically excited states of SO_2 is relatively unimportant for most conditions which occur within the troposphere. The oxidation of SO_2 within the natural troposphere is expected to occur largely by way of reactions 39, 31, and 33, with reaction 39 being the dominant path: $HO + SO_2$ (+M) -> $HOSO_2$ (+M) (39); $HO_2 + SO_3$ (31); $CH_3O_2 + SO_2$ -> $CH_3O + SO_3$ (33). By combining our kinetic estimates with the Crutzen and Fishman calculation of [HO], [HO_2], and [CH_3O_2] for the troposphere, we estimate that the total rates of SO_2 oxidation as high as 1.5% h^{-1} are expected at midday in July in the midlatitudes. Theoretical estimates of the monthly rates averaged over the northern hemisphere vary from a low of 0.1% h^{-1} in January to a maximum of about 0.2% h^{-1} in July. From our computer simulations of the reactions within an SO_2, NO_x, hydrocarbon, CO, aldehyde-polluted lower troposphere, it is predicted that the three reactions, 39, 31, and 33 occur with about equal rates; SO_2 oxidations for this case can procede homogeneously at rates as high as 4% h^{-1}. Considerations of the reactions in stack gas plumes suggest that a small maximum in the SO_2 photo-oxidation rate may occur during the early stages of the dispersion of a parcel of the stack gases into the air. This should be followed by a short period of slower oxidation. In theory the initial burst is expected to arise from NO_2 and HONO photolysis followed by reaction 39 and the reaction, $O(^3P) + SO_2$ (+M) -> SO_3 (+M). After the extensive dilution of the stack gases by polluted urban air, the rate of SO_2 homogeneous oxidation is expected to approach that for a typical polluted urban atmosphere (.4% h^{-1}). [Abstract reprinted by permission of Pergamon Press.]

202
CANADA, ATMOSPHERIC ENVIRONMENT SERVICE, 1981, A Canadian research activity catalogue on the long-range transport of air pollutants and acidic precipitation: Downsville, Ontario, Environment Canada, 372 p.

202 (continued)
A summary is given of 328 research projects being conducted in Canada to investigate the long-range transport of air pollutants. The objective, methods, costs, principal investigator, and anticipated results are given for each project.

203
CANADA, INLAND WATERS DIRECTORATE, WATER PLANNING AND MANAGEMENT BRANCH, 1981, Susceptibility of aquatic ecosystems to the effects of atmospheric pollutant fallout in Quebec: Environment Canada, Scientific Series no. 118, 46 p.

This article summarizes the impact of airborne pollutants on productivity and natural cycles in aquatic ecosystems and evaluates the sensitivity of natural waters to acidification in terms of pH, calcium, calcium saturation index, alkalinity, sulfates, and minor ions. Two interpretive methods were applied to water-quality data for 194 lakes in the Province of Quebec to evaluate the sensitivity of these lakes to acidification; a map showing susceptibility of Quebec lakes is given. Appendices list (1) principal committees on acid rain, (2) historic data sources, and (3) literature on acid rain.

204
CANTRELL, B. K., and WHITBY, K. T., 1978, Aerosol size distributions and aerosol volume formation for a coal-fired power plant plume, in Sulfur in the atmosphere, Proceedings, of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 323-333.

During the summer of 1976, the plume from the Labadie power plant near St. Louis, Missouri was mapped on two days using an instrumented aircraft. The mapping consisted of measuring horizontal and vertical concentration profiles of both aerosol and gas contaminants for cross-sections of the plume. Measurements were made for plume travel times of up to 2 h and distances downwind of up to 50 km.

Aerosol size distribution determinations were made in both the plume and surrounding background air mass. Characterization of these distributions were done in terms of two additive log-normal functions: one describing nuclei less than 0.03 µm in size, and the second describing accumulation mode aerosol between 0.03 and 1.0 µm. On the average, results show that distribution of the nuclei volume for aerosol size less than 0.03 µm in both plume and background can be parameterized with a geometric mean size of 0.021 ± 0.005 µm and a geometric standard deviation of 1.5 ± 0.1. Total nuclei volume is found to be about 1% of total submicron aerosol volume. For aerosol larger than 0.03 µm, the geometric mean size of aerosol volume distributions in a daytime plume under uniform

204 (continued)
meteorological conditions was found to be 0.18 ± 0.02 μm. This is significantly different from the 0.23 ± 0.01 μm measured for background air. The dispersion of the distribution in size range, measured by a geometric standard deviation of 1.92 ± 0.04, does not change significantly from in-plume to background. For a plume, measured in a morning transition period where average aerosol volume concentrations reached 87 $\mu m^3 cm^{-3}$, average volume mean geometric size for in-plume aerosol was 0.15 ± 0.01 μm vs 0.18 ± 0.01 μm in the background. Here, dispersion of the size distribution was narrower in the plume, with $s_g = 1.63 \pm 0.04$ vs 1.86 ± 0.3 for background aerosol.

Together with the integral Aitken nuclei concentration and ^{b}scat values, the aerosol size distribution measurements have been used to reconstruct the aerosol time history, up to two hours, for the various plumes investigated. Total aerosol volume flow through each cross-section of the plume has been calculated. When corrected for background levels, this flow is generally found to increase with time from levels as low as 60 $cm^3 s^{-1}$ to about 400 $cm^3 s^{-1}$. Assuming the excess volume formed is sulfuric acid in equilibrium with water vapor at the ambient r.h., we obtain an average SO_2 conversion rate of 0.7 ± 0.4% h^{-1} for the first 2 h of plume development. [Abstract reprinted by permission of Pergamon Press.]

205
CARLSON, C. L., and RAGSDALE, H. L., 1980, Effects of simulated acid rain on the uptake and accumulation of cadmium and zinc in *Pinus strobus* L.: Association of Southeastern Biologists Bulletin, v. 27, no. 2, p. 27.

[An abstract of paper presented at the 41st Annual Meeting of the Association of Southeastern Biologists, April 1980.]

Pinus strobus L. seedlings were potted in zinc-cadmium amended Norfolk loamy sand soil and treated for 10 weeks with solutions of pH 5.3, 4.0, 3.0, and 2.0. After the solutions were administered, leachate pH was about 6.0, indicating the strong buffering capacity of this soil. The solubility of cadmium and zinc increased at pH 2.0, at which the buffering capacity of the soil was exceeded.

206
CARLSON, R. W., 1979, Reduction in the photosynthetic rate of *Acer*, *Quercus* and *Fraxinus* species caused by sulphur dioxide and ozone: Environmental Pollution, v. 18, p. 159-170.

This article examines the relative sensitivity of photosynthesis in sugar maple *Acer saccharum* marsh, black oak *Quercus velutina* Lamb, and white ash *Fraxinus americana* L. to fumigation with sulfur dioxide (SO_2) and ozone (O_3). Trees were fumigated with each substance alone and in concert at different levels of light intensity and relative humidity. SO_2 reduced photosynthesis to 26, 57, and 93 percent for black oak, sugar maple, and white ash, respectively, after 3 weeks of fumigation; O_3 reduced photosynthesis to 57, 45, and 94 percent, respectively.

207
CARRICK, T. R., 1979, The effect of acid water on the hatching of salmonid eggs: Journal of Fisheries Biology, v. 14, p. 165-172.

The tolerance of salmon (*Salmo salar*), sea trout and brown trout (*Salmo trutta*) eggs to acid water and the effects of fertilizing eggs in acid water was studied for three winters. Results indicate a considerable yearly variation in the number of eggs that hatched, but little difference among the three species in the tolerances of the eggs to acid water. A pH value of 3.5 was lethal to all eggs within 10 days; at pH 4.5 and higher, there was no obvious difference in hatching attributable to acidity.

208
CARROLL, Dorothy, 1962, Rainwater as a chemical agent of geologic processes--a review: U.S. Geological Survey Water-Supply Paper 1535-G, 18 p.

This report presents chemical analyses of rainwater collected at sites in the United States, Europe, and southeastern Australia. It discusses the chemical composition and pH characteristics of rainwater extensively; including the geochemistry of the chemical components of rainwater. The pH values recorded for rainwater ranged from 3.0 to 9.8. The chemical composition of rainwater varied geographically, seasonally, and was affected by local conditions. The pH of rainwater varies considerably within any given area; both seasonal and regional patterns are noted.

209
CARTER, L. J., 1964, Effects of acidic and alkaline effluents on fish in seawater: Effluent and Water Treatment Journal, v. 4, no. 10, p. 484-486.

Survival times of several species of fish in acidic and alkaline seawater and brackish water under controlled conditions were measured in a laboratory. If the pH of seawater is within the range of 5.5 to 9.0, fish mortalities are unlikely. Large effluent discharges probably will not alter pH over substantial areas because of the buffering capacity of seawater.

210
CARTER, L. J., 1979, Uncontrolled SO_2 emissions bring acid rain: Science, v. 204, p. 1179-1182.

This article discusses "new source performance standards" (NSPS) issued by EPA to reduce sulfur dioxide (SO_2) emissions from newly constructed powerplants. Although NSPS limit SO_2 emissions from new plants to half the amount allowed under previous standards, total annual sulfur emissions from powerplants are expected to increase by nearly 2 million tons over the next 15 years. Because emission standards for coal-fired plants already in operation are not as stringent, many plants are not controlling SO_2 emissions at all. The article describes some alternative methods of controlling SO_2 emissions in existing plants.

211
CAVALLARO, N., and McBRIDE, M. B., 1980, Activities of Cu^{2+} and Cd^{2+} in soil solutions as affected by pH: Soil Science Society of America, v. 44, p. 729-732.

This study determines the pH dependence of copper and cadmium ions solubilities in soil solutions and water extractable organic materials from surface and subsurface horizons of a neutral and an acidic soil. Cu^{2+} solubility in soil is significantly dependent on pH because of the hydrolysis of Cu^{2+} in soils at pH values above 6 and removal of Al^{3+} and H^+ from exchange sites as the pH is raised. Cd^{2+} adsorption shows little pH dependence in comparison because of its tendency to hydrolyze and its inability to compete with other cations.

212
CHAKOUMAKOS, Charles, RUSSO, R. C., and THURSTON, R. V., 1979, Toxicity of copper to cutthroat trout (*Salmo clarki*) under different conditions of alkalinity, pH, and hardness: Environmental Science and Technology, v. 13, no. 2, p. 213-218.

Median lethal concentration values for acute copper toxicity is presented for nine combinations of alkalinity, hardness, and pH. Acute toxicity of copper is inversely correlated with water hardness and alkalinity. Results of copper biotoxicity studies conducted for 96 hours on small rainbow trout (*Salmo gairdneri*) are reported.

213
CHAMBERLAIN, A. C., 1980, Dry deposition of sulfur dioxide, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 185-197.

213 (continued)
Measurements of sulfur dioxide (SO_2) deposition are reviewed to provide estimates of dry deposition velocity under various conditions. The methods of study are broken into several major categories; data obtained by crop sulfur balances (budgets), atmospheric sulfur budgets, and direct gradient measurements are emphasized. The special cases of SO_2 deposition to forests, snow, and bare soil are also described, and a few exceptions to the results are noted. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

214
CHAMBERLAIN, A. C., and PENKETT, S. A., 1972, Atmospheric pollution--present trends and future problems: Contemporary Physics, v. 13, no. 2, p. 179-198.

This article discusses the sources and deposition of smoke and sulfur dioxide (SO_2) in the atmosphere with emphasis on particle size and chemistry of atmospheric aerosols at two sites in Great Britain. The amount of SO_2 in the air is much smaller than the amount of smoke in relation to the output of stacks, which suggests a rapid absorption of SO_2 at the ground surface. Pollution from motor vehicles and the influence of lead, nitrogen oxides, and hydrocarbons were investigated. Results indicate that the photochemical oxidation of SO_2 and NO_x and hydrocarbons may be more important than previously suspected. The article also discusses the effects of atmospheric pollution on visibility, vegetation, and human health.

215
CHANG, Fu-Hsian, and BROADBENT, F. E., 1980, Effect of nitrification on movement of trace metals in soil columns: Journal of Environmental Quality, v. 9, no. 4, p. 587-592.

Two soils, Omni silty clay and Delhi loamy sand, were treated with sludge to determine the effect of nitrification of ammonium in sludge on the mobility of cadmium (Cd), chromium (Cr), copper (Cu), magnesium (Mg), zinc (Zn), and lead (Pb). Nitrification resulted in a downward displacement of several of the metals, particularly Mn, Zn, Cu, and Cd in the untreated Delhi soil. Sludge had a distinct stabilizing influence on Cd and Zn, probably because of organo-metal complexes. Results of the study, however indicate that nitrification had relatively little effect on the mobility of metals.

216
CHAO, T. T., HARWARD, M. E., and FANG, S. C., 1962, Adsorption and desorption phenomena of sulfate ions in soils: Soil Science Society of America Proceedings, v. 26, p. 234-237.

216 (continued)
Equilibrium studies were conducted on 15 soil series to demonstrate the adsorption and desorption process of sulfate. Four soils exhibited a greater adsorption rate than the others. Results of isotopic exchange studies indicated that sulfate, which is retained by soils, is in kinetic equilibrium with sulfate in solution. Adsorption-desorption tests were conducted in retentive soils; results indicated that sulfate adsorption is dependent on the concentration of the equilibrium solution.

217
CHARLSON, R. J., COVERT, D. S., LARSON, T. V., and WAGGONER, A. P., 1978, Chemical properties of tropospheric sulfur aerosols, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 39-53.

Sulfur is widely recognized as an element present in atmospheric aerosol; however, only recently have data been acquired showing the dominance in industrial regions of submicrometer tropospheric aerosol by a family of sulfate compounds ranging from H_2SO_4 to $(NH_4)_2SO_4$. It is possible to infer the presence of other molecular forms and oxidation states. The overall picture is as yet qualitative, with semiquantitative evidence showing that both the urban and rural aerosols in the eastern third of the United States consist mainly of impure sulfate compounds containing substantial amounts of water, with metal and organic compounds as trace inclusions. Among chief physiochemical consequences of the dominance by sulfates are the fundamental nature of hygroscopic growth and predictable variations in refractive index. It is important to emphasize the role of omnipresent impurities and their possible effects. [Abstract reprinted by permission of Pergamon Press.]

218
CHARLSON, R. J., VANDERPOL, A. H., COVERT, D. S., WAGGONER, A. P., and AHLQUIST, N. C., 1974, Sulfuric acid--ammonium sulfate aerosol--optical detection in the St. Louis region: Science, v. 184, p. 156-158.

A nephelometric-sensing technique is used to determine the deliquescence of ammonium sulfate [$(NH_4)_2SO_4$] produced by the reaction of sulfuric acid (H_2SO_4) or ammonium bisulfate (NH_4HSO_4) aerosol with ammonia in the air. The system was operated at two urban sites and one rural site near St. Louis. Data from these experiments show that H_2SO_4, NH_4SO_4, and $(NH_4)_2SO_4$ are the dominant substances in the submicrometer, light-scattering aerosol.

219
CHEN, C. W., GHERINI, S. A., DEAN, J. D., and HUDSON, R. J. M., 1980, Overview of the integrated lake-watershed acidification study (ILWAS): Lafayette, California, Tetra Tech, Incorporated, 31 p.

The Integrated Lake-Watershed Acidification Study (ILWAS) began in 1977 and is conducted by staff from seven universities, a national laboratory, a federal agency, and a private research organization. The objectives of ILWAS are to investigate the lake-acidification process and develop a mathematical model of the transport and fate of the chemical constituents that are mobilized by acid precipitation. Field investigations are conducted at three forested watersheds in the Adirondack Mountains of New York. Each watershed has different basin characteristics, and the lakes differ in pH level. The major hypothesis of the study is that the differences in basin characteristics, topography, and vegetation among the three watersheds result in the differing pH values of the lake waters.

220
CHEN, C. W., GHERINI, S. A., and GOLDSTEIN, Robert, 1978, Modeling the lake acidification process: Palo Alto, California, Electric Power Research Institute, 58 p.

A mathematical model of the transport and fate of various chemical constituents that are mobilized by acid precipitation is being developed under the direction of the Electric Power Research Institute (EPRI). Lake acidification appears to be strongly influenced by the watershed vegetation, soil profile and composition, streams, and bogs. The model represents the total physical system by a cascade of compartments, which include components of the terrestrial and aquatic ecosystems. During its conceptual stage, the model is being used to determine future data needs. After the model is developed and verified, it will be used to test a system's response to decreased ambient levels of acidity in wet and dry deposition.

221
CHEN, C. W., and GOLDSTEIN, R. A., 1980, Integrated lake-watershed acidification study, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 230-232.

222
CHENEY, J. L., and HOMOLYA, J. B., 1979, Sampling parameters for sulfate measurement and characterization: Environmental Science and Technology, v. 13, no. 5, p. 584-588.

222 (continued)
This article evaluates a selective condensation system for use in determining primary sulfate emissions, with emphasis on sampling variables of flow rate and filter temperatures and their effects on separating gaseous H_2SO_4 from particulate-related sulfate. Non-comparable data are obtained when sampling includes variations of the variables. Flow rates in excess of 10 L/min and filter temperature of 271°C to 281°C are suggested.

223
CHOW, T. J., and EARL, J. L., 1970, Lead aerosols in the atmosphere--increasing concentrations: Science, v. 169, p. 577-580.

Geographic and seasonal trends in concentrations of atmospheric lead at San Diego, Calif. are studied in 1968-79. Results indicate that lead concentration in the atmosphere is increasing at 5 percent a year. The isotopic composition of lead aerosols is similar to that of lead additives in gasoline.

224
CHRISMAN, T. L., SCHULZE, R. L., BREZONIK, P. L., and BLOOM, S. A., 1980, Acid precipitation--the biotic response in Florida lakes, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 296-297.

225
CHRISTENSEN, E. R., and CHIEN, Nan-Kwang, 1981, Fluxes of arsenic, lead, zinc, and cadmium to Green Bay and Lake Michigan sediments: Environmental Science and Technology, v. 15, no. 5, p. 553-562.

This article presents fluxes of arsenic, lead, zinc, and cadmium for sediments in Green Bay and northern Lake Michigan and discusses the effect of manmade causes on these fluxes. Rivers and runoff flowing into Green Bay control the inflow of solids and trace elements to its sediments. Aerosol deposition is the major source of solids and Pb, Zn, and Cd in sediments at sites studied on northern Lake Michigan.

226
CHRISTOPHERSEN, Nils, BRUSTAD, K., DAHL, J. B., GULLIKSEN, T., NJOS, A., QVENILD, C., SEIP, H. M., and TOLLAN, Odd, 1980, Water residence distributions, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 284-285.

227
CHRISTOPHERSEN, Nils, and WRIGHT, R. F., 1980, Sulfate at Birkenes, a small forested catchment in southernmost Norway, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 286-287.

228
CHRISTOPHERSEN, Nils, and WRIGHT, R. F., 1981, Sulfate budget and a model for sulfate concentrations in stream water at Birkenes, a small forested catchment in southernmost Norway: Water Resources Research, v. 17, no. 2, p. 377-389.

A sulfate budget is developed for a gaged, coniferous-forested catchment on granitic bedrock of 0.41 km^2 in southernmost Norway. The budget is based on a 6-year record of precipitation quantity and chemical composition data and daily measurements of sulfur dioxide gas and sulfate aerosols. Fifteen percent more sulfate left the catchment in runoff than was added by dry and wet deposition. Inflow-outflow budget shows a seasonal pattern of accumulation of sulfate during summer and winter and washout during spring and autumn. Acidification of stream water and an increase in leaching of base cations from soil is a result of an annual sulfate flux that is five to tenfold greater than natural fluxes. A two-compartment model is developed that simulates sulfate concentrations in stream water and quantitatively accounts for cation leaching processes.

229
CHROST, L., and PINKO, L., 1980, The effect of calcium on the toxicity of zinc and lead compounds in the water medium, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 294-295.

230
CLESCERI, N. L., JOHANNES, A. H., ALTWICKER, E. R., KATZ, S., KOBAYASHI, S., SULESKI, T., and BARNES, C. R., 1978, Characterization of acidic precipitation in the Adirondack region: Rensselaer Fresh Water Institute at Lake George, FWI Report 78-4, 76 p.

The chemical composition of precipitation was monitored in three watersheds in the Adirondack Mountains of New York to determine temporal and spatial trends in acidic deposition. Samples were analyzed for pH, acidity, conductivity, and 11 major constituents. Data are given for January 1 through June 1978 A discussion of analytical methods is included.

231
CLESCERI, N. L., and VASUDEVAN, C., 1980, Acid precipitation, throughfall chemistry and canopy processes, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 258-259.

232
CLOUGH, W. S., 1973, Transport of particles to surfaces: Journal of Aerosol Science, v. 4, p. 227-234.

Deposition rates of particles to smooth surfaces and horizontal filter paper was measured in a large wind tunnel. Particles used for this experiment ranged from 0.08 to 30 μm. The effect of wind speed was also investigated. Deposition rates obtained through this experiment were then used to evaluate a dry deposition sampler made of filter paper, which has been used to sample natural aerosol.

233
CLYMO, R. S., 1967, Control of cation concentrations, and in particular of pH, in *Sphagnum* dominated communities, in Golterman, H. L., and Clymo, R. S., eds., Chemical environment in the aquatic habitat: Amsterdam, The Netherlands, Noord-Hollandsche, p. 273-284.

The pH of lake water in regions that are dominated by *Sphagnum* is generally below 4.5 and is sometimes below 3.0. Concentrations of organic acid anions in water samples from Sphagnum-dominated bog communities are not equivalent with the hydrogen ion (H^+) in these samples. The main source of H^+ is plants, but the equivalent organic acid anions remain in complex structural polymers in the plants.

234
COBOURN, W. G., HUSAR, R. B., and HUSAR, J. D., 1978, Continuous *in situ* monitoring of ambient particulate sulfur using flame photometry and thermal analysis, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 89-98.

The sulfur component of the St. Louis ambient aerosol has been continuously monitored using a flame photometric detector (FPD) to measure particluate sulfur concentration, and *in situ* thermal analysis to chemically analyze the aerosol for H_2SO_4 and its ammonium salts, NH_4HSO_4, $(NH_4)_3H(SO_4)_2$, and $(NH_4)_2SO_4$. During the sixteen day monitoring period, the sulfate aerosol varied with respect to chemical composition, but tended to be in the form of the ammonium salts rather than in the form of sulfuric acid. Comparison of particulate

234 (continued)
sulfur levels with the light scattering coefficient during the monitoring period indicates that particulate sulfur was a significant constitutent of the light scattering aerosol, but its mass accounted for less than half of the mass of the light scattering aerosol. [Abstract reprinted by permission of Pergamon Press.]

235
COFFIN, D. L., 1976, Acid precipitation--effects of sulfur dioxide and sulfate aerosol particles on human health: Ambio, v. 5, no. 5-6, p. 239-242.

Cationic substances associated with sulfur pollutants were studied to determine their relationship to pulminary infections. Results of research indicate that sulfuric acid and acid sulfates are more toxic to humans than previously suspected, and that additional research is needed to study conditions that accelerate oxidation of sulfur dioxide.

236
COGBILL, C. V., 1976, The history and character of acid precipitation in eastern North America: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 407-413.

The history and present distribution of precipitation acidity in eastern North America are reviewed. Preciptation chemistry from the 1920's indicates heavy ionic deposition, but low acidity (calculated) in Tennessee (pH 7.4) and New York (pH 6.15). However, high acidity was apparently widespread over northeast North America by 1955-56, and measured pH's below 4.5 were observed earlier. The geographic distribution of acid precipitation has spread through the present. Yearly average pH values for 1972-73 are not significantly different in New York and New Hampshire, indicating a regional consistency in acid (pH 4.10) deposition. Summer acidity is currently lower in Tennessee than in the northeast. Precipitation chemistry of individual storms reveals some local variation even within a 3 km range, but a storm in central New York is generally homogenous over 70 km. [Abstract reprinted by permission of D. Riedel Publishing Company.]

237
COGBILL, C. V., 1977, The effect of acid precipitation on tree growth in eastern North America: Water, Air, and Soil Pollution, v. 8, no. 1, p. 89-93.

Detailed study of the history of forest tree growth by tree-ring analysis is used to assess the effect of acid precipitation. The pattern and historical trends of acid precipitation deposition are compared with growth trends from mature forest stands in New Hampshire and Tennessee. No clear indication

237 (continued)
of a regional, synchronized decrease in tree growth was found. The residual variation of relative tree growth responses, after removal of variation due to weather, shows no recent time-dependent trend. Due to the unknown initiation date of acid preciptation and to the large variation of tree growth estimates, a correlation of forest growth and acid preciptation in eastern North America cannot be established at the present time. [Abstract reprinted by permission of D. Riedel Publishing Company.]

238
COGBILL, C. V., and LIKENS, G. E., 1974, Acid precipitation in the north-northeastern United States: Water Resources Research, v. 10, no. 6, p. 1133-1137.

Precipitation chemistry data from sites in New York and New England were studied from September 1972 to August 1973 to determine the causes and distribution of acid precipitation in the northeast. A consistent pH of less than 4.4 was found within the northeast; the expected pH is 5.6 based upon equilibrium with carbon dioxide. About 65 percent of acidity is due to sulfuric acid, 30 percent is due to nitric acid, and less than 5 percent is due to hydrochloric acid. Much of the acidity originates as a general source over industrial areas in the midwest.

239
COKER, W. B., and SHILTS, W. W., 1979, Lacustrine geochemistry around the north shore of Lake Superior--implications for evaluation of the effects of acid precipitation, in Current Research, Part C: Geological Survey of Canada Paper 79-1C, p. 1-15.

Geochemical data from the north shore of Lake Superior show that natural variations in the chemistry of bedrock lithologies, mineralization, and glacial sediment composition can be used to determine the effects of acid precipitation. The northeastern part of the area is underlain by a sheet of calcareous till and glaciolacustrine sediment transported southward and southwestward from carbonate bedrock of the Hudson Bay Lowland. Concentrations of trace metals in lake waters and sediments vary considerably and are affected by underlying bedrock types. Patterns formed by the concentrations of trace metals can be used to predict regions that are sensitive to metals mobilization as a result of terrain acidification.

240
COLE, D. W., 1968, A system for measuring conductivity, acidity, and rate of water flow in a forest soil: Water Resources Research, v. 4, no. 5, p. 1127-1136.

240 (continued)
This article describes a system for collecting, recording, and analyzing data on water flowing through a forest soil in the Seattle Cedar River watershed in Washington. Tension lysimeters are used, and solutions collected during periods of flow pass through cells that measure conductivity, acidity, and rate of water flow. The lysimeters do not disturb overlying soil and root systems. Computer analysis is used to convert data into tables and graphs.

241
COLE, D. W., 1974, The effect of pollution-induced acidic rainfall on cation leaching in a douglas-fir ecosystem [abstract]: EOS, Transactions of the American Geophysical Union, v. 55, no. 4, p. 248.

Fluxes of acidic precipitation in a Douglas-fir ecosystem in western Washington were monitored and the effect of fluxes on cation leaching were evaluated. Most of the incoming hydronium ions were removed by the forest canopy and litter; sulfate ions were not removed. This abstract compares carbonic acid system with sulfuric acid levels.

242
COLE, D. W., and JOHNSON, D. W., 1977, Atmospheric sulfate additions and cation leaching in a Douglas Fir ecosystem: Water Resources Research, v. 13, no. 2, p. 313-317.

The effects of atmospheric deposition of sulfuric acid on cation leaching in soils at the Thompson Research Center (TRC), Cedar River watershed, Washington, are studied. Most of the annual additions of hydrogen ions are removed by the forest canopy by an exchange process. Leaching by the forest canopy appears to be most affected by acid rain, and soil leaching appears to be controlled by ecosystem processes, such as carbonic acid leaching and the release of sulfur from decomposing litter.

243
CONROY, N. I., HAWLEY, K., KELLER, W., and LAFRANCE, C. J., 1975, Influences of the atmosphere on lakes in the Sudbury area: Journal of Great Lakes Research, v. 2 (Supplement 1), p. 146-165.

Water-quality data were collected for 150 lakes within a 200-km radius of a smelting complex in Sudbury, Ontario. Low pH and high concentrations of nickel and copper are attributed to atmospheric deposition of emissions from the smelting industry. Biological populations of acid lakes differ significantly from those of unaffected lakes, particularly in abundance and community structure.

244
CONROY, N. I., JEFFRIES, D. S., and KRAMER, J. R., 1974, Acid shield lakes in the Sudbury Ontario region, in Canadian Symposium on Water Pollution Research, 9th, University of Western Ontario, 1974, Proceedings: Toronto, Institute for Environmental Studies, University of Toronto, Water Pollution Research in Canada, no. 9, p. 45-61.

Water samples were collected from 50 lakes in the Sudbury, Ontario, region in 1973 and analyzed for conductivity, alkalinity, and 12 constituents. Of the lakes sampled, 29 percent have pH values less than 5.5, 24 percent are critically acidic, and 3 percent are susceptible to pH depression with continued atmospheric loading. A calcite saturation index (CSI) is developed and may be used to define groups of lakes as (1) affected (low pH), (2) unstable (probable declining pH), or (3) stable (relatively high pH).

245
CONROY, N. I., and KELLER, W., 1976, Geological factors affecting biological activity in Precambrian Shield lakes: Canadian Mineralogist, v. 14, p. 62-72.

This article investigates variables related to the lithosphere and atmosphere that effect biological activity in dilute, lentic environments in the Precambrian Shield. Biological activity in lakes in the Precambrian Shield near Sudbury, Ontario was monitored. Low biological activity was noted in lakes with small surface area-to-volume ratios and in poorly buffered lakes. Lakes with pH values less than 5.5 and in noncalcareous terrain had the lowest biological activity. Conversely, high biological activity was found in lakes with large surface area-to-volume ratios and in lakes in calcareous terrain.

246
COOK, R. C., 1980, Rapporteur summary of panel discussion on marine effects, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 66.

247
COOPER, C. F., 1980, Air pollution in forests--social costs, predictive models, and public policy, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 4-9.

Long time scales, spatial variation in ecosystems, and differing value judgments make models almost essential for societal consensus about air pollution. Three categories of policy-oriented models are described. Empirical time series models are good for immediate decisions but are inherently a short-term device. Detailed structural-functional models emphasize relationships among components and demonstrate the significance of interconnections. Small errors, however, can lead to erroneous quantitative results, limiting their value for direct policy decisions. Aggregated policy-oriented models provide better compliance between model output and validation data at the cost of loss of resolution. Good models should be clearly documented, results should be comprehensible, limits and probable error bands clearly stated, they should be flexible enough to deal with unanticipated problems without attempting total generality, and results should be clearly displayed. A model is an aid to decision making, not a decision maker. For it to be effective in that role, there must be mutually supportive interaction among modelers, biological and social scientists, and decision makers. Perhaps the most significatn role of models is in helping avoid suboptimization and in facilitating communication among disciplines and practitioners. [Abstract reprinted by permission of U.S. Forest Service.]

248
COOPER, H. B. H., Jr., LOPEZ, J. A., and DEMO, J. M., 1976, Chemical composition of acid precipitation in central Texas: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 351-359.

Studies were undertaken to determine factors affecting composition of acidic precipitation formation in the Austin area of central Texas. The study was initiated to determine background levels of acid and alkalinity producing constituents in an area with elevated natural dust levels from nearby limestone rock formations. Results showed normal rainfall pH values of 6.5 to 6.6 in the area, with extreme variations from 5.8 to 7.3. Significant Ca levels of 1 to 4 mgL^{-1} were observed from probably natural origin which appeared to have a buffering effect on acidity. Significant sulfate and nitrate ion concentrations occurred during the early stages of rainfall where rainfall pH was dependent on calcium-sulfate ratio. [Abstract reprinted by permission of D. Riedel Publishing Company.]

249
CORBETT, E. S., 1967, Measurement and estimation of precipitation on experimental watersheds, in Sooper, W. E., and Lull, H. W., eds., Forest hydrology: National Science Foundation Advanced Science Seminar, Oxford, N.Y., 1967, Proceedings: New York, Pergamon Press, p. 107-127.

249 (continued)
This literature review presents research on estimating and measuring precipitation in experimental watersheds. Among the topics discussed are instruments for measuring precipitation, selection of rain-gage sites, design of rain-gage networks, and extrapolation of point precipitation values to areal estimates. About 115 bibliographic references are cited.

250
CORNELL UNIVERSITY, Center for Environmental Research, 1981, Acid rain--whose responsibility?: Cornell University Cooperative Extension Synopsis, File no. 81-18, 8 p.

A summary is given of a conference held in May 1981, on the economic, social, and political aspects of acid precipitation, sponsored by the Canadian-American Center, State University of New York at Buffalo.

251
CORNELL UNIVERSITY, Center for Environmental Research, 1981, Sensitivity of the physical environment to acid precipitation in New York State, part I--rock formations: Cornell University Cooperative Extension Synopsis, File no. 81-17, 3 p., 1 col. pl.

This article presents a summary of research by Brookhaven National Laboratory on mapping the buffering capacity of rock formations in New York State. Results suggest a correlation between acidification of surface waters and bedrock types, particularly in areas with thin soil cover. A color plate is included.

252
COWELL, D. W., LUCAS, A. E., and RUBEC, C. D. A., 1981, The development of an ecological sensitivity rating for acid precipitation impact assessment: [Burlington, Ontario] Environment Canada, Lands Directorate, Working Paper no. 10, 42 p.

This report presents a rating system to evaluate the effects of acid precipation on the terrestrial environment of eastern North America. A sensitivity mapping system that uses the Ecodistrict data base developed by the Lands Directorate, Environment Canada, is based on bedrock type, surficial deposits, and vegetation characteristics.

253
COWLING, E. B., 1979, From research to public policy--progress in scientific and public understanding of acid precipitation and its biological effects, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 38-59.

254
COWLING, E. B., and DAVEY, C. B., 1981, Acid precipitation--basic principles and ecological consequences: Paper & Pulp, v. 55, no. 8, p. 182-185.

A short discussion of the environmental effects of acid precipitation is given. Acid precipitation is occurring in large regions of eastern U.S. and Canada, Europe, and Japan. Acid precipitation can affect the mobility, solubility, and toxicity of heavy metals. Nutrient deficiencies or imbalances caused by acid precipitation affect forest productivity. Aquatic and terrestrial organisms are likely to be damaged when a particularly sensitive life form or life stage, developing in poorly buffered waters or soils, coincides with major episodes of acid precipitation.

255
COWLING, E. B., and DOCHINGER, L. S., 1980, Effects of acidic precipitation on health and the productivity of forests, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 165-173.

Acid precipitation has become a dominant feature of man-induced change in the chemical climate of the earth. But acid precipitation is only one special feature of the changing chemistry of atmospheric deposition in developed and developing regions throughout the world. In recent decades, human activities (mainly increased combustion of fossil fuels and decomposition or combustion of waste products) have greatly increased the total emissions and deposition of beneficial nutrients and injurious substances (such as strong mineral acids) from the atmosphere. Projected increases in the use of fossil fuels, and especially in the use of coal, will add still further to the total burden of beneficial and injurious substances deposited on forest and rangeland ecosystems from the atmosphere. The purpose of this brief paper is to summarize certain important principles concerning the phenomena of acid precipitation and atmospheric deposition and their beneficial and detrimental effects on the health and productivity of forests. [Abstract reprinted by permission of U.S. Forest Service.]

256
COX, R. A., and PENKETT, S. A., 1970, The photo-oxidation of sulphur dioxide in sunlight: Atmospheric Environment, v. 4, p. 425-433.

This article investigates photo-oxidation of low concentrations of sulfur dioxide (SO_2)

256 (continued)
in the air and using natural sunlight. Conversion rates from aerosol measurements are higher than the accepted value of 0.1 per hour. This may be caused by trace impurities in the ambient air that are affecting photochemical reactions.

257
COX, R. A., and SANDALLS, F. J., 1974, The photo-oxidation of hydrogen sulphide and dimethyl sulphide in air: Atmospheric Environment, v. 8, p. 1269-1281.

This article investigates photo-oxidation of low concentrations of hydrogen sulfide and dimethly sulfide in air containing nitrogen oxides and hydrogen peroxide vapor. The oxidation of sulfur compounds appears to result from their reaction with free radicals such as oxygen and hydroxyl, which are generated by photochemical processes. This results in a major loss of hydrogen sulfide and dimethyl sulfide in the lower atmosphere.

258
COYNE, P. I., and BINGHAM, G. E., 1980, Photosynthesis and stomatal response to light and temperature in Ponderosa pine exposed to long-term oxidant stress, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 233.

259
CRAIG, G. R., 1974, Toxicity studies relating to acidic conditions in lake systems, in Ontario Industrial Waste Conference, Toronto, Ontario, 1974: Toronto, Ontario, Ministry of the Environment, Proceedings of the Ontario Industrial Waste Conference, v. 21, p. 158-162.

This article discusses the effects of pollutants contributed by metal-processing industries on the quality of lake water and on aquatic biota, and summarizes some recent studies on fish mortality conducted at (1) acid lakes in the La Cloche Mountains southwest of Sudbury, (2) Lake Panache, west of Sudbury, and (3) Lumsden Lake, in northern Ontario.

260
CRAIG, G. R., and BAKSI, W. F., 1977, The effects of depressed pH on flagfish reproduction, growth and survival: Water Research, v. 11, p. 621-626.

Breeding communities of flagfish (*Jordanella floridae*) were exposed to lake water with pH values of 6.0, 5.5, 5.0, and 4.5. Egg production and fertility and fry growth were impaired at all pH levels. Survival of flagfish fry were reduced at pH 5.5 nd 5.0; no fry survived at pH 4.5. Flagfish successfully reproduce at pH of 6.5.

261
CRAMPTON, C. B., 1980, Variations of pH with annual cumulative precipitation in acid forest soils: Canadian Journal of Soil Science, v. 60, no. 2, p. 385-387.

Colorimetric pH measurements in the A and B horizons of 230 soil profiles from Belcarra Mountains, British Columbia, were made yearly from 1975 to 1978. Results show an increase in pH in summer with total cumulative precipitation, but lower pH values were observed after dry winters. The increase in acidification on the sandy Podzols was so great compared to the less textured Brunisols that the normal increase in pH down the soil profile was reversed. It is suggested that extended periods of dry weather increase soil acidity, and a summer increase in acidity may also be influenced by soil texture. Podzolized sands contain no clay to help retain moisture, and the process of acidification extends to some depth, thus producing a decrease in pH. This process causes a reversal in the normal acidity gradient, which during summer causes the B horizon to have lower pH values than the A horizon.

262
CRIBBEN, L. D., and SCACCHETTI, D. D., 1977, Diversity in tree species in southeastern Ohio *Betula nigra* L. communities: Water, Air, and Soil Pollution, v. 8, no. 1, p. 47-55.

Quantitative data were obtained for arboreal species within 50 lowland forests in southeastern Ohio. Thirty-seven communities were dominated by *Betula nigra* L. and 13 were dominated by *Acer saccharinum* L. The acid soils collected from *B. nigra* communities contained toxic concentrations of exchangeable Al and low concentrations of Ca and Mg. Tree species diversity (Shannon-Weaver index) and species equitability were inversely related to high concentrations of exchangeable Al and H and directly related to high concentrations of exchangeable Ca and Mg and an increase in soil pH. [Abstract reprinted by permission of D. Riedel Publishing Company.]

263
CRISSMAN, H. A., and THERRIEN, C. D., 1969, Cytochemical analysis of liver histones in acid-exposed brook trout: Pennsylvania Academy of Science, Proceedings, v. 43, p. 49-52.

Nuclear histone composition of hepatic tissue from brook trout exposed to acidic water was determined by cytochemical analysis. Four-day exposure of fish to low pH did not affect this aspect of liver function.

264
CROCKER, T. D., and FORSTER, B. A., 1981, Decision problems in the control of acid precipitation--nonconvexities and irreversibilities: Journal of the Air Pollution Control Association, v. 31, no. 1, p. 31-37.

Dose-response functions for the effects of acid precipitation on ecosystems show nonconvexities and irreversibilities with some positive frequency. A model is presented for determining the economic losses caused by the effects of acid precipitation on the ecosystem. The shape of the dose-response function determines the shape of the marginal damage (benefit) function associated with different levels of acidity. The least economically desirable polity is to permit some intermediate level of harm to a variety of ecosystems to obtain the benefits of moderate increases in fossil fuel combustion. Natural science and economic research into the effects of acid precipitation should focus on systems on the verge of acidification.

265
CRONAN, C. S., 1979, Determination of sulfate in organically colored water samples: Analytical Chemistry, v. 51, p. 1333-1335.

This article presents a laboratory technique that minimizes the overestimation of sulfate in water samples having more than 100 to 200 units of coloration. The technique is used with standard automated methods for rapid determination of sulfate in naturally colored water samples.

266
CRONAN, C. S., 1979, Effects of acid precipitation on soil leaching processes in high elevation coniferous forests of the northeastern U.S., in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 146-161.

267
CRONAN, C. S., 1980, Consequences of sulfuric acid inputs to a forest soil, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 335-343.

One of the important concerns regarding acid precipitation and global sulfur pollution is the question of how acid rain and snowmelt interact with the soil system. Studies concerned with the ecological effects of atmospheric H_2SO_4 and HNO_3 upon soils have shown the following results: (i) atmospheric inputs of sulfuric acid may shift leaching processes from organic and carbonic acid control to sulfuric acid dominance throughout the soil zone of some forest ecosystems; (ii) in regions of noncalcareous bedrock, acid rain and acid snowmelt may alter aluminum transport, resulting in increased aluminum leaching through soils and into streams; (iii) depending upon environmental conditions, acid precipitation may cause increased leaching of essential nutrient cations from soils; and (iv) the impact of acid precipitation upon forest soils may be influenced in part by vegetation status and acid buffering processes in the forest canopy, by soil physical-chemical properties, and by geographic factors. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

268
CRONAN, C. S., 1980, Controls on leaching from coniferous forest floor microcosms: Plant and Soil, v. 56, p. 301-322.

Microcosms of a coniferous forest floor were examined to determine the potential influence of acid precipitation, temperature changes, and plant uptake on the chemistry of soil leachate solutions. Forest floors showed losses of calcium, magnesium, ammonium; potassium increased when the acidity of throughfall to the microcosms increased. Aluminum losses did not show this same pattern, which suggests a kinetic lag in the mobilization and leaching losses of calcium, potassium, ammonium, sulfate, nitrate, and organic anions. Leaching of potassium, nitrate, ammonium, and sulfate increased relative to field plots when plant uptake was excluded from microcosms.

269
CRONAN, C. S., 1980, Solution chemistry of a New Hampshire subalpine ecosystem--a biogeochemical analysis: Oikos, v. 34, p. 272-281.

Field studies were conducted to investigate ion transport in ecosystems receiving chronic acid precipitation. Changes in solution chemistry were recorded during rainfall percolation through a balsam fir forest in the subalpine zone of the White Mountains of New Hampshire. The behavior of ions in the fir zone seems to be influenced by atmospheric deposition rates, biological demand, ion-exchange affinities, acidity of the percolate, and rates of reaction.

270
CRONAN, C. S., REINERS, W. A., and REYNOLDS, R. C., Jr., 1980, The impact of acid precipitation on forest canopies and soils in the northeastern U.S., in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 158-159.

271
CRONAN,, C. S., REINERS, W. A., REYNOLDS, R. C., Jr., and LANG, G. E., 1978, Forest floor leaching--contributions from mineral, organic, and carbonic acids in New Hampshire subalpine forests: Science, v. 200, no. 4339, p. 309-311.

Soil-water and ground-water samples were collected at a subalpine, coniferous forest in New Hampshire during a 2-year field and laboratory study. Results of laboratory analysis indicate that sulfate anions supply 76 percent of the electrical charge balance in the leaching solution. Atmospheric deposition of sulfuric acid provides the greatest source of hydrogen ion for cation replacement and mobile anions for cation transport in subalpine soils of the northeast U.S. affected by acid precipitation. In mostly unpolluted regions, carbonic and organic acids dominate the soil-leaching processes.

272
CRONAN, C. S., and SCHOFIELD, C. L., 1979, Aluminum leaching response to acid precipitation--effects on high-elevation watersheds in the northeast: Science, v. 204, no. 4390, p. 304-306.

Atmospheric deposition of sulfuric acid and nitric acid causes increased leaching of aluminum from soils in noncalcareous, high-elevation watersheds in the White Mountains of New Hampshire. This process results in higher concentrations of dissolved aluminum in surface and ground waters. Transport of aluminum can result in fish mortality. Studies of regions in the United States and Europe underlain by silicate bedrock suggest that aluminum is a significant biogeochemical link between terrestrial and aquatic ecosystems exposed to acid precipitation.

273
CROSS, R. F., 1981, A canary in the rain: Conservationist, v. 36, no. 3, p. 2-6.

The loss of fish in Adirondack lakes believed to be caused by acid precipitation, is a warning of serious environmental problems for the region. The New York State Department of Environmental Conservation has documented the loss of sport-fish populations from 264 Adirondack lakes and ponds, totaling more than 11,000 acres. An additional 256 lakes, totaling 63,000 acres, are in danger of losing sport-fish populations. Amphibians such as salamanders, frogs, and toads are also adversely affected by acid precipitation. The low buffering capacity of the terrain of the Adirondacks makes this region particularly vulnerable to acid precipitation. (See also Pfeiffer, M. H., and Festa, P. J., 1980, herein.)

274
CROWTHER, Charles, and RUSTON, A. B., 1911, The nature, distribution, and effects upon vegetation of atmospheric impurities in and near an industrial town: Journal of Agricultural Science, v. 4, p. 25-55.

This article investigates the effect of atmospheric pollutants on growth rates of plants in Great Britain. Air pollutants seem to affect growth rates, especially near industrial cites such as Leeds. Although the greatest amount of air pollutants are found in the industrial areas of Leeds, pollutants may be transported over large areas, particularly by prevailing winds. Rain in these areas becomes particularly abundant in chlorides, sulfates, other sulfur compounds such as sulfur dioxide, nitrogen compounds (notably ammonia), and free acid.

275
CROWTHER, Charles, and STEUART, D. W., 1912, The distribution of atmospheric impurities in the neighborhood of an industrial city: Journal of Agricultural Science, v. 5, p. 391-408.

Rainwater samples were collected at 14 stations surrounding the city of Leeds, Great Britain. Samples were analyzed for sulfur, chloride, and nitrogen; results show marked differences in the purity of the atmosphere between industrial-rural areas and the purely agricultural area of Leeds. The sulfur content of leaves was used as an indicator of smoke pollution.

276
CULLEN, D. H., 1980, Rapporteur summary of panel discussion of fresh water effects, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 91-93.

277
CUNNINGHAM, P. T., and JOHNSON, S. A., 1976, Spectroscopic observation of acid sulfate in atmospheric particulate samples: Science, v. 191, p. 77-79.

This article presents infrared spectroscopic observations of acid sulfate in atmospheric samples of submicrometer-sized particles collected at urban sites and discusses temporal trends in the degree of acidity of these particles. The acidity of the particles is observed at all times of the day and may persist for several days in urban areas, but the degree of acidity is highly variable with time.

278
CUPITT, L. T., 1980, Fate of toxic and hazardous materials in the air environment: Research Triangle Park, N.C., U.S. Environmental Sciences Research Laboratory, EPA-600/3-80-084, 35 p.

This report discusses the fate of potentially hazardous chemicals in the atmosphere and evaluates chemical and physical removal processes. Forty-six materials are evaluated relative to their probable fates and tropospheric lifetimes.

279
CURTIN, G. C., KING, H. D., and NISHI, J. M., 1979, The concentration and mobility of elements in subalpine forest soils in Colorado and Idaho: U.S. Geological Survey Open-File Report 79-710, 26 p.

Leaching studies of soils from subalpine forests in Colorado and Idaho indicate that copper, cobalt, chromium, magnesium, barium, tin, strontium, and yttrium are highly mobile elements in these soils. Zirconium, lanthanun, nickel, and scandium are moderately mobile, and titanium is immobile. The highest concentrations of elements are found in the mull (02) horizon.

D

280
DAGGUPATY, S. M., MISRA, P. K., and MUNN, R. E., 1979, A numerical experiment in trajectory modelling for the transport of air pollutants over the Great Lakes Region, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 259-264.

281
DAHL, J. B., QVENILD, C., TOLLAN, O., CHRISTOPHERSEN, Nils, and SEIP, H. M., 1980, Use of radioactive tracers to study runoff and soil-water interactions in natural minicatchments, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 160-161.

282
DAHL, Knut, 1927, The effects of acid water on trout fry: Salmon and Trout Magazine, v. 46, p. 35-43.

This article investigates the effects of acidity on the mortality of trout fry. Trout fry in the yolk-sac stage were exposed to aquarium water ranging in pH from 6.4 to 4.7. Results indicate that the health of trout fry is affected at pH levels below 6. As the pH is lowered to 5.1, some mortality occurs, and if pH drops below 5.0, serious and probably total mortality follows. Discussions on seasonal trends in acidity of lakes in Norway and the effects of low pH on fish mortality are also given.

283
DAHLSTEN, D. L., and ROWNEY, D. L., 1980, Influence of air pollution on population dynamics of forest insects and on tree mortality, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 125-130.

Weakened trees are often predisposed to injury or death by insects, and in forest ecosystems particularly by bark beetles. In the San Bernardino National Forest the interaction between photochemical oxidant weakened Ponderosa pine and the western pine beetle (WPB) was examined in detail. The major results from this study suggest that oxidant damaged trees attacted by WPB produce about the same total brood with lower initial attacks compared to healthier trees. This higher productivity trend is most evident in generation 1 trees. Generation 2 trees, both damaged and healthy, are under much greater moisture stress and produce much less WPB brood than generation 1 trees regardless of oxidant damage. The implication of these results is that in stands with a higher proportion of damaged trees, a given population of WPB would kill more trees and increase at a greater rate than in a stand with a lower proportion of damaged trees. Simulation modelling with these results and other factors that affect Ponderosa pine mortality should provide a basis for predicting long term effects of air pollution on the WPB population and pine mortality. [Abstract reprinted by permission of U.S. Forest Service.]

284
DALBEY, W. E., 1980, Laboratory studies of biological effects of sulfur oxides, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 69-75.

Selected results from controlled exposures of laboratory animals to airborne sulfur oxides are briefly summarized. The main effect observed during acute exposures was reflex bronchoconstriction and a resultant increase

284 (continued)
in pulmonary resistance. The increase in resistance due to sulfur dioxide (SO_2) was potentiated by simultaneous exposure to aerosols under conditions that would increase the transfer of sulfur oxides into the respiratory tract and promote transformation to a higher oxidation state, especially one that is acid. Sulfate aerosols, particularly sulfuric acid aerosols, were more potent than SO_2 in causing bronchoconstriction. Chronic exposure to high concentrations (400-650 ppm) of SO_2 resulted in experimental bronchitis in several species. Long-term exposure to more realistic concentrations of SO_2 produced little or no change in respiratory function or morphology. Significant alterations in both pulmonary function and morphology have been reported after chronic exposure to sulfuric acid aerosols. Recent data indicate that changes in the lung may progress after cessation of such exposures. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

285
DAM, H. V., SURRMOND, G., and BRAAK, C. T., 1980, Impact of acid precipitation on diatoms and chemistry of Dutch moorland pools, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 298-299.

286
DAMPIER, Bill, 1980, Now even the rain is dangerous: International Wildlife, v. 10, no. 2, p. 17-20.

The environmental effects of acid precipitation have become more acute in the last decade. Research studies indicate that the effects are cumulative and increasing each year. One basic cause of acid precipitation is industrial emissions of sulfur dioxide and nitrogen oxides. This article describes some of the effects of acid precipitation on lake ecosystems and discusses remedial actions and political implications.

287
DANA, M. T., 1980, Overview of wet deposition and scavenging, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 263-274.

Methods for describing simple pollutant aerosol or gas interactions with hydrometeors are well developed, and reasonable predictions of removal may be made if the pollutant gas-phase concentration and particle size spectrum (or gas properties) are known. Scavenging processes involving attachment, condensation, or cloud-drop nucleation are less well known, and current models are limited in that supporting measurements are inadequate. The scavenging coefficient and scavenging ratio, the main parameters for describing precipitation scavenging, have usefulness which varies depending on the pollutant in question and the complexity of the removal processes involved. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

288
DANA, M. T., HALES, J. M., HANE, C. E., and THORP, J. M., 1974, Precipitation scavenging of inorganic pollutants from metropolitan sources: Washington, D.C., U.S. Environmental Protection Agency, EPA-650/3-74-005, 136 p.

This report presents a model to measure precipitation scavenging of urban pollutants in the St. Louis area. Balance of regional pollutions is an important initial consideration in studies of precipitation scavenging. Scavenging rate is defined as the mass of a given pollutant removed per unit distance along a storm path per unit of time. Scavenging rates were determined from concentrations measured during five convective storms in August 1972. For one storm, derived downstorm removal rates for sulfate and nitrate are comparable in magnitude to estimates of the urban emission rates.

289
DANA, M. T., HALES, J. M., SLINN, W. G. N., and WOLF, M. A., 1973, Natural precipitation washout of sulfur compounds: Washington, D.C., U.S. Environmental Protection Agency, EPA-R3-73-047, 202 p.

A computer model was developed for predicting reversible washout of sulfur dioxide (SO_2) emitted from powerplant plumes and other sources. Predictions of the model compare favorably with washout measurements made during 15 controlled-source experiments. When the model is applied to experimental conditions characterized by acid precipitation, "negative washout" occurs as a result of desorption of SO_4 from the rain below the SO_2 plume.

290
DANA, M. T., HALES, J. M., and WOLF, M. A., 1975, Rain scavenging of SO_2 and sulfate from power plant plumes: Journal of Geophysical Research, v. 80, no. 30, p. p. 4119-4129.

This article presents a mathematical model that predicts reversible washout of SO_2 emitted from powerplant plumes and other sources. Results of the model compare favorably with washout measurements made during controlled source experiments and four powerplant experiments. When high background levels of acid rain are applied to the model, "negative washout" occurs as a result of desorption of SO_2 from the rain below the SO_2 plume.

291
DaPAL, R. C., 1978, The effect of some meteorological parameters on the chemical composition of precipitation at the University Field Station, Trinidad, West Indies: Journal of Applied Meteorology, v. 17, p. 1625-1632.

Precipitation samples were collected at St. Augustine, Trinidad, for 3 years and analyzed for NH_4^-, NO_3^-, urea-N, Mg, Ca, Na, K, Cl, and SO_4. Total annual loads of constitutents correlated with the amount of precipitation. The amount of constituent load due to dry fallout was significant for NO_3^-, Mg, K, and SO_4 during the dry period, and for urea-N, Na, and Cl during wet and dry periods.

292
DAVIDSON, Ben, 1967, A summary of the New York Urban Air Pollution Dynamics Research Program: Journal of the Air Pollution Control Association, v. 17, no. 3, p. 154-158.

A mathematical model was developed to predict the transport and diffusion of pollutants in a large metropolitan region over a time and space scale. This paper presents some of the data that have been collected to validate the model and describes the air-quality monitoring network that was developed for this metropolitan New York study.

293
DAVIES, T. D., 1976, Precipitation scavenging of sulphur dioxide in an industrial area: Atmospheric Environment, v. 10, p. 879-890.

The removal of sulfur dioxide by precipitation was studied at Sheffield, Great Britain, an industrial area about 12 km^2. Statistical analysis of data collected during one year indicates some of the factors affecting washout. This paper also describes differences between winter and summer washout rate. The effect of precipitation on atmospheric SO_2 concentrations is difficult to determine by examining concentrations before and after a precipitation event. Wind-speed data seem to be more useful than precipitation data in determining the variation in atmospheric SO_2 concentrations.

294
DAVIES, T. D., 1979, Dissolved sulphur dioxide and sulphate in urban and rural precipitation (Norfolk, U.K.): Atmospheric Environment, v. 13, p. 1275-1285.

This article discusses the removal of sulfur dioxide (sulfite concentration) and total sulfur (sulfate concentration) by precipitation at urban and rural sites at Norfolk, Great Britain. Sulfur dioxide washout and sulfate scavenging rates are compared to precipitation amount and intensity, atmospheric sulfur dioxide, pH of rainfall, and weather type.

295
DAVIES, W. E., 1979, Comparison of the results of an eight layer regional model versus a single layer regional model for a short term assessment, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 297-304.

296
DAVIS, A. O., and GALLOWAY, J. N., 1981, Atmospheric lead and zinc deposition into lakes of the eastern United States, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 401-408.

297
DAVIS, A. O., GALLOWAY, J. N., and NORDSTROM, D. K., 1979, The effect of acid precipitation on lead sorption from the sediments of two Adirondack Lakes [abstract]: Geological Society of America, Abstracts with Programs, v. 11, no. 4, p. 176.

Water-quality data from two isolated lakes in the Adirondack Mountains show increases of lead in the top 10 cm of the lake sediment, which may be due to increased industrial emissions upwind of the area. Bulk atmospheric precipitation (10-12 ppb) is the major source of lead to the lakes. Lead levels of <0.5 ppb were found in the water column, interstitial water, ground water, lake outlets, and tributaries to the lake except for one period immediately prior to snowmelt in May, when outflow contained 2 ppb.

298
DAVIS, D. D., and WILHOUR, R. G., 1976, Susceptibility of woody plants to sulfur dioxide and photochemical oxidants--a literature review: Corvallis, Oregon, U.S. Environmental Protection Agency, EPA-600/3-76-102, 71 p.

Presented are the results of a review of the literature published in the U.S. and Europe on the sensitivity of woody vegetation to sulfur dioxide, ozone, peroxyacetyl nitrate (PAN), or nitrogen oxides. Sensitivity categories of "very susceptible" and "very tolerant" are probably the most useful in determining woody vegetation best suited for areas with high air pollution.

299
DAVIS, P., and OZBURN, G. W., 1969, The pH tolerance of *Daphnia pulex* (Leydig, emend., Richard): Canadian Journal of Zoology, v. 47, p. 1173-1175.

The effect of varying pH on the survival time and reproduction capability of female *Daphnia*

299 (continued)
pulex is reported. *D. pulex* survived a 32-hour experiment in river water within a pH range of 6.1-10.3; in aquarium water within a pH range of 4.3-10.4; and in distilled water at pH 6.4 and 7.6. None of the fish survived in solutions of aerated tap water.

300
DAVIS, R. B., and BERGE, F., 1980, Atmospheric deposition in Norway during the last 300 years as recorded in SNSF lake sediments, U.S.A. and Norway. II. Diatom stratigraphy and inferred pH, in Drablos, D., and Tollan, A., eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 270-271.

301
DAVIS, R. B., NORTON, S. A., BRAKKE, D. F., BERGE, F., and HESS, C. T., 1980, Atmospheric deposition in Norway during the last 300 years as recorded in SNSF lake sediments, U.S.A. and Norway. IV. Synthesis, and comparison with New England, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 274-275.

302
DAVIS, R. B., SMITH, M. O., BAILEY, J. H., and NORTON, S. A., 1978, Acidification of Maine (U.S.A.) lakes by acidic precipitation: International Association of Theoretical and Applied Limnology, Proceedings, v. 20, p. 532-537.

This article investigates the history of acid precipitation in Maine. Data indicate that the pH of precipitation in Maine has ranged from 4.4 to 5.0 since 1956. Soils in Maine are coarse, shallow, and derived mostly from granitic materials with a low buffering capacity for acidity. The low concentrations of dissolved solids found in lake basins in Maine is attributed to the low buffering capacity of the underlying rock.

303
DAWSON, G. A., 1978, Ionic composition of rain during sixteen convective showers: Atmospheric Environment, v. 12, p. 1991-1999.

Rainwater samples were collected during 16 summer convective showers over 2 years in the southwestern United States. Statistical analysis was used to determine sources, associations, and incorporation processes of nine constituents. Concentrations of constituents changed considerably during showers; these changes were primarliy by precipitation processes. The pH of rain typically decreased during a shower as a result of preferential washout of calcareous soil particles.

304
DAYE, P. G., 1981, The impact of acid precipitation on the physiology and toxicology of fish, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 29-34.

305
DAYE, P. G., and GARSIDE, E. T., 1975, Lethal levels of pH for brook trout, *Salvelinus fontinalis* (Mitchill): Canadian Journal of Zoology, v. 53, p. 639-641.

Fingerling brook trout, *Salvelinus fontinalis* (Mitchell) were tested for sensativity to pH stress. They were exposed to a series of dilutions of sulfuric acid or sodium hydroxide at 10°C and 20°C for maximum periods of 10,000 minutes after acclimation at 15°C and pH 6.8. Lethal limits of pH 3.5 and 9.8 were determined for both temperatures.

306
DeKONING, H. W., and JEGIER, Z., 1970, Effects of sulfur dioxide and ozone on *Euglena gracilis*: Atmospheric Environment, v. 4, p. 357-361.

This article discusses the effect of various concentrations of sulfur dioxide (SO_2) and mixtures of SO_2 ozone on the rate of photosynthesis of *Euglena gracilis*. When fumigated with 5.0 ppm of SO_2, the chlorophyll content of *E. gracilis* increases. The rate of photosynthesis is not reduced as a result of increased of chlorophyll, and the presence of SO_2 seems to cause stress in *E. gracilis*.

307
DeLISLE, C. E., KLOPPENBURG, J., and SYLVAIN, J., 1979, Le mecure et l'acidité dans les precipitations au nort-ouest Québécois: Eau du Quebec (Canada), v. 12, no. 2, p. 76-85. [In French with English abstract.]

Increases of mercury in aquatic fauna can be partly attributed to acidic deposition by snow and rain. This complex process begins with atmospheric washout of volatile gases such as sulfur dioxide and suspended particles, which are deposited into bodies of water with low pH values and buffering capacities. Ionization and bioassimilation of mercury increases as a result of this process. Mercury concentrations as high as 2.9 ppb and pH values as low as 2.8 in precipitation have been recorded in northwestern Quebec.

308
DELMAS, R. J., ARISTARAIN, A., and LeGRAND, M., 1980, Acidity of Antarctic snow—a natural reference level for acid rains, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 104-105.

309
DELMAS, R. J., and BOUTRON, C., 1978, Sulfate in Antarctic snow: Spatiotemporal distribution, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 723-728.

In this study, we report sulfate content measurements of eighty snow samples collected in East Antarctica. Stringent contamination-free techniques were used both for sampling and analysis (ionometric titration with a lead selective electrode after preconcentration). Sulfate concentrations (range: $50\text{-}100.10^{-9}$g g^{-1},, accuracy $\pm10\%$) do not show large variations along a 1100 km coast interior axis, if we except a narrow coastal area. The analysis of well dated snow samples (time range: 1950-1975) collected at South Pole Station and Dome C (124°E, 75°S) suggest a main marine contribution for the sulfate content, to which are added sporadic stratospheric injections linked with major volcanic events, such as Mt. Agung (1963), whose eruption is clearly recorded. There is no evident anthropogenic contribution to the measured values. [Abstract reprinted by permission of Pergamon Press.]

310
DEL PRETE, Anthony, and SCHOFIELD, C. L., 1981, The utility of diatom analyses of lake sediments for evaluating acid precipitation effects on dilute lakes: Archiv für Hydrobiologie, v. 91, no. 3, p. 332-340.

Sediment cores from three lakes in the Adirondack Mountains of New York having pH levels of 4.7, 5.2, and 6.5 were analyzed for diatom microfossils. Diatom microfossils were classified according to pH preference, and an index was developed based on the ratio of acidophilous to alkaliphilous units. The regression of the index for surficial sediments on lake pH was used to determine lake pH for historical sediment layers. Honnedaga Lake (pH 4.7) had a significant increase in acidophilous taxa in the uppermost layers of sediment and a decrease in estimated pH from 6.2 in historical sediments to pH 5.6 in recent sediments. No significant change was observed in the sediments of the other lakes. The historic data on the acidification of Honnedaga Lake verified the data collected in this study, which suggests that pH indices based on diatom microfossils are sensitive indicators of lake acidification.

311
DENISON, Robert, CALDWELL, Bruce, BORMANN, Bernard, ELDRED, Lindell, SWANBERG, Cynthia, and ANDERSON, Steven, 1977, The effects of acid rain on nitrogen fixation in western Washington coniferous forests: Water, Air, and Soil Pollution, v. 8, no. 1, p. 21-34.

311 (continued)
We investigated both the current status of N_2 fixation in western Washington forests, and the potential effects of acid rain on this vital process.

Even the low concentrations of SO_2 presently found in the Northwest are thought to have an adverse effect on N_2 fixation by limiting the distribution of the epiphytic N_2-fixing lichen, *Lobaria pulmonaria*, which is found mainly in deciduous forests. A close relative, *L. oregana*, was found to be the major N_2 fixer in old-growth coniferous forests. It fixes less N_2 following exposure to H_2SO_4 of pH 4 or less.

A more serious threat to N_2 fixation than acid rain is the practice of deliberately suppressing red alder to keep it from competing with Douglas fir. Also, *L. oregana* is a late successional species and does not develop in forests where short cutting cycles are practiced. [Abstract reprinted by permission of D. Riedel Publishing Company.]

312
DePINTO, J. V., EDZWALD, J. K., BECKER, W. C., and MILLENBACH, S. D., 1981, Chemical budgets and modeling of pH in an Adirondack acid lake, in American Chemical Society, Division of Environmental Chemistry, 182nd National Meeting, New York, N.Y., Preprints, v. 21, no. 2: Washington, D.C., American Chemical Society, p. 72-75.

313
DERUELLE, S., 1978, Étude comaprée de la sensibilité de trois methodes d'estimation de la pollution atmosphérique, en utilisant les lichens comme indicateurs biologiques, dans la region de Mantes (Yvelines): Revue Bryologique et Lichenologique, v. 44, no. 4, p. 429-441. [In French with English abstract.]

Lichens on isolated trees were monitored at 65 sites at Mantes, France. This article presents pollution-zone maps showing the aerial distribution of sulfur dioxide (SO_2). The maps were compiled by three different biological methods for assessing qualitative and quantitative changes in lichens. The sensitivity of each method for distinguishing zones of pollution using lichens as biological indicators is discussed.

314
DERWENT, R. G., 1979, Some aspects of the formation, transport and destruction of photochemical oxidants in north west Europe, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 149-156.

315
DETHIER, D. P., 1979, Atmospheric contributions to stream water chemistry in the North Cascade Range, Washington: Water Resources Research, v. 15, no. 4, p. 787-794.

This article investigates the contribution of bulk precipitation (wet plus dry) to runoff from a subalpine catchment in the North Cascade Range, Washington. Bulk precipitation contributes large quantities of cations and trace elements to the catchment. Mass budgets show that precipitation contributes 30 percent of major elements and 50 percent of minor elements leaving the catchment.

316
DE WYS, J. N., HILL, A. C., and ROBINSON, Elmer, 1978, Assessment of the fate of sulfur dioxide from a point source, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 633-639.

A simplified plume transport model is adopted to assess reaction and scavenging processes. Experimental data on the conversion rate of SO_2 to SO_4^{2-} and the uptake rates by vegetation and soil are used to calculate the relative importance of the various fates of sulfur dioxide. Meteorological parameters include wind speed, day and night mixing heights, night diffusion above the mixing height and plume dispersion angle. Other parameters considered are length of day and night, region, season, type of canopy, and emission rate of SO_2 from a point source. [Abstract reprinted by permission of Pergamon Press.]

317
DICKSON, W. T., 1975, The acidification of Swedish lakes: Drottningholm, Sweden, Institute for Freshwater Research, no. 54, 20 p.

This article describes the effects of acid precipitation on lakes in Sweden. Many acidified lakes are in isolated, virgin forests and are underlain by rock types with low buffering capacities. The article discusses remedial actions such as liming.

318
DICKSON, W. T., 1978, Some effects of the acidification of Swedish lakes: International Association of Theoretical and Applied Limnology, Proc., v. 20, p. 851-856.

The acidification of Swedish lakes is considered to be caused by increased, large-scale combustion of fossil fuels. The susceptibility of Scandinavia's lakes to acidification is attributed in part to the low buffering capacity of the bedrock. This article discusses the increase in leaching of aluminum in lake waters, and the rate of aluminum as a precipitator of humus and phosphorus; it also briefly discusses the toxicity of aluminum to fish.

319
DICKSON, W. T., 1980, Liming, in Hendrey, G. R., ed., Limnological aspects of acid precipitation: International Workshop, Sagamore Lake Conference Center, N.Y., 1978, Proceedings: Upton, N.Y. Brookhaven National Laboratory, p. 37-41.

320
DICKSON, W. T., 1980, Properties of acidified water, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 75-83.

321
DIEHL, W. T., 1972, A comparative study of plankton respiration in an acid polluted lake and its acid free embayments: West Virginia Academy of Science, Proceedings, v. 44, p. 24-32.

Respiration rates of plankton were measured in backwaters and an acidic impoundment of Cheat Lake, W. Va. Acid pollution appears to limit plankton abundance, which results in lower respiration rates in the community. An abundance of plankton may be a result of limited nutrients, as suggested by specific conductivity data.

322
DILLON, P. J., JEFFRIES, D. S., SCHEIDER, W. A., and YAN, N. D., 1980, Some aspects of acidification in southern Ontario, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 212-213.

323
DILLON, P. J., JEFFRIES, D. S., SNYDER, W. R., REID, R. A., YAN, N. D., EVANS, D., MOSS, J., and SCHEIDER, W. A., 1978, Acidic precipitation in south-central Ontario--recent observations: Journal of the Fisheries Research Board of Canada, v. 35, p. 809-815.

Mean pH of precipitation in south-central Ontario is between 3.95 and 4.38, and precipitation events having pH values less than 4.0 are common. A major component of the total acidity is strong mineral acid. High acid loadings are likely to lead to acidification of many lakes and streams in south-central Ontario in the future because most of the lakes have low buffering capacities.

324
DILLON, P. J., and REID, R. A., 1981, Input of biologically available phosphorus by precipitation to Precambrian lakes, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 183-198.

325
DILLON, P. J., YAN, N. D., SCHEIDER, W. A., and CONROY, N. I., 1979, Acidic lakes in Ontario, Canada--characterization, extent and responses to base and nutrient additions: Archiv Hydrobiologie Beihefte-Ergebnisse Limnologie, v. 13, p. 317-336.

Acidification of thousands of lakes in Ontario is inevitable if precipitation acidity remains high. Acidic precipitation in the Sudbury, Ontario region is associated with excessive deposition of copper, nickel, and iron, which results in the elevation of heavy-metal concentrations in lakes and streams. Major ion content of acidic lakes is altered by low pH values; major portions of heavy metals are in a "free" or ionic form. SO_4, Ca, Ng, Na, and K concentrations are elevated. Much of eastern Canada consists of the Precambrian Shield, which is formed by bedrock and overburden with little buffering capacity. This article gives details on the characterization of acidic lakes and the effects of base and phosphorus additions to acid lakes. Phytoplankton biomass, which is related to phosphorus rather than pH, and productivity are similar to circumneutral Precambrian lakes. The addition of base to acidic lakes raised the pH and lowered the heavy metal concentrations but did not change nutrient levels. Acidification and heavy metal contamination in these lakes are partially reversible.

326
DITTENHOEFER, A. C., and DE PENA, R. G., 1978, A study of production and growth of sulfate particles in plumes from a coal-fired power plant, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 297-306.

A number of airborne plume sampling experiments designed to examine the importance of sulfate particle-generating chemical reactions within coal-burning power station plumes are described. The flights were conducted downwind f the Keystone Generating Station in western Pennsylvania, with The Penn State University research aircraft, an Aerocommander 680E. On-board aerosol sampling instrumentation included a condensation nucleus counter, an optical particle counter, and an electrical aerosol analyzer. A casella cascade impactor containing electron microscope copper grids coated with carbon film was used to collect particles at varying distances from the stacks. These samples were analyzed for sulfate content and particle size distribution. Measurements of SO_2 were made with a rapid-response pulsed fluorescent analyzer. Atmospheric pressure, temperature, dewpoint, winds and aircraft position were also monitored. For each flight, a vertical spiral aircraft sounding was made upwind of the power station to determine atmospheric stability and background aerosol particle and SO_2 concentrations. Downwind,the flight pattern consisted of a series of cross wind and longitudinal plume penetrations out to distances at which SO_2 reached background levels. During the case in which cooling tower plume and stack plume merger occurred, sampling continued out to regions where the liquid plume had dissipated. It was found that when relative humidity was low, stability near-neutral, and solar radiation intense, the production of new Aitken particles was the primary mechanism of SO_2 oxidation. In the case of merger between the stack plume and the cooling tower plume, the formation of sulfate on preexisting particles predominated over the formation of new particles. During cases with intermediate meteorological conditions both processes were of equal importance. [Abstract reprinted by permission of Pergamon Press.]

327
DJOLOV, G. D., and SKRAKOV, D. E., 1979, Pressure and topography effects on long-range air pollutants transport, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 253-258.

328
DOCHINGER, L. S., and COWLING, E. B., 1979, Effects of acid rain on crops and trees, in Gunnerson, C. G., and Willard, B. E., eds., Acid rain: ASCE National Convention, Boston, Mass., 1979, Proceedings: New York American Society of Civil Engineers, p. 21-54.

329
DOCHINGER, L. S., and SELIGA, T. A., 1975, Acid precipitation and the forest ecosystem: Journal of the Air Pollution Control Association, v. 25, no. 11, p. 1103-1105.

This article is a review of the First International Symposium on Acid Precipitation and the Forest Ecosystem held in Columbus, Oh. The focus of the conference was on the magnitude of the global impact of acid precipitation. Papers were given on atmospheric chemistry, transport, and precipitation and the environmental effects of acid on aquatic ecosystems, forest soils, and forest vegetation.

330
DOCHINGER, L. S., and SELIGA, T. A., 1976, Acid precipitation and the forest ecosystem: BioScience, v. 26, no. 9, p. 564-575.

This article summarizes the topics discussed at the First International Symposium on Acid Precipitation and the Forest Ecosystem held at Columbus, Oh. These topics include (1) atmospheric transport, chemistry, and precipitation; and (2) effects of acidity.

331
DOHRENWEND, R. E., 1979, Acid snowfall on the Keweenaw Peninsula, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 73-83.

332
DOHRENWEND, R. E., SHETRON, S. G., STOTTLE-MYER, J. R., and OLSZEWSKI, R. J., 1980, Acid precipitation in the Keweenaw Peninsula of Michigan's Upper Peninsula, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 106-107.

333
DOLLARD, G. J., and VITOLS, V., 1980, Wind tunnel studies of dry deposition of SO_2 and H_2SO_4 aerosols, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 108-109.

334
DONAUBAUER, Edwin, 1980, Historical perspectives and international concerns about air pollution effects on forests, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 10-12.

Air pollution from man's activities has a long history; real hazards for forest vegetation occurred more than a century ago which marked the starting point of forest research in the field. The objectives of research have been subject to a steady metamorphosis from simple causal relationships to the task of investigating the long-term influence of pollutant mixtures on trees directly and on entire ecosystems. The IUFRO Subject Group S2.09, Air Pollution, encourages interdisciplinary work in the field and offers an organizational home for close cooperation on an international basis. The consideration of air pollution effects on forest ecosystems goes far beyond limited forest interests, the findings can provide fundamental data on the deterioration of the human environment. [Abstract reprinted by permission of U.S. Forest Service.]

335
DOUGLAS, Ian, 1968, The effects of precipitation chemistry and catchment area lithology on the quality of river water in selected catchments in eastern Australia: Earth Science Journal, v. 2, no. 2, p. 126-144.

Precipitation and river-water samples from two areas in north-east Queensland, Australia were analyzed and comparisons of water quality in the two areas was compared through ionic ratios. Precipitation contributes between 25 and 70 percent of the total solute loads of the rivers studied. Water quality of the rivers is affected more by catchment lithology than climate. Yet, chemistry of precipitation influences the ionic ratios of the rivers in the study.

336
DOVLAND, Harald, and ELIASSEN, Anton, 1976, Dry deposition on a snow surface: Atmospheric Environment, v. 10, p. 783-785.

Deposition velocities of airborne lead and sulfur compounds on a snow surface during a 2-week collection period with no precipitation were measured. The average deposition velocity for lead is 0.0016 m/s and 0.001 m/s for SO_2.

337
DOVLAND, Harald, and SEMB, Arne, 1980, Atmospheric transport of pollutants, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 14-21.

338
DRABLOS, D., and SEVALDRUD, I., 1980, Lake acidification, fish damage, and utilization of outfields--a comparative survey of six highland areas, southeastern Norway, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 354-357.

339
DRABLOS, D., SEVALDRUD, I., and TIMBERLID, J. A., 1980, Historical land-use changes related to fish status development in different areas in southern Norway, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 367-369.

340
DRISCOLL, C. T., Jr., 1980, Aluminum chemistry in dilute waters, in Hendrey, G. R., ed., Limnological aspects of acid precipitation: International Workshop, Sagamore Lake Conference Center, N.Y., 1978, Proceedings: Upton, N.Y., Brookhaven National Laboratory, p. 6-12.

341
DRISCOLL, C. T., Jr., 1980, Aqueous speciation of aluminum in the Adirondack region of New York State, U.S.A., in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 214-215.

342
DRISCOLL, C. T., Jr., BAKER, J. P., BISOGNI, J. J., Jr., and SCHOFIELD, C. L., 1980, Effect of aluminum speciation on fish in dilute acidified waters: Nature, v. 284, no. 5752, p. 161-164.

A consequence of lake and stream acidification is the mobilization of aluminum from the soil to the aquatic environment. This article discusses the characteristics of aluminum in acidified lakes and streams in the Adirondack Mountains of New York and assesses the relative toxicity of soluble aluminum species to fish.

343
DROPPO, J. G., 1976, Dry deposition processes on vegetation canopies, in Atmosphere-Surface Exchange of Particulate and Gaseous Pollutants, Richland, Wash., 1974, Proceedings: [Oak Ridge, Tenn.], U.S. Energy Research and Development Administration, ERDA Symposium Series 38, p. 104-111.

This article presents a brief review of forestry and agricultural literature relating to processes of dry deposition on plant canopies. A model is developed for simulating dry deposition processes in a vegetation canopy. The paper discusses various aspects of the processes in both high and low vegetation.

344
DROPPO, J. G., 1980, Experimental techniques for dry-deposition measurements, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 209-221.

Recent experimental approaches for measurement of dry surface fluxes of sulfur compounds are reviewed and discussed with emphasis on surface-layer studies. Evidence indicates that natural surfaces are sources as well as sinks for sulfur. Field results are related to requirements and implications in future studies of surface sulfur fluxes. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

345
DROPPO, J. G., and HALES, J. M., 1976, Profile methods of dry deposition, in Atmosphere-Surface Exchange of Particulate and Gaseous Pollutants, Richland, Wash., 1974, Proceedings: [Oak Ridge, Tenn.], U.S. Energy Research and Development Administration, ERDA Symposium Series 38, p. 192-211.

The present research program is directed at development of improved prediction models for dry deposition. The state-of-the-art in dry deposition modeling is at the point where additional input data from field experiments are needed. Possible methods of studying dry deposition are discussed in terms of their advantages, disadvantages and limitations. These methods include wind tunnels, static chambers, deposition-surface measurements, plume decay measurements, simultaneous depositing and nondepositing measurements, profile measurement methods, and flux-measurement methods.

The profile measurement method is identified as best meeting present needs for model development input. Its advantages include (1) independence from atmospheric chemical reactions, (2) the result in a measure of the total deposition effect, and (3 analysis from a single-point sampling. Disadvantages include (1) use of indirect measurements which depend on the determination of an appropriate eddy diffusivity and (2) the constraints relative to conditions and the locations where the model applies. A proposed field program based on a profile measurement method is described. [Abstract reprinted by permission of U.S. Department of Energy.]

346
DROZDOVA, V. M., and MAKHON'KO, E. P., 1970, Content of trace elements in precipitation: Journal of Geophysical Research, v. 75, no. 18, p. 3610-3612.

346 (continued)
Precipitation samples were collected monthly for 1 year at 16 stations in north, northwest, and central regions of the European territory of Soviet Union. Samples were analyzed by spectroscopic technique to determine average maximum and minimum concentrations of manganese, nickel, lead, and iron.

347
DRUMMOND, R. A., OLSON, G. F., and BATTERMAN, A. R., 1974, Cough response and uptake of mercury by brook trout, *Salvelinus fontinalis*, exposed to mercuric compounds at different hydrogen-ion concentrations: Transactions of the American Fish Society, v. 103, no. 2, p. 244-249.

Cough frequency is evaluated as an indicator of long-term effects of mercury on brook trout, *Salvelinus fontinalis*. This article describes the effects of methylmercuric chloride (MMC) and mecuric chloride on fish in waters of differing pH values. Cough frequency is a good short-term indicator of the long-term effects of MMC, and increases in cough frequency are proportional to the mercury concentration (3-12 µg/L) of both components at pH 7.5.

348
DUBROWSKI, Frances, 1981, American political options, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 161.

349
DUBROWSKI, Frances, 1981, Public action in the United States, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 131-132.

350
DUCE, R. A., and others, 1977, The collection and analysis of heavy metals in atmospheric particles from remote marine locations, in World Meteorological Organization, Air pollution measurement techniques: Geneva, Switzerland, World Meteorological Organization, Special Environmental Report no. 10, WMO-no. 460, p. 109-117.

351
DUCE, R. A., and ZOLLER, W. H., 1975, Atmospheric trace metals at remote northern and southern hemisphere sites--pollution or natural?: Science, v. 187, p. 59-61.

Trace-metal analysis of a series of atmospheric particulate samples collected near sea level over the North Atlantic show that Al, Se, Mn, Fe, Co, Cr, Na, Mg, Ca, K, V, Zn, Cu, Cd, Pb, Sb, and Se are derived from crustal weathering or the ocean. Relative quantities of these trace metals are compared to similar samples from the troposphere at the geographic South Pole. Anomalously high enrichment factors are attributed to natural rather than man-made sources; these metals may be involved in a vapor phase at their source.

352
DUDAS, M. J. 1981, Long-term leachability of selected elements from fly ash: Environmental Science and Technology, v. 15, no. 7, p. 840-843.

Ion release and weathering characteristics of fly ash from a power-generating plant are determined by a long-term leaching experiment. Initial ion-release characteristics of fly ash are mainly dominated by dissolution of various simple, inorganic salts admixed with glassy siliceous fly-ash particles.

353
DUMANOSKI, Dianne, 1980, Acid rain: Sierra, v. 65, no. 3, p. 38-45, 60.

This article gives an overview of the causes, ecological effects, and history of acid precipitation and discusses the control of emissions from industrial plants as well as air-pollution legislation such as the Clean Air Act.

354
DUNCAN, L. C., 1981, Acid precipitation in the Washington Cascades: Washington, D.C., U.S. Department of the Interior, Office of Water Research and Technology, Research Project Technical Completion Report, 20 p.

Precipitation samples were collected at five sites in the Washington Cascade Mountains from January through June 1981 and analyzed for pH. Average pH was substantially below 5.6, and pH varied with location. The lowest average pH (4.71) was at the Cascade Crest (Snoqualmie Pass). Sulfate was the dominant anion at all sites. Strong-acid concentration of precipitation increased during summer. Twenty-nine lakes in the Cascade Crest were monitored during the summer of 1981. Results indicate that all lakes were sensitive (but not acidified) to acid precipitation. Alkalinity ranged from 4 to 190 µeq/L.

355
DUNSON, W. A., and MARTIN, R. R., 1973, Survival of brook trout in a bog-derived acidity gradient: Ecology, v. 54, no. 6, p. 1370-1376.

Bog water was analyzed to determine the occurrence of volatile acid and species of fish that are present at different pH levels.

355 (continued)
Hatchery brook trout were tested for pH tolerence in a stream at points where native fish were present and absent. Survival times of the brook trout were directly related to pH; the tolerance of individual fish to low pH was quite varied.

356
DURHAM, J. L., OVERTON, J. H., and ANEJA, V. P., 1981, Influence of gaseous nitric acid on sulfate production and acidity in rain: Atmospheric Environment, v. 15, no. 6, p. 1059-1068.

A model of physico-chemical subcloud rain was used to simulate the effect of gaseous nitric acid (HNO_3) and nitrogen oxides (NO_x) on pH and sulfate ion (SO_4^{2-}) production in a 10 mm/h, 1,000-m fall distance rainstorm. Ambient gases in the chemical model are sulfur dioxide (SO_2) nitrogen oxide (NO), nitrogen dioxide (NO_2), nitric acid (HNO_3), ozone (O_3), and carbon dioxide (CO_2). Raindrops initially with a pH of 5.5, absorbed the gases and as they fell through a polluted zone, and produced SO_4^{2-} and NO_3^-. The oxidation of dissolved SO_2 by O_3 and the dissociation of HNO_3 produced the SO_4^{2-} and NO_3^-, which in turn reduced the pH. The absorption of gaseous HNO_3 controlled the acidification in the below-cloud washout of rain events, and inhibited the production of SO_4^{2-}.

357
DYMBE, L., and CHRISTOPHERSEN, Nils, 1980, Modelling sulfate concentrations in streamwater at Storgama, Southern Norway, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 288-289.

358
DYRING, E. [ed.], 1972, Sulphur pollution across national boundaries: Ambio, v. 1, no. 1, p. 15-20.

This article describes a case study of air pollution by sulfur prepared by a group of Swedish scientists and reported at the United Nations Conference on the Human Environment in 1971. About half of the sulfur deposited on Sweden is derived from long-range transport from abroad, and the major part of sulfur emitted in Sweden is transported to neighboring countries. The article gives a summary of damage to the environment by acid precipitation and discusses preventive measures to reduce the occurrence of anthropogenic sulfur in the atmosphere.

E

359
EATON, J. S., LIKENS, G. E., and BORMANN, F. H., 1973, Throughfall and stemflow chemistry in a northern hardwood forest: Journal of Ecology, v. 61, p. 495-508.

Research on the process of nutrient removal from the forest canopy by precipitation was conducted in 1969 at the Hubbard Brook Experimental Forest in the White Mountains of New Hampshire. Data on throughfall and stemflow chemistry were obtained from beneath American beech, sugar maple, and yellow birch trees. Nutrients associated with organic molecules such as phosphorus moved more slowly from the forest canopy to the forest floor than nutrients commonly found in ionic form.

360
EATON, J. S., LIKENS, Gene, and BORMANN, F. H., 1980, Wet and dry deposition of sulfur at Hubbard Brook, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 69-75.

361
EATOUGH, D. J., MAJOR, T., RYDER, J., HILL, M. W., MANGELSON, N. F., EATOUGH, N. L., HANSEN, L. D., MEISENHEIMER, R. G., and FISCHER, J. W., 1978, The formation and stability of sulfite species in aerosols, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 263-271.

Recent epidemiological and animal toxicological studies indicate that reactions between SO_2 and metal containing aerosols result in the formation of respiratory irritants. These studies point out the importance of understanding in detail the chemical species formed by such interactions. Using a combination of thermometric, ESCA and PIXE analysis techniques, it has been demonstrated that both inorganic and organic S(IV) species are stable constituents of aerosols associated with pollution sources containing SO_2 and transition metals or with pollution sources resulting from the combustion of fossil fuels. The data indicate the inorganic sulfite species are present as complexes with Fe(III), Cu(II), Zn(II), and possibly Pb(II). The concentration of these inorganic sulfite species is 10 to 30% of the sulfate concentration in primary aerosols produced by smelters. These inorganic sulfite species tend to be evenly distributed over the various particle sizes. In contrast, the

361 (continued)
inorganic sulfite in primary aerosols produced by fossil fuel burning sources tends to exist in the <3 μm size range and can vary from a negligible to a major fraction of the sulfur species produced. The factors which control this variability are presently unknown. The principal mode of formation of such species in the ambient atmosphere appears to be via SO_2 absorption. Oxidation of S^o or S(-II) species to form inorganic sulfite complexes or oxidation of the sulfite species to sulfate are both extremely slow, with time consants on the order of months. Aerosol samples collected from the plume, stack, or flue lines of coal burning facilities or collected in New York City or rural Utah produce sulfite when hydrolyzed with dilute aqueous acid. It is postulated this sulfite is produced from organic-SO_2 adducts in the sample. These organic S(IV) containing species are predominantly found in the respirable size range and are present at from 5 to 50% of the sulfate concentration. It is probable that some of these S(IV) species play an important role in the removal of $SO_2(g)$ from the atmosphere to form sulfur containing aerosol species. [Abstract reprinted by permission of Pergamon Press.]

362
EDGERTON, E. S., BREZONIK, P. L., and HENDRY, C. D., 1981, Atmospheric deposition of acidity and sulfur in Florida, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 237-258.

363
EDMAN, G., and FLEISCHER, S., 1980, The River Hogvadsan liming project--a presentation, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 300-301.

364
EGGLETON, A. E. J., and COX, R. A., 1978, Homogeneous oxidation of sulphur compounds in the atmosphere, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 227-230.

Work carried out under the European COST 61a Project on the homogeneous oxidation of sulphur compounds in the atmosphere is briefly reviewed. Mechanisms for sulphur dioxide can be divided into three classes: (a) oxidation by free radicals generated photochemically, (b) oxidation by intermediates produced in thermal reactions, and (c) direct photo-oxidation.

Only (a) makes a substantial contribution to SO_2 oxidation with calculated maximum rates of between 2 and 6% h^{-1} in sunlight irradiated urban air during summer months and 1-2% h^{-1} in unpolluted air. Most of the oxidation is brought about by the attack of the OH radical on SO_2 but the contribution of RO_2 radical attack is not well determined due to uncertainties in RO_2 rate constants. H_2S, CH_3SH and $(CH_3)_2S$ react with OH radicals giving atmospheric life-times about 1 day. [Abstract reprinted by permission of United Kingdom Atomic Energy Authority and Pergamon Press.]

365
EGNER, H., and ERIKSSON, Erik, 1955, Current data on the chemical composition of air and precipitation: Tellus, v. 7, p. 134-139.

A precipitation- and air-monitoring network was initiated in Scandinavia and Great Britain in 1954. The network initially contained 49 stations. Precipitation samples were analyzed for eight constituents and pH. Results were published in several issues of *Tellus*. [See also the next four references.]

366
EGNER, H., and ERIKSSON, Erik, 1955, Current data on the chemical composition of air and precipitation: Tellus, v. 7, p. 522-527.

367
EGNER, H., and ERIKSSON, Erik, 1956, Current data on the chemical composition of air and precipitation: Tellus, v. 8, p. 112-113, 283-285, 411-413, 513-517.

368
EGNER, H., and ERIKSSON, Erik, 1957, Current data on the chemical composition of air and precipitation: Tellus, v. 9, p. 140-143.

369
EGNER, H., and ERIKSSON, Erik, 1960, Current data on the chemical composition of air and precipitation: Tellus, v. 12, p. 112-118.

370
EISENREICH, S. J., HOLLOD, G. J., and JOHNSON, T. C., 1981, Atmospheric concentrations and deposition of polychlorinated biphenyls to Lake Superior, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 425-444.

371
EISENREICH, S. J., THORNTON, J. D., MUNGER, J. W., and GORHAM, Eville, 1980, Impact of land-use on the chemical composition of rain and snow in northern Minnesota, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 110-111.

372
ELDER, F. C., 1980, Overview of LRTAP Aquatic Effects Program, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 67-80.

373
ELGMORK, Kare, HAGEN, Arne, and LANGELAND, Arnfinn, 1973, Polluted snow in southern Norway during the winters 1968-1971: Environmental Pollution, v. 4, p. 41-52.

Snow in southern Norway is characterized by alternating white and dark gray layers. The gray layers are considerably more acidic, have a higher electrical conductivity, and have greater amounts of sulfur, heavy metals, and other elements than the white layers. The banding is caused by airborne particles. The resulting meltwater has sulfur concentrations as high as 8.5 mg/L, lead up to 98 µg/L, and pH as low as 3.25. The regional distribution of airborne pollution is reflected in the chemical stratification of snow. The presence of high acidity and large number of chemical constituents in the snow over a wide area suggest that the substances are brought into Norway by low-pressure systems from industrial areas of western and central Europe.

374
ELIAS, R. W., and PATTERSON, C. C., 1980, The toxicological implications of biochemical studies of atmospheric lead, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 391-403.

More than ninety-nine percent of the 400,000 metric tons of lead entering the atmosphere each year are from anthropogenic sources. Mass balance estimates of removal by precipitation and dry deposition are roughly equivalent to these inputs, with removal by dry deposition in remote terrestrial ecosystems being about twice that of preciptation. The impact of this anthropogenic lead, described in related studies, has served to elevate the amounts of lead in the critical storage reservoirs of plants, animals and humans by factors of 2-2000. From the biogeochemical reconstruction of Pb/Ca ratios, using the principle of biopurification, the levels of natural lead can be determined. These reconstructions suggest that lead levels in humans, both North Americans and Europeans, have been elevated about 2000-fold above natural prehistoric levels.

Since laboratory animals are contaminated by factors similar to humans, no research on the biochemical effects of lead has yet been conducted using controls free of anthropogenic

374 (continued)
lead. To determine the initial biochemical response to lead above natural levels, it is essential to raise control organisms in protected environments using special techniques to remove anthropogenic lead from the air, food, and water consumed by the organisms. [Abstract reprinted by permission of Plenum Press.]

375
ELIASSEN, Anton, 1978, The OECD study of long range transport of air pollutants--long range transport modelling, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 479-487.

A Lagrangian-type model has been used to quantify long range transport of sulphur over Europe on an annual basis (1974). Basic model assumptions are discussed. Calculated concentrations of sulphur dioxide and particulate sulphate are compared with observations. The agreement is variable for daily values, but better for annual averages. A sulphur dry deposition pattern for Europe for 1974 is estimated by an indirect method, in which the annual mean concentration of sulphate in precipitation is approximated by calculated air concentrations of particulate sulphate. The estimated total amounts of dry and wet deposition within the area considered (9 M km^2) are about 11 Mt and 6 Mt S respectively, as compared to a total emission of 20 Mt. [Abstract reprinted by permission of Pergamon Press.]

376
ELIZERMAN, A. W., 1981, Mechanisms of enrichment at the air-water interface, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 81-97.

377
ELSHOUT, A. J., VILJEER, J. W., and VAN DUUREN, H., 1978, Sulphates and sulphuric acid in the atmosphere in the years 1971-1976 in the Netherlands, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 785-790.

In 1971 an orientating study was started concerning the ground-level concentrations of sulphate and sulphuric acid relative to sulphur dioxide. In order to achieve a more selective method for the determination of sulphuric acid the separation of sulphuric acid from sulphates by isopropanol was used. After separation sulphuric acid and sulphate are determined specrophometrically with barium chloranilate. Air samples were taken with air samplers using 0.8 µm pore cellulose triacetate filters. In the winter 1971-1972 at Arnhem the ratio sulphate/total sulphur correlated significantly with the relative

377 (continued)
humidity and decreased with increasing SO_2 concentration. The mean value of the ratio was 12.5% at a mean SO_2 concentration of 71 μg m^{-3}. The mean ratio H_2SO_4/total sulphur was 0.34%. In summer 1972, with a mean ratio sulphate/total sulphur of 36.8% at a mean SO_2 level of 8 μg m^{-3}, there was a correlation between sulphate and NH_3 on days with a relative humidity >80%; this suggests an influence on the oxidation rate by NH_3. The amounts of NH_4^+, SO_4^{2-}, and NO_3^- give rise to the supposition that the greater part of sulphate and nitrate is present as ammonium salts. The measurements were continued at Arnhem and Rotterdam (Rijnmond area) in 1973, 1975 and 1976. In these years there was a strong decrease in SO_2 concentration with a less stronger decrease in sulphate concentration. This together with the uniform distribution of sulphates in The Netherlands indicates that the sulphate level is caused mainly by long range transport. There was no increased reactivity in the formation of sulphates in the industrial Rijnmond area as compared to the eastern part of The Netherlands. Increased H_2SO_4 concentrations occurred as a result of transport of aerosols over sea by western winds. In summer 1976 there were significant correlations between both sulphate and nitrate with ozone at all the measuring stations, from which the existence of photochemical reactions over large areas can be concluded. [Abstract reprinted by permission of Pergamon Press.]

378
EMANUELSSON, A., ERIKSSON, Erik, and EGNER, H., 1954, Composition of atmospheric precipitation in Sweden: Tellus, v. 6, no. 3, p. 261-267.

This study tabulates the geographic distribution of annual amounts of Na, Cl, K, Ca, NH_3-N, and NO_3-N deposited on land surface by preciptation, based on 2 years of data collected in Sweden. Ratios of the total amounts of constituents in precipitation to the total amount of Na deposited during the same time show systematic patterns of geographic distribution.

379
EMBER, L. R., 1979, Acid rain focus of international cooperation: Chemical and Engineering News, v. 57, no. 49, p. 15-18.

This paper discusses the first international agreement on transboundary air pollution. Thirty-three countries, including those in the United Nations Economic Commission for Europe, U.S., Canada, and Soviet Bloc countries agreed to limit, reduce, and prevent all forms of air pollution. Transboundary transport of hazardous emissions and acid precipitation are of special concern to the counties participating in the agreement.

380
EMBER, L. R., 1979, Atmospheric research at NCAR: Environmental Science and Technology, v. 13, no. 11, p. 1331-1334.

The National Center for Atmospheric Research (NCAR) is a private laboratory owned by the University Corporation for Atmospheric Research and conducts scientific investigations under contract with the National Science Foundation. NCAR and seven other institutions are conducting a $360,000 study to determine the atmospheric source of acid in rainwater. The article presents some of the preliminary findings of this study and discusses other projects conducted by NCAR.

381
EMMELIN, Lars, 1976, Effects of acid rain: Ambio, v. 5, no. 2, p. 83-84.

This article presents a discussion of the complex ecological problems resulting from sulfur in the atmosphere and the subsequent chemical and physical transformations of pollutants in the atmosphere. Remedial actions must be taken at the local level to control sulfur emissions to avoid large-scale spread of sulfur in the atmosphere. Decreased forest production, acidification of lakes and rivers, and decreased fish populations are some of the ecological effects of sulfur pollution.

382
ENGER, Leif, and HOGSTROM, Ulf, 1979, Dispersion and wet deposition of sulfur from a power plant plume: Atmospheric Environment, v. 13, p. 797-810.

Wet fallout of sulfate and the transformation rate of sulfur dioxide to sulfate was determined at an oil-fired powerplant in Sweden. In five tests, two-thirds of the wet deposition emitted was deposited within 80 to 120 km and, in one test, within 190 km. Transformation of sulfur dioxide to sulfate rates vary widely with humidity. Transformation rates may be accelerated by the presence of ammonia.

383
ERICKSON, R. E., YATES, L. M., CLARK, R. L., and McEWEN, David, 1977, The reaction of sulfur dioxide with ozone in water and its possible atmospheric significance: Atmospheric Environment, v. 11, p. 813-817.

The reaction rate between ozone and dissolved sulfur dioxide is strongly dependent on pH because of rapid reaction of sulfate ion. It is also reported that under some conditions, atmospheric oxidation of SO_2 may involve ozone.

384
ERIKSSON, Erik, 1952, Composition of atmospheric precipitation. I, Nitrogen compounds; and II, Sulfur, chloride, iodine compounds: Tellus, v. 4, p. 215-232, 280-303.

This paper summarizes chemical data on atmospheric precipitation throughout the world and discusses the different cycles for inorganic compounds in atmospheric precipitation. Part II includes a comprehensive bibliography containing 371 references.

385
ERIKSSON, Erik, 1957, The chemical composition of Hawaiian rainfall: Tellus, v. 4, no. 4, p. 509-520.

Rainwater samples were collected daily for about a month at two sites on Hawaii and analyzed for pH and several constituents. Using Na as a reference results showed an excess of Ca, Mg, K, SO_4 and sometimes Cl. The pH values were lower than would be expected from a dilute solution of sea salts and more cations than anions were found. The Hawaiian rainwater closely resembles rainwater collected near the Swedish west coast, except that the concentrations of ammonia and nitrate, are relatively low.

386
ERIKSSON, Erik, 1959, The yearly circulation of chloride and sulfur in nature; meteorological, geochemical and pedological implications, parts I and II: Tellus, v. 11, no. 4, p. 375-403 and v. 12, no. 1, p. 63-109.

These two detailed papers discuss the chemical composition of constituents in the atmosphere, and circulation, vertical transport, and sources of chloride and sulfur. The papers also present data on (1) the occurrence of sea-salt particles in the atmosphere and their yearly circulation between continents and the oceans, (2) chemical reactions of HCl, SO_3, and H_2SO_4 in the atmosphere, and (3) deposition of chloride and sulfur over the continents. A discussion on the sulfur cycle is included.

387
ERIKSSON, Erik, 1963, The yearly circulation of sulfur in nature: Journal of Geophysical Research, v. 68, no. 13, p. 4001-4008.

This paper presents quantitative data on the circulation of sulfur in the enviroment. The total amount of sulfur that passes through the atmosphere in a year is about 365 million tons. Industrial emissions contribute about 11 percent of the total.

388
ERIKSSON, Erik, 1981, Aluminum in groundwater--possible solution equiibria: Nordic Hydrology, v. 12, no. 1, p. 43-50.

388 (continued)
Studies of the ground-water quality in the west coast region of Sweden show that pH values are as low as 4, and concentrations of soluble aluminum are high. These effects are attributed to acid precipitation and to the low-buffering capacity of the soils in this area of Sweden. This paper discusses the chemistry of inorganic aluminum compounds in the rocks and soils as it relates to the acidification of ground water.

389
ESPOSITO, M. P., SZABO, M. F., and DEVITT, T. W., 1980, Acid rain--the impact of local sources: Morgantown, W. Va., U.S. Department of Energy, Report DOE/METC/14787-103, 25 p.

Data on fuel use and source emissions in the Adirondack Mountains of New York, Florida, and California suggest that local oil burning and automobile exhaust may contribute significantly to the occurrence of acid precipitation in these areas. In areas where large quantities of oil are burned, the effect of locally generated sulfates may equal or possibly exceed the amount of sulfates derived from distant coal-burning sources. Large quantities of oil are being consumed in areas receiving acid precipitation, according to fuel-consumption data. Nitric acid is believed to cause 30 percent of the acid precipitation in the northeastern United States and Florida and 30 to 75 percent in California. Local source-control strategies such as ammonia injection, desulfurization, metal catalysts, and enforced operating regulations may be needed to reduce sulfur dioxide and sulfate emissions from oil-fired boilers.

390
EUROPEAN INLAND FISHERIES ADVISORY COMMISSION, 1969, Water quality criteria for European freshwater fish--extreme pH values and inland fisheries: Water Research, v. 3, p. 593-611.

This article summarizes published and unpublished data on direct and indirect effects of extreme pH values on fish. Emphasis is on European species. Present data are insufficient to establish pH criteria for each major fish species. A gradual decline in fish population occurs as pH values decrease below the normal range. The pH range of 5 through 9 is not directly lethal to most fish, but the toxicity of several common pollutants is significantly affected by pH changes within this range. An acid stream may free enough carbon dioxide from bicarbonate in the water to be directly toxic or to cause the pH range 5 through 6 to become lethal. Fish mortalities may be expected below pH 5, but some species may become acclimated to values as low as 3.7.

391
EVANS, L. S., 1979, A plant developmental system to measure the impact of pollutants in rain water: Journal of the Air Pollution Control Association, v. 29, no. 11, p. 1145-1148.

Bracken ferns (*Pteridium aquilinum*) were used to monitor the effects of acid rain on plant development. Fertilization and spermatozoid motility in gameto-phytes of bracken fern are sensative to low pH, sulfate, nitrate, and chloride. Results indicate bracken fern to be a reliable indicator of pollutants in rainwater.

392
EVANS, L. S., 1980, Foliar responses that may determine plant injury by simulated acid rain, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 239-257.

Experiments were performed to categorize the responses of foliage of several plant species after exposure to simulated acid rain in order to predict the relative sensitivities of plants to acid precipitation in nature. The present investigations were performed to (1) identify leaf indumentum responses, (2) determine histological responses, and (3) determine whole plant and individual leaf responses that may be used to diagnose acid rain injury. Plants were exposed to simulated rain at pH levels of 5.7, 3.4, 3.1, 2.9, 2.7, 2.5, and 2.3. Sporophyte leaves of bracken fern (*P. aquilinum*) and foliage of pinto bean, soybeans, and sunflower were most sensitive to simulated acid rain among the species tested. About 5% of the surface area of older leaves of sunflower, soybeans, and pinto beans was injured after exposure to 4 rainfalls at pH 2.5 (a single-six min rainfall every four days). Foliage of pin oak (*Q. palustris*) exhibited less than one-percent leaf area injury after exposure to simulated rain at pH 2.5 after 10 rainfalls (one-twenty min rainfall daily). The responses of poplar (*Populus* sp.) and spiderwort (*Tradescantia* sp.) were intermediate between these two extremes. Histological observations show that lesion development results in collapsed leaf tissue in most sensitive species. Gall formation that resulted from both cell hypertrophy (abnormal cell enlargement) and hyperplasia (abnormal cell proliferation) occurred in lesions of spiderwort, poplar, and oak. Limited hyperplastic and hypertrophic reactions occurred in soybean foliage after exposure to simulated acid rain but no leaf galls resulted. Sporophyte foliage of *P. aquilinum* and leaves of pinto bean and sunflower exhibited neigher hyperplasia nor hypertrophy after exposure to simulated acid rain. Injury occurred most frequently near vascular tissues and trichomes in all species. In general, plant species that show cell hyperplasia and hypertrophy of leaf tissues after exposure to simulated acid rain are injured less than species that do not show these responses. [Abstract reprinted by permission of Plenum Press.]

393
EVANS, L. S., 1981, Biological effects of acidic precipitation on vegetation, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 19.

394
EVANS, L. S., and BOZZONE, D. M., 1977, Effect of buffered solutions and sulfate on vegetative and sexual development in gametophytes of *Pteridium aquilinum*: American Journal of Botany, v. 64, no. 7, p. 897-902.

This paper discusses the effects of buffered solutions on development and fertilization of gametophytes of bracken ferns (*Pteridium aquilinum*). Bracken ferns were exposed to buffered solutions for 3.5 hours to simulate acid rain. Flagellar movement of sperm was reduced at pH below 5.8. With the addition of 86 μm sulfate, fertilization decreased at least 50 percent at all pH levels. Limited fertilization and genetic recombinations could occur in *Pteridium aquilinum* under conditions of acid rain.

395
EVANS, L. S., CONWAY, C. A., and LEWIN, K. F., 1980, Yield responses of field-grown soybeans exposed to simulated acid rain, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 162-163.

396
EVANS, L. S., CONWAY, C. A., and LEWIN, K. F., 1980, Yield responses of field-grown soybeans exposed to simulated acid rain: Upton, N.Y., Brookhaven National Laboratory, BNL-27597, 7 p.

This article describes an investigation of the effects of acid preciptation on crop yield. Soybeans were given five treatments of simulated rain at pH of 4.0, 3.1, 2.7, and 2.3. Results indicate that seed mass per plant decreased with an increase of hydrogen ion applied to the plants. In addition to hydrogen ions (H^+) in ambient rain, total additions of 50, 397, and 998 μeq for the growing season decreased seed yields 3, 5, and 8 percent, respectively. Small additions of simulated acid rain to soybeans decreased the number of pods per plant.

397
EVANS, L. S., CUNNINGHAM, E. A., and LEWIN, K. F., 1981, Effects of simulated acidic rain on yields of field-grown garden beets and radishes, in American Chemical Society, Division of Environmental Chemistry, 182nd National Meeting, New York, N.Y., Preprints, v. 21, no. 2: Washington, D.C., American Chemical Society, p. 82-87.

398
EVANS, L. S., and CURRY, T. M., 1979, Differential responses of plant foliage to simulated acid rain: American Journal of Botany, v. 66, no. 8, p. 953-962.

This paper describes the responses of foliage of several clones of spiderwort (*Tradescantia*), bracken fern (*Pteridium aquilinum*), and soybean (*Glycine max*) to simulated acid rain. Initial injury from acid rain preferentially affected the leaf indumentum near trichomes and vascular tissues. Plant species that exhibited cell hyperplasia and hypertrophy of leaf tissues after exposure to simulated acid rain were injured less than species that did not show these responses.

399
EVANS, L. S., GMUR, N. L., and DA COSTA, Filomena, 1978, Foliar response of six clones of hybrid poplar: Phytopathology, v. 68, no. 6, p. 847-856.

The effects of simulated acid rain on hybrid clones of *Populus* supp. were investigated. Specific effects include (1) percentage of leaves injured, and (2) percentage of leaf area with lesions. Several types of lesions developed on foliage of six clones of *Populus* supp. hybrids after exposure to simulated acid rain with pH of 2.7 to 3.4. Lesions developed near the stomata and vascular tissues and occurred most frequently just before maximum leaf enlargement. Very young and older leaves were affected less frequently.

400
EVANS, L. S., GMUR, N. F., and KELSCH, J. J., 1977, Perturbations of upper leaf surface structures by simulated acid rain: Environmental and Experimental Botany, v. 17, p. 145-149.

Foliar injury to *Phaseolus vulgaris* and *Helianthus annuus* after exposure to simulated acid rain with pH of 5.7 (control), 3.0, and 2.7 was investigated. Lesions on leaves were initially localized near trichomes and stomata on adaxial leaf surfaces. Analysis by scanning electron micrographics showed that 75 percent of all lesions begin at the bases of spiked and grandular trichomes, 20 percent originated at or near stomata, and about 5 percent of lesions begin in other areas.

401
EVANS, L. S., and HENDREY, G. R., eds., 1979, International workshop on the effects of acid precipitation on vegetations, soils, and terrestrial ecosystems, Upton, N.Y., 1979, Proceedings: Upton, N.Y., Brookhaven National Lab., BNL-51195, 48 p.

The objectives of the workshop were to (1) define research priorities for determining the effects of acid precipitation on vegetation, soils, and terrestrial ecosystems, and (2) establish coordination among research groups. Plant injury caused by acid precitation is a major concern, particularly as it affects plant reproduction. Other research priorities identified were (1) interaction of acid precipitation with toxic elements such as aluminum, iron, and manganese, and (2) effects of acid precipitation on nutrient cycling.

402
EVANS, L. S., HENDREY, G. R., STENSLAND, G. J., JOHNSON, D. W., and FRANCIS, A. J., 1981, Acidic precipitation--considerations for an air quality standard: Water, Air, and Soil Pollution, v. 16, p. 469-509.

This paper evaluates the impacts of acidic precipitation on aquatic and terrestrial ecosystems. Current research shows that a maximum permissible weighted annual hydrogen ion concentration of 25 μeq/L for precipitation may protect the most sensitive regions from permanent lake acidification. Enforcement of this standard will probably protect other ecosystems also.

403
EVANS, L. S., and LEWIN, K. F., 1980, Effects of simulated acid rain on growth and yield of soybeans and pinto beans, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 299-308.

In order to assess the degree of damage that acid rain has or might have on plants, experiments were performed to determine the change in seed yield of soybeans and pinto beans after exposure to simulated rain of pH 5.7, 3.1, 2.9, 2.7, and 2.5. Moreover, the effects of simulated rain were determined on a variety of other experimental parameters to understand further how plants respond to this environmental stress. Simulated acid rain of pH 3.1 and below decreased the dry mass of seeds, leaves, and stems of pinto beans. On a percentage mass basis the decrease in seed yield was comparable with reductions in biomass of leaves and stems. The decrease in yield of pinto beans by simulated acid rain was attributed to both (1) a decrease in the number of pods per plant and (2) a decrease in the number of seeds per pod. In soybeans,

403 (continued)
simulated acid rain decreased the dry mass of both stems and leaves. Seed yield also decreased after treatment with rain of pH 2.5. However, an increase in seed yield occurred when plants were exposed to rain of pH 3.1. A larger dry mass per seed was responsible for the larger dry mass of seed per plant. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

404
EVANS, L. S., and MILLER, P. R., 1975, Histological comparison of single and additive O_3 and SO_2 injuries to elongating Ponderosa pine needles: American Journal of Botany, v. 62, no. 4, p. 416-421.

The histological effects of O_3, SO_2, and a combination of the two on Ponderosa pine needles were monitored. The objectives were to (1) provide a diagnostic means to identify injury to pine tissue promptly after exposure to specific air pollutants, (2) determine tissue injury targets, (3) determine the effect of leaf injury on tissue development, and (4) assay additive or synergistic tissue injury after exposure to SO_2 and O_3. Visual and histological injury was observed in distal parts of pine needles after exposure to SO_2 or to SO_2 and O_3. Most of the damage was caused by SO_2. Treatments with O_3 caused an aggravation of cytoplasm and cellular organelles into peripheral areas of plicate parenchyma cells.

405
EVERSMAN, Sharon, 1978, Effects of low-level SO_2 on *Usnea hirta* and *Parmelia chlorochroa*: The Bryologist, v. 81, no. 3, p. 368-377.

Respiration rates of *Usnea hirta* and *Parmelia chlorochroa* decreased significantly when exposed to SO_2 fumigation. Almost all algal cells were plasmolyzed within 60 days. Damage to lichens was more pronounced and occurred faster than in adjacent vascular vegetation.

F

406
FABIJANOWSKI, J., and LESINSKI, J. A., 1980, Reconstruction of species composition of stands as necessary condition for the survival of the Niepolomice Forest, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 164-165.

407
FAIRFAX, J. A. W., and LEPP, N. W., 1975, Effect of simulated "acid rain" on cation loss from leaves: Nature, v. 255, no. 5506, p. 324-325.

This paper discusses nutrient losses from leaves in response to low-pH rainfall. Tobacco leaves were selected from plants of the same age and same stage of maturity and were leached with deionized water at pH 6.7 and 3.0. Decreased pH in rainfall causes increased loss of foliar Ca^{2+}, and decreased loss of K^+.

408
FALCONER, Raymond, 1979, Acid rain and precipitation chemistry at Whiteface Mt., N.Y., in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 62-72.

409
FALKENMARK, Malin, 1980, International conference on the effects of acid rain urges more research on critical areas: Ambio, v. 9, no. 3-4, p. 198-199.

This article summarizes the International Conference on the Ecological Impact of Acid Precipitation, held in Sandefjord, Norway, in 1980. The six principal sessions described are (1) transport and deposition, (2) movement through vegetation and direct effects on vegetation, (3) impact on soil and direct effects on vegetation, (4) effects on water quality, (5) effects on aquatic biota, and (6) integrated studies.

410
FALLER, N., 1970, Effects of atmospheric SO_2 on plants: Sulphur Institute Journal, v. 6, p. 5-7.

An investigation was conducted to determine the effects of various atmospheric SO_2 concentrations on plants grown with no other supply of sulfur. Sunflowers, corn, and tobacco were grown in solutions with adequate amounts of all essential plant nutrients except sulfur, which was present in only very small amounts. Results indicate that the presence of alkali metals decreases the plant's resistance to excessive atmospheric SO_2 concentrations.

411
FARBER, P. S., 1980, Acid rain, an international concern: Air Pollution Control Association Journal, v. 30, no. 10, p. 1089-1098.

411 (continued)
This article is an edited version of a panel discussion on the international problem of acid precipitation, held at the 73rd annual meeting of the Air Pollution Control Association. Research-program objectives according to the Synfuels Bill (Public Law 96-294) are to (1) identify the causes and sources of acid precipitation, (2) evaluate environmental, social, and economic effects, (3) limit or eliminate the emissions identified as sources of acidity, and (4) ameliorate harmful impacts.

412
FARMER, G. J., GOFF, T. R., ASHFIELD, D., and SAMANT, H. S., 1981, Some effects of the acidification of Atlantic salmon rivers in Nova Scotia, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, Internation Atlantic Salmon Foundation Special Publication Series no. 10, p. 73-91.

413
FARRELL, E. P., NILSSON, I., TAMM, C. O., and WIKLANDER, G., 1980, Effects of artificial acidification with sulphuric acid on soil chemistry in a Scots pine forest, in Drablos, D., and Tollan, Arne, eds., 1980 Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 186-187.

414
FEDERAL INTERAGENCY WORK GROUP ON PRECIPITATION QUALITY, 1978, Research and monitoring of precipitation chemistry in the United States--present status and future needs: Reston, Va., U.S. Geological Survey, 64 p.

The deterioration in quality of atmospheric precipitation, particularly in the northeastern and north-central United States, is harmful to plants, animals, soils, natural waters, and building structures. A work group on precipation quality was established by the Federal Interagency Advisory Committee on Water Data in September 1976 to determine the information needed on chemistry of precipitation in the United States and to recommend procedures for obtaining the necessary data. The report gives recommendations for establishing a national precipitation-monitoring network.

415
FENNELLY, P. F., 1976, The origin and influence of airborne particulates: American Scientist, v. 64, p. 46-56.

Manmade and natural processes contribute to the concentration of particulate matter in the atmosphere. Human health, environment, and climate are adversely affected by particulates. Discussions are given on primary and secondary particulates, mechanisms of particulate formation, and deleterious effects of particulates. A comprehensive bibliography is included.

416
FERENBAUGH, R. W., 1975, Acid rain: Biological effects and implications: Environmental Affairs, v. 4, no. 4, p. 745-758.

Researchers in the Scandinavian countries and the northeastern United States have observed pH values of rain ranging from 3.0 to 4.0. Elsewhere in the United States, pH values as low as 2.1 have been recorded. High concentrations of sulfur in the atmosphere may cause biological changes in aquatic and terrestrial ecosystems. Some of the biological effects on fish include (1) decreased resistance to disease and toxic materials, (2) decrease in general vitality, and (3) changes in migratory and spawning behavior and in development of eggs. Acid precipitation may suppress microbial acitivity in soils entirely or may enhance the activity of some microorganisms while repressing the activity of others. Another effect of acid precipitation is to increase the leaching of nutrients from the soil. This paper proposes solutions to some of the environmental problems believed to be caused by acid precipitation.

417
FERENBAUGH, R. W., 1976, Effects of simulated acid rain on *Phaseolus vulgaris* L. (Fabaceae): American Journal of Botany, v. 63, no. 3, p. 283-288.

This paper discusses the histological, physiological, and biological effects of simulated acid rain on *Phaseolus vulgaris* L. (Fabaceae). Results of a laboratory study indicate that when pH is below 3.0, plants grew more slowly, and developed necrotic and wrinkled leaves. Histological effects resulted in (1) smaller cells in leaves, (2) less intercellular space, and (3) smaller starch granules within the chloroplasts. Photosynthesis rates of plants treated with the simulated acidic rain increased dramatically, but respiration rates increased only slightly.

418
FERGUSON, Patricia, and LEE, J. A., 1979, The effects of bisulphite and sulphate upon photosynthesis in *Sphagnum*: New Phytologist, v. 82, p. 703-712.

This paper discusses the effect of bisulfite (HSO_3^-) and sulfate (SO_4^{2-}) concentrations on photosynthetic oxygen in *Sphagnum*. Reductions in growth induced by HSO_3^- are not reversed by additions of bicarbonate ion (HCO_3^-). SO_3^{2-} has no effect on oxygen evolution. The effect of HSO_3 is strongly pH-dependent and is much greater at lower pH values.

419
FERGUSON, Patricia, and LEE, J. A., 1980, Some effects of bisulphite and sulphate on the growth of *Sphagnum* species in the field: Environmental Pollution (Series A), v. 21, p. 59-71.

This article presents results given of an experiment to determine the effects of prolonged applications of simulated rain consisting of sulfate and bisulfite on a *Sphagnum*-rich, ombrogeneous bog surface in North Wales. The degree of damage due to sulfate and bisulfite depends on concentration and environmental variables, such as lateral water movement in the bog. Applications of the simulated rain, even those of short duration and not exceeding 16 percent of the total rainfall in volume, can reduce growth severely. When simulated rain applications exceed 16 percent of the rainfall volume, sulfate and bisulfate may stop growth entirely.

420
FERGUSON, Patricia, LEE, J. A., and BELL, J. N. B., 1978, Effects of sulphur pollutants on the growth of *Sphagnum* species: Environmental Pollution, v. 16, no. 2, p. 151-162.

This article discusses the combined effects of acid rain and dry deposition of sulfur on several *Sphagnum* species in Great Britain. The species have differing responses to the pollutants. Applications of 0.5 mM of HSO_3^- are lethal to the most sensitive species and reduce the growth rate of *S. recurvum*, the most resistant species, by 35 percent. The article also presents data on vegetation changes in the southern Pennines and North Cheshire, Great Britain.

421
FERRIS, B. J., Jr., SPEIZER, F. E., BISHOP, Y. M. M., SPENGLER, J. D., and WARE, J. H., 1980, The Six-City Study--a progress report, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 99-108.

The Six-City Study was designed to test the adequacy of the present primary standards for SO_2 and particulates and whether they should be relaxed or made more stringent. The study was originally designed to examine the chronic effects of air pollutants. To accomplish this we selected two relatively clean cities, two with levels slightly below the primary standards, and two dirty cities that had levels often above the standards. The cities are: Clean--Topeka, Kansas, and Portage, Wisconsin; moderate--Watertown, Massachusetts, and Kingston-Harriman, Tennessee; and dirty--Steubenville, Ohio, and the southern tip of St. Louis, Missouri. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

422
FESTA, P. J., 1979, Acid waters and declining fisheries--the next step, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 7-14.

423
FETH, J. H., 1961, Effects of rainfall and geology on the chemical composition of water in coastal streams in California, in Short Papers in the Geologic and Hydrologic Sciences: U.S. Geological Survey Professional Paper 424-B, p. B202-B204.

Concentrations of dissolved solids in streams originating along the California coast vary between summer and winter, and the composition of dissolved solids varies between north and south. Differences in chemical composition of streams reflect major differences in the geologic environment and the amount of rainfall.

424
FETH, J. H., 1964, Chemical composition of snow in the northern Sierra Nevada and other areas: U.S. Geological Survey Water-Supply Paper 1535-J, 39 p.

Analyses of snow samples collected mostly from the northern Sierra Nevada and Utah, Denver, and Colorado show that melted snow is a dilute solution containing measurable amounts of some or all inorganic constituents commonly present in water. The chemical composition of snow varies regionally and also temporally. The dissolved-solids concentration of precipitation seems to increase with distance inland from the Pacific Ocean.

425
FETH, J. H., 1966, Nitrogen compounds in natural water--a review: Water Resources Research, v. 2, no. 1, p. 41-58.

This paper summarizes the distribution of nitrogen compounds in natural water. Sources of nitrogen include aerosols, precipitation, fixation by micro-organisms in soil and water, decaying organic matter, animal and industrial wastes, and probably undiscovered sources in consolidated and unconsolidated rocks.

426
FIANCE, S. B., 1978, Effects of pH on the biology and distribution of *Ephemerella funeralis* (Ephemeroptera): Oikos, v. 31, no. 3, p. 332-339.

This article reports the effects of simulated acidification on the life history, sex ratio, fecundity, food habits, microhabitat, and distribution pattern on *Emphemeralla funeralis*. This species decreased in abundance

426 (continued)
with decreasing stream pH and decreasing organic matter. The growth of new cohorts decreased with lowered pH and were nearly eliminated when pH was lowered to 4.

427
FIRESTONE, M. K., McCOLL, J. G., and BROOKS, P. D., 1980, Effects of acid precipitation on soil nitrogen transformations in the Rhizosphere [abstract]: Agronomy Abstracts, 1980, Meetings, American Society of Agronomy and Soil Science Society of America, p. 152.

Barley and clover were treated with ionic solutions of pH 5.6, 4.0, 3.0, and 2.0. Plants and soils were analyzed for nutrients, and microbial-activity assays of soils and roots were conducted at final harvest. Acetylene-reduction assays showed significantly higher rates of nitrogen fixation in clover roots treated with solutions of pH 2.0 than those treated with other solutions. The pH of the added solution had has little effect on nitrification in unplanted soil.

428
FISHER, B. E. A., 1975, The long range transport of sulphur dioxide: Atmospheric Environment, v. 9, p. 1063-1070.

This article describes a model to calculate the annual deposition of sulfur in Europe by dry deposition and precipitation scavenging. The model incorporates data on sulfur dioxide emissions in Europe. The deposition rate of sulfur over the United Kingdom is composed with that over Sweden, and other countries in Europe. The sulfur contribution to deposition over rural Sweden from Great Britain is about one half of the Swedish contribution and about 10 percent of the total deposition. Most of the deposition over the United Kingdom, except in southeast England, originates in the United Kingdom.

429
FISHER, B. E. A., 1978, The calculation of long term sulphur deposition in Europe, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 489-501.

A model based on statistical distributions of windspeed, wind direction and dispersion categories and of rainfall is used to calculate the annual wet and dry deposition of sulphur over Europe, using a detailed emission inventory. The model explicitly allows for vertical diffusion in the mixing layer and thereby the effect of source height. Wet and dry removal are taken into account as well as the conversion of sulphur dioxide to sulphate. In regions of Europe with heavy annual precipitation, such as southwest Norway, corrections to the deposition pattern are made.

429 (continued)
Other factors, such as the diurnal variation of mixing depth and large-scale synoptic vertical motions, are investigated and are not thought to change the overall pattern of annual deposition. The calculated pattern compares favourably with measurements and calculations based on trajectory models. The results show that the highest total deposition rates occur over the major emission areas (10 g m^{-2} y^{-1} SO_2) and decrease to low values (1 g m^{-2} y^{-1} SO_2) in outlying areas of the U.K., France, Italy, and in Scandinavia. The wet deposition does not show such pronounced maxima close to emissions. The decrease in wet deposition is also modified in regions of heavy annual precipitation, such as southern Norway.

A sulphur budget is constructed for a region of southern Norway. The calculated total deposition, which agrees fairly well with the measured total deposition, is analyzed according to the sectors containing the main source areas. The contribution from each source sector is only estimated approximately (to within a factor of two) but shows the expected dependence on source strength and frequency of sulphate in precipitation not directly attributable to man-made sources in Europe.

The model calculation excludes the contribution from sources within about 100 km of a receptor site. The depositon at any sampling site is dependent on details of the source emissions within the neighbourhood of the site. However, the average regional deposition from sources within the receptor region can be assessed. It is small for southern Norway because of the low emissions in the region. Source height strongly influences the local deposition, but on a larger scale is less important than other factors, such as the frequency of wind direction, rainfall and uncertainties in the emission inventory. [Abstract reprinted by permission of Pergamon Press.]

430
FISHER, B. E. A., 1978, Long-range transport and deposition of sulfur oxides, in, Nriagu, J. O., ed., Sulfur in the environment, part 1--The atmospheric cycle: New York, John Wiley, p. 243-295.

431
FISHER, D. W., 1968, Annual variations in chemical composition of atmospheric precipitation eastern North Carolina and southeastern Virginia: U.S. Geological Survey Water-Supply Paper 1535-M, 21 p.

Precipitation samples were collected at 12 sites in eastern North Carolina and southeastern Virginia from 1962-64 and analyzed for major ions. Areal and seasonal distributions were determined for chloride, calcium,

431 (continued)
magnesium, sodium, potassium, sulfate, and nitrate. Annual changes in loads and in geographical distribution of sulfate and nitrate were small. Cation concentrations in precipitation samples seemed to depend on localized sources, probably soil dust. Bicarbonate and hydrogen ion in rainfall were closely correlated to relative concentrations of sulfate and calcium. The reaction of an acidic sulfur-containing aerosol with an alkaline calcium source seems to be a principal control on precipitation alkalinity and pH.

432
FISHER, D. W., GAMBELL, A. W., LIKENS, G. E., and BORMANN, H. F., 1968, Atmospheric contributions to water quality of streams in the Hubbard Brook Experimental Forest, New Hampshire: Water Resources Research, v. 4, no. 5, p. 1115-1126.

This article describes atmospheric contributions of selected mineral constituents in streams at the Hubbard Brook Experimental Forest, N.H. It tabulates (1) additions and discharge of sulfate, ammonium, and nitrate as calculated from hydrologic data, and (2) chemical analyses of precipitation and streamwater samples collected weekly for 2 years. Precipitation contributes most of the 30 through 50 kilograms of sulfate per hectare carried annually by the streams. Inflows of ammonium and nitrate exceed outflows. Hydrogen ion is one of the major cations in precipitation.

433
FITZGERALD, J. W., 1978, Naturally occurring organosulfur compounds in soils, in Nriagu, J. O., ed., Sulfur in the environment, part II--ecological impacts: New York, John Wiley, p. 391-443.

434
FLACK, W. W., and MATTESON, M. J., 1980, Mass transfer of gases to growing water droplets, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 61-85.

The absorption of gases by clouds, fogs and water droplets is a key step in the removal process for many trace gases in the atmosphere. The high acid content of rainfall in many industrial regions is attributed to the absorption of sulfur and nitrogen oxides. Upon the release of fossil fuel stack gases, containing water vapor, which are rapidly cooled from 250°F to ambient temperatures, much of the associated oxides of sulfur and nitrogen is dissolved as the water is condensed upon suspended particles and the smoke plume is formed.

434 (continued)
The object of the work reported here is to determine the rates of absorption of SO_2, NO_2 and oxygen at stack gas concentration by water droplets undergoing growth due to water vapor condensation. [Abstract reprinted by permission of Plenum Press.]

435
FLEETWOOD, Ake, 1969, The chemical composition of the precipitation and surface water and its relation to evaporation on Bjornoya Island, Norway: Tellus, v. 21, no. 1, p. 113-126.

Water samples from lakes, rivers, and snow were collected from May through June 1965 at Bjornoya Island and analyzed for several constituents. Results indicate that ion concentrations are related to rock type of the study area. Evaporation from the concentrations of different ions is about 72 percent.

436
FLEH, R. J., 1981, Chemical, microbiological and physical interactions of acidic precipitation within a lake and its drainage basin: Rexdale, Ontario, Limnology and Toxicity Section, Ontario Ministry of the Environment, 1 v.

This report summarizes the major chemical interactions between rainfall and lake water within watersheds in the Canadian Shield, southern Ontario. Acid precipitation probably increases the rate at which soil-buffering reactions occur; hence, the finite quantity of buffers in soils will be more rapidly consumed. If the production of natural soil acids is high relative to man-made contributions, the soils should be minimally affected by the additional acids contributed by man. If the rate of natural soil production is relatively low, then additional contributions of acid to the soil may significantly accelerate the consumption of soil-buffering material.

437
FLYGER, H., LEWIN, E., THOMSEN, E. L., FENGER, J., LYCK, E., and GRYNING, S. E., 1978, Airborne investigations of SO_2 oxidation in the plumes from power stations, in Sulfur in the atmosphere, Proceedings, of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 295-296.

The Danish contribution to the EUROCOP COST 61a project is described. Work concerned the physical and chemical reactions of sulphur dioxide released from a power station. The investigation was based on the application of two tracers. Inactive, inert SF_6 is used to monitor the dispersion of and deposition from the plume; it was intended to use radioactive $^{35}SO_2$ to determine the degree of oxidation of sulphur released from the stack; so far,

437 (continued)
however, public reaction has prevented the use of a release of activity in field experiments. Some attempts have been made to base the investigations of analyses of inactive samples only. Previously published results obtained at an oil-fired power station suggest a half-life of about 30 min for SO_2 in the first part of the plume. New results obtained at a mainly coal-fired power station give a half-life of about 90 min. [Abstract reprinted by permission of Pergamon Press.]

438
FOGG, T. R., and FITZGERALD, W. F., 1979, Mercury in southern New England coastal rains: Journal of Geophysical Research, v. 84, section C, no. C11, p. 6987-6989.

Rainwater samples were collected at coastal sites in Connecticut and at Cape Cod, Mass. during late summer, fall, and winter of 1975 through 1976. Samples were analyzed for mercury (Hg) and results indicate concentrations averaged 10±5 ng/L in 29 analyses. Global mercury budgets estimate concentrations of 30 to 80 ng/L and may overestimate the flux of Hg in rainfall to the ocean.

439
FORLAND, E. J., 1973, A study of the acidity in the precipitation in southwestern Norway: Tellus, v. 25, no. 3, p. 291-298.

This article discusses the influence of remote and local sources of acid precipitation in southwestern Norway. The distribution of pH values for various wind directions indicates that the acidity in the area is not from local sources. Trajectories of rain-bearing air masses indicate that the highest acidity in southwestern Norway is in air masses passing over major industrial areas in Central Europe and the United Kingdom.

440
FORLAND, E. J., and GJESSING, Y. T., 1975, Snow contamination from washout, rainout and dry deposition: Atmospheric Environment, v. 9, p. 339-352.

Deposition patterns of air pollutants in snow in western Norway may be studied by an inexpensive method. This article discusses pH, conductivity, and deposition patterns of sulfate, magnesium, calcium, and zinc. The rate of dry deposition in rural areas is significantly lower than the rate of washout and rainout; these two rates were similar in the urban area.

441
FOSBERG, M. A., RECORD, Hollis, 1980, Emissions and air resource management within forests, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 13-23.

Substantial portions of the emissions inventory within forested lands are from dispersed intermittent sources. Chief sources are smoke from wildfire and prescribed fire, emissions associated with concentrated recreation and second-home developments, and fugitive dust from unpaved roads and eolian soils. Effects of smoke on flora range from reduced photosynthetic efficiency at low dosages in tissue necrosis at high dosages. Effects on fauna are not clearly defined. Effect of smoke on social values, primarily visibility, is recognized but not understood. Dispersion process in complex terrain, the physiographic setting for most forested lands, is complicated by topography and spatially varying wind fields, a higher degree of anisotropy of turbulence, and a wider range of turbulence intensities than found over level ground. Management of air resources within forested areas is limited to land management planning activities because of the complexity of emission characteristics, dispersion processes, and effects of pollutants from within forest sources. [Abstract reprinted by permission of U.S. Forest Service.]

442
FOWLER, David, 1978, Dry deposition of SO_2 on agricultural crops, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 369-373.

A micrometeorological method has been used to estimate dry deposition rates of sulphur dioxide on agricultural crops from vertical gradients of SO_2 concentration, windspeed and air temperature above the crop surface. Field measurements in a wide range of atmospheric and surface processes enabled nalysis of the results to separate the various atmospheric and sulfur processes controlling the flux. For wheat, deposition velocity (Vg) 1 m above the surface varied between 0.1 and 1.5 cm s^{-1} and was controlled primarily by surface processes, surface resistance generally contributing 70% of total resistance (rt). Values of surface resistance are determined essentially by deposition at two sinks, the sub-stomatal cavity, and leaf cuticle acting in parallel. With stomata open, 1/3 of the total SO_2 flux was to the leaf surface and 2/3 to the sub-stomatal cavity. When foliage was wet with

442 (continued)
rain or dew, provided the pH of the liquid was >3.5, surface resistance is negligible and *Vg* then controlled by atmospheric resistance may exceed 1 cm s^{-1}. For agricultural areas of Britain (14 x 106 ha) dry deposition has been estimated at 72 kg SO_2 ha^{-1} annually, 60% of which is deposited during the winter (October-March, inclusive), equivalent to a deposition velocity of 0.6 cm s^{-1} for the area considered. [Abstract reprinted by permission of Pergamon Press.]

443
FOWLER, David, 1980, Removal of sulphur and nitrogen compounds from the atmosphere in rain and by dry deposition, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 22-32.

444
FOWLER, David, 1980, Wet and dry deposition of sulfur and nitrogen compounds from the atmosphere, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 9-27.

445
FOWLER, David, CAPE, J. N., NICHOLSON, I. A., KINNAIRD, J. W., and PATERSON, I. S., 1980, The influence of a polluted atmosphere on cuticle degradation in Scots pine (*Pinus sylvestris*), in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 146-147.

446
FOWLER, David, and UNSWORTH, M. H., 1974, Dry deposition of sulphur dioxide on wheat: Nature, v. 249, p. 389-390.

Approximately 6 million tons of sulfur dioxide (SO_2) are emitted into the atmosphere over Great Britain each year. This article reports results of a series of measurements of dry deposition rates on a field of winter wheat and discusses factors that may limit deposition rate. Surface wetness has a major influence on dry deposition rates, and surface resistance controls deposition to vegetated surfaces.

447
FOX, D. G., 1976, Modeling atmospheric effects--an assessment of the problems: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 173-198.

447 (continued)
Our ability to simulate atmospheric processes that affect the life cycle is reviewed. The transport process is considered on three scales: (a) the near-source or single-plume dispersion problem, (b) the multiple-source dispersion problem, and (c) the long-range transport. Modeling the first of these is shown to be well within the capability of generally available techniques, although determining the input parameters is often difficult. The second scale has been well studied within the context of urban diffusion and is a very productive area of current research. Finally, long range transport is treated mainly as a meteorological problem. The state of the art in modeling the various meteorological processes is reviewed. Removal of pollutants is discussed in the form of both dry deposition and preciptation scavenging. It is suggested that dry removal is especially effective in forested areas, and that the forests may enhance accumulation of pollutants.

An approximate transport model is developed which is used to calculate the ambient concentration of SO_2 throughout the United States. Associated calculations include dry deposition and the ratio of dry to wet removal for each state of the contiguous United States. [Abstract reprinted by permission of D. Riedel Publishing Company.]

448
FOX, C. A., and NASH, T. H., III, 1980, The effect of air pollution on western larch as detected by tree-ring analysis, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 234.

449
FRANCIS, A. J., OLSON, D., and BERNATSKY, R., 1980, Effect of acidity on microbial processes in a forest soil, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 166-167.

450
FRANZIN, W. G., and McFARLANE, G. A., 1980, Fallout, distribution and some effects of Zn, Cd, Pb, Cu and As in aquatic ecosystems near a base metal smelter on Canada's Precambrian Shield, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 302-303.

451
FRANZIN, W. G., McFARLANE, G. A., and LUTZ, Andrew, 1979, Atmospheric fallout in the vicinity of a base metal smelter at Flin Flon, Manitoba, Canada: Environmental Science and Technology, v. 13, p. 1513-1522.

Atmospheric fallout near a base-metal smelter at Flin Flon, Manitoba, was monitored from August 1976 through July 1977. Bulk precipitation samples were collected throughout the study, and snow samples from the surfaces of frozen lakes that were collected during winter. Both sets of samples indicated that the smelter was a major source of zinc, arsenic, cadmium, lead, and copper in bulk precipitation in the Flin Flon area. Estimates of metal deposition averaged only 55 percent of the values calculated from the winter snow samples.

452
FREEDMAN, B., and HUTCHINSON, T. C., 1980, Long-term effects of smelter pollution at Sudbury, Ontario, on forest community composition: Canadian Journal of Botany, v. 58, p. 2123-2140.

Forest vegetation was monitored along a south-southeast transect from the largest smelter in the Sudbury region. Pollution from the smelter affects forest communities at distances up to 8 km. Pockets of remnant forest communities within this zone are mainly on protected slopes and in valley bottoms. Generally, most hilltops are without vegetation, denuded of soil, and blackened from the effects of SO_2 fumigations. Beyond the 8-km range, the forests are generally continuous, although some bare hilltops occur as far as 15 km from the smelter. Forest canopy appears to be more affected by SO_2 fumigations than ground flora. Some changes in plant communities close to the smelter have occurred since the addition of a tall smokestack. These changes are mostly at sites where soils remain and residual soil toxicity is not excessive. Recovery of denuded hilltips will be slower on naked Precambrian bedrock.

453
FREEDMAN, B., and HUTCHINSON, T. C., 1980, Pollutant inputs from the atmosphere and accumulations in soils and vegetation near a nickel-copper smelter at Sudbury, Ontario, Canada: Canadian Journal of Botany, v. 58, p, 108-132.

The areal deposition of airborne pollutants was determined from bulk dustfall-rainfall and snow samples taken along a 60-km transect originating at a large nickel and copper smelter near Sudbury. Samples were analyzed for nickel (Ni), copper (Cu), iron (Fe), sulfur (S), and atmospheric sulfur dioxide (SO_2). All bulk samples collected along the transect were acidic, with pH values less than 4.0. No clear gradient of acidity relative to distance from the smelter was observed, which suggests that the acid precipitation is regional rather than isolated near local sources of pollution. The contamination of forest soils and soil litter and vegetation by Cu, Ni, Fe, and S at sites near the smelter is caused by past and current emissions. Metals are concentrated mostly in the surface organic horizon of the soil. Surface soils show elevated Ni and Cu concentrations up to 70 km from the smelter.

454
FREEDMAN, B., and HUTCHINSON, T. C., 1980, Smelter pollution near Sudbury, Ontario, Canada, and effects on forest litter decomposition, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 395-434.

455
FREEMAN, R. A., and EVERHART, W. H., 1971, Toxicity of aluminum hydroxide complexes in neutral and basic media to rainbow trout: Transactions of the American Fisheries Society, v. 100, no. 4, p. 644-658.

This study investigates the toxic effects of soluble anionic species and neutral precipitates of aluminum hydroxide complexes under known conditions of pH and concentration on rainbow trout. Toxicities of various concentrations of aluminum >1.5 ppm cause severe physiological and behavioral aberrations and acute mortality. At lower concentrations, toxicity of suspended aluminum is more noticeable than that of dissolved Al, but toxic effects of the suspended form are less dependent on concentration than those of dissolved forms.

456
FREEMAN, B., and OGDEN, J. G., III, 1981, Sources and consequences of acid rain: Halifax, Nova Scotia Environmental Control Council, 27 p.

This article discusses the sources and environmental effects of acid precipitation. Most of the precipitation in Nova Scotia has a pH less than 4.7 with occasional values as low as 3.8. Some remedial actions are recommended, such as (1) emission control by flue-gas scrubbing and fuel quantity regulation, (2) application of neutralizing agents, and (3) introduction of acid-tolerant species to acidified ecosystems.

457
FREIBERG, Johnny, 1976, [Discussion] On the uncatalyzed oxidation of atmospheric SO_2 by oxygen on aqueous systems: Atmospheric Environment, v. 10, p. 787-789.

This article discusses a paper by S. Beilke, D. Lamb, and J. Muller on the heterogeneous oxidation of sulfur dioxide in water solution, which appeared in *Atmospheric Environment*, v. 9, 1975, p. 1083-1090. The authors' reply to Freiberg's discussion and a further discussion by J. Freiberg are included.

458
FREIBERG, Johnny, 1978, Conversion limit and characteristic time of SO_2 oxidation in plumes, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 339-347.

The oxidation of sulfur dioxide to sulfate in expanding plumes is modeled for three oxidation reactions; a first order direct homogeneous oxidation, a heterogeneous catalytic oxidation, and a second order homogeneous oxidation. The model is general enough to include the commonly used pseudo-first order oxidation as a particular case, but simple enough to yield analytical solutions for the sulfate yield and the characteristic reaction time. The model predicts that, for all oxidation reactions except the first order direct homogeneous, the conversion proceeds to a fractional asymptotic limit, a fact observed in many field investigations. The values of the fractional asymptotic limit as well as the values of the half lives of reaction depend on the ratios of the 'chemical' parameters to the 'dispersion' parameters. The model shows that the values of the half life of reaction are bounded above and below by limits which are constant for any dispersion pattern rather than dependent on rate constants and other chemical parameters. It also shows that most of the oxidation will occur early in the plume's life, a conclusion which is consistent with the findings of a number of field investigations. In addition, the model suggests that the heterogeneous SO_2 oxidation in plumes is better characterized as a quasi-second order process than as a pseudo-first order process. The applicability of the model as it is affected by the concentration of ammonia gradient in the plume is discussed. [Abstract reprinted by permission of Pergamon Press.]

459
FRENCH, J. G., 1975, Health effects of acid aerosols, in Acid precipitation: Conference on Emerging Environmental Problems, Rensselaerville, N.Y., 1975, Proceedings: New York, U.S. Environmental Protection Agency, p. 88-95.

460
FRIBERG, F., OTTO, C., and SVENSSON, B. S., 1980, Effects of acidification on the dynamics of allochthonous leaf material and benthic invertebrate communities in running waters, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 304-305.

461
FRIEDLANDER, S. K., 1973, Chemical element balances and identification of air pollution sources: Environmental Science and Technology, v. 7, no. 3, p. 235-240.

Chemical elements in the atmosphere over urban and industrial basins such as Los Angeles have been identified. Elements such as sodium, chlorine, silicon, and aluminum are associated with natural background aerosol. Lead, zinc, and barium found in the atmosphere are attributed to man-made sources. A characteristic set of elements in approximately fixed proportions are emitted by sources of air pollution. This paper discusses an empirical method for estimating contributions from pollutant sources on the basis of elemental concentrations.

462
FRIEDLANDER, S. K., 1978, A review of the dynamics of sulfate containing aerosols, in Sulfur in the atmosphere, Proceedings, of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 187-195.

463
FRIEND, J. P., 1972, Sulfur mobilization as a result of fossil fuel combustion: Science, v. 175, p. 1278-1279.

This article discusses a paper on the amounts of trace elements that are mobilized by weathering processes and by the burning of fossil fuels, by K. K. Bertine and E. D. Goldberg, which appeared in *Science*, v. 173, 1971, p. 233. A reply by Bertine and Goldberg is also given.

464
FRINK, C. R., and VOIGT, G. K., 1977, Potential effects of acid precipitation on soils in the humid temperate zone: Water, Air, and Soil Pollution, v. 7, no. 3, p. 371-388.

Unmanaged soils in the northeast United States generally tend toward increasing acidity which results from several natural processes in the soil. Possible effects of acid precipitation on these processes may be caused by hydrogen ions associated with excess anions in the precipitation and, in addition, the anions may also have specific

464 (continued)
effects. This is especially true for N and S, both of which have important ecological implications. It is likely that direct effects of the H ion will be modest. As an example, the acidity of 114 cm of rainfall per year (Connecticut's average) with a pH of 4.3 would require 28.5 kg ha^{-1} of limestone for neutralization. By contrast, agronomic practice in Connecticut frequently dictates limestone conditions as high as several thousand kg ha^{-1} to neutralize acidity generated by a combination of natural processes and fertilizer amendments. Studies of rainfall composition in Connecticut from 1929 to 1948 showed no clear trends with time and indicated levels of sulfate and nitrate in rainwater similar to those reported today. In a 10-yr lysimeter study in Connecticut in which tobacco was grown using conventional fertilization techniques, soil pH decreased from 5.4 to 5.0 and both gains and losses of soil cations were recorded. Thus it appears that changes in unmanaged soils induced by acid preciptation alone will be modest and subtle and probably cannot be expressed completely by measuring changes in soil pH. [Abstract reprinted by permission of D. Riedel Publishing Company.]

465
FRITZ, E. S., 1980, Potential impacts of low pH on fish and fish populations: U.S. Fish and Wildlife Service, Office of Biological Services, Air Pollution and Acid Rain Report no. 2, 14 p.

Laboratory experiments show that the effect of low pH on fish varies among species, populations, and age groups of the same species. Toxicity of low pH is compounded by other water-quality characteristics. Low pH could (1) increase susceptibility to disease, (2) impair osmoregulation and ion regulation, (3) inhibit hormone production or activity, (4) cause genetic damage, (5) alter predator-prey relations, (6) degrade habitat, and (7) increase the availability of toxic substances.

466
FRIZZOLA, J. A., and BAIER, J. H., 1975, Contaminants in rainwater and their relation to water quality, part II: Water and Sewage Works, v. 122, no. 9, p. 94-95.

This article gives data on the major anions in rainwater collected at three stations on Long Island. Nitrogen in precipitation contributes significantly to concentrations found in ground water. Factors affecting the pH of precipitation are discussed; it is suggested that the term "total acid effect" be used in reference to composite sample pH values and "scavenging acid effect" for the pH and other properties of storm-water samples obtained directly from precipitation. (See also Baier, J. H., 1975, herein.)

467
FROHLINGER, J. O., and KANE, Robert, 1975, Precipitation--its acidic nature: Science, v. 189, p. 455-457.

A comparison of free hydrogen-ion concentration and total hydrogen ion concentration of rainwater samples indicates that rain is a weak acid. The presence of weak acid species in precipitation suggests that pH of rainfall is not controlled by the solubility of carbon dioxide in precipitation; it also casts doubts on the assumption that strong acids account for low pH of rain.

468
FROMM, P. O., 1980, A review of some physiological and toxicological responses of freshwater fish to acid stress: Environmental Biology of Fishes, v. 5, no. 1, p. 79-83.

This article summarizes the physiological, pathological, and behavioral responses of fish to acid stress. Effects on reproduction appear to be related to disturbances in calcium metabolism and faulty deposition of protein in developing oocytes. No decrease in fish reproduction is evident at pH 6.5. Most species seem to be unaffected by pH at values between 10.5 to 5.5. Severe acid stress causes alteration of gill membranes and(or) coagulation of gill mucus, and lengthening the water-blood diffusion distance may cause death by hypoxia. Acid stress also upsets electrolyte homostasis in fish.

469
FUGAS, M., and GENTILIZZA, M., 1978, The relationship between sulphate and sulphur dioxide in the air, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 335-337.

The relationship between the sulphate in suspended particulates and sulphur dioxide in the air was studied in various urban and industrial areas. The relationship is best described by the equation $y = ax^b$, where y is the percentage of the sulphate S in the total S (sulphate and sulphur dioxide) and x is the concentration of the total S in the air. The regression coefficients a and b seem to be characteristics of the area. In urban area studied so far, a was between 316 and 378 and b between -0.74 and -0.83. In industrial areas polluted by dust which contains elevated concentrations of metals, a was between 91 and 107 and b between -0.35 and -0.49. In the area polluted by cement dust there was practically no correlation between the sulphate S (%) and the total S, but a relatively high correlation between absolute amounts of the sulphate S and the total S. The relations indicate that the limitation of SO_2

469 (continued)
conversion is influenced by aerosol composition. Aerosols containing certain metals may promote the conversion by a catalytic effect while alkaline substances [promote the conversion] by increasing the pH. Whether this can only happen in the plume or in the air as well remains to be clarified. [Abstract reprinted by permission of Pergamon Press.]

470
FUGELLI, K., ROSSELAND, B. O., and VISLIE, T., 1980, Physiological responses to acid water in fish, SNSF project--preface, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 345.

471
FUGELLI, K., and VISLIE, T., 1980, Physiological responses to acid water in fish, SNSF project, 1. Effects from changes in plasma osmolality and ion concentration on heart ventricle water content and intracellular concentrations of K^+ and taurine in the brown trout (*Salmo trutta* L.), in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 346-347.

472
FUHS, G. W., 1979, A contribution to the assessment of health effects of acid precipitation, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 113-116.

473
FUHS, G. W., 1979, Research on acid rain at the Environmental Health Center, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 5-6.

474
FUSILLO, T. V., SCHORNICK, J. C., Jr., KOESTER, H. E., and HARRIMAN, D. A., 1980, Investigation of acidity and other water-quality characteristics of upper Oyster Creek, Ocean City, New Jersey: U.S. Geological Survey Water-Resources Investigations 80-10, 30 p.

Persistently low pH is observed in the waters of the upper Oyster Creek drainage basin. Mean concentrations of major inorganic ions are less than 6.0 mg/L. Mean concentrations of total nitrogen and total phosphorus are 0.15 mg/L and 0.01 mg/L, respectively. Streams draining cedar swamps typically have low pH levels. The pH of Oyster Creek decreases downstream because of chemical and biological processes. The pH of water in swamps is one-half unit or more lower than in adjacent streams.

G

475
GAHNSTROM, G., ANDERSSON, G., and FELEISCHER, S., 1980, Decomposition and exchange processes in acidified lake sediment, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 306-307.

476
GALBALLY, I. E., 1977, Measurement of nitrogen oxides in the background atmosphere, in World Meteorological Organization, Air pollution measurement techniques: Geneva, Switzerland, World Meteorological Organization, Special Environmental Report no. 10, WMO-no. 460, p. 179-185.

477
GALBALLY, I. E., GARLAND, J. A., and WILSON, M. J. G., 1979, Sulphur uptake from the atmosphere by forest and farmland: Nature, v. 280, p. 49-50.

The uptake of sulfur from the atmosphere by a forest in the absence of precipitation (dry depostion) was measured. A fast-response sulfur detector and the eddy correlation method were used to measure sulfur uptake. Sulfur uptake ranged from 0 to 0.1 $\mu gm^{-2}s^{-1}$ (as SO_2) for atmospheric sulfur concentrations up to 35 μgm^{-3} (expressed as SO_2). About 75 percent of the atmospheric sulfur is in gaseous form.

478
GALLOWAY, J. N., 1976, Critical factors in the collection of precipitation for chemical analysis: Journal of Great Lakes Research, v. 2, supplement no. 1, p. 65-81.

This article describes tests of 22 precipitation collectors of 10 different designs to determine which type gives the most representative samples for determining pH, Ca, Mg, Na, K, NH_4, NO_3, SiO_4, PO_4, Cl, and SO_4. Results indicate that (1) precipitation samples must exclude dry deposition for accurate determination of chemical constituents; (2) precipitation samples become contaminated when glass collectors are used for inorganic components or plastic collectors for organic components; (3) of the inorganic components in precipitation samples of pH 3.5 through 4.5, only PO_4 and Cl showed significant changes in

478 (continued)
concentration when stored at 4°C for 8 months, and (4) precipitation samples should be collected at no longer than weekly intervals if quantitative information on chemical composition is required.

479
GALLOWAY, J. N., 1979, Acid precipitation--spatial and temporal trends, in Gunnerson, C. G., and Willard, B. E., eds., Acid rain: ASCE National Convention, Boston, Mass., 1979, Proceedings: New York American Society of Civil Engineers, p. 1-20.

480
GALLOWAY, J. N., 1980, pH and acidity measurements, in Hendrey, G. R., ed., Limnological aspects of acid precipitation: International Workshop, Sagamore Lake Conference Center, N.Y., 1978, Proceedings: Upton, N.Y. Brookhaven National Laboratory, p. 1-2.

481
GALLOWAY, J. N., COSBY, B. J., Jr., and LIKENS, G. E., 1979, Acid precipitation: Measurement of pH and acidity: Limnology and Oceanography, v. 24, no. 6, p. 1161-1165.

This paper discusses sources and magnitude of errors associated with measuring pH in solutions of low ionic strength and procedures to reduce or eliminate these errors. Suggestions include using dilute solutions of strong acids as standards, equilibrating all standards and test solutions to the same temperature, and measuring quiescent solutions. Errors may then be reduced to less than 5 percent. Recommendations are given for using Gran's plot of titrations to determine total acidity.

482
GALLOWAY, J. N., and COWLING, E. B., 1978, The effects of precipitation on aquatic and terrestrial ecosystems--a proposed precipitation chemistry network: Air Pollution Control Association Journal, v. 28, no. 3, p. 229-235.

This article summarizes the impact of changes in precipitation quality on the productivity and stability of aquatic and terrestrial ecosystems. Included is a discussion on (1) areas that are sensitive to changes in precipitation chemistry, and (2) the need to identify these areas on a regional basis. A precipitation-monitoring network in the U.S. and Canada is needed to monitor changes in the deposition of beneficial nutrients and potentially harmful substances. Data from a precipitation-monitoring network would facilitate management of man-made atmospheric trace constituents and their transformation products that are deposited on aquatic and terrestrial ecosystems.

483
GALLOWAY, J. N., COWLING, E. B., GORHAM, EVILLE, and McFEE, W. W., 1978, A National program for assessing the problem of atmospheric deposition (acid rain): Fort Collins, Colorado State University, Natural Resource Ecology Laboratory, 97 p.

The National Atmospheric Deposition Program was established to determine the magnitude of atmospheric deposition of beneficial and injurious substances and to assess the effect of these substances on terrestrial and aquaic ecosystems. A monitoring network has been established to investigate spatial and temporal trends in the deposition of beneficial nutrients and injurious substances in precipitation and dry particulate matter in selected regions of the United States. The program also coordinates research on the effects of changes in atmospheric deposition on productivity of crops and forests.

484
GALLOWAY, J. N., EISENREICH, S. J., and SCOTT, B. C., eds., 1980, Report of a workshop on toxic substances in atmospheric deposition--a review and assessment: Charlottesville, Va., University of Virginia, National Atmospheric Deposition Program NC-141, 146 p.

This article presents a review and assessment of trace metals and trace organics in atmospheric deposition, and a guide for estimating deposition rates of gases and aerosols. The metals predicted to show the greatest increases in atmospheric deposition are silver, cadmium, copper, lead, selenium, antimony, and zinc; smaller increases are predicted for chromium and vanadium. Little or no increases are expected for cobalt, manmanganese, and niobium. Metals are deposited wet or dry from the atmosphere, and, depending on the metal and site, concentrations in dry deposition can be as great or greater than in wet deposition. Analyses of vapor pressure of metals and metal oxides indicate that only mercury, arsenic, selenium, and possibly cadmium could have a significant fraction of their atmospheric concentration in vapor phase.

485
GALLOWAY, N. J., and LIKENS, G. E., 1976, Calibration of collection procedures for the determination of precipitation chemistry: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 241-258.

Precipitation is currently collected by several methods, including several different designs of collection apparatus. We are investigating these differing methods and designs to determine which gives the most representative sample of precipitation for the analysis of some 25 chemical parameters.

485 (continued)
The experimental site, located in Ithaca, New York, has 22 collectors of 10 different designs. The designs include bulk (wet and dry deposition collected together), wet only (only rain and snow) and wet/dry (collects wet and dry deposition separately). In every sampling period, which varies from 1 day to 1 mo, depending on the time variable being tested, the following chemical parameters are determined: conductivity, pH, Ca, Mg, Na, K, NH_4, NO_3, N_{total}, Cl, SO_4, DOC, Zn, Cu, Mn, Fe, Al, Ni, Cd, Pb, Ag, DDT, DDE, Dieldrin and PCB's.

The results of the investigation lead us to conclude that: (1) Precipitation samples must exlude dry deposition if accurate information on the chemical amount of precipitation is required. (2) Substantial contamination results when glass and plastic collectors are used to sample precipitation for inorganic and organic components, respectively. (3) The inorganic components of precipitation samples of low pH (3.5 to 4.5), with the exception of PO_4 and Cl, exhibited no significant change in concentration when stored at 4°C for a period of 8 mo. We believe this is due to the stabilizing influence of a large concentration of H ions. (4) If quantitative information on the chemical composition is required, precipitation samples should be collected at no longer than weekly intervals if immediate collection is not possible. [Abstract reprinted by permission of D. Riedel Publishing Company.]

486
GALLOWAY, J. N., and LIKENS, G. E., 1977, Acid precipitation--the importance of nitric acid [abstract]: EOS, Transactions of the American Geophysical Union, v. 58, no. 6, p. 390.

This abstract discusses sources of acids in precipitation, based on data collected at the Hubbard Brook Experimental Forest, N.H., for 10 years and at Ithaca, N.Y., for 20 years. Results indicate that sulfuric acid is the dominant acid in precipitation, but nitric acid is the major source of increased deposition of hydrogen ion. Major sources of nitric acid in the atmosphere are industrial emissions and automotive fixation of dinitrogen from the atmosphere.

487
GALLOWAY, J. N., and LIKENS, G. E., 1977, Atmospheric enhancement of metal deposition in Adirondack lake sediments: Washington, D.C., U.S. Department of the Interior, Office of Water Research and Technology, Research Project Technical Completion Report, 40 p.

Sediment cores were collected from Woodhull Lake in the Adirondack Mountains of New York, in July 1975 and analyzed for 44 trace metals by neutron activation and atomic adsorption spectroscopy. Increases in Ag, Au, Cr, Ni, Pb, Sb, and V in upper layers are attributed to increases in the atmospheric deposition of these metals.

488
GALLOWAY, J. N., and LIKENS, G. E., 1978, The collection of precipitation for chemical analysis: Tellus, v. 30, p. 71-82.

This article gives results of experiments to evaluate the efficiency of precipitation collectors, sample preservation, monthly variation of wet and dry deposition, methods of sample storage, length of sampling period, choice of collector location, and sources of variability in precipitation data. Results suggest that dry fallout should be excluded from rain and snow samples and that samples should be collected on an event basis. Some of the variability in precipitation data is due to sampling errors and site location.

489
GALLOWAY, J. N., and LIKENS, G. E., 1979, Atmospheric enhancement of metal deposition in Adirondack lake sediments: Limnology and Oceanography, v. 24, no. 3, p. 427-433.

Sediment cores were collected from Woodhull Lake in the Adirondack Mountains of New York, in July 1975 and analyzed for 44 trace metals by neutron activation and atomic absorption spectrophotometry. Nine of the metals (Ag, Au, Cd, Cr, Cu, Pb, Sb, V, and Zn) showed increased deposition rates in the last 30 years; this is attributed to an increase in precipitation.

490
GALLOWAY, J. N., and LIKENS, G. E., 1981, Acid precipitation--the importance of nitric acid: Atmospheric Environment, v. 15, no. 6, p. 1081-1085.

Maximum contributions of sulfuric acid (H_2SO_4) and nitric acid (HNO_3) to acidity of precipitation in northeastern United States are 73 and 31 percent in summer and 59 and 61 percent in winter, respectively. The influence of H_2SO_4 on acidity of precipitation has decreased by about 30 percent relative to HNO_3, and HNO_3 has increased by about 50 percent relative to H_2SO_4, according to chemical precipitation data from the Hubbard Brook Experimental Forest, N.H. during 1964-79.

491
GALLOWAY, J. N., LIKENS, G. E., and EDGERTON, E. S., 1976, Acid precipitation in the northeastern United States--pH and acidity: Science, v. 194, p. 722-724.

491 (continued)
The relative effects of strong, weak, and Bronsted acids and particulate matter on the free and total acidity of precipitation were studied through titration, chemical analyses, and equilibrium calculations. Results suggest that acid precipitation (pH <5.6) in the northeastern United States is caused by sulfuric acid and nitric acid, strong mineral acids, and weak acids. Bronsted acids and other proton sources contribute to the total acidity of precipitation, but have a minimal influence on the free acidity (ambient pH) of precipitation.

492
GALLOWAY, J. N., LIKENS, G. E., and EDGERTON, E. S., 1976, Hydrogen ion speciation in the acid precipitation of the northeastern United States: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 423-433.

The acidity of precipitation in rural, forested areas of the northeastern United States is dominated by the strong mineral acids: H_2SO_4 and HNO_3. Weak acids have a negligible effect on the measured acidity (pH) of precipitation. These conclusions are based on total acidity titrations and detailed analysis of organic and inorganic components in precipitation. [Abstract reprinted by permission of D. Riedel Publishing Company.]

493
GALLOWAY, J. N., NORTON, S. A., HANSON, D. W., and WILLIAMS, J. S., 1980, Changing pH and metal levels in streams and lakes in the eastern United States caused by acidic precipitation, in International Symposium on Inland Waters and Lake Restoration, Portland, Maine, 1980, Restoration of lakes and inland waters: Washington, D.C., U.S. Environmental Protection Agency, EPA-440/5-81-010, p. 446-452.

Average pH of precipitation east of the Mississippi River is less than 5.0, with some pH values as low as 4.0 locally. The pH of rain and snow has decreased as much as 0.75 units during the past 25 years. Studies of preciptation and snowmelt in Virginia, the Adirondack Mountains of New York, and the Hubbard Brook Experimental Forest in New Hampshire show that only mildly acidic (pH 5 to 6) or circumneutral (pH 6 to 7+) streams may undergo severe pH depression (1 to 3 pH units). Paleolimnologic data from New England and the Adirondack Mountains show an increase in atmospheric fluxes of many metals, particularly lead (Pb) and zinc (Zn) in recent decades. Data on the acidified soils and lake sediments suggest that concentrations of these metals have also increased in surface waters during the past 50 years.

494
GALLOWAY, J. N. and PARKER, G. G., 1980, Difficulties in measuring wet and dry deposition on forest canopies and soil surfaces, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 57-68.

495
GALLOWAY, J. N., SCHOFIELD, C. L., HENDREY, G. R., ALTWICKER, E. R., and TROUTMAN, D. E., 1980, An analysis of lake acidification using annual budgets, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 254-255.

496
GALLOWAY, J. N., SCHOFIELD, C. L., HENDREY, G. R., PETERS, N. E., and JOHANNES, A. H., 1980, Sources of acidity in three lakes acidified during snowmelt, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 264-265.

497
GALVIN, P. J., and CLINE, J. A., 1978, Measurement of anions in the snow cover of the Adirondack Mountains: Atmospheric Environment, v. 12, p. 1163-1167.

Snow-cover samples were collected in the Adirondack Mountains of New York and analyzed for inorganic ions by ion chromatography. Sulfate and nitrate were the only inorganic ions found in appreciable quantities. Nitrate concentrations were greater than sulfate concentrations, and the absence of chloride suggests that the snow cover samples originated from inland. The article also discusses a sampling technique for estimating total nitrate and sulfate in the meltwater of a watershed.

498
GALVIN, P. J., and COFFEY, P. E., 1979, Acid precipitation studies, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 15-32.

499
GALVIN, P. J., SAMSON, P. J., COFFEY, P. E., and ROMANO, David, 1978, Transport of sulfate to New York State: Environmental Science and Technology, v. 12, no. 5, p. 580-584.

499 (continued)
High sulfate concentrations during summer in high-pressure systems over the Adirondack Mountains of New York result from sulfur dioxide emissions in areas south and southwest of New York State. Air that stagnates over an industrial region such as the Ohio River Valley can contain a 24-hour average sulfate concentration in excess of 20 $\mu g/m^3$ when it reaches New York. Air that has not passed over industralized regions in the last 1000 km before reaching New York contains sulfate concentrations less than 5 $\mu g/m^3$. Nitric oxide emissions from these industralized regions do not occur in the air masses as inorganic nitrates.

500
GAMBELL, A. W., 1963, Sulfate and nitrate content of precipitation over parts of North Carolina and Virginia, in Geological Survey Research, 1963: U.S. Geological Survey Professional Paper 475-C, p. C209-C211.

This paper discusses preliminary data from the first month of operation of a 34,000 mi^2 precipitation-sampling network in North Carolina and Virginia. Data on average concentration and approximate total load of major ionic constituents in precipitation are reported in the article. Analysis of data from the network suggest that the atmosphere is a major source of sulfate and nitrate in stream waters of southern Virginia and eastern North Carolina.

501
GAMBELL, A. W., and FISHER, D. W., 1964, Occurrence of sulfate and nitrate in rainfall: Journal of Geophysical Research, v. 69, no. 20, p. 4203-4210.

The mineral composition of individual rainfalls at Prince William National Forest, Va. was monitored. Chemical variations during six storms suggest that sulfate (SO_4) in rainfall is formed from the oxidation of sulfur dioxide (SO_2) in cloud droplets. Atmospheric nitrogen dioxide (NO_2) acts as a major catalyst in this reaction. SO_4, NO_3, and NH_4^+ in rainfall are derived primarily from gaseous constituents of the atmosphere.

502
GAMBELL, A. W., and FISHER, D. W., 1966, Chemical composition of rainfall in eastern North Carolina and southeastern Virginia: U.S. Geological Survey Water-Supply Paper 1535-K, 41 p.

Composite rainwater samples were collected monthly at 27 sites in eastern North Carolina and southeastern Virginia and analyzed for major ions. Most constituents display distinct seasonal and areal distribution patterns. Concentrations of sulfate not derived from sea-salt aerosols increases with distance from the ocean, and the areal distribution may be related to thermal variation of the atmosphere. Gaseous compounds are probably the major source of the observed sulfate excess. Nitrate distribution is similar to that of sulfate, but the controlling factors are uncertain.

503
GAMBRELL, R. P., KHAID, R. A., COLLARD, V. R., REDDY, C. N., and PATRICK, W. H., Jr., 1976, The effect of pH and redox potential on heavy metal chemistry in sediment-water systems affecting toxic metal bioavailability, in Dredging--Environmental Effects of Technology: World Dredging Conference, 7th, San Francisco, Calif., 1976, Proceedings: San Pedro, Calif., The Conference, p. 581-604.

This paper discusses (1) the influence of pH, redox potential, and sediment properties on the chemistry of selected metals in sediment-water systems, and (2) the effect of pH and redox potential on heavy-metal uptake by plants grown on dredged sediment. Redox potential and pH influence solubility of heavy metals and their geochemical forms and also affect the accumulation rate of some toxic metals in plants grown on dredged material.

504
GANJEI, J. E., and MORRISON, G. H., 1977, An investigation of the particulate phase of acid precipitation: U.S. Department of the Interior, Office of Water Research and Technology, Research Project Technical completion report, 10 p.

This paper discusses the feasibility of using the light microscope and ion microprobes for analysis of particulates in rain. The light microscope is suitable for qualitative analysis but not quantitative determinations. It is sensitive enough to detect minor elements within small particles, but the lack of appropriate standards at present precludes its use for quantitative analyses.

505
GANNON, James, 1978, Acid rain fallout--pollution & politics: National Parks and Conservation Magazine, v. 52, no. 10, p. 17-21.

Acid precipitation has caused massive fishkills in the last 25 years and has seriously altered lake ecosystems in several parts of the world. Air pollution from industrial areas is being transported to wilderness areas in Canada, New England, and New York. Lakes most vulnerable to acid precipitation are those in areas where the rocks and soils have low buffering capacities. This paper gives an overview of current research.

506
GARLAND, J. A., 1976, Dry deposition of SO_2 and other gases, in Atmosphere-Surface Exchange of Particulate and Gaseous Pollutants, Richland, Wash., 1974, Proceedings: [Oak Ridge, Tenn.], U.S. Energy Research and Development Administration, ERDA Symposium Series 38, p. 212-227.

Measurements of the rate of dry deposition (direct reaction of gas molecules with the underlying surface) of SO_2 have been made both in the field and in the laboratory using two techniques. One technique involves the release of the radioactive tracer $^{35}SO_2$ above the surface to be studied. In the other, the concentration gradient of the gas above the surface is measured. The gradient method is more convenient for field measurement since it does not result in radioactive contamination, but it can be used only over extensive uniform surfaces and may not be sensitive ehough to estimate small deposition velocities.

Measurements of deposition velocities for SO_2 to grass, soil and water surfaces give mean values a little below 1 cm s^{-1}. Similar values can be found by considering the sulphur balance of the atmosphere over Great Britain or Western Europe. The significance of this removal rate in the global balance of sulphur in the atmosphere is discussed.

The gradient method is also applicable to the study of dry deposition of ozone, nitrogen oxides and other trace gases. Measurements with ozone show that soil and vegetation remove the gas from the atmosphere at a rate similar to that for SO_2. [Abstract reprinted by permission of U.S. Department of Energy.]

507
GARLAND, J. A., 1978, Dry and wet removal of sulphur from the atmosphere, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 349-362.

Dry deposition and removal in precipitation of SO_2 and of particulate sulphate are considered in turn. Many assessments of the dry deposition of SO_2 to various surfaces give deposition velocities of about 0.8 cm s^{-1}, although variations with season and weather conditions are important. The deposition velocity of the sulphate aerosol is probably about 0.1 cm s^{-1}. Removal of SO_2 in rain is also a rather inefficient process, and theoretical and experimental results suggest that the sulphur in precipitation results chiefly from the rainout of cloud condensation nuclei. The removal time constants for SO_2 and sulphate by moderate rain are probably of order 10^{-5} and $10^{-4}s^{-1}$, respectively. A much simplified model suggests that about a half of the SO_2 emitted to the atmosphere is removed by dry deposition, the remainder is oxidized to sulphate and removed in precipitation, and the atmospheric residence time is about 5 days for sulphur. The method and climatological statistics for a more realistic treatment do not yet appear to be available. [Abstract reprinted by permission of United Kingdom Atomic Energy Authority and Pergamon Press.]

508
GARLAND, J. A., 1979, Dry deposition of gaseous pollutants, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO no. 538, p. 95-104.

509
GATZ, D. F., 1976, Wet deposition estimation using scavenging ratios: Journal of Great Lakes Research, v. 2, supplement no. 1, p. 21-29.

Ratios of concentrations (scavenging ratios) in precipitation and air may be used for estimating mean deposition of particulate matter having ground-based sources in precipitation over large areas for long periods (monthly or seasonal). The method applies to materials and sources for which the atmosphere is an important pathway; it is not suitable for estimating scavenging of gases or impaction scavenging of individual stack plumes. Results of the study show that scavenging ratios increase with particle size and distance from urban sources and decrease with amount of precipitation. [A discussion of this paper is given by A. N. Dingle on p. 30-32 of the same journal.]

510
GATZ, D. F., 1980, An urban influence of deposition of sulfate and soluble metals in summer rains, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 245-261.

Recent observations of abnormally acidic precipitation have raised questions regarding the distribution of acidic precipitation, its time trend, its sources of acidity, and the relevant physical and chemical processes involved in its formation. This paper attempts to answer some of these questions based on the content of sulfate and other materials in the atmosphere and in samples of summer convective rainfall from mesoscale sampling networks near St. Louis.

510 (continued)
These and other observations in the literature agree that rainfall deposits locally emitted sulfur at short distances downwind of cities. This causes enhanced deposition and concentration of sulfur in local rainfall and increases the local variability of these parameters relative to that of rainfall volume and crustally derived materials, on both daily and seasonal scales.

Airborne sulfate concentrations vary by a factor of at least 2-4 from urban areas on individual days. This is similar to the observed variation of sulfate deposition or concentrations in rain. Thus, there may be no need to invoke extensive SO_2 scavenging in rain systems to explain the observed enhancements; nucleation scavenging of atmospheric sulfate appears adequate. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

511
GATZ, D. F., BARTLETT, Janyce, and HASSETT, J. J., 1981, Metal pollutants in agricultural soils and the St. Louis urban rainfall anomaly: Water, Air, and Soil Pollution, v. 15, p. 61-75.

Concentrations of zinc (Zn), cadmium (Cd), and lead (Pb) were measured in soils northeast of St. Louis, Mo. This paper evaluates the role of the urban rainfall anomaly in metal deposition in this area. Soil samples were collected from three different layers from agricultural fields at 21 sites downwind of near St. Louis. Samples were analyzed for heavy metals, pH, texture, cation-exchange capacity, and total organic carbon. Slightly elevated concentrations of the metals over background levels were found in the area of the rainfall anomaly; the present rate of atmospheric deposition accounts for these slightly elevated metal concentrations.

512
GAURI, K. L., 1978, The preservation of stone: Scientific American, p. 126-136.

Atmospheric sulfur oxides and nitrogen oxides are becoming more prominent as agents of stone decay. This article describes the reactions of sulfur dioxide and nitrous oxides with building materials and the mechanisms of weathering; it also gives information on stone preservation and cleaning by chemical treatments.

513
GAURI, K. L., 1980, Deterioration of architectural structures and monuments, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 125-145.

513 (continued)
Natural stone, concrete and mortar are the common materials exposed at the facade of architectural structures. Carbonate and silicate minerals are the essential constituents of these materials. These minerals are susceptible to attack by atmospheric CO_2. The weathering of these minerals has increased at an alarming rate in the industrial countries due to NO_2 and SO_2 emanations.

The SO_2 attack has produced sulfate crusts on ancient buildings. The continuing reactivity behind these crusts has resulted in the removal of stone in layers obliterating the original sculptural details and causing serious damage to the structures.

Most ancient buildings and monuments contain florescences. Evaporation of water at the surface tends to accumulate the florescences in subsurface regions fo the stone; their migration is facilitated by increased ionic concentration resulting from atmospheric pollution.. Repeated dissolution and crystallization of the florescences in subsurface regions and the accelerated oxidation of reinforcing metals generate stresses which disintegrate the stone.

Weathering also changes the physical properties such that the stone becomes more susceptible to atmospheric attack. These properties relate to mechanical strength, water absorption and permeability of the stone. Design of conservation treatment should include regeneration of these properties so that the stone performs as though it has been established anew in the existing environment. [Abstract reprinted by permission of Plenum Press.]

514
GAURI, K. L., and HOLDREN, G. C., Jr., 1981, Pollutant effects on stone monuments: Environmental Science and Technology, v 15, no. 4, p. 386-390.

The construction of an oil refinery about 30 km upwind of the Taj Mahal in Agra, India, poses a serious threat to the preservation of the monument. Sulfur will be emitted from the refinery at a rate of 25 to 30 tons per day. These emissions may corrode the marble in the same manner as at the Feld Museum of Natural History in Chicago.

515
GEORGE, C. J., 1980, The fishes of the Adirondack Park: Albany, New York State Department of Environmental Conservation, 94 p.

This report summarizes the occurrence and origin of fishes of the Adirondack Park in northern New York and gives notes on 92 species. Introductory material includes taxonomic and zoogeograhical synopses. The report

515 (continued)
also discusses the effects of acid precipitation on fishes in the Park. About 200 ponds no longer support a viable fishery, and fish losses are expected to continue. Lakes most seriously affected are those on the western upland receiving total annual precipitation greater than 115 cm.

516
GEORGII, H. W., 1963, Oxides of nitrogen and ammonia in the atmosphere: Journal of Geophysical Research, v. 68, no. 13, p. 3963-3970.

Oxides of nitrogen (N) are reactive partners in gas reactions that occur in the atmosphere under certain conditions. This paper discusses three of eight known oxides of N in the atmosphere--nitrous oxide (N_2O), nitrogen dioxide (NO_2), and nitrogen oxide (NO) in terms of distribution, concentration, possible sources and sinks in different layers of the atmosphere, and their reactions with other gaseous components in the atmosphere.

517
GEORGII, H. W., 1978, Large scale spatial and temporal distribution of sulfur compounds, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 681-690.

The paper contains new results on the large-scale distribution of SO_2, H_2S and sulfate-aerosols. Recently developed analytical methods permit the measurement of SO_2 in the upper troposphere and lower stratosphere as well as first measurements of the background-concentration of H_2S. Measurements of H_2S close to the ground and in relation to the air-temperature above the ground shows a temperature-dependence of H_2S release from the soil by biogenic activity. The measurement of sulfate-aerosols over the ocean clarified the picture of the formation of maritime sulfate-aerosols and explained the existence of excess sulfate in the maritime atmosphere. Decay of SO_2 and transformation of SO_2 to sulfate was also studied in a mesoscale study over the continent which supplied further information on the influence of anthropogeneous SO_2 sources on the large-scale sulfur budget. Vertical profiles of SO_2 resulting from aircraft measurements over the continent and the Atlantic Ocean are compared. They are of importance to evaluate the transport and decay of SO_2 over long distances and also indicate the sink function of the ocean surface for the uptake of SO_2. [Abstract reprinted by permission of Pergamon Press.]

518
GIBBS, R. J., 1970, Mechanisms controlling world water chemistry: Science, v. 170, p. 1088-1090.

Atmospheric precipitation rates, predominant rock type, and the evaporation-crystallization process are the three major forces controlling the chemistry of world surface waters. Less important factors such as relief, vegetation, and composition of material within a basin dictate only minor water-quality fluctuations in relation to chemical characteristics established by the three major forces.

519
GIBSON, J. H., 1981, Atmospheric deposition (acid rain)--its origin and effects--an overview, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 5.

520
GIDDINGS, Jeffrey, and GALLOWAY, J. N., 1976, The effects of acid precipitation on aquatic and terrestrial ecosystems, in Literature reviews on acid precipitation: Ithaca, N.Y., Cornell University, Center for Environmental Quality Management and Water Resources and Marine Sciences Center Paper no. 1, p. 1-40.

This paper is a literature review on the ecological effects of acidic deposition. Acid precipitation affects forests, agricultural crops, and lakes in many regions of the world. Some of the effects are (1) reduced forest growth and crop yields, and (2) interference with reproductive physiology of fish. The literature review also cites research papers on patterns of acidic deposition.

521
GILBERT, O. L., 1970, A biological scale for the estimation of sulphur dioxide pollution: New Phytologist, v. 69, p. 629-634.

Average annual levels of sulfur dioxide (SO_2) were estimated from the distribution of lichens and bryophytes along a 17-km transect near New Castle upon Tyne, Great Britain. A scale for estimating SO_2 pollution is developed based on the general order of tolerance of lichens and bryophytes to SO_2 levels.

522
GILBERT, O. L., 1970, Further studies on the effect of sulphur dioxide on lichens and bryophytes: New Phytologist, v. 69, p. 605-627.

Bryophytes and lichens are strikingly similar in their response to sulfur dioxide (SO_2) despite wide differences in their botanical affinity. On the basis of these observations, it is suggested that these lower plants can colonize in hospitable habitats only by adaptations that carry an inherent susceptibility to air pollution. Shelter, pH and the buffering capacity of the substratum,

522 (continued)
and nutrient flushing are among the strongest modifying influences of habitat on the survival of the species.

523
GILLANI, N. V., 1978, Project MISTT: Mesoscale plume modeling of the dispersion, transformation and ground removal of SO_2, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 569-588.

A diagnostic β-mesoscale (25-250 km) plume model is developed using an existing steady-state model as a building block. This quasi-steady, Lagrangian model incorporates the diurnal variability of the planetary boundary layer (PBL) structure and of the parameters governing the chemical conversion and ground removal of SO_2. The vertical inhomogeneity of atmospheric dispersion is simulated by the use of an assumed height- and stability-dependent profile of the eddy diffusion coefficient. Two important dimensionless system parameters are identified which govern pollutant dilution and ground removal. Model inputs are derived from Project MISTT aircraft data and the ground monitoring data of the St. Louis Regional Air Pollution Study (RAPS). On 9 and 18 July 1976, the plume of the 2400 MW, coal-fired Labadie power plant near St. Louis was sampled from aircraft out to 300 km. Model application is considered specifically for the data of these two days, and corresponding quantitative information about the dispersion, transformation and ground removal of SO_2 is extracted. The results show that peak daytime SO_2 conversion rates reached 1.8 and 3.0% h^{-1} on 9 and 28 July, respectively; the corresponding peak dry deposition velocities were between 1.5 and 2.0 cm s^{-1}. The model is used to investigate the effects of source height, time of SO_2 release and eddy diffusion on the overall sulfur budget of the plume. The mid- and late-afternoon plumes appear to have the highest potential for long range transport and sulfate formation. Ground removal is strongly influenced by the profile of vertical eddy diffusion in the surface layer, and much less by the profile shape and magnitude higher up. [Abstract reprinted by permission of Pergamon Press.]

524
GILLANI, N. V., 1980, Formation and transport of ozone and aerosols in power plant plumes: Annals of the New York Academy of Sciences, v. 338, p. 276-296.

The formation of ozone may be related to aerosols in powerplant plumes. Significant factors affecting the cogeneration of ozone and aerosols on warm summer days are (1) condition of background air mass, (2) extent of interactions between plume and background, and (3) photochemical processes. Three stages of daytime plume development are identified through data of the Midwest Interstate Sulfur Transformation and Transport Project (MISTT) sponsored by the U.S. Environmental Protection Agency. The formation rate of secondary pollution in the plume increases rapidly as the stages develop. As the plume gradually advances, secondary pollution dominates and it contributes to the regional background.

525
GILLANI, N. V., HUSAR, R. B., HUSAR, J. D., PATTERSON, D. E., and WILSON, W. E., Jr., 1978, Project MISTT: Kinetics of particulate sulfur formation in a power plant plume out to 300 km, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 589-598.

As part of the 1976 field program of Project MISTT, the plume of the coal-fired Labadie power plant near St. Louis was positively identified and sampled from aircraft over a range exceeding 300 km and 10 h of transport during day and night on July 9 and July 18. Measurements were made of SO_2, NO_x, ozone, particulate sulfur and various other pollutant and meteorological parameters. For both days, it is found that the gas-to-particle conversion of sulfur occurred mostly during daylight hours. The ratio of particulate to total sulfur was related linearly with the total solar radiation dose on both days. Production of ozone was also observed within the plume on both occasions. Ground removal of total sulfur was found to be about 25% in the first 200 km, and its magnitude is compared to that of the gas-to-particle conversion. [Abstract reprinted by permission of Pergamon Press.]

526
GILLANI, N. V., KOHLI, Sanjai, and WILSON, W. E., 1981, Gas-to-particle conversion of sulfur in power plant plumes--1. Parametrization of the conversion rate for dry, moderately polluted ambient conditions: Atmospheric Environment, v. 15, no. 10/11, p. 2293-2313.

A conversion rate of sulfur under dry, summer conditions (relative humidity <75 percent) is formulated from data of 5 days of transport of a powerplant plume. Results compare well with observed rates and are consistent with present understanding of the chemistry of gas-phase oxidation of sulfur dioxide under moderately polluted conditions.

527
GILLETTE, D. G., 1975, Sulfur dioxide and material damage: Journal of the Air Pollution Control Association, v. 25, no. 12, p. 1238-1243.

527 (continued)
Sulfur dioxide (SO_2) data were collected from about 200 sites near heavily populated or polluted areas. Data on material threshold damage is correlated with SO_2 levels, and an estimate of costs in terms of increased maintenance and replacement costs is given. A substantial decrease in ambient SO_2 levels, mostly in larger urban areas, has been observed during the past 5 years. The estimated annual amount of material damage from SO_2 in the United States decreased from $900 million to less than $100 million.

528
GJEDREM, T., 1980, Genetic variation in acid tolerance in brown trout, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 308.

529
GJEDREM, T., 1980, Growth and survival of fingerlings in acidic water, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 309.

530
GJESSING, E. T., 1975, Effects of polluted precipitation on water quality: Progress in Water Technology, v. 7, no. 3-4, p. 725-731.

The pH of salmon rivers in southern Norway has been reduced significantly in recent years. During the last five years, pH has decreased by 0.05 units per year. The yield of inland fisheries has declined significantly in recent decades because of the changes in water quality. Air pollution affects the quality of surface waters. Increases in sulfate, nitrate, and hydrogen-ion concentration in streams in Norway have been noted.

531
GJESSING, E. T., 1980, Effect of polluted precipitation on water quality--the situation in Norway: Aqua, no. 7, p. 139-140.

The acidifictaion of surface waters of North America, Great Britain, and Scandinavia is attributed to the deposition of strong acids from the atmosphere. Inorganic acidic components, heavy metals, and trace organic components are present in rain and snow, and affect surface-water quality. The significance of these analytical results in relation to drinking-water quality still undetermined.

532
GLASS, G. E., 1980, Susceptibility of aquatic and terrestrial resources of Minnesota, Wisconsin and Michigan to impacts from acid precipitation-Informational requirements, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 112-113.

533
GLASS, G. E., BRYDGES, T. G., and LOUCKS, O. L., 1981, Impact assessment of airborne acidic deposition on the aquatic environment of the United States and Canada: Duluth, Minn., U.S. Environmental Protection Agency, EPA-600/10-81-000, 150 p.

This report discusses the effect of acidic atmospheric deposition on aquatic ecosystems. It presents data on recent changes in water quality and assesses the significance of sulfate versus nitrate in the acidification processes. It also reviews mathematical models that estimate acid loadings within the buffering capacity of watersheds in the U.S. and Canada.

534
GLASS, G. E., and LOUCKS, O. L., 1980, Impacts of airborne pollutants on wilderness areas along the Minnesota-Ontario border: Duluth, Minnesota, U.S. Environmental Protection Agency, EPA-600/3-80-044, 187 p.

This report describes the potential environmental effects of a proposed powerplant at Atikokan, Ontario, on aquatic and terrestrial ecosystems in the Boundary Waters Canoe Area Wilderness (BWCA) and Voyageurs National Park (VNP), Minn. The authors believe that total emissions from the proposed powerplant, including increased loadings of sulfuric and nitric acids, fly ash, and mercury, in addition to other regional sources, will have significant negative effects on the aquatic and terrestrial systems in the BWCA-VNP region. The most significant effect will be on sport fisheries and other aquatic resources.

535
GLASS, N. L., 1979, U.S. Federal program on effects of acid rain, in Gunnerson, C. G., and Willard, B. E., eds., Acid rain: ASCE National Convention, Boston, Mass., 1979, Proceedings: New York, American Society of Civil Engineers, p. 92-110.

536
GLASS, N. R., 1979, Environmental effects of increased coal utilization--ecological effects of gaseous emissions from coal combustion: Environmental Health Perspectives, v. 33, p. 249-272.

536 (continued)
This paper summarizes the effects of nitrogen oxide, sulfur oxide, fine particulate, photochemical oxidant, and acid precipitation on natural resources and ecosystems and identifies resulting economic implications. Higher sulfur oxide and nitrogen oxide emissions are projected for 1985 and 2000 than occurred in 1975; this will cause substantial increases in total acid deposition. Acid precipitation is most abundant in the north-central and northeastern United States.

537
GLASS, N. R., GLASS, G. E., and RENNIE, P. J., 1979, Effects of acid precipitation: Environmental Science and Technology, v. 13, no. 11, p. 1350-1355.

Precipitation in the northern region of North America is highly acidic when compared with the normal pH (5.6) of rainwater in equilibrium with carbon dioxide. The pH of precipitation from the mid-1950's to mid-1970's in northeastern U.S. and Canada has declined dramatically and the occurrence of acid precipitation is spreading southward and westward in the United States. The most severely affected area in the U.S. is the northeast and an extensive area of eastern Canada. Some of the effects of acid precipitation on soils, forests, agriculture, and lakes are (1) reduced lake pH to the point at which fish stop reproducing, (2) reduced tree growth, (3) elimination of useful soil microorganisms; and (4) increased leaching of toxic metals such as aluminum and manganese.

538
GLASS, N. R., POWERS, C. F., LEE, J. J., RAMBO, D. L., and O'GUINN, D. W., 1980, The sensitivity of the United States environment to acid precipitation, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 114-115.

539
GLOOSCHENKO, W. A., SIMS, R., GREGORY, M., and MAYER, T., 1981, Use of bog vegetation as a monitor of atmospheric input of metals, in Eisenreich, S.J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 389-399.

540
GLOVER, G. M., KALLEND, A. S., MANCH, A. R. W., and WEBB, A. H., 1980, Ion relationship in acid precipitation and stream chemistry, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 95-109.

541
GLOVER, G. M., and WEBB, A. H., 1979, Weak and strong acids in the surface waters of the Tovdal region in S. Norway: Water Research, v. 13, no. 8, p. 781-783.

The concentration of weak and strong acids in surface waters of the Tovdal region of southern Norway were monitored during spring snowmelt of 1977. Concentrations were determined by pH titration using Gran's plot. Concentration of weak acids and their contribution to the hydrogen ion concentration were smallest during the most rapid thaw.

542
GODZIK, S., and SASSEN, M. M. A., 1978, A scanning electron microscope examination of *Aesculus hippocastanum* L. leaves from control and air-polluted areas: Environmental Pollution, v. 17, p. 13-18.

The surface structure of *Aesculus hippocastanum* leaves from control and air-polluted areas were examined by a scanning electron microscope. Leaves from polluted areas have stomata that appeared abnormal even though they were not occluded by dust particles. Thin sections of leaves differed markedly in thickness and structure of the outer epidermal cell walls.

543
GOLDSTEIN, R. A., CHEN, C. W., CHERINI, S. Arne, and DEAN, J. D., 1980, A framework for the integrated lake-watershed acidification study, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 252-253.

544
GOLTERMAN, H. L., 1980, Mutual relationship pH/eutrophication--acid rain [abstract], in International Symposium on Inland Waters and Lake Restoration, Portland, Maine, 1980, Restoration of lakes and inland waters: Washington, D.C., U.S. Environmental Protection Agency, EPA-440/5-81-010, p. 479.

Two different processes may occur after an increase of pH in eutrophic lakes. In hard waters, where calcium concentration may control phosphate solubility, the formation of apatite (calcium phosphate) will counteract eutrophication by withdrawal of phosphate from solution. If, however, phosphate concentration is controlled by ferric hydroxide, a pH increase may mobilize phosphate from the sediments and stimulate eutrophication. Two processes make a theoretical approach of the calcium carbonate ($CaCO_3$) system extremely difficult. The occurrence of $CaCO_3$ supersaturation is well documented, and the degree of supersaturation is related to pH. Diffusion of carbon

544 (continued)
dioxide into lake waters apprears to be a more complicated process than simple models predict because wind stress and microsaturation in lakes depend on physical and climatic factors than cannot be realistically quantified.

545
GOODMAN, C. H., 1980, Sulfur dioxide emission controls--what are the costs?, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 13-20.

546
GORDON, A. G., and GORHAM, Eville, 1963, Ecological aspects of air pollution from an iron-sintering plant at Wawa, Ontario: Canadian Journal of Botany, v. 41, p. 1063-1078.

Vegetation at Wawa, Ontario, has been severely damaged by sulfur dioxide pollution from an iron-sintering plant. Sulfur fallout was monitored along a 36-mile transect from the plant during June 1960. Twenty-five water samples were collected at this time from nearby small lakes and ponds and analyzed for sulfate, calcium, and pH. Damage to vegetation was mainly along a narrow strip northeast of the sinter plant, which coincides with the predominantly southwest winds. Sulfate in lakes and ponds increased from 0.2 to 0.3 meq/L to greater than 0.5 meq/L within 11 miles northeast of the plant; sulfate levels as high as 2 meq/L were observed in lakes within 2 miles (northeast) of the plant. The pH of water within 5 miles northeast of the plant ranged from 3.2 to 3.8.

547
GORHAM, Eville, 1955, On the acidity and salinity of rain: Geochemica et Cosmochimica Acta, v. 7, p. 231-239.

Rainwater samples were collected at the English Lake District in 1954 and analyzed for pH, Na, Ca, K, Mg, HCO_3, Cl, SO_4, and PO_4. The main source of Na, Mg, and Cl is sea spray, the main source of SO_4 is soot. Free H_2SO_4 frequently accounts for the appreciable proportion of total ions. This article discusses the ecological significance of ions in rainwater.

548
GORHAM, Eville, 1957, The chemical composition of lake waters in Halifax County, Nova Scotia: Limnology and Oceanography, v. 2, p. 12-21.

Water samples were collected from lakes in a healthy spruce forest in Halifax County, Nova Scotia, during December 1955 and analyzed for concentrations of total ions, Na, Ca, K, Mg, HCO_3, Cl, SO_4, dissolved carbon, optical density, pH, and specific conductance. Results of the analyses indicate that the lakes are dilute, low in calcium bicarbonate, and high in sodium chloride. The principal factors influencing the chemical composition of these lake basins are (1) characteristics of the geologic substratum, (2) accumulation of mineral sediments and peat in and near the lake basins, and (3) proximity of lake basins to the sea.

549
GORHAM, Eville, 1957, The chemical composition of rain from Rosscahill in County Galway: The Irish Naturalists' Journal, v. 12, p. 122-126.

Rainwater samples were collected at Rosscahill County, Galway, Ireland, from April 1955 to January 1956 and analyzed for pH, Na, K, Ca, Mg, HCO_3, Cl, SO_4, NO_3^-. Results show that sodium is the dominant cation and that, except for a sample collected in August, chloride slightly exceeds bicarbonate. These data are compared to precipitation data from the English Lake District. Higher values of sodium and chloride at the Rosscahill site are probably caused by a greater exposure to sea spray; higher concentrations of sulfate and hydrogen ions at the English Lake District (average pH is 4.5), are probably due to atmospheric pollution by industrial compounds oxidizing to sulfuric acid.

550
GORHAM, Eville, 1958, Atmospheric pollution by hydrochloric acid: Royal Meteorological Society Quarterly Journal, v. 84, p. 274-276.

Precipitation samples collected at the English Lake District were analyzed for pH and chloride. Results show a positive correlation between chloride and acidity in precipitation samples havine pH less than 5.7. First-order correlation coefficients for hydrogen ions and chloride in deposits from Sheffield, Manchester, and Salford were significant, but those for hydrogen ions and sulfate were not. The role of hydrochloric acid should be considered in studies to assess causes of acidic precipitation in urban areas.

551
GORHAM, Eville, 1958, Free acid in British soils: Nature, v. 181, p. 106.

This paper reports on the acidity of pools in peat bogs at seven sites in Great Britain. Hydrogen-ion concentration of the waters ranges from 0.03 to 0.13 meq/L and sulfate concentration ranges from 0.06 to 0.24 meq/L. The coefficient correlation between free

551 (continued)
hydrogen ions and sulfate is 0.985 when the contribution from sea spray is subtracted from total sulfate. The high coefficient correlation suggests that the low pH of the bog waters is due to sulfuric acid. The highest acidity is observed at bogs near industrial areas, and the lowest are at bogs in remote areas. The combustion of fossil fuels produces large amounts of sulfur dioxide, which oxidize to form sulfuric acid (SO_4), which increases the acidity of nearby bogs.

552
GORHAM, Eville, 1958, The influence and importance of daily weather conditions in the supply of chloride, sulfate, and other ions to fresh waters from atmospheric precipitation: Philosophical Transactions of the Royal Society of London, Series B., v. 241, no. 769, p. 147-178.

This paper summarizes the effects of weather on the supply and distribution of chloride, sulfate, sodium, potassium, calcium, hydrogen, and nitrate ions in precipitation. Precipitation samples were collected for 1 one year at sites in the English Lakes District and analyzed for the above constituents and pH. Atmospheric precipitation is a major source of major dissolved ions to bogs, upland tarns on hard volcanic rocks, and to heavily leached soils with raw humus layers. Large amounts of sulfuric acid contributed from the atmosphere are expected to accelerate the deterioration of leached soils in the Lake District.

553
GORHAM, Eville, 1961, Factors influencing supply of major ions to inland waters, with special reference to the atmosphere: Geological Society of America Bulletin, v. 72, p. 795-840.

The atmospheric contribution of ions to natural inland waters is frequently underestimated. Atmospheric materials are deposited on surface waters by rain, snow, dry fallout, or as a gaseous form. Sources of atmospheric materials are the sea, land surfaces, volcanoes, combustion products, and organic debris. The interaction of climate, geology, topography, biota, and time determines the ionic concentration and composition of atmospheric precipitation, soil solutions, and surface waters.

554
GORHAM, Eville, 1976, Acid precipitation and its influence upon aquatic ecosystems--an overview: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 457-481.

554 (continued)
The impact of acid precipitation reflects a usually deleterious balance between good and bad effects, which may lead to serious and sometimes extreme degradation of aquatic as well as terrestrial ecosystems, particularly around metal smelters. Addition of H ions as H_2SO_4, HNO_3, and HCl can alter and impoverish the species composition of biotic communities, and lead to severe leaching of beneficial metal cations such as Ca from ecosystems. Heavy metals and other trace elements which accompany acid precipitation may reach toxic levels, particularly where acid fallout leaches additional amounts from the soil into streams and lakes. Complex and often toxic hydrocarbons also comprise a little-known organic component of acid precipitation.

Alternatively, acid precipitation usually is enriched in plant nutrients such as nitrate- and ammonia-nitrogen, K, Ca, and S; and at certain concentrations some of the associated trace elements may also be beneficial. Moreover the initial effect of soil leaching by acid fallout may be to enrich aquatic ecosystems in metal cations such as Ca.

Basic materials in air pollution, biogenic NH_3 from the soil, dust fall from arid regions, and soils rich in adsorbed metal cations or in carbonates may neutralize some of the harmful effects of acid precipitation upon ecosystems. However, associated heavy metals, other trace elements, and toxic hydrocarbons may still constitute serious problems in many environments. [Abstract reprinted by permission of D. Riedel Publishing Company.]

555
GORHAM, Eville, 1979, A recommended program of research, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 65-69.

556
GORHAM, Eville, 1980, Long range transport of air pollution--a United States perspective on acid rain as an ecological problem, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 5-18.

557
GORHAM, Eville, 1981, Biological options, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 155-156.

558
GORHAM, Eville, and CRAGG, J. B., 1960, The chemical composition of some bog waters from the Falkland Islands: Journal of Ecology, v. 48, p. 175-181.

Bog waters in the Falkland Islands contain high salt concentrations, probably a result of sea-spray deposition. The acidity of the bogs is attributed to the exchange of metal cations in sea spray for hydrogen ions absorbed on the peat colloids. The oxidation of hydrogen sulfide generated by peat decomposition may partly cause some of the acidity.

559
GORHAM, Eville and GORDON, A. G., 1960, The influence of smelter fumes upon the chemical composition of lake waters near Sudbury, Ontario, and upon the surrounding vegetation: Canadian Journal of Botany, v. 38, p. 477-487.

Water samples were collected from 102 lakes and ponds near Sudbury, Ontario, in the metal-smelting district; samples were analyzed for sulfate, calcium, and pH. Results show that high sulfur concentrations are common in lakes within 5 miles of the smelters. Beyond a 15-mile radius, the contribution of sulfur from smelters is negligible.

560
GORHAM, Eville, and GORDON, A. G., 1960, Some effects of smelter pollution northeast of Falconbridge, Ontario: Canadian Journal of Botany, v. 33, p. 307-312.

Sulfate concentration was measured in soils and ponds along a transect northwest from a metal smelter near Sudbury, Ontario. Soil-drainage waters show strong sulfate accumulation within 2 to 20 miles of the smelter, but surface soils show strong sulfate accumulation within only about 1 mile. The number of species present in the flora declines sharply within 4 miles of the smelter.

561
GORHAM, Eville, and GORDON, A. G., 1963, Some effects of smelter pollution upon aquatic vegetation near Sudbury, Ontario: Canadian Journal of Botany, v. 41, p. 371-378.

Results of a flora survey of 29 lakes and ponds near metal smelters at Sudbury, Ontario, show that the number of submerged and floating macrophyte species is inversely related to the concentration of dissolved sulfates. Species numbers are low even where sulfuric acid is nearly neutralized and pH exceeds 6.

562
GORHAM, Eville, and McFEE, W. W., 1980, Effects of acid deposition upon outputs from terrestrial to aquatic ecosystems, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 465-480.

563
GOSLING, L. M., and BAKER, S. J., 1980, Acidity fluctuations at a broadland site in Norfolk: Journal of Applied Ecology, v. 17, p. 479-490.

The acidity of Calthorpe Broad, a wetland in Norfolk, Great Britain, changed abruptly from circumneutral to about pH 3. At this time, the community of fish and freshwater mussels perished, as did most aquatic macrophytes. This period of acute acidity was followed by a return to neutrality, but similar fluctuations occurred in most years between 1971 and 1979. The increase in acidity is attributed to the oxidation of pyrite in the soil and the formation of sulfuric acid. Neutral water was maintained in 1978 by the addition of lime to the wetland, but the acidity of water in nearby ditches continued to fluctuate.

564
GRAHN, Olle, 1977, Macrophyte succession in Swedish lakes caused by deposition of airborne acid substances: Water, Air, and Soil Pollution, v. 7, p. 295-305.

Biological investigations were conducted at six small lakes north of Gothenburg on the Swedish west coast. All but one are clearwater lakes high above sea level, with no industrial or populated areas in the surroundings. Acidic atmospheric deposition to these lakes induces long-term biological perturbations at all trophic levels in the lake ecosystem. The abundance of *Sphagnum* mat, which greatly affects the dynamics of a lake system, is negatively correlated to the pH of the lake water.

565
GRAHN, Olle, 1980, Fish kills in two moderately acid lakes due to high aluminum concentration, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 310-311.

566
GRAHN, Olle, and HULTBERG, Hans, 1974, Effects of acidification on oligotrophic lake ecosystems--integrated changes in the species co-position dynamics: Gothenburg, Swedish Water and Air Pollution Research Lab., Report IVL-B-192, 25 p.

566 (continued)
This report discusses the trophic levels of six acid lakes in Sweden. The supply of acid compounds induce changes in the microbiological community, fauna, and flora. Biological perturbations result in oligotrophication, which may accelerate the acidification process.

567
GRAHN, Olle, and HULTBERG, Hans, 1975, The neutralizing capacity of 12 different lime products used for pH-adjustment of acid water: Vatten, v. 2, p. 120-132.

Twelve lime products were tested in a pool plant and in laboratory experiments to determine their neutralizing capacity. The solubility of lime products can be divided into the following four groups: (1) soluble calcium oxide (CaO) and calcium hydroxide (CaOH), (2) basic slags of mono- and dicalcium silicate type ($CaSiO_2$), (3) finely ground calcium carbonate ($CaCO_3$), and (4) granulated or coarse-grained calcium carbonate ($CaCO_3$). Basic slags containing dicalcium silicate as the major component were the most effective neutralizer during high flow of water through the pools; calcium carbonates were most effective during low flows.

568
GRAHN, Olle, HULTBERG, Hans, and LANDNER, L., 1974, Oligotrophication--a self-accelerating process in lakes subjected to excessive supply of acid substances: Ambio, v. 3, no. 2, p. 93-94.

Data on trophic levels in six acid lakes having pH values between 4.4 and 5.4 were studied to determine the dynamics of acidified aquatic ecosystems. A continuous supply of acid substances to a lake system induces profound, long-term changes and produces an oligotrophic state. The oligotrophication of lakes tends to accelerate the process of acidification.

569
GRANAT, Lennart, 1972, Deposition of sulfate and acid with precipitation over northern Europe: Stockholm, Sweden, University of Stockholm Report AC-20, 1 v.

The report gives data on temporal and areal trends in the sulfur deposition in northern Europe. Excess sulfur deposition is decreasing northward and southward from a maximum over Holland and Belgium. Large fluctuations in the yearly sulfate deposition rate are observed, and several sampling stations at adjacent areas show similar fluctuations. Results indicate that areal distribution of excess acid deposition is more complex than that of excess sulfur. Maximum acidity is found over Holland and Belgium; however, Denmark, southern Norway, and the west coast of Sweden receive a substantial amount of acidity.

570
GRANAT, Lennart, 1972, On the relation between pH and the chemical composition in atmospheric precipitation: Tellus, v. 24, no. 6, p. 550-560.

Two thousand rainwater samples collected throughout Europe were analyzed to determine the relationship between the total amount of acid and base, respectively. The theoretical relationship between pH and total amount of acid or bicarbonate is calculated. A regular deviation between the empirically found and theoretically calculated relationship was observed. A model based on the stoichiometric relation between acids and bases was developed to predict the amount of acid in precipitation and to predict future acidic atmospheric deposition.

571
GRANAT, Lennart, 1974, On the deposition of chemical substances by precipitation (as observed with the aid of the atmospheric chemistry report in Scandinavia): University of Stockholm, Department of Meteorology, Report AC-27, 24 p.

The deposition of chemical substances by preciptation is monitored by the European Atmospheric Chemistry Network. This study presents information on measurements of mesoscale deposition at sampling stations in Scandinavia and investigates possible errors in calculation of published areal deposition rates.

572
GRANAT, Lennart, 1975, On the variability of rainwater composition and errors in estimates of areal wet deposition: Stockholm, University of Sweden, Department of Meteorology Report AC-30, 31 p.

Rainwater samples were collected monthly at 110 stations in Sweden, and daily samples were collected at 104 stations. Samples were analyzed for 8 major constituents. The report discusses errors in wet-deposition estimates for areas of different sizes and for different averaging intervals.

573
GRANAT, Lennart, 1976, Principles in network design for precipitation chemistry measurements: Journal of Great Lakes Research, v. 2, supplement no. 1, p. 42-55.

Important criteria to consider when planning precipitation-monitoring networks are (1) specific needs for data and (2) knowledge of the areal variations in the relationship between concentration and deposition. The paper discusses the probable error in estimates of areal averages of wet deposition and the usefulness of additional temporary collectors in network design.

574
GRANAT, Lennart, 1977, On the variability of rainwater composition and errors in estimates of areal wet deposition, in Precipitation scavenging, Champaign, Ill., 1974, Proceedings: [Oak Ridge, Tenn.], U.S. Energy Research and Development Administration, ERDA Symposium Series 4, p. 531-551.

Rainwater samples from about 50 collectors at distances 20 to 50 km apart were collected monthly. A few samples were collected daily from about 150 collectors in 100 km^2 area. Data from the European Atmospheric Chemistry Network are used to study the characteristics of nine major constituents in rainwater and deposition patterns. These data also provide a basis for evaluating rain chemistry data from the European Atmospheric Chemistry Network and provide useful information on network design intended primarily for monitoring large-scale deposition but also for investigating local fallout on a short-term basis.

575
GRANAT, Lennart, 1977, Siting criteria for precipitation chemistry measurements--a method for direct evaluation, in World Meteorological Organization, Air pollution measurement techniques: Geneva, Switzerland, World Meteorological Organization, Special Environmental Report no. 10, WMO no. 460, p. 78-88.

576
GRANAT, Lennart, 1978, Sulfate in precipitation as observed by the European Atmospheric network, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 413-424.

The temporal variation in sulfur concentration/deposition involves long term fluctuations which show striking similarities within certain areas but are different between areas in different positions relative to major sulfur emission areas in Europe. As an example, the deposition has been constant or decreasing during the last ten years in most of the area covered by the network, indicating that an increasing amount of the sulfur emitted in Europe is transported and deposited elsewhere, possibly in an eastward direction.

The seasonal variation in deposition resembles that for amount of precipation and shows a maximum during the summer or autumn for most areas. The concentration shows a maximum in the spring and a minimum in the autumn at most stations.

The concentration field has a maximum approximately over Belgium and Holland with decreasing concentrations towards SW to NE (over W) but with comparatively high levels extending up over Finland. (Areas to the east and south are not covered by the network.)

The deposition field was, based on a brief discussion of the relation between concentration and amount of precipitation, obtained as the product of these latter fields. High deposition rates are found in the south of Norway, and in the middle of Britain in addition to the areas with high concentration.

Sulfur and hydrogen ion are the dominating ions in precipitation followed by ammonium and nitrate except in coastal areas and in places where the soil is bare.

Sources of errors in the data base are discussed and the results from a large number of additional sampling sites around and between the regular network sampling sites are most helpful in this regard. These latter measurements also permit an estimate of the uncertainty in areal concentration averages which are due to local and mesoscale variability.

Finally, past and future importance of continuous measurements (as in the EACN) is discussed briefly. [Abstract reprinted by permission of Pergamon Press.]

577
GRANAT, Lennart, and RODHE, Henning, 1973, A study of fallout by precipitation around an oil-fired power plant: Atmospheric Environment, v. 7, p. 781-792.

This study investigates the distribution of atmospheric deposition near an oil-fired powerplant 40 km north of Goteborg on the west coast of Sweden. Precipitation samples were collected during seven events in late fall and were analyzed for sulfur, pH, alkalinity, and sodium. The long-term average deposition of acid derived from the powerplant within 15 km of the plant is estimated to be 10 to 15 percent of the total amount.

578
GRANAT, Lennart, RODHE, Henning, and HALLBERG, R. O., 1976, The global sulphur cycle: Ecological Bulletin, v. 24, p. 89-134

Regional and global sulfur budgets are developed to assess the impact of man-made emissions on ecosystems and the radiation balance via aerosol formation. In section 1, a preindustrial sulfur budget is formulated for the pedosphere in which a balance between weathering, atmospheric deposition, and river runoff is assumed. In section 2, atmospheric sulfur data are analyzed, and a budget is developed. Emphasis is on the emission of

578 (continued)
sulfur in submicron particles and its precursors. The final chapter presents an atmospheric budget for northwest Europe is developed in which more than 80 percent of the total sulfur in the atmosphere is emitted from human related sources.

579
GRANAT, Lennart, and SODERLUND, Rolf, 1975, Atmospheric deposition due to long and short distance sources--with special reference to wet and dry deposition of sulfur compounds around an oil fired power plant: Stockholm, University of Sweden, Department of Meteorology, Report AC-32, 148 p.

The annual deposition rate of sulfur and acid from a large sulfur dioxide source at Stenungsund on the west coast of Sweden is estimated and compared to regional deposition rates from long-distance emissions. The additional concentration of sulfur in precipitation due to the powerplant emissions is difficult to assess because of spatial variations in background levels. Dry deposition provides the most significant contribution; the contribution from wet deposition is insignificant.

580
GRANDE, Magne, and ANDERSEN, Sigbjorn, 1979, Toxicity of acid snowmelt water to brown trout (*Salmo trutta* L.): Vatten, v. 35, no. 1, p. 27-32.

Many soft-water lakes and rivers in southern Norway have lost their fish populations because of acidic atmospheric deposition. Rapid changes in water quality occur during heavy rainfalls and snowmelt. Yolk-sac fry of brown trout (*Salmo trutta* L.) were exposed to snowmelt waters at seven sites. The snowmelt water was toxic to fish; this is attributed to the combined effect of low pH and low concentration of dissolved salts. The degree of toxicity among the meltwaters studied is dependent on pH.

581
GRANDE, Magne, MUNIZ, I. P., and ANDERSEN, Sigbjorn, 1978, Relative tolerance of some salmonids to acid waters: International Association of Theoretical and Applied Limnology, Proc., v. 20, p. 2076-2084.

This paper gives data on the relative tolerance of different strains and species of salmonid fishes to acidic water. Salmonids were stocked in small and medium-sized lakes 10 to 60 m above sea level in southern Norway, where the terrain is characterized by granitic bedrock, peatlands, and coniferous forests. Of the species tested, brook trout were the most tolerant to low pH, followed by brown trout, Atlantic salmon, and rainbow trout. Factors other than pH, such a genetic variability, age of fish, physical conditions, and quality of water also affect fish mortality. Acid snowmelt is probably one of the causes of fish kills and reproduction failure in winter and spring.

582
GRAVENHORST, Gode, 1978, Maritime sulfate over the North Atlantic, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 707-713.

Laboratory and field experiments were undertaken to determine sulfate sources in the aerosol over the North Atlantic. In artificially produced sea salt aerosol no fractionation between sodium and sulfate was found. This result is supported by a calculation of Gibb's surface adsorption which showed a negligible enrichment of all sodium compared to sulfate in the surface film of seawater. In the maritime aerosol, however, *ca.* three times as much sulfate was found as would be calculated from the seawater ratio and concentrations. Sulfur isotope ratios in the aerosol were smaller than the seawater value. Half of the excess sulfate and almost all ammonium belonged to particles smaller than 0.45 μm. In this size range the aerosol was acidic. Based on these findings it is suggested that most of the maritime excess sulfate near the sea surface is not produced by ion fractionation in the surface film of seawater nor by interactions with cloud droplets but by gas phase reactions. [Abstract reprinted by permission of Pergamon Press.]

583
GRAVENHORST, Gode, BEILKE, Siegfried, BETZ, Martin, and GEORGII, H. W., 1980, Sulfur dioxide absorbed in rain water, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 41-55.

584
GRAVENHORST, Gode, JANSSEN-SCHMIDT, T. EHHALT, D. H., and ROTH, E. P., 1978, The influence of clouds and rain on the vertical distribution of sulfur dioxide in a one-dimensional steady-state model, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 691-698.

It was attempted to include wet chemical removal rates for sulfur dioxide in a one-dimensional steady-state model. The interactions with liquid water were separated into the removal of absorbed sulfur dioxide by

584 (continued)
rain and into the formation of sulfate in cloud- and rain-formation so that equilibrium conditions between gas-phase and liquid-phase were assumed. The most sensitive parameters affecting the wet chemical removal of SO_2 seem to be the pH value of rain-water and the formation rate of sulfate in atmospheric water. The gas-phase destruction proceeds predominantly through the oxidation by OH radicals. The calculated SO_2 volume mixing ratio decreases from 1 ppb at the ground level to *ca.* 0.01 in 15 km altitude. Integrated over a vertical column the gas-phase destruction is about 2 times larger than wet chemical removal. The relative proportions, however, depend strongly on the chosen parameters for rain- and cloud-water. The direct SO_2 deposition onto the ground seems to be larger than the sum of the removal rates within the atmosphere. [Abstract reprinted by permission of Pergamon Press.]

585
GRAVES, C. K., 1981, Rain of troubles: Science 80, v. 1, no. 5, p. 75-79.

This article presents in nontechnical language information on the causes and effects of acid precipitation. The greatest impact of acid precipitation has been on lake ecosystems. The susceptibility of lakes to acidifiction depends on their size, elevation, and geological characteristics. The article also discusses long-range transport of acidic sulfates. Acid precipitation has been considered a regional problem of the Northeast; however, the water quality of some streams and lakes in the Rocky Mountain region is now being adversely affected by acidity.

586
GREENHALGH, G. N., and BEBAN, R. J., 1978, Response of *Rhytisma acerinum* to air pollution: British Mycolgical Society, Transactions, v. 71, no. 3, p. 491-494.

Rhytisma acerinum is a nonlichenized ascomycete that causes tar spot, a common leaf disease of Sycamore, and is also sensitive to air pollution. Tar Spot seems to be inhibited by air pollution and, although no direct evidence indicates that sulfur dioxide is responsible for inhibiting *R. acerinum*, the causal relationship is accepted.

587
GRENNARD, Alf, and ROSS, F. F., 1974, Progress report on sulfur dioxide: Combustion, v. 45, no. 7, p. 4-9.

This article summarizes recent developments in research on the global sulfur and on effects of sulfur dioxide emissions on air quality, human health, plants, soil, tree growth, precipitation quality, and lakes.

588
GRENNFELT, Peringe, 1979, Oxidized nitrogen compounds in long-range transported polluted air masses, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 199-206.

589
GRENNFELT, Peringe, BENGTSON, Curt, and SKARBY, Lena, 1980, An estimation of the atmospheric input of acidifying substances to a forest ecosystem, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 29-40.

590
GRILL, D., ESTERBAUER, H., and KLOSCH, U., 1979, Effect of sulphur dioxide on glutathione in leaves of plants: Environmental Pollution, v. 19, no. 3, p. 187-194.

Healthy leaves of *Picea, Pinus, Larix*, and *Betula* and leaves exposed to sulfur dioxide (SO_2) were analyzed to determine the content of total water-extractable sulfhydryl (SH) compounds. SH concentrations in control leaves increased by a factor of 4 to 6 with increasing SO_2 concentration. Glutathione (GSH) was the most abundant SH compound in both control and SO_2-affected leaves; about 95 percent of the total SH content was GSH.

591
GRODZINSKA, Krystyna, 1977, Acidity of tree bark as a bioindicator of forest pollution in southern Poland: Water, Air, and Soil Pollution, v. 8, no. 1, p. 3-7.

pH values and buffering capacity were determined for bark samples of five deciduous trees (oak, alder, hornbeam, ash, linden), one shrub (hazel) and one coniferous tree (scots pine) in the Cracow Industrial Region (southern Poland) and, for comparison, in the Bialowieza Forest (northeastern Poland). The correlation was found between acidification of tree bark and air pollution by SO_2 in these areas. All trees showed the least acidic reaction in the control area (Bialowieza Forest), more acidic in Niepolomice Forest and the most acidic in the center of Cracow. The buffering capacity of the bark against alkali increased with increasing air pollution. The seasonal fluctuations of pH values and buffering capacity were found. Tree bark is recommended as a sensitive and simple indicator of air pollution. [Abstract reprinted by permission of D. Riedel Publishing Company.]

592
GRODZINSKA, Krystyna, 1979, Tree bark--sensitive biotest for environment acidification: Environment International, v. 2, no. 3, p. 173-176.

Tree bark was used as a bioindicator of acidification of the Niepolomice Forest near Kracow, Poland. The pH and buffering capacity of bark in three tree species is reported. The bark of all species tested ranged from pH 2.2 to 4.7. Buffering capacity of bark varies spatially with increasing sulfur dioxide (SO_2) concentration in the air.

593
GROTERUD, Olav, 1970, Hydrographical data from two soft water lakes with special reference to precipitation (melt water): Archiv fuer Hydrobiologie, Beihefte, v. 70, no. 3, p. 277-324.

This paper discusses the effects of acid precipitation on the quality of meltwater. Two lakes in Norway were selected for the study. Ovre Heimdalsvatn is a high-altitude, mountain lake; Lake Sandtjern is 599 m above sea level in a small catchment. Precipitation is acidic in both lake basins, with pH values between 4 and 5. Concentration of sulfate (SO_4) and pH of precipitation are clearly related. Meltwater influences the water quality of both lakes, particularly Lake Sandtjern.

594
GROTERUD, Olav, 1972, Ice analyses--data from three Norwegian lakes: Hydrobiologia, v. 40, no. 3, p. 371-391.

Ice from the three lakes in Norway was analyzed for several components, water color, optical density, and specific conductance. The paper discusses (1) verticle and horizontal distribution of components, (2) the influence of nutrients in the ice cover, and (3) the relationship between the ionic balance of the ice and the lake water.

595
GROTERUD, Olav, 1972, Zooplankton and fish in relation to acid melt water and anaerobic deep water in a lake: Vatten, v. 28, p. 329-331.

Water samples were collected from Lake Sandtjern, an anaerobic deep water lake in Norway, during winter stagnation, when acidic snowmelt affects the pH of the lake water. Distribution estimates of *Copepoda cyclops* and *Cladocera bosmina* in the lake are given. Both *Copepoda cyclops* and fish appear to be influenced by low pH in the surface stratum and by oxygen depletion (H_2S) in deep water.

596
GUARI, K. L., 1979, Effects of acid rain on structures, in Gunnerson, C. G., and Willard, B. E., eds., Acid rain: ASCE National Convention, Boston, Mass., 1979, Proceedings: New York American Society of Civil Engineers, p. 70-91.

597
GUCINSKI, H., GOUPIL, D. D., and BAIER, R. E., 1981, Sampling and composition of the surface microlayer, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 165-180.

598
GUDERIAN, R., and KUEPPERS, K., 1980, Response of plant communities to air pollution, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif, U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 187-199.

Under the influence of air pollution two retrogressive processes are set in motion in plant communities: By means of direct and indirect effects, changes occur in structure and function of the community leading up to total destruction. Parallel to this degradation (retrogression) is a spontaneous or man initiated process during which the original adaptive resistant members of the existing community as well as new arrivals undergo secondary succession. The causes and mechanisms for air pollution-induced changes in plant communities are demonstrated by means of literature analysis, and the interaction of dose response determining factors is summarized. In order to emphasize the existing potential danger and to set remedial procedures in motion, research themes are pointed out that must receive immediate attention. [Abstract reprinted by permission of U.S. Forest Service.]

599
GUPTA, R. K., CHHABRA, R., and ABROL, I. P., 1981, The relationship between pH and exhangeable sodium in a sodic soil: Soil Science, v. 131, no. 4, p. 215-219.

Sodic soils have distinct geographic distribution and physiochemical properties and are formed under the influence of sodium carbonate. The pH of calcareous, sodic soils is defined by the equilibrium partial pressure of carbon dioxide and alkalinity. High pH and exchangeable soil ratio (ESR) of calcareous sodic soils are caused by high alkalinity and low carbon dioxide (CO_2) in salt environments.

H

600

HAAPALA, H., SEPPONEN, P., and MESKUS, E., 1975, Effect of spring floods on water acidity in the Kiiminkijoki area, Finland: Oikos, v. 26, p. 26-31.

The acidity of Kiiminkijoki River and its tributaries increases considerably during spring. The pH of water in the largest tributary increases from 5.0 to the 6.4-6.8 range just before spring floods,and reaches a maximum range of 7.0-7.8 during summer. The pH of water in other tributaries decreased during spring; this is attributed to abundant meltwater, which ranges from pH 4.5 to 5.0.

601

HACKNEY, J. D., LINN, W. S., JONES, M. P., BAILEY, R. M., JULIN, D. R., and KLEINMAN, M. T., 1980, Short-term respiratory effects of sulfur-containing pollutant mixtures--some recent findings from controlled clin-ical studies, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 77-84.

Elevated ambient levels of sulfur dioxide (SO_2) or sulfate have been associated with increased respiratory morbidity in a number of epidemiologic studies. Conversely, controlled laboratory exposures of volunteers to SO_2 or individual sulfate compounds generally have shown no significant respiratory changes at concentations similar to ambient, suggesting that interactions between sulfur oxides and other airborne substances may be important in producing adverse health effects of ambient exposure (if any actually occur). A number of recent controlled exposure studies have thus addressed pollutant mixtures. The SO_2-ozone (O_3) mixture has been investigated repeatedly; the more recent results suggest that SO_2 does not enhance the respiratory responses to O_3 if relatively little sulfate aerosol is present. We studied 19 healthy volunteers exposed to a mixture containing SO_2, O_3, and sulfuric acid (H_2SO_4) aerosol under conditions simulating "worst-case" ambient exposures. Modest but significant decrements in forced expiratory performance occurred, but it is not yet possible to determine the extent to which H_2SO_4 and/or SO_2 contributed to these effects. A similar study of mixed SO_2 and nitrogen dioxide (NO_2) showed little effect on lung function; however, respiratory symptoms showed a small significant increase with exposure. [Abstract reprinted by permission of Ann Arbor Science Pubishers.]

602

HAGEN, Arne, and LANGELAND, Arnfinn, 1973, Polluted snow in southern Norway and the effect of the meltwater on freshwater and aquatic organisms: Environmental Pollution, v. 5, p. 45-57.

Contaminated snow has a considerable influence on the quality of water in lakes and brooks in Norway during winter and spring. Analyses of snow and ice samples indicate increased quantities of sulfate, nitrate, zinc, and lead. High concentrations of zinc and low acidity are dangerous to fish. Oligotrophic lakes are more susceptible to snow-related contamination than dystrophic lakes.

603

HAGVAR, Sigmond, 1980, Effects of acid precipitation on soil and forest, 7. Soil animals, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 202-203.

604

HAINES, B. L., 1979, Acid precipitation in southeastern United States: A brief review: Georgia Journal of Science, v. 37, p. 185-191.

This article discusses the effects of acid precipitation on fish and its potential negative impact on mineral-element cycling and plant production in terrestrial ecosystems. It also describes the causes and extent of acid precipitation in the region south of Washington, D.C. and east of the Mississippi. Precipitation data from 1955-78 show a southward spread of increased acidity.

605

HAINES, B. L., STEFANI, Marcia, and HENDRIX, Floyd, 1980, Acid rain--threshold of leaf damage in eight species from a forest succession, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 235.

606

HAINES, B. L., STEFANI, Marcia, and HENDRIX, Floyd, 1980, Acid rain--threshold of leaf damage in eight plant species from a southern Appalachian forest succession: Water, Air, and Soil Pollution, v. 14, p. 403-407.

Eight plant species were treated with simulated acid rain with pH 2.5, 2.0, 1.5, 1.0, and 0.5 to determine the threshold of plant injury and to observe symptoms of damage. Droplets of pH 2.0 caused brown necrotic

606 (continued)
spots on all species except *Pinus*; droplets of pH 1.0 produced necrosis on all leaves of all species studied. The size of necrotic spots increased with acidity. Results also suggest that developing leaves are more easily damaged than mature leaves.

607
HAINES, B. L., and WAIDE, Jack, 1980, Predicting potential impacts of acid rain on elemental cycling in a southern Appalachian deciduous forest at Coweeta [North Carolina], in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 335-340.

608
HAINES, E. B., 1976, Nitrogen content and acidity of rain on the Georgia coast: Water Resources Bulletin, v. 12, no. 6, p. 1223-1231.

This article gives an estimate of the contribution of nitrogen from rain to the Georgia coastal ecosystem. Water samples were collected during 34 storms for 12 months and were analyzed for ammonia, nitrate plus nitrite, and dissolved organic nitrogen. Rain contributes nitrogen to the coast at a rate of 0.3 g/m^2 annually. More than half the rain samples had pH values less than 5.6. Total acidity was measured for 12 samples taken in summer. Sampling results of seven different storms show a linear relationship between hydrogen ion concentration and total acidity. The slope of the regression line indicated that increases in acidity did not result only from the addition of strong acid.

609
HAINES, T. A., 1980, Acidic precipitation, in Carter, W. R., [ed.], AFS draft policies on two issues of environmental concern: Fisheries, v. 5, no. 6, p. 2-5.

This position paper on acidic precipitation supported by the Environmental Concerns Committee of the American Fisheries Society discusses the effects of acidic precipitation on (1) aquatic environments; (2) fish, shellfish, and related organisms; and (3) remedial and mitigation actions.

610
HAINES, T. A., 1981, Acid rain fisheries research in the United States, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 103-112.

611
HAINES, T. A., 1981, Acidic precipitation and its consequences for aquatic ecosystems--a review: Transactions of the American Fisheries Society, v. 110, p. 669-707.

This article presents some of the ecological effects of acid precipitation on water and soil. When the acid-neutralizing capacity of soils and water is low, the pH of streams and lakes decreases, and metal concentrations increase. The abundance, production, and growth of aquatic organisms at all trophic levels are adversely affected. Among fish, acute fish mortality, reduced growth, skeletal deformities, and reproductive failure are noted.

612
HAINES, T. A., 1981, Effects of acid rain on Atlantic salmon rivers and reforestation efforts in the United States, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 57-63.

613
HAINES, T. A, and SCHOFIELD, C. L., 1980, Responses of fisheries to acidification of streams and lakes in eastern North America, in International Symposium on Inland Waters and Lake Restoration, Portland, Maine, 1980, Restoration of lakes and inland waters: Washington, D.C., U.S. Environmental Protection Agency, EPA-440/5-81-010, p. 467-473.

Acid precipitation has caused the pH of lakes and streams in parts of eastern North America to decline and concentrations of heavy metals to increase, particularly during snowmelt and heavy rains. Changes in water quality through acidic atmospheric deposition have adversely affected fish populations, as evidences by a decreased growth rate, increasing frequency of skeletal deformities, and the elimination of sensitive species through mortality or reproductive failure.

614
HALES, J. M., 1978, Wet removal of sulfur compounds from the atmosphere, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 389-399.

This paper presents a brief overview of our current capability to calculate sulfur scavenging rates. The general wet removal process can be decomposed into several individual pathways. These include direct sulfur dioxide scavenging, direct sulfate scavenging, and combined scavenging and chemical reaction. Modeling approaches for these pathways are discussed, and pertinent

614 (continued)
research areas for improvement of our present modeling capability are recommended. At the present time the calculaton of direct sulfur dioxide scavengig appears to be well in hand, although more careful network measurements of dissolved sulfur dioxide concentrations in rainwater are needed to establish the relative importance of this phenomenon on a regional scale. Direct sulfate scavenging presents a more difficult calculational problem, and much more data regarding particle-size relationships of sulfate-containing aerosols is required before an adequate understanding of this pathway can be achieved. Sulfur scavenging via the pathway of sulfur dioxide absorption followed by aqueous-phase conversion is expected to be rate limited by the chemical conversion step under most circumstances. Much additional information regarding aqueous-phase transformation chemistry is necessary before a reliable calculational basis for describing this pathway can be obtained. [Abstract reprinted by permission of Pergamon Press.]

615
HALES, J. M., 1981, Atmospheric processes leading to the occurrence of acid precipitation, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 7.

616
HALES, J. M., and DANA, M. T., 1979, Precipitation scavenging of urban pollutants by convective storm systems: Journal of Applied Meteorology, v. 18, no. 3, p. 294-316.

A precipitation chemistry network was operated during the summers of 1972 and 1973 in the St. Louis metropolitan area to determine the effectiveness of convective storms in removing airborne contaminants. The data were used to develop a precipitation-scavenging model. The study focused on the effects of storms on inorganic nonmetallic species and found precipitation scavenging to be an efficient mechanism to remove airborne pollutants. Much of the rainborne sulfate and nitrate is incorporated into the rain by diffusion of gaseous precursors. Rapid oxidation of sulfur dioxide to sulfate, which occurs in cloud systems in warm, polluted environments, seems to be the cause of seasonal trends in sulfate levels.

617
HALES, J. M., and SUTTER, S. L., 1973, Solubility of sulfur dioxide in water at low concentrations: Atmospheric Environment, v. 7, p. 997-1001.

This article examines the relationships between sulfur dioxide (SO_2) solubility, concentration, and hydrogen-ion impurity at background levels. The solubility of SO_2 at low-concentrations was studied by adding HCl to water solutions; the pH of the solutions ranged between 3 and 7. The influence of acidity on the solubility of SO_2 is predicted using extrapolation methods.

618
HALL, R. J., and LIKENS, G. E., 1980, Ecological effects of experimental acidification on a stream ecosystem, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 375-376.

619
HALL, R. J., and LIKENS, G. E., 1980, Ecological effects of whole-stream acidification, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 443-451.

A natural mountain stream was experimentally acidified to determine the effects on abiotic and biotic parameters. Sulfuric acid was added in dilute concentrations to Norris Brook within the Hubbard Brook Experimental Forest. Stream water pH was lowered to 4.0 for five months in 1977.

Increased acidity resulted in significant mobilization of Al and Ca in the stream water. Mg, K, and Na concentrations were not significantly greater in the acidified sections relative to the reference section of the stream. Macroinvertebrate collectors, scrapers, and predators showed a change in drift acitivity for the first week of acid addition; thereafter, drift behavior was not different for reference and treatment areas. Drift density of species within the shedder functional group was not altered by pH 4.0 stream water. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

620
HALL, R. J., and LIKENS, G. E., 1981, Chemical flux in an acid-stressed stream: Nature, v. 292, no. 5821, p. 329-331.

The pH of Norris Brook, a stream in the Hubbard Brook Experimental Forest in New Hampshire, was lowered from the pH range 5.4-6.4 to the range 3.9-4.2 by sulfuric acid treatments from April 18 to September 22, 1977. The acidification treatment was divided into two categories--acute (5-day treatment simulating spring snowmelt) and chronic (25-day treatment simulating chronic effects of acid precipitation). Experimental stream acidification to pH 4 decreased the chemical and biological flux. Aluminum decreased more than any other inorganic

620 (continued)
component. Carbon, nitrogen, and phosphorus were lost from the ecosystem in the biologically bound form and in the particulate organic fraction.

621
HALL, R. J., LIKENS, G. E., FIANCE, S. B., and HENDREY, G. R., 1980, Experimental acidification of a stream in the Hubbard Brook Experimental Forest, New Hampshire: Ecology, v. 61, no. 4, p. 976-989.

This article examines the effects of acid precipitation on the ecology of aquatic ecosystems. Dilute concentrations of sulfuric acid were added to Norris Brook, a stream in the Hubbard Brook Experimental Forest in New Hampshire. Stream-water concentrations of Al, Ca, Mg, and probably K, Mn, Fe, and Cd increased at higher acidity, but no change occurred in dissolved organic carbon, Na, NO_3, NH_4, Ni, Pb, Cu, or Zn. Increased acidity stressed the food-chain dynamics of the stream ecosystem. Rates and timing of physiological functions of biota may be altered at lower pH without an increase in population mortality.

622
HALLGREN, Jan-Eric, 1978, Physiological and biochemical effects of sulfur dioxide on plants, in Nriagu, J. O., ed., Sulfur in the environment, part II--ecological impacts: New York, John Wiley, p. 163-209.

623
HALLIDY, L. A., and ANDERSON, J. M., 1974, A model for the dispersal of sulfur dioxide over an urban area: Environmental Letters, v. 6, no. 1, p. 55-75.

A computer model was developed to simulate the generation of sulfur dioxide by stationary and moving urban sources, its dispersal into the atmosphere, its oxidation to sulfuric acid, and the precipitation of sulfate particles and sulfuric acid. The model is based on the techniques of system dynamics and is programmed for the DYNAMO language. The model is useful for determining trends in sulfur dioxide and sulfate concentrations as functions of local weather conditions; it may also provide a basis for adjusting emission standards to local environments.

624
HAMILTON, L. D., 1979, Health effects of acid precipitation, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 117-134.

625
HAMILTON, P. M., VAREY, R. H., and MILLAN, M. M., 1978, Remote sensing of sulphur dioxide, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 127-133.

There are many possible methods for the remote sensing of sulphur dioxide but only two are sufficiently sensitive to measure trace amounts: correlation spectrometry and differential lidar.

The correlation spectrometer measures line integrals of concentration, or bur-dens (in atm-μm or ppm-m) by analysing incident radiation in the ultraviolet for absorption by sulphur dioxide. It has already been widely used to measure vertical burdens against a skylight background. Measurements of emission rate have been derived from traverses of a plume near its source: they are limited by the accuracy of the associated wind speed rather than by the spectrometer. Comprehensive measurements of horizotal dispersion and its dependence on times of travel and sampling have also been obtained from traverses farther downwind. The instrument has proven particularly valuable as a sensitive plume locator on mobile surveys.

The differential lidar provides range-resolved measurements of concentration by reflecting pulses of laser light at two wavelengths with different absorption coefficients from particles along the line of sight. It offers a sensitivity of a few parts per billion (ppb) to ranges in excess of 1 km with resolution in space and time of 100 m and 10 s. The instrument has already been demonstrated in prototype form and is now being developed for operational use. [Abstract reprinted by permission of Pergamon Press.]

626
HANDA, B. K., 1973, Chemical composition of monsoon rainwater over Chandigarh in 1971: Indian Geohydrology, v. 9, no. 1, p. 31-37.

Results of a study of the chemical composition of rainwater over Chandigarh, India, indicate that the predominant ions are bicarbonate and calcium. The concentration of potassium ion is low, but sometimes exceeds that of sodium ion. Chemical analyses of sea and rainwater indicates little resemblance between the two, but river water is similar to rainwater in the relative proportion of the various ions. Chemical analyses of rain from successive showers show that the composition of rainwater is variable through time.

627
HANSEN, D. A., 1981, Acid rain--how long and how bad?: Electric Perspectives, Fall 1981 issue, p. 17-25.

Historical trends in the acidity of precipitation are difficult to determine because long-term data are inadequate and data-collection methods are inconsistent. Several national networks for monitoring precipitation quality were established in the 1950's and 60's, but the time periods differed, and many areas were not monitored. Thus, some trend analyses compare data on precipitation chemistry that do not have a common basis for comparison.

628
HANSEN, D. A., HIDY, G. M., and STENSLAND, G. J., 1981, Examination of the basis for trend interpretation of historical rain chemistry in the eastern United States: Westlake Village, Calif., Environmental Research and Technology, Inc., ERT Document no. P-A097, 1 v.

This report evaluates the data from which historic trends in precipitation acidity in the eastern States may be determined. The conclusion is that data are insufficient to define any long-term trends in precipitation acidity during the past 50 years. The pH of rain during 1955-56 was higher than in the 1970's, and the analyses show that the precipitation in the eastern United States is acidic. Sampling methods, sample-preservation and storage techniques, and methods of chemical analyses differ widely. Some of the published analyses of historical trends contain computational errors and fail to define the relative errors, biases, and uncertainties in estimating changes of pH.

629
HANSSEN, J. E., RAMBAEK, J. P., SEMBA, A., and STEINNES, E., 1980, Atmospheric deposition of trace elements in Norway, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 116-117.

630
HARCOURT, S. A., and FARRAR, J. F., 1980, Some effects of simulated acid rain on the growth of barley and radish: Environmental Pollution (series A), v. 22, p. 69-73.

This article presents results of a study to determine the effects of sulfite and low pH on the growth of barley and radishes. Radish and barley seedlings were sprayed with simulated acid rain. Leaf and root growth of radishes were consistently reduced when pH was lowered from 3.5 to 2.5. In one experiment, when pH ranged from 5.5 to 3.5, early growth of barley was reduced in some aspects by sulfite but not by increased acidity.

631
HARDY, J. T., and CRECELIUS, E. A., 1981, Is atmospheric particulate matter inhibiting marine primary productivity?: Environmental Science and Technology, v. 15, no. 9, p. 1103-1106.

This article examines the effect of airborne particulate matter on marine phytoplankton productivity. Present deposition rates of atmospheric particulates are not great enough to inhibit marine primary productivity, except at the sea surface microlayer. When milligram/liter quantities of air particulate matter are added to seawater, the result is an exponential reduction in photosynthetic ^{14}C assimilation of natural marine phytoplankton populations. Airborne particles from urban areas are six times more toxic than those from rural areas.

632
HARPER, H. J., 1943, Sulfur content of Oklahoma rainfall: Oklahoma Academy of Science, Proceedings, v. 23, p. 73-82.

Rain samples were collected at Stillwater, Okla. from 1927-42 and analyzed for sulfur. The largest concentration of sulfur (S) in rain occurred during October, November, and December, but the largest quantity of sulfur occurred during April, May, and June. The average sulfur content per volume of rain was similar to that in other regions with little industrial development.

633
HARR, T. E., and COFFEY, P. E., 1975, Acid precipitation in New York State: Albany, New York State Department of Environmental Conservation, Environmental Quality Research Unit Technical Paper no. 43, 52 p.

This paper summarizes a literature review of 86 documents on the occurrence of acid precipitation and its effects on aquatic and terrestrial ecosystems in New York. Initial effects have been observed in lakes in the western Adirondack region. The buffering capacity of these lakes is believed to have declined by approximately 50 percent during the past 2 decades and is now near zero. Some native fish populations have disappeared from many of these lakes during the past 2 decades, and it has been difficult to maintain stocked salmonid populations.

634
HARRIMAN, R., and MORRISON, B., 1980, Ecology of acid streams draining forested and nonforested catchments in Scotland, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 312-313.

635
HARRISON, Halstead, CHARLSON, R. J., CHRISTIAN, G. D., HORIKE, N. R., KNUDSON, E. J., LARSON, T. V., RILEY, H., VANDERWORT, R., and WEISS, R., 1977, Acid rain in Puget Sound, in Precipitation scavenging, Champaign, Ill., 1974, Proceedings: [Oak Ridge, Tenn.], U.S. Energy Research and Development Administration, ERDA Symposium Series 41, p. 602-610.

Rainwater collected in the Puget Sound basin at Seattle, Wash., has a mean pH near 4.5 and extremes of 3.2 and 6.6. The pH varies rapidly and randomly within single rain episodes. Low pH values correlate with wind direction, ambient sulfur dioxide, and aerosol concentration in air.

636
HARRISON, P. R., and WINCHESTER, J. W., 1971, Area-wide distribution of lead, copper, and cadmium in air particulates from Chicago and northwest Indiana: Atmospheric Environment, v. 5, p. 863-880.

This article discusses the area-wide distribution of lead (Pb), cadmium (Cd), copper (Cu) and bismuth (Bi) in aerosol particles from the Chicago and northwest Indiana regions and presents data for sulfur dioxide (SO_2), suspended particulates, and trace metals.

637
HARRISON, R. M., PERRY, R., and WELLINGS, R. A., 1975, Lead and cadmium in precipitation--their contribution to pollution: Journal of the Air Pollution Control Association, v. 25, no. 6, p. 627-630.

Precipitation samples were collected at six sites in London, Great Britain and at one rural site and were analyzed for lead, cadmium, pH, and conductance. This article relates the data to local sources of air pollution and compares these data with data on the contribution of airborne metal from other sources. It also discusses the effects of precipitation acidity on the solubility of lead and cadmium.

638
HARROWSMITH, 1980, The acid earth: Harrowsmith, v. 27, p. 32-41, p. 93.

This article gives an overview of the probable causes and effects of acid precipitation on terrestrial and aquatic ecosystems. Emphasis is on the effects of low pH on the soil system. The article discusses the vulnerability of coniferous forests to acid rain and explains the relationship of acid rain to the release of heavy metals in the soil, such as lead, nickel, mercury, and cadmium, as well as clay-derived elements such as aluminum, iron, and manganese, into solution.

639
HART, G. E., SOUTHARD, A. R., and WILLIAMS, J. S., 1973, Influence of vegetation and substrate on streamwater chemistry in northern Utah: Logan, Utah, Center for Water Resources Research, Utah State University, 53 p.

The chemical composition of precipitation, throughfall, and streamwater from two mountain-brush drainages in northern Utah were monitored for 2 years. Samples were analyzed for sodium, calcium, magnesium, potassium, phosphorus, nitrate, nitrogen, conductance, and acidity. Dry fallout dust caused by agricultural activities or dry salt flats upwind of the study area affected precipitation. Cation concentrations were 3 to 16 times greater under trees than in open areas.

640
HARTE, John, SCHNEIDER, Richard, and LOCKETT, Greg, 1981, Acid precipitation risk on the western slope of the Colorado Rockies, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 33.

641
HARVEY, H. H., 1975, Fish populations in a large group of acid-stressed lakes: International Association of Theoretical and Applied Limnology, Proceedings, v. 19, p. 2406-2417.

This article describes the effects of environmental stress on the number and diversity of fish species in a group of acidic lakes in the La Cloche Mountains of Canada along the north shore of Georgia Bay and North Channel of Lake Huron. Included are data from detailed limnological surveys conducted on 68 lakes from May to September of 1972 and 1973. The article also lists relative abundance of fish, plankton, and macrophytes from different habitats, ranked on a scale of 0 to 100, and tabulates species diversity according to Shannon's Index.

642
HARVEY, H. H., 1979, Effects on aquatic ecosystems--acid rain, poison snow. Is this our Fate?, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 19-23.

643
HARVEY, H. H., 1980, Widespread and diverse changes in the biota of North American lakes and rivers coincident with acidification, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 93-98.

644
HARVEY, H. H., 1981, Where have all the fishes gone?, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 9-12.

645
HAURY, G., JORDAN, S., and HOFMANN, C., 1978, Experimental investigation of the aerosol-catalyzed oxidation of SO_2 under atmospheric conditions, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 281-287.

One of the most important processes affecting the chemical and physical form of atmospheric sulfur dioxide is the interaction of gaseous SO_2 with solid or liquid aerosol particles. The investigation of the catalytic activity of some synthetic aerosols and dust particles of different industrial origin under real atmospheric conditions (i.e. a wide range of relative humidity and temperature) have been investigated in the course of an experimental research program at Karlsruhe Nuclear Research Center, Germany. The experiments were carried out in a 4.5 m^3 climate-controlled reaction chamber especially designed for SO_2-experiments in the ppm-concentration range. Starting with SO_2 concentrations of 3-5 mg m^{-3} the removal of SO_2 from gas phase in the presence of moist aerosol-free air and moist aerosol-polluted air was investigated as was the change of chemical composition of aerosols due to SO_2-adsorption and catalytic oxidation. The results of these experiments with synthetic $MnSO_4$ aerosols and fly-ash particles of a hard coal fired power plant are presented. They indicate a strong dependence of the catalytic oxidation rate on the relative humidity but no disappearance of the catalytic activity at low relative humidities. [Abstract reprinted by permission of Pergamon Press.]

646
HAVAS, Paavo and HUTTUNEN, Satu, 1980, Some special features of the ecophysiological effects of air pollution on coniferous forests during the winter, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 123-131.

647
HAWKINS, David, 1979, Energy and environment goals, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 178-183.

648
HAWKSWORTH, D. L., and ROSE, F., 1970, Qualitative scale for estimating sulphur dioxide air pollution in England and Wales using epiphytic lichens: Nature, v. 227, p. 145-148.

Lichens were studied in England and Wales to determine the amount of sulfur dioxide in the air. Air pollution was measured on a 10-point scale that reflects pollution on rough bark of low pH on deciduous trees, especially *Quercus* and *Fraxinus*, in open areas.

649
HAWLEY, John, 1977, Acid rain: The Conservationist, v. 31, no. 6, p. ii-iv.

This article discusses the effects of acid rain on human health, building materials, and aquatic and terrestrial ecosystems. Emphasis is on the sulfur cycle and the formation of nitric acid in precipitation.

650
HAZRATI, A. M., 1979, The use of metal films in studying sulfuric acid droplets in the atmosphere: Journal of the Air Pollution Control Association, v. 29, no. 4, p. 372-377.

This paper presents an air-quality analysis technique to detect and measure with high accuracy the concentration and size spectra of sulfuric acid droplets. Light-extinction measurement through reaction spots is used to yield size distribution of sulfuric acid droplets on thin metal film. The size distribution and concentration of urban particulate sulfuric acid is calculated by photometry through optical microscope or densitometry on electron micrographs from exposed thin metal films (with less than 12 percent error).

651
HEESE, Maria, JACOBSEN, Ingo, MULLER, Eberhard, and PANKRATH, Jurgen, 1979, On the effect of meteorological simplifications in the numerical simulation of regional transport processes, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 329-336.

652
HEGG, D. A., and HOBBS, P. V., 1978, Oxidation of sulfur dioxide in aqueous systems with particular reference to the atmosphere, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 241-253.

652 (continued)
Laboratory studies of the uncatalyzed liquid phase oxidation of SO_2 by oxygen are reviewed; significant discrepancies exist between the derived pseudo first order rate coefficients. The production rate is independent of the concentration of oxygen. For pH <7 the activation energy for this reaction is 7.1×10^3 J mol^{-1}, and for $7 \leq pH \leq 9.5$ it is 8.9×10^4 J mol^{-1}. The mechanism of oxidation is probably via a free radical chain involving SO_3^- and SO_5^-. Sulfates may also be produced in solution by the oxidation of SO_2 by ozone. In this case, the rate of production of sulfates varies linearly with the concentration of ozone and bisulfite, and the activation energy is 1.6×10^4 J mol^{-1}. Laboratory studies of the catalyzed liquid phase oxidation of SO_2 suggest that $d[SO_4^{2-}]/dt = K[M^+]-[H^+][SO_3^{2-}]$, where $[M^+]$ is the concentration of the metal catalyst (e.g. Fe^{3+}, Mn^{2+}, Cu^{2+}). There is some evidence, which needs confirmation, that catalysis by certain 'mixed salts' produces an oxidation rate about ten times greater than with either salt alone. The oxidation of SO_2 in solution is inhibited by a large number of compounds present in the atmosphere. Consequently, the net effect of positive and negtive catalysts on the oxidation rate of SO_2 in cloud and rain water could be small. Extrapolation of laboratory results to the atmosphere suggests that in 'clean' (rural) air, the uncatalyzed oxidation (urban) air, uncatalyzed oxidation and iron catalyzed oxidation should be competitive, but, if manganese is present in solutions in concentration above 10^{-6} m, the manganese catalyzed oxidation may dominate. However, extrapolation of laboratory results to the atmosphere is fraught with danger. Some field observations of the concentrations of cloud condensation nuclei and sulfates in air entering and leaving clouds suggest that the producton of sulfates by the oxidation of SO_2 in clouds is important. Also, preliminary calculations suggest that the liquid phase oxidations of SO_2 in clouds may be the dominant world-wide source of sulfates in the atmosphere. Suggestions are made for further laboratory, field, and modeling studies, which should improve our understanding of liquid phase SO_2 oxidation in the atmosphere. [Abstract reprinted by permission of Pergamon Press.]

653
HEIDORN, K. C., 1978, Sulfate and nitrate in total suspended particulate in Ontario: Journal of the Air Pollution Control Association, v. 28, no. 8, p. 803-806.

This paper discusses the composition of suspended particulates in Ontario and compares sulfates and nitrates in total suspended particulate in 1971 with those in 1976. Sulfates showed a general decrease at all but two of 43 sites. Decreases in sulfates correlate well with decreases in sulfur dioxide. Data from most stations show an increase in nitrates in 1976; however, the overall trend during 1971-76 was nearly constant.

654
HEIDORN, K. C., 1979, Incidents of elevated nitrate in southern Ontario: Water, Air, and Soil Pollution, v. 12, p. 417-429.

Elevated levels of nitrate (in excess of 9.9 $\mu g/m^3$) in suspended particulate in the lower Great Lakes region of southern Ontario during 1976-77 occurred simultaneously across the region on certain days, many of which were from October through February. The low variability of nitrate concentrations at stations in the Ontario monitoring network and the historic pattern of air-mass movement suggest that long-range-transport is partly responsible for the elevated nitrate levels.

655
HEINTZENBERG, Jost, and TRAGARDH, Claes, 1979, Physical and chemical properties of aerosols under varying European influence: Stockholm, University of Sweden, Department of Meteorology, Report AC-48, 105 p.

Physical and chemical properties of aerosol in air masses with varying degrees of contamination were measured at Velen, south Sweden. Trajectory calculations were used to determine aerosol properties of air masses to study the influence of combustion products. Maximum light absorption and scattering coincide with the time of maximum particle concentration and ammonium and sulfate ion concentrations. Trajectory analysis indicates a southeastern European source for these ions and a marine or local Scandinavian source for other elements.

656
HEIT, M., TAN, Y. Y., KLUSEK, C., and BURKE, J. C., 1981, Anthropogenic trace elements and polycyclic aromatic hydrocarbon levels in sediment cores from two lakes in the Adirondack acid lakes region: Water, Air, and Soil Pollution, v. 15, p. 441-464.

This article discusses historical changes in the deposition of trace elements and polycyclic aromatic hydrocarbons (PAHs) in remote, acidic lakes in the Adirondack Mountains of New York. Sediment cores from Sagamore and Woods Lakes show that all parental PAHs except perylene and several metals have increased significantly compared to natural integrated deposits and background levels for the lakes. Manmade combustion is believed to be the prime source of 3- to 7-ring PAHs and trace elements that were measured. Manmade derived materials decrease in concentration with depth to baseline

656 (continued)
levels in sediment layers estimated by Cs_{137} analysis to be approximately 30 years old. Concentrations of biogenically or crustally derived species remain constant or increased with core depth.

657
HELVEY, J. D., PATRIC, J. H., 1965, Canopy and litter interception of rainfall by hardwoods of eastern United States: Water Resources Research, v. 1, no. 2, p. 193-206.

A review is given of studies on rainfall interception under forest conditions in the eastern hardwood region. Results of numerous studies show that hardwood throughfall and stemflow vary over a narrow range. Combined regression equations relating gross rainfall, throughfall, and stemflow can be modified for specified forest conditions or for use with seasonal rainfall.

658
HEM, J. D., 1972, Chemical factors that influence the availability of iron and manganese in aqueous systems: Geological Society of America, v. 83, p. 443-450.

The principal factors that affect aqueous chemical behavior of iron and manganese are shown in Eh-pH diagrams of dominant solute species, stable solid forms, and solubility. Small shifts in Eh or pH can change considerably the equilibrium solubility of the metals.

659
HEMOND, H. F., 1980, Biogeochemistry of Thoreau's bog, Concord, Massachusetts: Ecological Monographs, v. 50, no. 4, p. 507-526.

Thoreau's bog in Concord, Mass., is a floating-mat *Sphagnum* bog in a glacial kettle hole. The pH of the bog is 3.8 and is maintained by organic acids at concentration of 1 meq/L. Cation exchange does not appear to significantly affect bog acidity. Contribution to bog acidity by acid precipitation is offset by increases in alkalinity of the same magnitude resulting from sulfate reduction and uptake of nitrate. Alkalinity and nitrate uptake are essentially buffering mechanisms against acid precipitation in the bog.

660
HENDERSON, G. S., SWANK, W. T., and HORNBECK, J. W., 1980, Impact of sulfur deposition on the quality of water from forested watersheds, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 431-441.

660 (continued)
Nutrient discharge in streamflow resulting from five manipulative treatments to experimental watersheds was used to evaluate the potential impact of sulfur and associated acid deposition on cation-leaching and content of water. Observed stream discharge of nitrate nitrogen was used to calculate H^+ production due to accelerated nitrification in response to forest harvest. This value or a calculated value for H^+ production following urea fertilization was combined with observed cation discharge, which had been corrected for release from organic matter decomposition, to estimate cation release ratios from the soil exchange complex due to H^+. These ratios were then used to estimate potential increases in watershed discharge of cations if precipitation acidity were to change from pH 4.3 to pH 4.0, 3.5, or 3.0. The potential increases in annual Ca, Mg, K, and Na discharge were calculated to be less than 0.5 kg/ha at pH 4.0 and less than 2.5 kg/ha at pH 3.5, increases which would be difficult to detect among natural variations in stream water chemistry. Calculations for precipitation at pH 3.0 suggest a potential increase in cation discharge which could be as great at 8.5 kg/ha for individual elements, a change which would be more easily detected. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

661
HENDERSON-SELLERS, A., 1980, Air pollution levels: Difficulties of assessment of area values and trends: Water, Air, and Soil Pollution, v. 13, p. 173-186.

This paper describes current levels and general trends of smoke and SO_2 in the County of Merseyside, Great Britain, and discusses problems encountered during the study of these pollutants. Unsatisfactory values for smoke and SO_2 levels were estimated due to errors in calculation. Estimates of pollutant levels at scales as small as county areas should be made with considerable care because of the difficulty in obtaining long-term atmospheric monitoring data.

662
HENDREY, G. R., 1979, Acidification of aquatic ecosystems--ecosystem sensitivity and biological consequences, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 72-90.

663
HENDREY, G. R., 1980, Biological processes, in Hendrey, G. R., ed., Limnological aspects of acid precipitation: International Workshop, Sagamore Lake Conference Center, N.Y., 1978, Proceedings: Upton, N.Y., Brookhaven National Laboratory, p. 25-30.

664
HENDREY, G. R., 1980, Effects of acidity on primary productivity in lakes--phytoplankton, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 357-371.

Relationships between phytoplankton communities and lake acidity in three Adirondack Mountain lakes are being studied at Woods Lake (pH ca. 4.9), Sagamore Lake (pH ca. 5.5), and Panther Lake (pH ca. 7.0). Numbers of phytoplankton species observed as of July 31, 1979, are Woods, 27; Sagamore, 38; and Panther 64, conforming to observations at many other sites that species numbers decrease with increasing acidity. Peak chlorophyll *a* and productivity values, respectively, were Woods, 6.8 mg m^{-2} and 21 mg m^{-2} hr^{-1}; Sagamore, 12.2 mg m^{-2} and 16 mg m^{-2} hr^{-1}; and Panther, 23 mg m^{-2} and 52 mg m^{-2} hr^{-1}. Patterns of increasing biomass and productivity in Woods Lake may be atypical of similar oligotrophic lakes in that they develop rather slowly to maxima six weeks after ice-out instead of rapidly very close to ice-out. Phytoplankton productivities averaged from ice-out through July 31, 1979, were 12 mg M^{-2} hr^{-1}, 10 mg m^{-2} hr^{-1}, and 30 mg m^{-2} hr^{-1} for Woods, Sagamore, and Panther. Contributions of net plankton (net > 48 μm), nannoplankton (48 > nanno > 20 μm), and ultraplankton (20 > ultra > 0.45 μ) to productivity per square meter show that the smaller plankton are relatively more important in the more acid lakes: Woods > Sagamore > Panther ($p < 0.05$). This pattern could be determined by nutrient availability (lake acidification is suspected of leading to decreased availability of phoshorus). The amount of ^{14}C-labeled dissolved photosynthate (^{14}C-DOM), as a percent of total productivity, is ordered Woods > Sagamore > Panther. This is consistent with a hypothesis that microbial heterotrophic acitivity is reduced with increasing acidity, but the smaller phytoplankton may be more "leaky" at low pH. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

665
HENDREY, G. R., 1980, Temporal perspective on acid deposition research: Upton, N.Y., Brookhaven National Lab., BNL-28141, 14 p.

This article presents data on regional and temporal characteristics of acid precipitation in the northeastern U.S. Data on forest productivity suggests that the impact of acid precipitation is either slight or that it cannot be measured by present techniques or that a long period of latent injury occurs before measureable impacts are detected. The article discusses research needs such as further investigations on the ecological effects of acid precipitation. [This paper was presented to the Subcommittee on Natural Resources, Committee on Science and Technology, U.S. House of Representatives.]

666
HENDREY, G. R., BAALSRUD, Kjell, TRAAEN, T. S., LAAKE, Morten, and RADDUM, G. G., 1976, Acid Precipitation--some hydrobiological changes: Ambio, v. 5, no. 5/6, p. 224-227.

The acidification of freshwaters by precipitation causes changes in naturally occurring communities of aquatic organisms. This article examines the effects of acid precipitation on communities of microdecomposers, algae, aquatic macrophytes, zooplankton, and zoobenthos and includes a brief discussion of the effects of acidification on fish.

667
HENDREY, G. R., and BARVENIK, F. W., 1979, Impacts of acid precipitation on decomposition and plant communities in lakes, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 92-103.

668
HENDREY, G. R., FRANCIS, A. J., and QUINBY, H. L., 1980, Integrated lake watershed acidification study (ILWAS): Upton, N.Y., Brookhaven National Laboratory, BNL 28059, 65 p.

Microbial decomposition of allochthonous litter in acid, circumneutral, and neutral lakes in the Adirondack Mountains of New York was investigated. Leaf packs containing beech, sugar maple, red maple, leather leaf, and red spruce leaves were incubated in the lakes at various depths. After 7- and 21-day incubations, the leaf packs were analyzed for loss in dry weight, changes in leaf surface area, microbial numbers, chlorophyll, carbon, and nitrogen content. Water and sediment samples were collected at 1-, 3-, and 5-m depths and analyzed for total counts of bacteria by epifluorescence microscopy. Data are given on population of bacteria leaf packs and in sediment and water samples.

669
HENDREY, G. R., GALLOWAY, J. N., NORTON, S. A., SCHOFIELD, C. L., BURNS, D. A. and SCHAFFER, P. W., 1980, Sensitivity of the eastern United States to acid precipitation impacts on surface waters, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 216-217.

670
HENDREY, G. R., GALLOWAY, J. N., NORTON, S. A., SCHOFIELD, C. L., SHAFFER, P. W., and BURNS, D. A., 1980, Geological and hydrochemical sensitivity of the eastern United States to acid precipitation: Corvallis, Oregon, U.S. Environmental Protection Agency, EPA-600/3-80-024, 90 p.

A model based on analysis of bedrock geology maps of the eastern United States is used for predicting areas that may be affected by acid preciptation. The model allows greater resolution for detecting sensitivity than methods previously available. Map accuracy was verified by examination of alkalinity and pH of waters in test areas in Maine, New Hampshire, New York, Virginia, and North Carolina. Regions predicted to be highly sensitive show generally low alkalinities (less than 200 μeq/L) at upstream sites. Surface waters in many areas of the eastern United States are sensitive to acidification, especially upland reaches.

671
HENDREY, G. R., GALLOWAY, J. N., and SCHOFIELD, C. L., 1980, Temporal and spatial trends in the chemistry of acidified lakes under ice cover, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 266-267.

672
HENDREY, G. R., and VERTUCCI, F. A., 1980, Benthic plant communities in acidic Lake Colden, New York--sphagnum and the algal mat, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 314-315.

673
HENDREY, G. R., and WRIGHT, R. F., 1976, Acid precipitation in Norway--effects on aquatic fauna: Journal of Great Lakes Research, v. 2, supplement no. 1, p. 192-207.

This article presents data collected during a regional lake survey in Norway in 1974 and discusses the effects of acid precipitation on aquatic ecosystems, with emphasis on aquatic fauna. The acidification of freshwaters severely affects invertebrate fauna by reducing the number of species, shortening food chains, and effecting population strength at different trophic levels. The sensitivity of aquatic insects to low pH varies during their life cycle. Zooplankton species numbers are reduced as acidity increases; the *Daphnia* species is rare in waters with pH below 6.0. Acid precipitation has caused severe damage to fish stocks; salmonid fish are particularly vulnerable.

674
HENDREY, G. R., YAN, N. D., and BAUMGARTNER, K. J., 1980, Responses of freshwater plants and invertebrates to acidification, in International Symposium on Inland Waters and Lake Restoration, Portland, Maine, 1980, Restoration of lakes and inland waters: Washington, D.C., U.S. Environmental Protection Agency, EPA-440/5-81-010, p.457-466.

Biota of acidic oligotrophic waters in many regions of Canada are similar; the phytoplankton, Dinophyceae and, to a lesser extent, Chrysophyceae, dominate. Production of 25 lakes in the Canadian Shield region ranges from 25 to 240 $(mg/cm^2)/d$. Biomass and production seem to be controlled by the availability of phosphorus rather than pH. Watershed acidification processes such as leaching of aluminum may reduce total phosphorus loading to lakes, even below pH 5. Zooplankton community biomass is reduced at low pH, and small-bodied forms may dominate. Removal of fish predation on benthos allows a relative increase in invertebrate predators and reduction of herbivores and subsequently results in increases of benthic algae.

675
HENDRY, C. D., and BREZONIK, P. L., 1980, Chemistry of precipitation at Gainesville, Florida: Environmental Science and Technology, v. 14, no. 7, p. 843-849.

Fluxes of nutrients (nitrogen and phosphorus forms) and major ions to aquatic and terrestrial systems from bulk and wet precipitation in north-central Florida were determined from June-July 1976. Also studies were principal acids responsible for the observed. Results indicate that volume-weighted mean pH of wet-only precipitation is 4.56; that of bulk precipitation is slightly higher. The lowest pH values occur in spring and summer. Sulfuric acid contributes 69 percent of the total rainfall acidity; nitric acid contributes 23 percent.

676
HENDRY, C. D., BREZONIK, P. L., and EDGERTON, E. S., 1980, Acid precipitation in Florida (U.S.A.)--results of a statewide monitoring network, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 118-119.

677
HENDRY, C. D., BREZONIK, P. L., and EDGERTON, E. S., 1981, Atmospheric deposition of nitrogen and phosphorus in Florida, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 199-215.

678
HENMI, Teizi, 1979, Long-range transport model of SO_2 and sulphate and its application to the eastern United States, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 321-328.

679
HENRIKSEN, Arne, 1972, Quantitative chemical analysis of snow: Vatten, v. 28, no. 5, p. 409-412.

The gray color of snow observed in Norway is attributed to air pollution originating from industrial areas in Europe. This article presents data on total yearly fallout of chemical components of the air at Oslo, Norway, and gives estimates of the chemical constituent load on watersheds during spring snowmelt.

680
HENRIKSEN, Arne, 1979, A simple approach for identifying and measuring acidification of freshwater: Nature, v. 278, p. 542-545.

Excess sulfate concentrations or current calcium concentrations and alkalinity values may be indicators of the first stage of acidification in lakes and rivers. If bicarbonate is still present, alkalinity of surface waters will not indicate whether acidification has occurred unless alkalinity data from the preacidification stage are available. Preacidifiction alkalinities can be estimated from present calcium concentrations. The equation for quantifying acidity is:

Acidification = pre-acidification alkalinity minus present day alkalinity.

681
HENRIKSEN, Arne, 1980, Acidification of freshwaters--a large scale titration, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 68-74.

682
HENRIKSEN, Arne, and SEIP, H. M., 1980, Strong and weak acids in surface waters of southern Norway and southwestern Scotland: Water Research, v. 14, no. 7, p. 809-813.

Lake-water samples were collected regionally in southern Norway and from small lakes and creeks in New Galloway, Scotland and analyzed for pH, strong and weak acids, and concentrations of major ions. Analyses from both locations show a similar relationship between strong acid and H^+ concentration as calculated from the pH of samples. When pH exceeds 5.5, strong acid concentration becomes negative and corresponds to the presence of bicarbonate or other bases. When pH ranges from 4.8 to 5.5, the strong-acid concentration is usually positive, but less than the H^+ concentration, which suggests contributions from weak acids. These weak acids may have existed as bases before excess inflow of strong acids began.

683
HENRIKSEN, Arne, and WRIGHT, R. F., 1977, Effects of acid precipitation on a small lake in southern Norway: Nordic Hydrology, v. 8, p. 1-10.

This article presents results of a hydrochemical investigation of an acidified lake basin in south-central Norway about 100 km northwest of Oslo. Two major tributaries to the lake show rapid response to influxs of acid precipitation and long recovery periods between episodes. Spring and fall precipitation episodes differ in their effect on the lake chemistry. The large amounts of H^+ that are released in the first phases of spring snowmelt reduced pH only in the surface layers of the ice-covered lake; many of the meltwater constituents are discharged. In the fall, acid inputs are readily mixed through the water column during the autumnal circulation period. Spring and fall are the periods of the greatest acid contribution and the periods most critical for reproduction of fish and aquatic organisms.

684
HENRIKSEN, Arne, and WRIGHT, R. F., 1978, Concentrations of heavy metals in small Norwegian Lakes: Water Research, v. 12, p. 101-112.

Concentrations of zinc (Zn), lead (Pb), copper (Cu), and cadmium (Cd) were measured in surface- and bottom-water samples collected from small, pristine lakes in Norway. These remote, undisturbed lakes were selected for sampling because both natural and manmade constituents arrive via the atmosphere. Concentrations of Zn and Pb in lakes in southern Norway exceed the background levels in lakes in northern and central Norway. Higher concentrations of heavy metals in these lakes may be a result of increased mobilization due to acidification of the soil and surface waters by atmospheric deposition.

685
HENRIKSON, L., OSCARSON, H. G., and STENSON, J. A. E., 1980, Does the change of predator system contribute to the biotic development in acidified lakes?, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 316-317.

686
HERMAN, F. A., and GORHAM, Eville, 1957, Total mineral material, acidity, sulphur and nitrogen in rain and snow at Kentville, Nova Scotia: Tellus, v. 9, no. 2, p. 180-183.

Monthly precipitation samples and individual snow samples were collected at Kentville, Nova Scotia from June 1952 through May 1954 and analyzed for total ash, pH, ammonia, and nitrate nitrogen. Average pH was 5.7; more acidic rains had levels of nitrate and sulfur that were above the annual mean. Snow samples contained lower concentrations of ash, sulfur, and nitrogen than rainwater samples; this may indicate a lower efficiency of snow in removing airborne material.

687
HERRMAN, R., and BARON, J., 1980, Aluminum mobilization in acid stream environments, Great Smoky Mountains National Park, U.S.A., in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 218-219.

688
HERZBERG, P. J., 1980, The interstate carriage of pollutants--the legal problem and existing solutions, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 463-475.

689
HICKS, B. B., 1980, On the dry deposition of acid particles to natural surfaces, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 327-339.

Monitoring programs conducted over the northeastern continental USA during the past few years have indicated that sulfate particles present in air near the surface are often acidic. These particles, which are typically small and hygroscopic, might be expected to attach themselves to foliage, thus imparting a strong but very localized dose of acid. At this time, the efficiency with which small particles attach themselves to leaf surfaces and the conditions under which they might be re-emitted by abrasion, for example, are largely unknown, and so a considerable uncertainty must be associated with any evaluation of the net effect. Application of deposition velocities in the range presently advocated for sulfate particles suggests acid fluxes by dry deposition that average about two orders of magnitude less than those probably resulting from rainfall. This should not be interpreted as an indication that dry deposition effects can be neglected, since it is clear that acid particles might reside on surfaces for considerable times, perhaps until washed off by rain or sufficiently diluted by dewfall. [Abstract reprinted by permission of Plenum Press.]

690
HICKS, B. B., and SHANNON, J. D., 1979, A method for modeling the deposition of sulfur by precipitation over regional scales: Journal of Applied Meteorology, v. 18, no. 11, p. 1415-1420.

Sulfur deposition by wet process is estimated as a function of the half-power of the amount of precipitation. Measurements of sulfur concentrations in summer rainfall collected at Argonne National Laboratory and the Department of Energy precipitation network support this hypothesis. This article presents a method for estimating buld removal rate of airborne total sulfur by precipitation. Regional dispersion modeling is discussed. The rate can be used in modeling regional dispersion of sulfur.

691
HICKS, B. B., and WESELY, M. L., 1980, Turbulent transfer processes to a surface and interaction with vegetation, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 199-207.

Strong dirunal variations are associated with both aerodynamic and surface resistances to the transfer of gaseous and particulate pollutants. Eddy flux measurements made over a Loblolly pine plantation in July 1977 indicate that nocturnal aerodynamic resistances can frequently exceed 1 sec/cm and sometimes be considerably more than 10 sec/cm. Residual surface resistances to ozone transfer ranged from about 1.4 sec/cm during daytime to about 5 sec/cm at night. For small particles and sulfur compounds, similar daytime residual resistances were measured, but nocturnal resistances were typically about 50% of the ozone values. Exceedingly few nocturnal particle resistances were determined, however, because the trees then appeared to constitute more of a source than a sink. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

692
HICKS, B. B., and WILLIAMS, R. M., 1980, Transfer and deposition of particles to water surfaces, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 237-244.

692 (continued)
Consideration of the nature of open water in moderate and high winds leads to the expectation that breaking waves and foaming white water might play a critical role in determining the rate at which particles are deposited to open water surfaces. Corresponding models of the deposition process can be derived. These indicate that particle deposition veolcities are not likely to exceed 1 cm/sec except in high winds. Micrometeorological formulations of flux-gradient relationships in the air immediately above the surface indicate that experimental verification of such predictions of relatively small deposition velocities will be exceedingly difficult to obtain. For application of the familiar gradient method it appears necessary to resolve concentration differences of the order of 1%, and concentration fluctuations that must be measured in the eddy correlation method will be of similar magnitude. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

693
HIDY, G. M., 1980, A knowledge gap--pollution sources and precipitation: Westlake Village, Calif., Environmental Research and Technology, Inc., 31 p.

This report discusses the environmental effects of acid precipitation and the relationship between air pollution sources and precipitation chemistry. Regional susceptibility is relatively localized in the northeast and depends on soil character and natural surface-water interactions. Natural acidity of precipitation is variable and depends on climatic factors and cation-anion balance.

694
HIDY, G. M., and BROCK, J. R., 1971, An assessment of the global sources of tropospheric aerosols, in International Clean Air Congress, 2nd, 1970, Washington, D.C., Proceedings: New York Academic Press, p. 1088-1097.

This article presents a preliminary calculation of aerosol sources; emphasis is on man-made sources. Worldwide air pollution by aerosols could potentially reach significant proportions. Man's contribution to worldwide production of aerosols is about 6 percent. The largest anthropogenic sources are (1) smoke from combustion of fossil fuels, industrial emissions, and ore processing, and (2) production of sulfate particles from oxidation of sulfur dioxide and hydrogen sulfide in the atmosphere.

695
HIDY, G. M., and MUELLER, P. K., 1980, Monitoring airborne contaminants, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 407-434.

695 (continued)
This paper gives a brief survey of air quality monitoring practice in the United States. The reasons for monitoring are outlined, and the concept of monitoring systems is introduced. This "system" includes measurement instrumentation, calibration, data recording and transmission, data management including validation, processing and archiving, quality control and quality assurance. Techniques for measurement of ambient concentrations and surface deposition are surveyed. Examples of user displays illustrate management of monitoring data for different purposes. Finally, the dilemmas inherent in limitations of measurements for monitoring, data accessibility, and the user identification are discussed in the light of future directions in monitoring. [Abstract reprinted by permission of Plenum Press.]

696
HIDY, G. M., MUELLER, P. K., LAVERY, T. F., and WARREN, K. K., 1979, Assessment of regional air pollution over the Eastern United States--results from the Sulfate Regional Experiment (SURE), in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 65-76.

697
HIDY, G. M., MUELLER, P. K., and TONG, E. Y., 1978, Spatial and temporal distributions of airborne sulfate in parts of the United States, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 735-752.

The current knowledge of the spatial and temporal distribution of airborne, water soluble sulfate is surveyed for two "scales" of atmospheric activity. The "urban" scale with episodes extending over a day or two over distances of about 100 km is illustrated for two comparable American cities--Los Angeles and New York. The regional scale with episodes extending up to several days over distances over 1000 km is exemplified by case studies in the greater eastern United States. Examination of available data reveals several features of the spatial and temporal variation in sulfate occurrence, including seasonal changes, and correlations with aerometric parameters. The importance of water vapor and air mass character on sulfate concentrations is assessed in both the urban and regional conditions. The results of initial attempts to simulate the impact of sulfur oxide emissions on ambient sulfate distributions are compared with an episode case

697 (continued)
extending over several days in July 1974. [Abstract reprinted by permission of Pergamon Press.]

698
HILEMAN, Bette, 1981, Acid precipitation: Environmental Science and Technology, v. 15, no. 10, p. 1119-1124.

This article discusses the detrimental effects of acid precipitation on fish and other wildlife, manmade structures, and the aquatic ecosystem. Industrial emissions that cause acid precipitation are likely to increase. Although SO_2 emissions have decreased by 5 percent in the U.S. from 1975-80, NO_x emissions have increased by at least 5 percent. Furthermore, methods for controlling NO_x emissions are not as well developed as those for SO_2.

699
HILL, A. C., 1971, Vegetation--a sink for atmospheric pollutants: Journal of the Air Pollution Control Association, v. 21, no. 6, p. 341-346.

Chamber studies were conducted to determine the uptake rate of the major air pollutants by typical vegetation canopies. An alfalfa canopy removed gases from the atmosphere in the following order: (1) hydrogen fluoride, (2) sulfur dioxide, (3) chlorine, (4) nitrogen dioxide, (5) ozone, (6) peroxyacetyl nitrate, (7) nitric oxide, and (8) carbon monoxide. Uptake increased linearly with increasing concentration except for ozone and chlorine. Constituent removal rate is affected by wind velocity above the plants, height of the canopy, and light intensity.

700
HILL, A. C., and CHAMBERLAIN, E. M., Jr., 1976, The removal of water soluble gases from the atmosphere by vegetation, in Atmosphere-Surface Exchange of Particulate and Gaseous Pollutants, Richland, Wash., 1974, Proceedings: [Oak Ridge, Tenn.], U.S. Energy Research and Development Administration, ERDA Symposium Series 38, p. 153-170.

The absorption of water soluble gases by a typical vegetation canopy was investigated using environmental chambers specifically designed for this purpose. These chambers were constructed to simulate, within acceptable limits, different field environmental conditions by controlling wind velocity, CO_2 concentration, temperature, relative humidity, light intensity, and pollutant concentration.

Standard alfalfa canopies removed gaseous pollutants from the atmosphere in rates of the following order: hydrogen fluoride (HF) > sulfur dioxide (SO_2) > chlorine (Cl_2^-) > nitrogen dioxide (NO_2) > ozone (O_3) > peroxyacetyl nitrate (PAN) > nitric oxide (NO) > carbon monoxide (CO). HF, SO_2, and NO_2 concentration profiles indicated that these substances were efficiently removed from the atmosphere by the surface and subsurface vegetation of the upper portion of the plant canopy.

Wind velocity, canopy height, and light intensity were shown to affect the rate of pollutant removal by the vegetation. The rate of pollutant removal was also found to increase linearly with the increase of pollutant concentration over the ranges of concentration which may be found in ambient air and which are low enough not to cause stomatal closure. The absorption rate of the various gaseous pollutants was shown to be related to their solubility in water.

It was concluded that vegetation may be an important sink for many gaseous air pollutants. [Abstract reprinted by permission of U.S. Department of Energy.]

701
HILL, F. B., and ADAMOWICZ, R. F., 1977, A model for rain composition and the washout of sulfur dioxide: Atmospheric Environment, v. 11, p. 917-927.

A chemical model was developed for the washout of sulfur dioxide from the atmosphere. The model accounts for mass transfer of sulfur dioxide into well-mixed drops, ionic equilibrium of sulfur compounds in solution, oxidation of dissolved species to sulfate ion, and the presence of strong acid or base in rain. Expressions were devised to predict the composition of rain as a function of fall distance, the time scale for SO_2 removal from the atmosphere, and composition of ground-level transients during a rain event. The model may also be modified for study of other reactive gases.

702
HINDAWI, I. J., REA, J. A., and GRIFFIS, W. L., 1980, Response of bush bean exposed to acid mist: American Journal of Botany, v. 67, no. 2, p. 168-172.

Bush bean plants (*Phaseolus vulgaris*) were used in experiments to determine the effect of acidic precipitation. The plants were treated with simulated acid mist at pH levels ranging from 5.5 to 2.0. Plants exposed to acid mists below pH 3 developed leaf injury; many leaves exhibited a flecking symptom similar to that caused by ozone. Seed and pod growth were reduced before visible foliar injury developed.

703
HITCHCOCK, D. R., 1976, Atmospheric sulfates from biological sources: Journal of the Air Pollution Control Association, v. 26, p. 210-215.

Sulfate levels were monitored at four coastal and three inland nonurban sites where sulfur dioxide emissions are absent or negligible and at eight coastal and ten inland urban sites. All sites were in New England or the Middle Atlantic States. At nonurban sites summer sulfate levels significantly exceeded winter levels, and at urban sites sulfate levels in summer were nearly the same as at nonurban sites. New York sites near polluted water showed higher levels of sulfate in spring, summer, and fall than sites near pristine water, but both were similar in winter. Most of the sulfate observed in cities during summer and fall is attributed to biogenic sulfate sources.

704
HITCHCOCK, D. R., SPILLER, L. L., and WILSON, W. E., Jr., 1980, Sulfuric acid aerosol and HCl release in coastal atmospheres--evidence of rapid formation of sulfuric acid particulates: Atmospheric Environment, v. 14, no. 2, p. 165-182.

Particulate samples were collected during two summer experiments at coastal locations in North Carolina and analyzed for sea-salt constituents, ammonium ion (NH_4^+), and nitrate ion (NO_3^-). Average stoichiometry of samples classified by backwards air-mass trajectories of sampled air was examined to determine the origin and chemisry of non-seasalt sulfate. Results indicated an excess of sulfate in all samples and a strong association with loss of chloride from seasalt particulates. Most of the excess sulfate in concentrations ranging from 1 to 20 $\mu g\ m^3$ was present as sulfuric acid and active in volatilizing chloride from the samples. Sulfuric acid was formed by extremely rapid gas-particle reactions in the sea-salt aerosols, which reduced the pH required for chloride volatilization.

705
HOCKING, Drake, and HOCKING, M. B., 1977, Equilibrium solubility of trace atmospheric sulphur dioxide in water and its bearing on air pollution injury to plants: Environmental Pollution, v. 13, p. 57-64.

This article presents curves of simple equilibrium between sulfur dioxide (SO_2) in air and in water over the range of temperatures and SO_2 concentrations in the air that cause acute injury to plants. Relationships between the principal species occurring in solution are tabulated. Toxicity of SO_2 to plants occurs through two stages--passage across cell walls or membranes, and biochemical injury within the cells.

706
HOEFT, R. G., KEENEY, D. R., and WALSH, L. M., 1972, Nitrogen and sulfur in precipitation and sulfur dioxide in the atmosphere in Wisconsin: Journal of Environmental Quality, v. 1, no. 2, p. 203-208.

This article describes the seasonal distribution of atmospheric sulfur and nitrogen in Wisconsin and results of a greenhouse experiment to evaluate the adsorption of atmospheric sulfur dioxide (SO_2) by alfalfa (*Medicago sativa*). Atmospheric SO_2 levels were low in summer and increased in winter at all rural and urban sites; levels in urban areas were about twice those in rural areas.

707
HOFFMAN, D. J., and ROSEN, J. M., 1980, Stratospheric sulfuric acid layer--evidence for an anthropogenic component: Science, v. 208, p. 1368-1370.

Measurements of small aerosol paticles in the stratosphere over Laramie, Wy., show low-concentration background conditions. Comparison of present background concentrations with those measured 20 years ago indicates an increase of 9 percent per year. The aerosol particles are mostly sulfuric acid droplets that form in the stratosphere from trophospheric, sulfur-containing gases; this suggests that the increase in particles may be related to manmade sulfur emissions.

708
HOFFMAN, W. A., Jr., LINDBERG, S. E., and TURNER, R. R., 1980, Precipitation acidity--the role of the forest canopy in acid exchange: Journal of Environmental Quality, v. 9, no. 1, p. 95-100.

This article explores the role of strong and weak acids in the aqueous chemistry of a deciduous forest watershed in Tennessee and evaluates sources of leachable organic components. Weak acids constituted at least 30 percent of the total acidity of incident rain; this inreased to more than 50 percent in throughfall. The increase could not be entirely attributed to organic acids.

709
HOFFMAN, W. A., Jr., LINDBERG, S. E., and TURNER, R. R., 1980, Some observations of organic constituents in rain above and below a forest canopy: Environmental Science and Technology, v. 14, no. 8, p. 999-1002.

Precipitation samples were collected at the Walker Branch Watershed, Oak Ridge, Tenn., on an event basis above and below the canopy of a deciduous forest and analyzed for organic constituents. Plasticizers and chlorohydrocarbons identified in the analyses are attributed to sources external to the vegetation. Some organic compounds in single-event

709 (continued)
samples are probably derived from processes such as deposition, leaching, and weathering in a forest system. Event sampling is recommended as the best method for identifying sources of organic components in rain because it provides quantities that are within the detection limits and minimizes contamination and time averaging that can arise with bulk samples.

710
HOGSTROM, Ulf, 1973, Comments on "Local Fallout and long-distance transport of sulfur": Ambio, v. 2, no. 3, p. 90-91.

The author comments on points raised by other scientists on his article titled "Residence time of sulfurous air pollutants from a local source during precipitation", which appeared in Ambio, v. 2, no. 1-2,, p. 37-41. [See reference no. 711.]

711
HOGSTROM, Ulf, 1973, Residence time of sulfurous air pollutants from a local source during precipitation: Ambio, v. 2, no. 1-2, p. 37-41.

This article discusses the transport of sulfur component released during precipitation. In five sampling periods at Uppsala, Sweden, residence time for sulfate and strong acid in the atmosphere is 1 to 2 hours, corresponding to travel distances in the range of 50 to 100 km. The relative contribution from local sources to the observed total sulfur fallout in given geographical areas may be estimated, provided the corresponding source locations are known.

712
HOGSTROM, Ulf, 1974, Wet fallout of sulfurous pollutants emitted from a city during rain or snow: Atmospheric Environment, v. 8, p. 1291-1303.

This article presents results of a study to determine wet fallout of sulfurous compounds released during rain or showfall at Uppsala, Sweden. Eight tests were conducted at 100 sampling points, each a maximum distance of 60 km from the probable source. Complex fallout patterns of sulfate and free hydrogen ions were noted in each test. The characteristic scale of fallout is determined by quantitative analysis of these patterns. In most cases, the fallout range was 50 to 100 km from the source. Nearly all of the sulfur found was deposited as sulfate, although an insignificant amount was deposited as sulfur dioxide fairly close to the source.

713
HOGSTROM, Ulf, 1978, Dispersal models for sulfur oxides around chimneys and tall stacks, in Nriagu, J. O., ed., Sulfur in the environment, part 1--the atmospheric cycle: New York, John Wiley, p. 123-169.

714
HOGSTROM, Ulf, 1979, Initial dry deposition and type of source in relation to long distance transport of air pollutants: Atmospheric Environment, v. 13, p. 295-301.

A model was developed to estimate dry deposition before complete mixing in the boundary layer of the atmosphere. The rate of vertical dispersion in an urban area is more rapid than in a rural area; consequently, the proportion of sulfur dioxide emitted that is deposited locally is larger in a small city than in a large city, provided the velocity of dry deposition is the same. Sulfur dioxide was measured at a site in Paris and at a site about 37 km from Paris to estimate dry deposition. The proportion lost as dry deposition ranged from 5 to 10 percent; this is in agreement with model calculations for dry deposition velocity of 8×10^{-3} to 16×10^{-3} m/s. The results indicate that the major portion of the SO_2 emitted in Paris is not lost during the initial phase of mixing.

715
HOGSTROM, Ulf, 1979, Initial dry deposition and type of source in relation to long distance transport of air pollutants, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 305-306.

716
HOLT, B. D., CUNNINGHAM, P. T., and KUMAR, Romesh, 1981, Oxygen isotopy of atmospheric sulfates: Environmental Science and Technology, v. 15, no. 7, p. 804-808.

Oxygen isotopy of atmospheric sulfate was measured to determine the predominant mechanism of their formation from SO_2. Samples of aerosol sulfate and water vapor were continuously collected at Argonne, Illinois in 1977 and analyzed for oxygen-18. Rain and snow samples were collected at the same site during the same time. Oxygen isotopy of precipitation sulfate and aerosol sulfate indicate that the mechanisms of sulfate formation differ throughout the year. Heterogeneous oxidation in the aqueous phase may be the predominant mechanism for the formation of sulfate associated with precipitation at all times. Aerosol sulfate may be formed by the

716 (continued)
same mechanism during late fall, winter, and early spring; a homogeneous mechanism seems to be predominant during late spring, summer, and early fall.

717
HOLT, B. D., KUMAR, Romesh, and CUNNINGHAM,. P. T., 1981, Assessment of primary sulfates in rainwater by oxygen isotope measurements, in American Chemical Society, Division of Environmental Chemistry, 182nd National Meeting, New York, N.Y., Preprints, v. 21, no. 2: Washington, D.C., American Chemical Society, p. 28-30.

718
HOLT-JENSEN, Arild, 1973, Acid rains in Scandinavia: Ecologist, v. 3, p. 378-382.

Increasing acidity in precipitation in Scandinavia is attributed to the long-range transport of atmospheric sulfur from the industrialized regions of northwest Europe. This article discusses recent changes in the acidity of precipitation in Scandinavia and the effects on naturally acidic soils, lakes, rivers, freshwater fish, and building materials.

719
HOLTZ, B. D., CUNNINGHAM, P. T., and KUMAR, Romesh, 1979, Use of oxygen isotopy in the study of transformations of SO_2 to sulfates in the atmosphere, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 207-212.

720
HOMOLYA, J. B., and CHENEY, J. L., 1979, A study of primary sulfate emissions from a coal-fired boiler with FGD: Journal of the Air Pollution Control Association, v. 29, no. 9, p. 1000-1004.

The emissions of sulfur dioxide (SO_2) and primary sulfate materials from a boiler burning fossil fuel and using a wet-limestone scrubber (flue gas desulfurization, FGD) for SO_2 removal were monitored. The average SO_2 scrubbing efficiency was 76 percent; efficiency decreased over a 5-day operation and maintenance cycle. Average SO_4 scrubbing efficiency was 29 percent. The scrubbing efficiency for SO_2 and sulfate are assessed.

721
HONGVE, Dag, 1978, Buffering of acid lakes by sediments: International Association of Theoretical and Applied Limnology, Proceedings, v. 20, p. 743-748.

This article examines buffering mechanisms in natural lake systems. The limnology of 10 lakes in Norway was studied from 1967 through 1977. Sediment samples were collected and analyzed during the same period. Calcium concentrations in the lake waters were lower than expected and may be absorbed by sediments. Lake sediments also absorb sodium, and when sodium hydroxide is added, the changed ionic balance results in an exchange of sodium, calcium, and magnesium for hydrogen ions. Sulfate reduction may occasionally occur in the bottom waters of some lakes and sediment. Another process in the acid-base balance in waters and sediments is the production of ammonia during decomposition of organic matter. When nitrogen is liberated as ammonia, after deamination of organic compounds, an equivalent amount of acid is neutralized by the formation of ammonium ions. If ammonium is subsequently nitrificed the opposite reaction occurs.

722
HORNBECK, J. W., 1981, Acid rain--facts and fallacies: Journal of Forestry, v. 79, no. 7, p. 438-443.

The sources and effects of acid precipitation are complex and difficult to define. Major sources are believed to be atmospheric emissions from urban industrial areas; however, long-range transport of emissions further complicates the problem. Additional research on the sources of emissions, transport of these emissions, and the chemical processes involved in acidification is needed. The lack of long-term records on the acidity of precipitation has made temporal trends of acidity difficult to assess.

723
HORNBECK, J. W., and LIKENS, G. E., 1974, The ecosystem concept for determining the importance of chemical composition of snow, in Interdisciplinary Symposium on Advanced Concepts and Techniques in the Study of Snow and Ice Resources, 1973, Monterey, Calif.: Washington, D.C., National Academy of Sciences, p. 139-151.

The chemical composition of snowpack at the Hubbard Brook Experimental Forest in New Hampshire was monitored during the winter of 1972-73. This article summarizes the chemical contributions from the snowpack to the forest ecosystem and streams. The snowpack is slightly less acid than incident precipitation and has about the same or lower concentrations of calcium, nitrate, and sulfate. Potassium occurs in higher concentration in the snowpack than in precipitation, possibly

723 (continued)
because of potassium leaching from organic matter in the snowpack. Before the spring melt, the snowpack contained about 50 percent of the total calcium and 25 percent of the total nitrate and sulfate added to the ecosystem by atmospheric precipitation in winter. The amount of ions stored in the snowpack was small compared to the amount lost in streamflow.

724
HORNBECK, J. W., LIKENS, G. E., and EATON, J. S., 1977, Seasonal patterns in acidity of precipitation and their implications for forest stream ecosystems: Water, Air, and Soil Pollution, v. 7, no. 3, p. 355-365.

Data collected since 1965 at a network of nine stations in the northeastern United States show that precipitation is most acid in the growing season (May-September) and least acid in winter (December-February). For the Hubbard Brook station in New Hampshire, where the mean hydrogen ion content of preciptation ranges between 46 μeq l^{-1} in winter and 102 μeq l^{-1} in summer, the seasonal pattern in acidity correlates closely with seasonal differences in S deposition from the atmosphere. As summer precipitation passes through the forest canopy, H ion concentrations are lowered by an average of 90%, primarily as a result of exchange with other cations. In winter, the H ion content of incident preciptation is lowered from a mean of 50 μeq l^{-1} to a mean of 25 μeq l^{-1} during storage in the snowpack. [Abstract reprinted by permission of D. Riedel Publishing Company.]

725
HORNBECK, J. W., and PIERCE, R. S., 1978, Acidity of rain and snow--a potential problem for New Hampshire: New Hampshire Forest Notes no. 6, 2 p.

This short article gives an overview of the precipitation chemistry studies conducted at the Hubbard Brook Experimental Forest in New Hampshire. Acid precipitation is largely a result of human activities. Some of the impacts of acid precipitation that are discussed are leaching of nutrients from foliage and the weakening of foliage and plant organs.

726
HORNTVEDT, Richard, 1970, SO_2 injury to forests: Journal of Forest Utilization, v. 78, no. 2, p. 278-286. [In Norwegian.]

This article describes sulfur dioxide (SO_2) injury to a forest at Rjukan, Norway and summarizes cases of SO_2 injury to plants in Sweden and Germany. The article also discusses genetic and environmental factors determining the amount of injury and some pathogens that often follow SO_2 injury.

727
HORNTVEDT, Richard, DOLLARD, G. J., and JORANGER, E., 1980, Effects of acid precipitation on soil and forest, 2. Atmosphere--vegetation interactions, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 192-193.

728
HORST, T. W., 1980, A review of Gaussian diffusion-deposition models, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 275-283.

The assumptions and predictions of several Gaussian diffusion-deposition models are compared. A simple correction to the Chamberlain source-depletion model is shown to predict ground-level airborne concentrations and dry-deposition fluxes in close agreement with the exact solution of Horst. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

729
HOV, Oystein, 1979, Generation of secondary pollutants in the atmospheric boundary layer in a high pressure situation, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 173-180.

730
HOVMAND, M. F., 1980, Atmospheric long range transport of lead in Denmark: Tellus, v. 32, p. 42-47.

Bulk precipitation samples were collected in Keldsnor, Langeland, Denmark and analyzed for lead. Trajectories are computed to determine the origin of rain-bearing air masses. The mean lead concentrations of bulk precipitation in samples derived from air trajectories from central Europe, England, and the Atlantic Ocean, respectively, are significantly different at the 0.1-percent level. It is estimated that about two thirds of the lead deposited in the rural environment of Denmark is transported from long distances.

731
HOWARD, E. A., BOYD, L. M., BROCK, W. M., MORSE, D. W., SHIN, S. S., and STEEL-SABO, K. L., 1980, Prioritization of research on air quality related resources of the national parks, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 236.

732
HRYNIEWICZ, R. A., 1979, An assessment of wet removal of sulphur from air by rainfall in Poland, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 223-230.

733
HUBERT, J. S., and CANTER, L. W., 1980, Acid rain and ground water quality: Norman, Oklahoma, National Center for Ground Water Research, Report no. NCGWR 80-25(TP), 15 p.

Reactions between acid precipitation and soils may increase leaching of metals and nutrients into the ground water. Factors that influence the rate of leaching are (1) soil type, (2) soil composition and texture, (3) soil pH, (4) soil oxidation-reduction potential, and (5) associated ions in the water phase.

734
HUBERT, J. S., and CANTER, L. W., 1980, Effects of acid rain on ground water quality: Norman, Oklahoma, National Center for Ground Water Research Report no. NCGWR 80-7, 226 p.

This article identifies the substances and chemical reactions that produce acid in precipitation and summarizes results of recent research on deposition, transport, effects, and fate of acid precipitation and associated pollutants. Research on the transport of heavy metals in soils indicates that the metals are removed by precipitation of their insoluble hydroxides. Studies are needed on the liberation of these precipitated hydroxides. Additional research is also needed to determine the possible synergesic effects of acid precipitation on heavy metal concentrations in ground water. The report includes an annotated bibliography.

735
HUEBERT, B. J., 1980, HNO_3 vapor vs altitude at the Pawnee Grasslands, in Delaney, A. D., ed., Proceedings [of a] Summer Colloquium 1980: Boulder, Colo., National Center for Atmospheric Reseach, p. 67-71.

Atmospheric nitric acid (HNO_3), resulting from oxidation of NO_x gases, may be rained out, dry-deposited, converted to aerosol or photolyzed to NO_2. The adsorption of HNO_3 onto vegetation, soils, natural waters, and buildings removes large amounts from the atmosphere. An increase in HNO_3 concentration with altitude above the Pawnee grasslands is cited as evidence of dry deposition at ground level. The flux and deposition velocities have not been calculated.

736
HUFF, F. A., 1976, Relation between atmospheric pollution, precipitation, and streamwater quality near a large urban-industrial complex: Water Research, v. 10, p. 945-953.

This article describes a study conducted in St. Louis, Mo. to assess the magnitude of the atmospheric contribution to streamwater pollution and how the atmospheric contribution is affected by weather conditions. The amount and intensity of precipitation do not significantly affect water quality in small basins subject to urban and rural contaminants. Results indicate that streamwater pollutant concentrations change only slightly during and shortly after storms and that chemical concentration of streamwater has no strong relationship to weather conditions.

737
HULTBERG, Hans, 1977, Thermally stratified acid water in late winter--a key factor inducing self-accelerating processes which increase acidification: Water, Air, and Soil Pollution, v. 7, no. 3, p. 279-294.

Ion separation of acid air pollutants out of snow causes sudden, deep pH-drops in lakes and running waters at an early stage of snowmelting. These pH-drops have drastic effects on fish populations and are suggested to be the main cause of *Sphagnum* invasion and changes in the microflora already at an early stage of acidifiction, i.e. when summer pH-values are about 6. These effects in turn reduce the nutrient recycling and accelerate the acidification process. [Abstract reprinted by permission of D. Riedel Publishing Company.]

738
HULTBERG, Hans, 1980, Benthic organisms, in Hendrey, G. R., ed., Limnological aspects of acid precipitation: International Workshop, Sagamore Lake Conference Center, N.Y., 1978, Proceedings: Upton, N.Y. Brookhaven National Laboratory, p. 15-16.

739
HULTBERG, Hans, and GRAHN, Olle, 1976, Effects of acid precipitation on macrophytes in oligotrophic Swedish lakes: Journal of Great Lakes Research, v. 2, Supplement no. 1, p. 208-221.

A study was conducted to determine the effects of acidic atmospheric deposition on macrophytes in six lakes in Sweden. The most significant effect on macrophytes is the development of peat moss *Sphagnum* as a submergent rather than terrestrial plant in lakes. The lake ecosystem is effected by larger bottom areas of dense *Sphagnum* mats because several ions, most of which are important for biological production, are bound to the moss tissue as a result of its strong ion-exchange capacity. The dense mats, *Sphagnum* remains, fungus hyphae, and benthic algae absorb plant nutrients such a phosphorus and nitrogen released by delayed decomposition, reducing exchange of nutrients between the sediment and water.

740
HULTBERG, Hans, and WENBLAD, A., 1980, Acid groundwater in southwestern Sweden, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 220-221.

741
HUNTER, K. A., and LISS, P. S., 1981, Principles and problems of modeling cation enrichment at natural air-water interfaces, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 99-127

742
HUNTZICKER, J. J., CARY, R. A., and LING, Chaur-Sun, 1980, Neutralization of sulfuric acid aerosol by ammonia: Environmental Science and Technology, v. 14, p. 819-824.

The rate of neutralization of sulfuric acid (H_2SO_4) aerosol by ammonia gas was measured in a laboratory flow reactor for particle diameters between 0.3 and 1.4 μm and at relative humidities between 8 and 80 percent. A model of H_2SO_4 aerosol generation and neutralization in the atmosphere shows that sulfate aerosol that is more acid than ammonium bisulfate should be present only during periods of rapid oxidation of the precursor sulfur dioxide (SO_2) and high ratios of [SO_2] to [NH_3]. Another condition when this occurs is when the equlibrium vapor pressure of NH_3 over the partially neutralized H_2SO_4 droplet exceeds ambient NH_3 partial pressure.

743
HUNTZICKER, J. J., HOFFMAN, R. S., and LING, Chaur-Sun, 1978, Continuous measurement and speciation of sulfur-containing aerosols by flame photometry, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 83-88.

A sulfur-specific flame photometer has been used for the realtime measurement of sulfur-containing aerosols. Specificity for the aerosols was achieved with a diffusion tube stripper which removed sulfur-conaining gases from the air stream by diffusion to an adsorbing wall but transmitted particles to the flame photometer. The sensitivity of the flame photometer to $(NH_4)_2SO_4$ and NH_4HSO_4 aerosols was identical, but a reduced response was found for H_2SO_4 to the wall before reaching the flame. The addition of NH_3 to the sample air just upstream of the burner converted H_2SO_4 to $(NH_4)_2SO_4$ or NH_4HSO_4 and produced the expected increase in the flame photometer response. Heating the aerosol upstream of the diffusion stripper converted the sulfates to sulfur-containing gases over a temperature range characteristic of the aerosol being sampled. These gases were removed in the stripper, therby decreasing the flame photometer output. The normalized response to aqueous H_2SO_4 aerosol decreased from unity at 50°C to 0.04 at 110°C and for $(NH_4)_2SO_4$ and NH_4HSO_4 aerosols from unity at 115°C to zero at 190°C. When the aerosol contained both H_2SO_4 and $(NH_4)_2SO_4$, the resultant thermogram was a function of both the $(NH_4)_2SO_4/H_2SO_4$ ratio and the manner in which the two components were mixed in the particles comprising the aerosol (i.e. homogeneously with constant $(NH_4)_2SO_4/H_2SO_4$ ratios or heterogeneously with varying ratios). [Abstract reprinted by permission of Pergamon Press.]

744
HUSAIN, L., and PAREKH, P., 1981, Temporal variation and spatial influx of particulate sulfate in ambient air at Whiteface Mountain, New York, in American Chemical Society, Division of Environmental Chemistry, 182nd National Meeting, New York, N.Y., Preprints, v. 21, no. 2: Washington, D.C., American Chemical Society, p. 64-67.

745
HUSAR, R. B., 1979, Distribution of pollutants and dust transport in time and space, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 9.

746
HUSAR, R. B., PATTERSON, D. E., HUSAR, J. D., GILLANI, N. V., and WILSON, W. E., Jr., 1978, Sulfur budget of a power plant plume, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 549-568.

As part of the Midwest Interstate Sulfur Transformation and Transport (MISTT) study, the summer sulfur budget of the plume of the 2400 MW coal-fired Labadie power plant near St. Louis, Missouri is assessed via aircraft data, ground monitoring network data, and a two-box model. The particulate sulfur (S_p) formation rate is obtained from three-dimensional plume mapping combined with a high time-resolution S_p sampling technique. During noon hours the SO_2 conversion rate is found to be 1-4% per hour, compared to night rates below 0.5% per hour. Plume excess light scattering coefficient (b_{scat}) and excess S_p correlated well ($r = 0.87$), indicating most S_p is formed in the light-scattering size range.

During daytime the well-mixed plume is transported at 5 m s^{-1} on the average; at night the July average wind speed at plume height is 12 m s^{-1} due to the low-level jet. The nocturnal plume is less than 100 m thick at 400 m above ground, and is decoupled from the surface until morning. Ground monitoring data from the Regional Air Pollution Study (RAPS) show that plume entrainment into the rising mixing layer is completed by 1000 Central Daylight Time (CDT). Due to daytime vertical mixing and nocturnal decoupling, the dry removal rate for the elevated plume is highest near noon. In a daily cycle, the plume sequentially passes through a reservoir regime, dissociated from delivery to the ground, and then enters the mixing-removal regime.

A two-box model representing the two regimes, with diurnally periodic rate constants for transformation and removal, is employed to estimate plume sulfur budgets. Ignoring wet removal, 30-45% of the SO_2 is estimated to be converted to S_p, half within the first day. Particulate sulfur is formed unevenly: the afternoon plume contributes more than its share because it rises so high that it has more time to react before removal begins. In short: transformation and removal occur mainly during the daytime, while transport is fastest at night. After a hard day of convection, reaction and deposition, the lower atmosphere relaxes at dusk while the midwestern plume takes off overnight on a jet stream and begins the next day's work 300-400 km from the stack. [Abstract reprinted by permission of Pergamon Press.]

747
HUTCHESON, M. R., and HALL, F. P., Jr., 1974, Sulfate washout from a coal fired power plant plume: Atmospheric Environment, v. 8, p. 23-28.

Sulfate washout near a coal-fired generating station in Alabama was monitored for two years. Sulfate aerosol scavenging alone cannot account for the observed washout pattern; sulfur dioxide (SO_2) scavenging by rain is the primary washout mechanism. An empirical expression for the SO_2 washout coefficient based on knowledge of SO_2 scavenging is presented, and may be used in data analysis.

748
HUTCHINSON, T. C., 1980, Effects of acid leaching on cation loss from soils, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 481-497.

749
HUTCHINSON, T. C., 1980, Impact of heavy metals on terrestrial and aquatic ecosystems, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 158-164.

The high toxicity of many metals and metalloids to a wide range of biota, coupled with their long residence times in the soils, in sediments and in the oceans has lead to real concern about their role in environmental deterioration. Residence times in watersheds are commonly measured in hundreds of years, while residence of metals in air is rarely as long as several days. Overall industrial activity and transportation leads to widespread metal dispersion. Major elevations in many metals occur around mines and smelters and for lead especially, alongside highways. Coal-burning and applications of fertilisers and pesticides add metals to agricultural soils and to natural ecosystems. The surface organic layers of both soils and sediments act as adsorption and exchange sites so that major accumulations may occur. Yet, this shallow organic layer is the critical site for many microbial activities, including those esential for nutrient cycling, nitrogen fixation and for pathogens. Genetic and physiological tolerances are shown in a wide array of different organisms which have survived in metal-stresses habitats. Most recently, acid precipitation has mobilized Al, Mn, Fe and Zn from the soil and sediment.

749 (continued)
These are now producing particular stresses for aquatic biota. [Abstract reprinted by permission of U.S. Forest Service.]

750
HUTCHINSON, T. C., and COLLINS, F. W., 1978, Effect of H+ ion activity and Ca^{2+} on the toxicity of metals in the environment: Environmental Health Perspectives, v. 25, p. 47-52.

The effect of acidic or acidifying environments on plants is discussed with special attention to calcium interactions. Hydrogen ion concentration in soils increases the solubility of heavy metals such as aluminum, manganese, zinc, iron, copper, and nickel. Soils with low pH are also generally low in calcium, potassium, sodium, and phosphorus, which are all major elements for plant growth. Magnesium is toxic in soils with a pH less than 5.0 however, calcium alleviates its toxicity. Calcium also reduces acidity in freshwaters. The pH, redox, and valency state are critical in determining nutrient availability and metal speciation.

751
HUTCHINSON, T. C., and WHITBY, L. M., 1974, Heavy-metal pollution in the Sudbury mining and smelting region of Canada. I, soil and vegetation contamination by nickel, copper, and other metals: Environmental Conservation, v. 1, no. 2, p. 123-132.

This article assesses the degree of heavy-metal contamination that has occurred in the Sudbury region of Ontario as a result of airborne emissions from a nickel-copper smelter. Soils in the region contain elevated levels of nickel and copper. Concentrations decrease with distance to 50 km. Surface soils are the most contaminated; heavy metal concentrations increase with depth. Soils within 3 km of the smelter are markedly more acidic and have higher conductance than those further away.

752
HUTCHINSON, T. C., and WHITBY, L. M., 1977, The effects of acid rainfall and heavy metal particulates on a boreal forest ecosystem near the Sudbury smelting region of Canada: Water, Air, and Soil Pollution, v. 7, no. 4, p. 421-438.

Sulphur dioxide and particulate pollution have been occurring over a wide area in the Sudbury region, Ontario, as a result of massive smelting operations. In excess of 3½ million short tons of SO_2 were released into the atmosphere in the area in 1972, and this pollutant is now discharged through a 1250-foot smokestack. The particulate contribution is an additional complicating and phytotoxic factor. For example, in 1971, 192 tons of nickel, 145 tons of copper, 1130 tons of iron and 4.5 tons of cobalt per 28 days from two of the smelters were released as airborne pollutants (Hutchison and Whitby, 1974). The natural vegetation of the area is a mixed deciduous boreal forest, with white pine (*Pinus strobus*), jack pine (*Pinus banksiana*), red maple (*Acer rubrum*), red oak (*Quercus rubra*), etc. as dominant trees. This forest, which previously surrounded the mining town of Sudbury, has been devasted over the past 50 yr, especially by the SO_2 emissions and the increased acidity of rainfall and soils. An area in excess of 100 mi^2 is now almost devoid of vegetation, and damage to the forest vegetation is visible over an area of approximately 1800 mi^2. The increased stack heights to dilute local pollution problems have spread the problem more widely. The pH of rainfall sampled up to 12 miles east of the smallest shelter in 1970 was less than 4.3 and that within 2 mi of the stacks was frequently less than pH 3.0. Soil erosion has occurred on a large scale as a consequence of loss of vegetation. Metal accumulation in the soils has also been a complicating and probably highly persistent phenomenon. Concentrations of nickel in excess of 3000 ppm and copper of 2000 ppm in surface soils occur widely. The increased acidity of these soils has increased metal mobility and solubility, presenting phytotoxic problems. The effects on the soil chemistry, especially of organic composition have been profound. They involve an increased metal binding capacity of the soils, and very high levels of sulphur in the purified 'fluvic acid' fraction itself. Indeed, the evidence is suggestive of the incorporation of sulphonic groups into the changed extracts. Such profound and damaging changes may be merely a consequence of the extreme conditions experienced at Sudbury or they may be a harbinger of things to come in many potentially podsolic soils in areas of increasing acidity of rainfall. [Abstract reprinted by permission of D. Riedel Publishing Company.]

753
HUTTON, J. T., and LESLIE, T. I., 1958, Accession of non-nitrogenous ions dissolved in rainwater to soils in Victoria: Australian Journal of Agricultural Research, v. 9, p. 492-507.

Analyses of rainwater samples collected at 24 stations in Victoria, Australia, indicate that the effect of the ocean on the concentration of dissolved ions decreases with distance from the coast. The ionic ratio of sodium to potassium concentration falls below 10 about 150 miles inland, and calcium becomes the dominant cation. Terrestrial material such as dry surface of soils affects these ionic ratios. Sulfate ions are present in smaller amounts than in other countries; this may be a cause of sulfur deficiencies in plant nutrition.

754
HUTTUNEN, Satu, LAINE, K., and PAKONEN, T., 1980, Air pollutants as additional stress factors of conifers under northern conditions, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 168-169.

I

755
IKARI, K. 1975, Acid rain in the Karatsu district [Japan]: Air Pollution News, v. 66, p. 4-6.

This article reports the effect of acidic rainfall on morning glories in Karatsu, Japan. Discoloration of the petals occurred, and in some cases discolored spots became necrotic and the cell walls were destroyed. Rain pH collected in Karatsu in early morning was as low as 3.9.

756
IMHOFF, Claude, and DESBAUMER, Eric, 1973, Influence de la pollution atmospherique sur les preciptations [Influence of pollution agents in the atmosphere on the composition of precipitation]: Staub Reinhaltung der Luft, v. 33, no. 6, p. 241-245. [In French.]

An expreimental study was conducted in Geneva, Switzerland, to correlate atmospheric sulfur oxides, nitrogen oxides, hydrocarbons, and chlorine with sulfates, nitrates, hydrocarbons, and chlorides in rainwater and snow. Within the city, atmospheric NO_x did not show great variation, but SO_2 showed strong seasonal variations. Concentrations in city rainfall are compared with those from the country.

757
INTERNATIONAL ELECTRIC RESEARCH EXCHANGE, 1981, Effects of SO_2 and its derivatives on health and ecology: Palo Alto, California, Electric Power Research Institute, 4 v.

This series addresses the effects of sulfur dioxide and its derivatives on human health and the environment. The four volumes review about 900 documents on epidemiology, animal and human experiments, pollution experiences, and wet and dry deposition of sulfur oxides. Past air-pollution episodes, at significantly higher levels than occur today, have caused illness and death. Sulfuric acid is believed to be a stronger irritant than sulfur dioxide; however, human air passages contain a protective lining. Sulfur dioxide can travel long distances and can be partly transformed to sulfuric acid or sulfates on the way. High

757 (continued)
concentrations of sulfur dioxide can cause visible injury to plants. Surprisingly, a long-term trend of increasing acidity of wet deposition in Europe and North America is not proven. Although acidic atmospheric deposition can be a source of acidification in lakes, the extent of acidification depends on the characteristics of the soil in the watershed.

758
IRVING, P. M., and MILLER, J. E., 1980, Response of field-grown soybeans to acid precipitation alone and in combination with sulfur dioxide, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 170-171.

759
ISAKSEN, I. S. A., 1979, Transport and distribution of pollutants in the troposphere, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 347-358.

760
ISAKSEN, I. S. A., HESSTVEDT E., and HOV, O., 1978, A chemical model for urban plumes--test for ozone and particulate sulfur formation in St. Louis urban plume, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 599-604.

A chemical model with anthropogenic sources of nitrogen oxides and hydrocarbons is applied to simulate the chemical behaviour of pollutants in the St. Louis urban plume. It is suggested that a substantial increase in peroxy radical concentrations (HO_2, RO_2) in the polluted air mass outside its source region leads to an effective formation of secondary pollutants like ozone generation in the plume of a few hours. Maximum ozone mixing ratio of 115 ppb is predicted after 4 h transport time outside the source region. Conversion rates of SO_2 and H_2SO_4 through gas phase reactions with hydroxyl and peroxy radicals are estimated to be 1-5% h^{-1}. This leads to an approximate 25% conversion of SO_2 to particulate sulfur in the plume during the day. Agreement with measured ozone concentrations and flow rates of ozone and particulate sulfur in the St. Louis plume on 18 July 1975 can be taken as strong indications that ozone and sulfate particle formation in the plume proceeds through the suggested mechanisms. [Abstract reprinted by permission of Pergamon Press.]

761
IZRAEL, Yu. A., MIKHAILOVA, J. E., and PRESSMAN, A. J., 1979, A model for operative evaluation of transboundary flows of pollutants (sulphur dioxide and sulphates), in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/ Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 271-280.

J

762
JAAKKOLA, S., KATAINEN, H. S., KELLOMAKI, S., and SAUKKOLA, P., 1980, The effect of artificial acid rain on the spectral reflectance and photosynthesis of Scots pine seedlings, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 172-173.

763
JACKSON, T. A., KIPPHUT, George, HESSLEIN, R. H., and SCHINDLER, D. W., 1980, Experimental study of trace metal chemistry in soft-water lakes at different pH levels: Canadian Journal of Fisheries and Aquatic Sciences, v. 37, p. 387-402.

This paper gives results of a comparative study of the biogeochemical behavior of a variety of trace metals in soft-water lakes of the Canadian Shield at both natural and artificially lowered pH, with emphasis on the forms of the metals and the relative affinities of the metals for different binding agents in the water and sediments. Most metals are strongly chemisorbed or complexed by mud and organic ooze, and only barium could be redissolved by cation exchange. Acidification of lakes to pH 5.1 interferes with the accumulation of mercury and other metals by organic ooze. Acidification lowers the concentration of NaOH-extractable colloidal phosphate in the ooze but has no effect on NaOH-extractable orthophosphate content.

764
JACKSON, W. F., and FROMM, P. O., 1980, Effect of acute acid stress on isolated perfused gills of rainbow trout: Comparative Biochemistry and Physiology, v. 67C, p. 141-145.

This article describes the response of isolated perfused gills of rainbow trout to acid exposure. Results show that lowering bath pH from 7.2 to 3.5 had no significant effect on transfer capacity of gills from *Salmo gairdneri* perfused with 10 μmol/L epinephrine. Exposure of gills to acidic environment did not result in elevated vascular resistance. In every experiment epinephrine significantly elevated transfer capacity of gills above and reduced vascular resistance below the levels found in trout not treated with epinephrine.

765
JACOBSON, J. S., 1979, Effects on agriculture and forestry, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 136-137.

766
JACOBSON, J. S., 1980, Experimental studies on the phytotoxicity of acidic precipitation--The United States experience, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 151-160.

767
JACOBSON, J. S., 1980, The influence of rainfall composition on the yield and quality of agricultural crops, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 41-46.

768
JACOBSON, J. S., 1981, Acid rain and environmental policy: Journal of the Air Pollution Control Association, v. 31, no. 10, p. 1071-1073.

The environmental problem associated with acid precipitation cannot be solved by scientific solutions only. Three aspects that need to be studied are (1) science, (2) economics, and (3) identification of societal values. The long-range transport of pollutants across the U.S.-Canada border and across state borders is a serious political issue.

769
JACOBSON, J. S., HELLER, L. I., and VAN LEUKEN, P., 1976, Acidic precipitation at a site within the northeastern conurbation: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 339-349.

Rain and snow were collected in plastic beakers either manually or with a Wong sampler during 58 precipitation events in 1974 at Yonkers, New York approximately 24 km north of the center of New York City. Determinations were made of total dissolved ionic species, free H ions, total H ions, sulfate, nitrate, chloride, and fluoride. Conductivity measurements ranged from 6.8 to

769 (continued)
162 µmhos, pH from 3.4 to 4.9, total acidity from 36 to 557 µeq l^{-1}, sulfate from less than 1 to 20 mgl^{-1}, nitrate from less than 1 to 14 mgl^{-1}, and chloride from less than 1 to 7 mgl^{-1}. All fluoride concentrations were less than 0.1 mgl^{-1}.

The results indicate that precipitation at this suburban location adjacent to New York City is consistently acidic and contains concentrations of sulfate, nitrate, and chloride which are similar to values found for other locations in the northeastern United States. Positive correlations were found between nitrate and sulfate concentrations and acidity suggesting that the atmospheric contaminants SO_2 and NO_2 are causally-related to the occurrence of acidic precipitation. Further research will be necessary to clarify the relative influence of natural and man-made sources of N and S compounds and the contributions of gaseous and particulate contaminants in the atmosphere to the acidity of precipitation at this location. [Abstract reprinted by permission of D. Riedel Publishing Company.]

770
JACOBSON, J. S., TROIANO, J., COLAVITO, L. J., HELLER, L. I., and McCUNE, D. C., 1980, Polluted rain and plant growth, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 291-305.

Experiments were performed to determine whether the effects of acidic precipitation on agricultural crops of the eastern U.S. are altered by differences in the supply of nitrate and sulfate in rain or the concentration of ozone in the atmosphere. In tests with greenhouse-grown lettuce plants, better growth was obtained by treatment with simulated acidic rain at pH 3.2 containing high sulfate to nitrate ratios. When acidic precipitation at pH 2.8, 3.4, and 4.0 was applied intermittently to field-grown soybeans, the more acidic treatments produced a shift in the partitioning of photosynthate from the vegetative (leaves and stems) to the reproductive organs (seeds) in those plants exposed to low concentrations of ozone (hourly average concentration did not exceed 0.03 ppm during the growing season). No shift in photosynthate partitioning was observed when simulated acidic rain was applied to soybeans exposed to ozone concentrations that reached a maximum of 0.125 ppm and significantly reduced growth and yield. These results demonstrate that both the nutrition of plants and the atmospheric concentrations of ozone must be controlled or carefully monitored in experiments on the effects of acidic precipitation on agricultural crops. [Abstract reprinted by permission of Plenum Press.]

771
JAENICKE, R., 1978, Physical properties of atmospheric particulate sulfur compounds, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 161-169.

Integral properties of the total aerosol--which are usually measured first--tend to be related to certain limited size ranges only and do not represent the aerosol in its entire particle size range. The connection between integral and differential properties will be discussed, as well as the consequences with respect to the presentation of total sulfur mass and the sulfur size distribution. The question of the mixture state will be discussed and data given for the internal and external mixture ratio of ammonium sulfate as the most abundant sulfur compound in aerosols. Finally, a discussion is given of the particle sizes which must be produced to maintain the observed aerosol size distribution by any nucleation processes converting sulfuric gases into particles. [Abstract reprinted by permission of Pergamon Press.]

772
JAESCHKE, Wolfgang, 1978, New methods for the analysis of SO_2 and H_2S in remote areas and their application to the atmosphere, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 715-721.

New techniques have been developed and examined for measuring H_2S and SO_2 in the atmosphere. The calibration curves of the methods are reported and the detection limits are discussed by considering the deviation of the blank values. The atmospheric detection limits are demonstrated to be 0.01 µg H_2S m^{-3} and 0.03 µg SO_2 m^{-3}. Results of test measurements dealing with the reproducibility of the measured values and the sampling efficiency are reported. A short summary of some results which have been obtained by applying the methods to the atmosphere are given. [Abstract reprinted by permission of Pergamon Press.]

773
JAESCHKE, Wolfgang, and HAUNOLD, W., 1977, New methods and first results of measuring atmospheric H_2S and SO_2 in the ppb range, in World Meteorological Organization, Air pollution measurement techniques: Geneva, Switzerland, World Meteorological Organization, Special Environmental Report no. 10, WMO-no. 460, p. 193-198.

774
JANSEN, J. J., 1979, Acid precipitation--a review of the issue and its uncertainties: Birmingham, Ala., Southern Company Services, Inc., Research and Development Department, 17 p.

774 (continued)
An overview is given on the environmental effects of acid precipitation. Methods previously used to define trends in acidity may be inadequate. Uncertainties as to the contribution of chemical species and their transformations have prevented the relative contributions from various sources from being defined.

775
JANSEN, J. J., 1981, Rationale for quality precipitation chemistry sampling: Palo Alto, California, Electric Power Research Institute, Special Report EA-1682-SR, 1 v.

This article presents the rationale for selected procedures and principles used in monitoring precipitation chemistry. Among topics described are site selection and preparation, field operations, methods of laboratory analysis, and implementation of a thorough quality assurance plan.

776
JEFFRIES, D. S., COX, C. M., and DILLON, P. J., 1979, Depression of pH in lakes and streams in central Ontario during snowmelt: Journal of Fisheries Research Board of Canada, v. 36, p. 640-646.

The pH of snowpack in central Ontario watersheds in the winter of 1977-78 was 4.0 to 4.5. Spring runoff in three watersheds was characterized by a 2- to 13-fold increase in H+ concentration. Of the total yearly H+ transport from the watersheds, 36 to 77 percent occurred in April. Similar pH depressions were observed in most of the 17 other streams that were sampled less frequently and in the littoral zones, surface waters, and outflows of five lakes.

777
JEFFRIES, D. S., SNYDER, W. R., SCHEIDER, W. A., and KIRBY, M., 1977, Small-scale variations in precipitation loading near Dorset, Ontario: Water Pollution Research of Canada, v. 13, p. 73-84.

Bulk precipitation (wet and dryfall) was collected at five stations on Red Chalk Lake near Dorset, Ontario, on a event basis during spring, summer, and fall of 1976 and 1977. Samples were analyzed for pH, nutrients, and major ions. Significant variation in precipitation quantity and chemical loading occurred between sample periods but not between stations during a given storm. The same result was observed when the Red Chalk stations were compared to a similar station on a lake 25 km to the northwest.

778
JEFFRIES, D. S., and ZIMMERMAN, A. P., 1980, Comments on the analysis and sampling of low conductivity natural waters for alkalinity: Canadian Journal of Fisheries and Aquatic Sciences, v. 37, p. 901-902.

778 (continued)
The authors recommend that an accurate inventory of lake and stream water buffering capacities be taken to indicate which geographic areas are most susceptible to acidification. An inventory of buffering capacity information may be used in conjunction with models developed from detailed lake studies to predict future effects of continued acidic precipitation on water bodies. The total inflection point (TIP) method (Gran analysis) is recommended for determining alkalinity. Volume-weighted sampling procedure is the most effective sampling method and it should be used instead of collecting samples at the lake's surface.

779
JENSEN, K. W., and SNEKVIK, Einar, 1972, Low pH levels wipe out salmon and trout populations in southernmost Norway: Ambio, v. 1, no. 6, p. 223-225.

Acid precipitation is causing a decrease in pH of many Scandinavian rivers and lakes. Eggs, fry, and alevins of salmon and brown trout are more susceptible to acidic water than older fish. Increasing acidity of trout biotopes causes a reduction in the natural trout reproduction rate because eggs and fry succumb. Low pH has eliminated brown trout from many lakes and rivers in southern Norway.

780
JERNELOV, Arne, 1980, The effects of acidity on the uptake of mercury in fish, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 211-222.

The effect of pH on the transformation, transport, and bioaccumulation of mercury are discussed. Through its effect on mercury retention in the water-body, and on the biomass and growth rate of aquatic organisms, low pH leads to higher mercury levels in fish. For a better understanding of mercury turnover and transport, however, greater knowledge concerning reemission of mercury from both land and water is required. [Abstract reprinted by permission of Plenum Press.]

781
JEWELL, M. E., 1922, The fauna of an acid stream: Ecology, v. 3, p. 22-28.

This article describes the susceptibility of various aquatic fauna to hydrogen ion concentration at different stages of development. The pH of the Big Muddy River at southern Illinois ranges from 5.8 to 7.2, with lower values in winter. Bottom fauna is characterized by abundant clams and shrimp and the absence of branchiate snails and ephemerid nymphs. Fish fry and fingerlings are plentiful during summer, when pH increases to 6.8

782
JOHANNES, A. H., and ALTWICKER, E. R., 1980, Atmospheric inputs to three Adirondack lake watersheds, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 256-257.

783
JOHANNES, A. H., ALTWICKER, E. R., and CLESCERI, N. L., 1981, Characterization of acidic precipitation in the Adirondack region: Palo Alto, Calif., Electric Power Research Institute, Report EA-1826, 1 v.

Atmospheric contributions to three lake watersheds in the Adirondack Mountains of New York were investigated from May 1978 to August 1979. Precipitation samples were analyzed for pH, conductance, SO_4, NO_3, Cl, NH_4, Ca, Mg, K, and Na. Although precipitation quantity and quality were similar among the three watersheds on a monthly and annual basis, individual storms fluctuated in sulfate-nitrate ratios. The chemical composition of wet deposition falling through the forest canopy was significantly affected by cation enrichment.

784
JOHANNES, A. H., GALLOWAY, J. N. and TROUTMAN, D. E., 1980, Snow pack storage and ion release, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 260-261.

785
JOHANNESSEN, Merete, 1980, Aluminum, a buffer in acidic waters?, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 222-223.

786
JOHANNESSEN, Merete, 1980, Regional lake surveys, in Hendrey, G. R., ed., Limnological aspects of acid precipitation: International Workshop, Sagamore Lake Conference Center, N.Y., 1978, Proceedings: Upton, N.Y. Brookhaven National Laboratory, p. 3-5.

787
JOHANNESSEN, Merete, DALE, Torstein, GJESSING, E. T., HENRIKSEN, Arne, and WRIGHT, R. F., 1977, Acid precipitation in Norway--the regional distribution of contaminants in snow and the chemical concentration processes during snowmelt, in Isotopes and Impurities in Snow and Ice Symposium, Grenoble, 1975, Proceedings: International Association of Hydrological Sciences Publication no. 118, p. 116-120.

787 (continued)
Southeastern Norway receives massive deposition of atmospheric pollutants such as hydrogen ion, sulfate ion, nitrate ion, and several heavy metals. Contaminated snow has been reported in northernmost Norway. The concentration of these substances is 2 to 3 times higher in the first snowmelt than in the bulk snow. Spring snowmelt causes sudden drops in pH, which has marked effects on the chemistry of freshwater ecosystems in Norway.

788
JOHANNESSEN, Merete, and HENRIKSEN, Arne, 1978, Chemistry of snow meltwater--changes in concentration during melting: Water Resources Research, v. 14, no. 4, p. 615-619.

As part of the SNSF Project, "Acid Precipitation--Effects on Forest and Fish", a study was conducted to investigate the release of chemical components from snow samples within different constituent loads in the field and in a laboratory. When little or no thawing of snow occurs before spring, most of the constituent load accumulated in the snowpack is retained. During the study, from 50 to 80 percent of the pollutant load was released with the first 30 percent of the meltwater. Average concentration of pollutants in this meltwater was 2 to 2.5 times the concentration in the snowpack itself.

789
JOHANNESSEN, Merete, SKARATVEIT, A., and WRIGHT, R. F., 1980, Streamwater chemistry before, during, and after snowmelt, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 224-225.

790
JOHANSSON, Niklas, and MILBRINK, Goran, 1976, Some effects of acidified water on the early development of roach (*Rutilus rutilus* L.) and perch (*Perca fluviatilis* L.): Water Resources Bulletin, v. 12, no. 1, p. 39-48.

Perch and roach fertilized eggs were reared in waters of differing pH in the field and laboratory. Both species showed at least a 50-percent decrease in hatching frequency when pH decreased below 5.6. At pH less than 4.6, both species failed to reproduce. Roach are more sensitive than perch to low pH.

791
JOHANSSON, Niklas, RUNN, Per, and SOHTELL, Morgan, 1981, Perivitelline pH of salmon eggs in relation to ambient pH: Water Resources Bulletin, v. 17, no. 6, p. 994-999.

791 (continued)
Eggs of salmon and brown trout were reared in solutions ranging from pH 4.1 through 7.5. The pH of perivitelline fluid was measured during successive stages of egg development by micropuncture with an antimony microelectrode system. The pH of perivitelline fluid decreased with that of the ambient solution; no point of equilibrium was observed at lower pH levels. When salmon and brown trout eggs were reared in solutions of pH 4.1 through 4.7, the perivitelline fluid of salmon eggs was 0.4 pH units above that of the ambient solution; perivitelline fluid in brown trout eggs was 1.0 pH units above the ambient solution.

792
JOHNSEN, Ib, 1980, Estimation of adverse effects of air pollution on Danish forests, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 237.

793
JOHNSEN, Ib, 1980, Regional and local effects of air pollution, mainly sulfur dioxide, on lichens and bryophytes in Denmark, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 133-140.

794
JOHNSON, A. H., 1979, Acidification of headwater streams in the New Jersey Pine Barrens: Journal of Environmental Quality, v. 8, no. 3, p. 383-386.

This article summarizes 16 years of pH measurements from McDonalds Branch and Oyster Creek, two headwater streams of the Pine Barrens region, New Jersey. Average yearly pH of the two streams decreased about 0.2 to 0.5 units during the 16 years. Hydrogen ion concentration is correlated with sulfate ion in approximately a 1:1 ratio by equivalents, which suggests that sulfuric acid is an important source of acidity.

795
JOHNSON, A. H., 1979, Evidence of acidification of headwater streams in the New Jersey Pinelands: Science, v. 206, p. 834-836.

A trend of acidification is indicated by 17 years of pH data from two small streams in the New Jersey Pine Barrens that drain relatively undisturbed areas. The pH declined by about 0.4 unit, with an estimated increase in hydrogen ion (H^+) concentration of about 50 microequivalents per liter. Data are consistent with the postulation of an atmospheric source of increased H^+.

796
JOHNSON, A. H., 1980, Acidification of headwater streams in the New Jersey Pine Barrens [abstract]: Geological Society of America, Abstracts with Programs, v. 12, no. 2, p. 43.

A trend in the acidification of two relatively undisturbed headwater streams in New Jersey's Pine Barrens is indicated by 16 years of stream pH data. The average yearly pH decreased by 0.2 to 0.5 units during the 16-year period.

797
JOHNSON, A. H., and REYNOLDS, R. C., Jr., 1977, Chemical character of headwater streams in Vermont and New Hampshire: Water Resources Research, v. 13, no. 3, p. 469-473.

Stream-water samples were collected from 17 watersheds in Vermont and New Hampshire in the fall during periods of base flow and analyzed for major dissolved solids. Results show that dissolved solids are qualitatively and quantitatively related to type of bedrock. Streams draining watersheds underlain by plutonic bedrock are acidic, mixed-cation sulfate waters having little buffering capacity and low solute content. Streams draining watersheds of metamorphic and sedimentary terrains are characterized by neutral pH, alkaline earth cations, and mixed anions or bicarbonate.

798
JOHNSON, D. R., 1979, Systematic stratospheric-tropospheric exchange through quasi-horizontal transport processes within active baroclinic waves, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 401-408.

799
JOHNSON, D. W., 1980, Site susceptibility to leaching by H_2SO_4 in acid rainfall, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 525-535.

800
JOHNSON, D. W., 1981, The natural acidity of some unpolluted waters in southeastern Alaska and potential impacts of acid rain: Water, Air, and Soil Pollution, v. 16, no. 2, p. 243-252.

Natural organic acids cause some unpolluted streams draining surface and bog soils near Petersburg, Alaska, to have low pH ($\leq$4.7), whereas some nearby streams, also affected by organic acids are only slightly acidic (pH$\geq$6). Projections of the potential effects of sulfuric acid based on a worst-case model for soil-solution equilibrium indicate that the greatest declines in pH will occur in the most acid waters, whereas little change will occur in near neutral waters. Model results indicate that ground waters draining mineral soils and stream waters are insensitive to acid precipitation, whereas acid sphagnum bog ground waters and the 02 horizon solutions are most sensitive.

801
JOHNSON, D. W., and COLE, D. W., 1977, Sulfate mobility in an outwash soil in western Washington: Water, Air, and Soil Pollution, v. 7, no. 4, p. 489-495.

The effect of acidic precipitation on cation leaching in a second-growth Douglas-fir ecosystem at the Thompson Research Center is reviewed. Sulfate mobility and soil pH buffering power were tested by applications of heavy doses of H_2SO_4 to the study plot. Sulfate at high concentrations proved to be immobilized, presumably by adsorption to soil sesquioxide surfaces. Soil sulfate adsorption was determined at varying sulfate concentrations, and two mechanisms of adsorption are implied by the shapes of the isotherms. [Abstract reprinted by permission of D. Riedel Publishing Company.]

802
JOHNSON, D. W., and COLE, D. W., 1980, Anion mobility of soils--relevance to nutrient transport from forest ecosystems: Environment International, v. 3, p. 79-90.

Anion production and mobility increases nutrient leaching from forest ecosystems after acidic atmospheric deposition, harvesting, fire, fertilization, and wastewater application. This article describes some processes regulating the production and mobility of anions in soils and how these processes affect elemental flux through forest soils. The production of bicarbonate is regulated by soil CO_2 pressure and pH. The mobility of nitrate is regulated almost entirely by biological processes, but chloride is relatively uninvolved in either biological or inorganic chemical reactions. Sulfate is involved to an intermediate degree in both biological and inorganic chemical reactions. Organic anions are frequently dominant in cold-region soils, but little information is available on the complex factors affecting mobility.

803
JOHNSON, D. W., COLE, D. W., and GESSEL, S. P., 1979, Acid precipitation and soil sulfate adsorption properties in a tropical and in a temperate forest soil: Biotropica, v. 11, no. 1, p. 38-42.

This article compares atmospheric sulfuric acid contribution and leaching processes in a tropical forest with those of a temperate forest. Hydrogen ion (H^+) is mostly removed by the forest canopy in both forests. The tropical forest seems to accumulate sulfate (SO_4^{--}), whereas the temperate forest seems near steady state. Tropical forest soil has a large capacity for retaining sulfate, which is probably related to its high sesquioxide content.

804
JOHNSON, D. W., COLE, D. W., GESSEL, S. P., SINGER, M. J., and MINDEN, R. V., 1977, Carbonic acid leaching in a tropical, temperate, subalpine, and northern forest soil: Arctic and Alpine Research, v. 9, no. 4, p. 329-343.

The influence of carbonic acid as a soil cation leaching agent decreases as annual temperature decreases among four sites ranging from tropical rain forest to subalpine and northern forest. Carbonic acid dissociation is suppressed by low pH in the subalpine and northern soil solutions. Bicarbonate anion has a major effect on yearly cation transport through a soil. The authors hypothesize that the reduced bicarbonate concentrations at low pH in the subalpine and northern sites reduces nutrient loss from the rooting zone.

805
JOHNSON, D. W., and HENDERSON, G. S., 1979, Sulfate adsorption and sulfur fractions in a highly weathered soil under a mixed deciduous forest: Soil Science, v. 128, no. 1, p. 34-40.

This article discusses the accumulation of sulfur by sulfate adsorption in a mixed deciduous forest soil. Sesquioxide-rich subsurface soils have a large reservoir of phosphate-soluble, adsorbed sulfate-S but do not permanently adsorb more. Surface soils have no detectable adsorbed sulfate but have a substantial reserve of water-soluble sulfate-S. Surface soils are capable of absorbing sulfate into forms not extractable with water or phosphate solution. Sulfate concentrations in headwater streams increase during peak storm periods, perhaps because of leaching from surface horizons in the other source areas of a watershed.

806
JOHNSON, D. W., HENDERSON, G. S., and TODD, D. E., 1981, Evidence of modern accumulations of absorbed sulfate in an east Tennessee U.S.A. forested ultisol: Soil Science, v. 132, no. 6, p. 422-426.

Studies on sulfate content and adsorption in a forested ultisol indicate that although considerable amounts of adsorbed, insoluble sulfate are present in B horizon samples, additional accumulations into this form could not be induced with additions of sulfate. This article investigates the proportion of current adsorbed, insoluble sulfate that is a result of man's activities. Field studies, a lysimeter investigation, and sulfate salt applications show that sulfate has accumulated in the soils during the last 80 years and could continue to accumulate at higher rates.

807
JOHNSON, D. W., HORNBECK, J. W., KELLY, J. M., SWANK, W. T., and TODD, D. E., 1980, Regional patterns of soil sulfate accumulation--relevance to ecosystem sulfur budgets, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 507-520.

Analyses of soils from Walker Branch, Camb Branch, and Cross Creek, Tennessee; Coweeta, North Carolina; and Hubbard Brook, New Hampshire, support the hypothesis that watershed sulfur accumulation is due to inorganic sulfate adsorption in soils. Analyses of soils from lysimeter study sites at La Selva, Costa Rica, and Thompson site, Washington, produced similar results. In laboratory adsorption studies, only soils from Coweeta retained substantial (50 to 100%) additional amounts of sulfate in insoluble forms.

Soil adsorbed sulfate content and adsorption capacity were positively correlated with free iron content but negatively correlated with organic matter content. Organic matter apparently blocks adsorption sites, preventing sulfate adsorption in iron-rich A horizons and Spodosol B2ir horizons. This blockage may account for the accumulation of adsorbed sulfate in B horizons in temperate and tropical soils and the susceptibility of New England Spodosols to leaching by H_2SO_4. [Abstract reprinted by permission of D. Riedel Publishing Company.]

808
JOHNSON, N. M., 1979, Acid rain: Neutralization within the Hubbard Brook ecosystem and regional implications: Science, v. 204, p. 497-499.

808 (continued)
The neutralization of strong acids from precipitation occurs mostly in the soil zone (75 percent) by rapid reaction with basic aluminum salts and biologic matter. The hydrologic effect of acid rain on stream-water quality is mainly in low-order drainage systems, especially in basins where the bedrock is chemically unreactive, as in igneous and metamorphic terrains. Acid rain neutralization occurs rapidly in the marble belts of New England by the solution of carbonate minerals. Lakes whose watersheds are underlain by igneous or metamorphic bedrock and which receive water from low-order streams will tend to be acidified and rich in aluminum.

809
JOHNSON, N. M., DRISCOLL, C. T., Jr., EATON, J. S., LIKENS, G. E., and McDOWELL, W. H., 1981, "Acid rain," dissolved aluminum and chemical weathering at the Hubbard Brook Experimental Forest, New Hampshire: Geochimica et Cosmochimica Acta, v. 45, p. 1421-1437.

This paper discusses the interaction between acid rain, aluminum solubility, and chemical weathering as observed at the Hubbard Brook Experimental Forest in New Hampshire. Neutralization occurs in a two-phase process. Hydrogen-ion acidity is neutralized by the dissolution of reactive alumina found primarily in the soil zone. Aluminum-rich surface waters typically have a pH of 4.7 to 5.2 at this stage of neutralization. In the second phase, hydrogen ion acidity and aluminum acidity are neutralized by chemical weathering of primary silicate minerals such as the alkali and alkaline earths contained in the bedrock and glacial till of the watershed. The chemical weatering process is much slower than the alumina dissolution reaction; hence the aluminum acidity state (pH 4.7 to 5.2) persists for substantial periods.

810
JOHNSON, N. M., LIKENS, G. E., BORMANN, F. H., FISHER, D. W., and PIERCE, R. S., 1969, A working model for the variation in stream water chemistry at the Hubbard Brook experimental forest, New Hampshire: Water Resources Research, v. 5, no. 6, p. 1353-1363.

This article discusses transient changes in stream chemistry in terms of mixing processes and mass balance considerations. Stream-water chemistry varies hyperbolically with stream discharge, as indicated by four decades of discharge change at the Hubbard Brook Experimental Forest. The dilution processes is not based solely on the mixing of rain water and surface water with deeper soil water. Sodium and silica concentrations in stream water are highly diluted during high discharge periods, whereas hydrogen ion, aluminum, and nitrate concentrations are increased.

811
JOHNSON, N. M., REYNOLDS, R. C., Jr., and LIKENS, G. E., 1972, Atmospheric sulfur--its effect on the chemical weathering of New England: Science, v. 177, p. 514-516.

The acidity and sulfuric content of the upland streams of New England are caused by rainout and washout of sulfuric acid from the atmosphere. The rate of cation leaching from upland watersheds is relatively low despite the excess acid flux over New England.

812
JOHNSON, W. B., WOLF, D. E., and MANCUSO, R. L., 1978, Long term regional patterns and transfrontier exchanges of airborne sulfur pollution in Europe, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977, New York, Pergamon Press, p. 511-527.

This paper reports on progress to date of an ongoing effort to develop, evaluate, and apply a European Regional Model of Air Pollution (EURMAP). This model is capable of calculating long-term (monthly, seasonal, and/or annual) averages of the contributions from SO_2 in individual emittor countries to SO_2 and SO_4^{2-} concentrations, dry deposition, and wet deposition in receptor countries. The model covers all of western and central Europe, a geographical area 2,00 km x 2250 km in size. A trajectory-type approach is used, which involves the tracking of pollutant 'puffs' released from each emissions cell in an extensive 32 x 36 grid. Meteorological data in the form of wind and precipitation values from some 45 upper-air and 535 surface stations are input at 6-hourly intervals for use in the calculations of puff transport and wet deposition. A wet deposition coefficient is used that depends upon precipitation rate.

The preliminary model has been used to calculate annualized as well as monthly mean maps for January, April, July, and October 1973 of SO_2 and SO_4^{2-} concentrations, dry deposition, and wet deposition patterns resulting from SO_2 emissions in 13 countries in western and central Europe. The dry and wet deposition patterns are presented, along with values of calculated international exchanges of SO_2 and SO_4^{2-} wet and dry deposition among the various countries. The EURMAP results are compared with those from Fisher's (1975) model and the LRTAP model (Ottar, 1978; OECD, 1977). In many (but not all) respects the results from the three models are similar. The possible reasons for the differences revealed by this comparison are examined. [Abstract reprinted by permission of Pergamon Press.]

813
JONES, E. P., 1980, An overview of long range transport of air pollutants and the oceans, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 57-61.

814
JONES, H. G., OUELLET, N., and BRAKKE, D. F., 1980, The evolution of acidity in surface waters of Laurentides Park (Quebec, Canada) over a period of 40 years, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 226-227.

815
JONES, K. H., and MIRRA, R. R., 1979, Estimating future trends in acid rainfall, in Gunnerson, C. G., and Willard, B. E., eds., Acid rain: ASCE National Convention, Boston, Mass., 1979, Proceedings: New York American Society of Civil Engineers, p. 120-131.

816
JONES, U. S., 1978, Sulfur content of rainwater in South Carolina, in Environmental Chemistry and Cycling Processes, Proceedings of a Symposium, Augusta, Ga., 1976: Oak Ridge, Tenn., Technical Information Center, U.S. Department of Energy, CONF-760429, p. 394-402.

Rainwater samples were collected at 15 sites in South Carolina from 1973 to 1975 and analyzed for sulfur. Results of these analyses are compared to analyses of samples collected during 1953-55 near Clemson, Columbia, and Charleston. The principal source of sulfur in the atmosphere and rainwater, particularly during winter, is believed to be the discharge of combustion gases from fossil fuels burned in homes. Seasonal variations in sulfur content of rainwater were observed.

817
JONES, U. S., HAMILTON, M. G., and PITNER, J. B., 1979, Atmospheric sulfur as related to fertility of ultisols and entisols in South Carolina: Soil Science Society of America Journal, v. 43, no. 6, p. 1169-1171.

Atmospheric sulfur (S) contributions to soil fertility at 15 locations in South Carolina are estimated for 1973-77 by measuring the S content of precipitation samples collected over 30-day intervals and by measuring the S

817 (continued)
collected in lead peroxide samplers exposed to the air at the same time intervals. The S content of precipitation is compared with similar data collected at three locations from 1953-55. Results suggest that 20 years ago in South Carolina, S in the atmosphere contributed only a minor amount of the S required by crops; whereas atmospheric S today is a major contributor.

818
JONES, U. S., and SUAREZ, E. L., 1980, Impact of atmospheric sulfur deposition on agroecosystems, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 377-396.

In South Carolina, S supplies in precipitation increased from an annual average of 6.3 kg/ha in 1953-1955 to 11.3 kg/ha in 1973-1975. Annual S fallout in precipitation in Iowa, Tennessee, and Wisconsin rural areas during the 1970s was about twice that in South Carolina. Twenty years ago, S in the atmosphere made a minor contribution to the S required by agroecosystems in South Carolina, but current data indicate that it now makes a major contribution.

Should S in precipitation approach the 200-kg/ha/year quantity added by S fungicides and be deposited on a peach ecosystem growing on poorly buffered sandy soils, the health of the trees would decline. South Carolina sandy soil data show that, at 0 to 30 cm deep, soil S, soil pH and soil Al are significantly correlated with each other and with peach-tissue Al concentration and that the higher the Al, the greater the mortality of trees. The health of cotton and soybean ecosystems also declines when planted on peach orchard sites which had been formerly sprayed with 200 to 250 kg/ha/year of S fungicide.

At the present rural levels of air SO_2 and subsoil SO_4, the possibility that plant health of eastern U.S. agroecosystems is being influenced by too much or too little atmospheric S is slight. In South Carolina, one crop (corn) out of eight crops and one soil (Norfolk loamy sand) out of five indicated response to S at the 10% probability level. At none of the 15 locations was there an indication of too much atmospheric S for healthy agroecosystems. [Abstract reprinted by permission of D. Riedel Publishing Company.]

819
JONSSON, Bengt, 1977, Soil acidification by atmospheric pollution and forest growth: Water, Air, and Soil Pollution, v. 7, no. 4, p. 497-501.

819 (continued)
In recent years concern has been expressed about the danger of harmful pollution deposits which affect areas at great distances from the emission sources.

The investigation was so designed that a possible reaction in growth resulting from a supposed acidification could be observed as far as possible. A poorer growth development was observed in regions which are suspected of being more susceptible to acidification than those retions which are presumed to be less susceptible in this respect. We have found no good reason for attributing the reduction in growth to any cause other than acidification. [Abstract reprinted by permission of D. Riedel Publishing Company.]

820
JONSSON, BENGT, and SUNDBERG, ROLF, 1972, Has the acidification by atmospheric pollution caused a growth reduction in Swedish forests?: Stockholm, Sweden, Royal College of Forestry, Research Note no. 20, 48 p.

Forest production in regions of southern Sweden that are sensitive to acidification is compared with production in nonsensitive regions. Poorer forest growth development is noted in regions susceptible to acidification. Annual reductions of 0.3 and 0.6 percent during 1951-65 are noted.

821
JORANGER, E., SCHAUG, J., and SEMB, Arne, 1980, Deposition of air pollutants in Norway, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 120-121.

822
JOST, D., 1974, Aerological studies on the atmospheric sulfur budget: Tellus, v. 26, no. 1-2, p. 206-212.

Aircraft ascents are a method of measuring air pollution and trace substances in the atmosphere. Concentrations of sulfur dioxide (SO_2), ammonia (NH_3), sulfate ion (SO_4^{2-}), hydrogen sulfide (H_2S), and heavy metals were studied under differing meteorological situations and air masses in Europe. SO_2 residence time in the atmosphere is estimated to range from 1 hour to several days as calculated from the concentration distribution of several trace substances (SO_2, CO_2) in the troposphere.

823
JUDEIKIS, H. S., and STEWART, T. B., 1976, Laboratory measurement of SO_2 deposition velocities on selected building materials and soils: Atmospheric Environment, v. 10, p. 769-776.

823 (continued)
Sulfur dioxide (SO_2) deposition velocities were measured in a laboratory through a cylindrical flow reactor. Resulting data were analyzed by mathematical models that specifically account for diffusive transport in the system. The model deposition velocities are independent of diffusion processes and represent maximum removal rates that would be encountered in the environment under turbulent atmospheric conditions.

824
JUDEIKIS, H. S., STEWART, T. B., and WREN, A. G., 1978, Laboratory studies of heterogeneous reactions of SO_2: Atmospheric Environment, v. 12, p. 1633-1641.

This article describes the rates and capacities of heterogeneous reactions of sulfur dioxide (SO_2) with several solids likely to be found in urban aerosols. Rates of SO_2 removal gradually diminish as the time of SO_2 exposure increases. With prolonged exposure, the solids completely lose their ability to remove SO_2 from the gas phase. Freshly emitted aerosols can be effective in converting gaseous SO_2 to particulate SO_4.

825
JUDEIKIS, H. S., and WREN, A. G., 1978, Laboratory measurements of NO and NO_2 depositions onto soil and cement surfaces: Atmospheric Environment, v. 12, p. 2315-2319.

Laboratory measurements were made of the deposition of NO and NO_2 onto soil and cement surfaces. Deposition is observed as largely irreversible and decreases with time, which suggests a finite capacity of these surfaces to remove these species from the gaseous phase. However, results of other experiments suggest that surface activity in the environment can be regenerated in the case of NO_2, but not NO, by interaction with atmospheric ammonia. Uptake of NO by ground-level surfaces in the environment is expected to be considerably less than that of NO_2 because of lower deposition rates and capacities and more limited regeneration of surface activity for NO than for NO_2.

826
JUNGE, C. E., 1958, The distribution of ammonia and nitrate in rain water over the United States: Transactions, American Geophysical Union, v. 39, no. 2, p. 241-248.

This article presents maps of the distribution of ammonia and nitrate concentrations in rainwater over the United States. Major sources for both components are near the ground and over land. Ammonia distribution is controlled mostly by the acidity of the soil. Although, no correlation to other geographical factors could be found for nitrate, the soil seems the most probable.

827
JUNGE, C. E., 1960, Sulfur in the atmosphere: Journal of Geophysical Research, v. 65, no. 1, p. 227-237.

Sulfur in polluted regions occurs as SO_4^{2-} in aerosols and SO_2 and H_2S gas. Sources of SO_4^{2-} are the ocean, soil, and oxidation of the gaseous compounds. A considerable source of SO_2 is man-made, but most of the H_2S appears to be natural. Both gases seem to have equal concentrations. About 30 percent of the global atmospheric sulfur is of anthropogenic origin, excluding SO_4^{2-} in sea-salt particles. This article discusses the possibility that the global sulfur cycle is not closed and that most of the excess sulfur in river waters is of anthropogenic origin and will stay in the oceans.

828
JUNGE, C. E., 1963, Air chemistry and radioactivity: New York, Academic Press, 382 p.

This book examines the constituents and chemical processes of the stratosphere and mesosphere. The chapter on precipitation chemistry presents a physico-chemical analysis of wet and dry deposition. The discussion of pH and sulfate in water suggests that the high acidity observed in the southern and coastal areas of Sweden is probably due to pollution from central and western Europe. This theory is supported by data on seasonal variations in pH, wherein the lowest values occur during winter, when air flow is from the south and pollution greatest. Sulfuric acid is probably the controlling agent for low pH values in rainwater.

829
JUNGE, C. E., and RYAN, T. G., 1958, Study of the SO_2 oxidation in solution and its role in atmospheric chemistry: Royal Meteorological Society Quarterly Journal, v. 48, p. 46-55.

This article describes the oxidation of SO_2 in diluted catalytic solutions. SO_2 can be photochemically oxidized by sunlight without the presence of droplets and NH_3, and it might react with other gases or aerosol particles containing $CaCO_3$ or other alkaline compounds. The mechanism of sulfate ion (SO_4^{2-}) formation accounts for observed SO_4^{2-} concentrations in rain, fog, and smog only if some neutralizing cations in the aerosols or traces of NH_3 in the air are present.

830
JUNGE, C. E., and SCHEICH, G., 1969, Studien zur Bestimmung des Säuregehaltes von Aerosolteilchen: Atmospheric Environment, v. 3, p. 423-441. [In German with English abstract.]

830 (continued)
Aerosol samples were collected at London, Gotenborg, Belsenkirchen, and Mainz. Hydrogen-ion concentrations of aerosol samples dissolved in neutral water were determined by titration and pH measurement. Concentrations of sulfide and soluble matter in aerosols, sulfur dioxide, and some other chemical constituents of the atmosphere, which may influence the formation of hydrogen ions in aerosols, were also measured. Results of analyses indicate that the titration method gave higher hydrogen-ion concentrations than the pH measurement method. This suggests that the measured hydrogen ion concentrations present in aerosol particles are caused by either weak or strong acids that are buffered by weak bases.

831
JUNGE, C. E., and WERBY, R. T., 1958, The concentration of chloride, sodium, potassium, calcium, and sulfate in rain water over the United States: Journal of Meteorology, v. 15, no. 5, p. 417-425.

This article describes the distribution of concentrations of chloride, sodium, potassium, calcium, and sulfate in rain water over the United States. The major source of Cl^- is the ocean; however, the Cl^-/Na^+ ratio in rain is considerably less than in sea water, possibly as a result of excess Na^+ from the soil. Highest concentrations of Ca^{++} are over the southwest, whereas Na^+ and K^+ are uniformly distributed. Most of the SO_4^{2-} over the ocean is believed to originate from sea spray, but some is derived from the land.

832
JYGALOVSKAYA, T. N., NAZAROV, I. M., RENNE, O. S., and FRIDMAN, S. D., 1979, Snow cover as an indicator of a long-range pollutant transport in the monitoring system, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 105-108.

K

833
KADLECEK, J. S., FIUST, T., and MOHNEN, V. A., 1979, General composition of precipitation at Whiteface Mountain, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 54-61.

834
KALISZ, P. J., and STONE, E. L., 1980, Cation exchange capacity of acid forest humus layers: Soil Science Society of America Journal, v. 44, p. 407-412.

This article discusses the relationship between organic matter content and exchange capacity at the air-dried or "field pH" in several populations of forest soils, mainly in New York and New England. Organic matter is the chief source of exchange capacity at all sites studied. Cation-exchange capacity (CEC) at field pH of mors from the Adirondack Mountain region (pH $\leq$4.1) and mulls from central New York (pH 4.9 to 5.4) averaged 52 and 123 meq/100 g organic matter, respectively, as compared with 183 and 236 meq/100 g when determined at pH 7. Base saturation calculated from the lower CEC at field pH ranged from 15 to 30 percent for H layers below pH 4 and from 81 to 94 percent for mull layers at pH 5.4. Reduced CEC measured at field pH and the wide range of total exchange capacity affect the retention of recycled bases and cations added as fertilizer. Acidification and nutrient depletion due to acid precipitation is influenced by base saturation and the total quantity of bases retained by the humus layer.

835
KAMPRATH, E. J., 1972, Possible benefits from sulfur in the atmosphere: Combustion, v. 44, p. 16-17.

Sulfur (S) is essential for plant growth. The main supply of S in topsoils is organic sulfur. In recent years, widespread use of fertilizers containing little S has resulted in a need for supplemental S in crop production. Sulfur dioxide (SO_2) in the atmosphere is another source; however, in high concentrations it may damage plants. Current SO_2 concentrations in most metropolitan areas are probably not detrimental to plant growth except where highly concentrated.

836
KAPLAN, D. J., and HIMMELBLAU, D. M., 1981, A cylindrical PbO_2 diffusion tube for separating SO_2 from an airstream: Environmental Science and Technology, v. 15, no. 5, p. 558-562.

This report describes a sulfur dioxide stripper or denuder. The device has a high capacity for absorbing SO_2 at ambient levels, and the lifetime (time over which the SO_2 output remained constant) is estimated to be several hundred hours at an input SO_2 concentration of 1 ppm. The main drawbacks are that the wall is delicate, and replacing the PBO_2 is somewhat difficult. The high efficiency and absorptive capacity outweigh these drawbacks, however.

837
KAPLAN, Edward, THODE, H. C., Jr., and PROTAS, Alicia, 1981, Rocks, soils, and water quality. Relationships and implications for effects of acid precipitation on surface water in the northeastern United States: Environmental Science and Technology, v. 15, no. 5, p. 539-544.

The distribution of rocks and soils in the northeast was investigated to determine the degree to which they influence pH and alkalinity of surface waters. A data base describing rocks, soils, and land use east of the 100th meridian was merged with water-quality, socioeconomic, and energy data from 317 counties in New England and the Middle Atlantic. Rocks are shown to contribute to the buffering capacity of surface water. The presence of a high percentage of alfisol soils is a better indicator of waters with high alkalinity and thus a greater resistance to the effects of acid precipitation.

838
KARNOSKY, D. F., 1980, Changes in southern Wisconsin white pine stands related to air pollution sensitivity, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 238.

839
KAROL, I. L., and MYATCH, L. T., 1972, Contribution to the planning of the station network for measuring the chemical composition of precipitation: Tellus, v. 24, no. 5, p. 421-427.

This article gives chemical data on the composition of precipitation from 1958-65 at 28 stations on the European territory of the USSR and includes correlation functions of Ca, Na, and SO_4 ion and ion sum concentrations in precipitation and deposition. Correlation distances for various ions range from 90 to 450 km. Mean square random errors in ion composition measurements (35-45 percent) determined from calculated correlation functions are also given.

840
KASINA, Stanislaw, 1980, On precipitation acidity in southeastern Poland: Atmospheric Environment, v. 14, p. 1217-1221.

Acid precipitation is widespread in southeast Poland. The pH of precipitation is higher in industrial areas than rural areas, and total acidity is significantly higher in the vicinity of emission sources. No correlation is detected between the increase in sulfate and the decrease in pH of precipitation.

841
KASSLER, Helene, 1976, Acid rain: Horticulture, v. 54, p. 33-35.

Pure rain has been contaminated by air pollutants and is becoming increasingly acidic. As a result, acid rain may be damaging to plant life. Acid rain may affect all of a plant's metabolism by causing interference with cell functions; it also disrupts the nitrogen fixation in the soil, which in turn interferes with plant development.

842
KATZENSTEIN, A. W., 1981, An updated perspective on acid rain: New York, Edison Electric Institute, 43 p.

This booklet is a layman's guide to possible causes and environmental effects of acid precipitation. Recent scientific information on the natural processes of aquatic and terrestrial environs is providing researchers with a broader understanding of the nature of acidic deposition. The author concludes that pH 5.6 is an unrealistic reference point for determining acidity of precipitation. In many regions of the world, including locations a long distance from industrial activity, the pH of rain is frequently lower than pH 5.6. Reports that claim an increase in acid precipitation in the Northeast are unsubstantiated. No evidence exists that supports the hypothesis that the acidity of precipitation or lakes in the Adirondack Mountains would be significantly altered if coal-burning powerplants in the Ohio River basin were required to install scrubbers.

843
KELLER, W., GUNN, J., and CONROY, N. I., 1980, Acidification impacts on lakes in the Sudbury, Ontario, Canada area, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 228-229.

844
KELLOGG, W. W., CADLE, R. D., ALLEN, E. R., LAZRUS, A. L., and MARTELL, E. A., 1972, The sulfur cycle: Science, v. 175, p. 587-596.

This article compares the manmade contribution of sulfur compounds to the atmosphere and oceans with that from natural sources. Man contributes about half as much as natural sources to the total atmospheric load of sulfur compounds, but this percentage is expected to double by the year 2000, especially in industrialized regions. Removal processes are slow enough that increased concentrations are noted thousands of kilometers downwind of the source.

845
KELLY, J. M., 1980, Sulfur distribution and flux in two forested watersheds in eastern Tennessee, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 230-231.

846
KELLY, T. J., and STEDMAN, D. H., 1980, Effect of urban sources on acid precipitation in the western United States: Science, v. 210, p. 1043.

This article comments on a paper by W. M. Lewis, Jr. and M. C. Grant, titled "Acid precipitation in the western United States," and raises questions as to the effect of intermittent transport of pollutants from urban sources on the occurrence of acid precipitation in the western United States. A reply by Lewis and Grant is included. (See also Lewis, W. M., Jr., and Grant, M. C., 1980, herein.)

847
KENNEDY, V. C., 1981, Chemistry of rainfall in coastal northern California, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 21.

848
KENNEDY, V. C., ZELLWEGER, G. W., and AVANZINO, R. J., 1979, Variation of rain chemistry during storms at two sites in northern California: Water Resources Research, v. 15, no. 3, p. 687-702.

This article documents changes in rainfall chemistry during storms in the Mattole River basin in southwestern Humbold County, Calif. The chemical quality of rainfall at Menlo Park, on San Francisco Bay, is compared with rainfall near the coast at Petrolia, about 500 km north of San Francisco. The range in pH is smaller in rural than in metropolitan areas, and average H^+ activity corresponds to a pH of 5.1 to 5.2 in both areas. The pH decreased with increased dissolved salts in rainfall at Petrolia, but no similar relationship was noted at Menlo Park.

849
KERCHER, J. R., and AXELROD, M. C., 1980, Modeling the impact of SO_2 pollution on the community structure and succession in a coniferous forest of the western U.S.A., in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 174-175.

850
KERCHER, J. R., AXELROD, M. C., and BINGHAM, G. E., 1980, Forecasting effects of SO_2 pollution on growth and succession in a western conifer forest, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 200-202.

A simulator has been developed for the mixed conifer forest type of the Sierra Nevada, California to forecast the effects of SO_2 on forest growth and succession. The model simulated recruitment, growth, and death of each tree and is based on a northestern USA simulator with extensive modifications. These modifications include the introduction of fire ecology, temporal seed crop patterns unique to the Sierra, and water stress. Pollutant stress is modeled as an effect on tree growth. The model simulates the shift from the ponderosa pine dominated forest type to the white fir dominated mixed conifer type as elevation increases from 5000 to 6000 ft. It also simulates the fire-suppression of white fir and the fire-climax of ponderosa pine. For a 10% growth reduction of ponderosa pine from pollutant stress and with growth reductions in other species as determined by their relative sensitivities, standing crops of ponderosa pine were reduced and white fir increased. [Abstract reprinted by permission of U.S. Forest Service.]

851
KEREKES, J. J., 1980, Acid rain investigations on three lake basins in Kejimkujik National Park, N.S., in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 81.

852
KEREKES, J. J., 1980, Preliminary characterization of three lake basins sensitive to acid precipitation in Nova Scotia, Canada, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 232-233.

853
KERR, R. A., 1981, Is all acid rain polluted?: Science, v. 212, p. 1014.

Incidents of acid rain have been reported in some of the world's most isolated areas. A 5000-km pathway is traced between Asian sources and the Pacific through which pollutants are carried in much the same fashion as those

853 (continued)
entering the Arctic from western Europe. Rainwater samples from the Hawaiian islands show sulfuric acid to be the principal acid in the polluted rain, but a sufficient source could not be found on the islands. Sulfuric acid may be transported thousands of kilometers in the same way that Asian dust reaches Enewetak, a site in the Pacific, north of the equator.

854
KERR, R. A., 1981, Pollution of the arctic atmosphere confirmed: Science, v. 212, p. 1013-1014.

Air pollutants that are being detected in the Arctic resemble those produced thousands of kilometers to the south. Data collected at Barrow, Alaska, suggest that industrial pollution is penetrating into the Arctic and that these pollutants make up much but not all of the winter-spring Arctic aerosol. About 50 percent of the total aerosol mass (excluding water) is sulfate, organic matter, soot, and other pollutants.

855
KERR, R. A., 1981, There is more to "acid rain" than rain: Science, v. 211, p. 692-693.

This article describes a few watershed studies and the difficulties in measurement of several types of dry deposition. Dry deposition of toxic chemicals contributes 10 to 30 percent of the total acidic deposition and in some places may contribute more than 50 percent. Measurement of dry deposition is difficult because some substances, such as sulfur dioxide, form particles so small that they fall slowly or not at all. Finely divided particles and gases that do not "fall out" are often caught on natural surfaces. Most of the sulfur not collected by samplers may be in the form of sulfur dioxide, which is not collected efficiently by either wet or bulk deposition samplers.

856
KHAN, S. M., 1980, The relationship between acid content of particulates and rainfall in Bangkok [Thailand]: Journal of Environmental Science and Health, v. A15, no. 6, p. 561-572.

Rain and air samples were collected at nine stations in the Bangkok metropolitan area and analyzed for acidity. Average concentrations of particulate acidity ranged from 5.38 to 10.15 $\mu g/m^3$; weighted average acidity of rain ranged from pH 5.57 to 6.32. A close correlation was noted between pH and sulfate concentration of rainwater.

857
KHEMANI, L. T., and MURTY, Bh. V. R., 1968, Chemical composition of rain water and rain characteristics at Delhi [India]: Tellus, v. 20, p. 284-292.

Rain samples were collected at 2- to 40-minute intervals during several storms in successive seasons at Delhi, and were analyzed for chloride, sulfate, sodium, potassium, and calcium. Chemical characteristics of precipitation are dependent on the amount of airborne soluble particles present in the cloud-forming air.

858
KICKERT, R. N., and GEMMILL, Barbara, 1980, Data-based ecological modeling of ozone air pollution effects in a southern California mixed conifer ecosystem, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 181-186.

The purpose of this research was to determine the effects of ozone air pollution on a mixed conifer forest ecosystem in the San Bernardino National Forest, California.

We used an ecological systems modeling approach in concert with various biological specialists. This required conceptual model development, computer programming, and the analysis of original project data for model calibration.

We found that this process led to the investigators conducting new research of an integrative nature. A structure for complex interactions of forest effects was produced. Insights on changes in ecosystem dynamics and a worst-case scenario of future forest changes were derived.

We conclude that sudden qualitative changes in conifer forest composition can occur under the influence of ozone air pollution and the exclusion of natural fire events. [Abstract reprinted by permission of U.S. Forest Service.]

859
KINNE, O., and ROSENTHAL, H., 1967, Effects of sulfuric water pollutants on fertilization, embryonic development and larvae of the herring, *Clupea harengus*: Marine Biology, v. 1, p. 65-83.

Biological effects of sulfuric pollutants on the early life cycles of herring (*Clupea harengus*) were monitored at River Schlei, North Germany in April 1967. Large quantities of sulfuric acid (H_2SO_4) and ferrous

859 (continued)
sulfate ($FeSO_4$) are scheduled to be released by industries daily into the North Sea at Helgoland, Germany, to which herring larvae are carried by water currents from their spawning ground. The pollutants under consideration pose a danger to herring eggs and larvae at dilutions of 1:32,000 or less.

860
KISH, Tony, 1981, Acid precipitation--critical questions still remain unanswered: Journal of the Water Pollution Control Federation, v. 53, no. 5, p. 518-521.

This article gives an overview of the causes and sources of acidic atmospheric deposition and discusses its effects on aquatic ecosystems and human health. More research is needed on methods of reducing emissions of sulfur oxides and nitrogen oxides. Damage caused by acid precipitation is difficult to monetarily asses, but the Council on Environmental Quality estimates architectural losses alone to be $2 billion per year.

861
KITTELSON, D. B., McKENZIE, R. L., VERMEERSCH, M., DORMAN, F., PUI, D. Y. H., LINNE, M., LIU, B. Y. H., and WHITBY, K. T., 1978, Total sulfur aerosol concentration with an electrostatically pulsed flame photometric detector system, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 105-111.

This paper describes a new system for continuous measurement of ambient aerosol sulfur concentrations. The system consists of a pulsed electrostatic precipitator followed by a total sulfur flame photometric detector (FPD). With this system the output signal of a FPD is composed of a DC signal related to the gas phase sulfur concentration and an AC signal by a phase and frequency selective lock-in amplifier. Using a standard Meloy SA-28 FPD and operating at a chopping frequency of 0.2 Hz the system has a sensitivity of about 0.2 $\mu g\ m^{-3}$ (as sulfur) for ammonium sulfate at a signal to peak-to-peak noise ratio of one and has a system response time of about 1.5 min. Some interference from SO_2 exists but should be minimized by modification of the precipitator and of the linearizer electronics of the FPD. A thermal speciation system has been developed for use in conjunction with the system to yield information on the chemical composition of the aerosol sulfur measured. Preliminary field evaluations of the instrument were performed at the Los Angeles Roadway Study. The instrument performed well and aerosol total sulfur concentrations measured with it were in good agreement with measurements by other methods. [Abstract reprinted by permission of Pergamon Press.]

862
KLEIN, A. E., 1974, Acid rain in the United States: The Science Teacher, v. 41, no. 5, p. 36-38.

An acid rain survey of the U.S. was conducted by secondary school students in cooperation with researchers at Cornell University and the U.S. Environmental Data Service, National Oceanic and Atmospheric Administration (NOAA). The students collected rain-water samples from all states, most Canadian provinces, Guam, Canal Zone and several foreign countries. Samples were analyzed for pH with indicator paper. Results were published in Current Science, a weekly classroom science news magazine. A computer-plotted map showing pH of rain in the United States was developed by Dr. Godshall (NOAA) from the data and published with the article. Except for a few isolated areas, acid precipitation is not widespread in the western portion of the United States. Widespread measurements of pH less than 5.0 occurs in rural regions of northeastern United States.

863
KLOCKOW, D., JABLONSKI, B., and NEIBNER, R., 1979, Possible artifacts in filter sampling of atmospheric sulphuric acid and acidic sulphates: Atmospheric Environment, v. 13, p. 1665-1676.

Possible artifacts in sulfuric acid sampling and analysis were investigated by X-ray microanalysis, X-ray fluorescence spectrometry and radio thermal diffusion analysis. The sources of these artifacts were (1) interactions between sulfuric acid aerosol and filter material, (2) reactions of gaseous ammonia with previously collected acidic sulfate, and (3) topochemical reactions of particles already collected on the filter. This article identifies severe interferences in sampling technique that result from reaction with gaseous ammonia and the reaction of the collected acid aerosol with previously sampled particles.

864
KLOPATEK, J. M., HARRIS, W. F., and OLSON, R. J., 1980, A regional ecological assessment approach to atmospheric deposition--Effects on soil systems, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 539-553.

A regional ecological overview of the potential effects of acid precipitation on soils is presented. Computer maps of soil pH, CEC, base saturation, and base content in the eastern United States are displayed using county-level data. These maps are then overlain with a computer map of the hydrogen ion loading, and resultant maps of acid-

864 (continued)
sensitive soils are presented. Of 1572 counties in the eastern United States, only 117 are classified as being acid-sensitive. A number of qualifications concerning the data and the implications for management are discussed. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

865
KNABE, Wilhelm, 1976, Effects of sulfur dioxide on terrestrial vegetation: Ambio, v. 5, no. 5-6, p. 213-218.

Low doses of sulfur dioxide (SO_2) may have beneficial effects on plants because sulfur is a major nutrient. Increased uptake of SO_2 causes changes in plant systems that are at first reversible but later become irreversible at higher concentrations. Acute injury occurs with rapid absorption of toxic concentrations of SO_2; cells collapse and show plasmolysis under the light microscope. This article discusses the socioeconomic effects of vegetation injury due to SO_2 pollution and some air-quality criteria in relation to vegetation.

866
KOMABAYASI, M., 1962, Enrichment of inorganic ions with increasing atomic weight in aerosol, rainwater and snow in comparison with sea water: Journal of the Meteorological Society, v. 40, no. 1, p. 25-38.

Inorganic constitutents of maritime aerosol, rainwater, and snow in Japan differ systematically from those in seawater. The logarithm of the enrichment coefficient of several ions has an increasing linear relation to the logarithm of their atomic weight. Sodium, magnesium, potassium, calcium, carbonate, strontium, and iodine are characterized by this relationship. Fluorine, iron, aluminum, and sulfate deviate from it, and chlorine is intermediate.

867
KOROLEV, S. M., and RYABOSHAPKO, A. G., 1979, Investigation of parameters of dilution and removal of sulphur dioxide and lead during transport above the ocean, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 117-124.

868
KOROPALOV, V. M., and NAZAROV, I. M., 1979, Atmospheric transport of organochlorine pesticides, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 127-132.

869
KOZLOWSKI, T. T., 1980, Impacts of air pollution on forest ecosystems: BioScience, v. 30, no. 2, p. 88-93.

Air pollutants cause changes in forest ecosystems that are not always visible even though they affect growth, yield, and quality of plants and plant products. Plant leaves are injured by gaseous air pollutants when they are absorbed through stomata. Acute injury is severe and occurs after rapid absorption of enough pollutants to kill tissue. Leaf cells collapse during or soon after exposure, and necrotic patterns subsequently appear. Chronic injury is a result of rapid absorption of sublethal amounts of pollutants over a long time and is characterized by chlorosis.

870
KRAMER, J. R., 1978, Acid precipitation, in Nriagu, J. O., ed., Sulfur in the environment, part 1--the atmospheric cycle: New York, John Wiley, p. 325-370.

871
KRAMER, J. R., 1978, Alkalinity of soft waters and acid rain [abstract]: Geological Society of America, Abstracts with Programs, v. 10, no. 7, p. 438.

Waters with alkalinity less than or equal to 0.2 meq/L and with pH values ranging from 5 to 7 may derive their hydrogen ion assimilation from mineral equilibria such as $CaCO_3$, Fe_2O_3, alumino-silicates, and MnO_2, adsorption minerals, colloids, organic detritus, and from ion exchange with clay minerals and organic acids. A Gran analysis of waters in 0.1-M KCl produces conditional stability constants for HCO_3/H_2CO_3. These constants are precise to within ±0.01 log units. This suggests that watershed buffering is a result of water mixing with a saturated H_2O-$CaCO_3$ system that may be related to ground water.

872
KRAMER, J. R., 1979, Susceptible lands in Canada and USA, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 30-37.

873
KRAMER, J. R., 1980, Effects of LRTAP on soils, in Workshop on Long Range transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 45.

874
KRAMER, J. R., 1980, Future trends in acid precipitation and possible programs, in International Symposium on Inland Waters and Lake Restoration, Portland, Maine, 1980, Restoration of lakes and inland waters: Washington, D.C., U.S. Environmental Protection Agency, EPA-440/5-81-010, p. 474-478.

The assessment of critical height of a source emission leading to the production of acidic aerosols should be a research priority. Modeling may be the best approach for determining standards for point-source emissions for various heights. Liming, nutrient enrichment, and modification of watershed hydrology are possible remedial actions. Mass balance calculations and field studies are needed to evaluate these remedial alternatives.

875
KRAMER, J. R., BOOTY, W. G., and STROES, S., 1981, Acid neutralizing capacity of fine soil fractions, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 327-337.

876
KRAUSE, G. H. M., and KAISER, Hildegard, 1977, Plant response to heavy metals and sulphur dioxide: Environmental Pollution, v. 12, p. 63-71.

This article investigates the effects of sulfur dioxide (SO_2) and several heavy metals on ion uptake through leaves and on yield and foliar injury. SO_2 did not influence uptake or translocation of heavy metals in any of the plant species used for analysis but decreased the uptake of manganese and lead. Yield was reduced in all species that were treated with heavy metals. Foliar injury caused by heavy metals increased when plants were treated with SO_2.

877
KRESS, L. W., 1980, Effect of O_3 + NO_2 on growth of tree seedlings, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 239.

878
KRISHNA, Daya, 1953, Effect of changing pH on developing trout eggs and larvae: Nature, v. 171, p. 434.

The effect of pH on trout eggs and larvae was measured by rearing the eggs in tap water adjusted to different pH levels with hydrochloric acid and sodium hydroxide. Eggs developed normally in a wide range of pH 5 through 9 rose in morality abruptly above and below the range. Eyed ova and larvae were equally susceptible to pH changes, but green ova were more resistant. Average mortality rates at differing pH levels are given.

879
KRUPA, S. V., CHEVONE, B. I., BECHTHOLD, J. L., and WOLF, J. L., 1980, Vegetation--Effects of sulfur deposition by dry-fall processes, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 309-319.

Atmospheric inputs of sulfur into a terrestrial ecosystem were studied relative to a coal-fired power plant. Dry- and wet-fall inputs into cornfields in the vicinity of the sulfur source were calculated to be 0.82 and 4.41 kg/ha during the crop season. High wet-fall inputs of sulfur seemed to be due to regional transport and import of SO_4 into the area rather than due to the point source. Wet-fall inputs of sulfur did not increase linearly during the four-year study, while dry-fall input did. Foliar sulfur concentration in vegetation also increased temporally. It is suggested that this increase in foliar sulfur is due to the incremental dry fall of atmospheric sulfur. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

880
KRUPA, S. V., COSCIO, M. R., Jr., and WOOD, F. A., 1976, Evaluation of a coulometric procedure for the detection of strong and weak acid components in rainwater: Journal of the Air Pollution Control Association, v. 26, no. 3, p. 221-223.

This article describes a rapid coulometric procedure for identifying nonvolatile strong acids and volatile and nonvolatile weak acids in rain samples. A constant current is passed into the sample, with or without volatiles, and the changes in electromotive force are monitored with a potentiometer. Molarities of the various acids are calculated by plotting the function of the electromotive force against time in seconds according to Gran's theory. The procedure is useful at acid concentrations of 10^{-6} to 10^{-4} M.

881
KRUPA, S. V., COSCIO, M. R., Jr., and WOOD, F. A., 1976, Evidence for multiple hydrogen-ion donor systems in rain: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 415-422.

An integrated analytical system consisting of combined scanning electron microscopy and X-ray analysis, atomic absorption, colorimetry

881 (continued)
and coulometry was used to study rain water chemistry. The coulometry facilitated the determination in molarities of strong and non-volatile and volatile weak acids. The pH of individual rains in St. Paul-Minneapolis, Minnesota, ranged from 4.0 to 5.65 during the summer of 1974. Samples of a given rain from different sites had different qualitative and quantitative bases for the measured pH. Increase in strong acid concentrations with a decrease in pH was not an exclusive phenomenon. Molarities of weak acids (volatile and/or non-volatile) also increased with an increase in the acidity. Studies conducted on Twin Cities rain samples indicated that the total salt content expressed from the electrical conductivity could not be accounted for by the total concentrations of individual metals quantified (Fe, Pb, Zn, Mn, Cu, Cr, Cd, Ca, Mg, Na, and K). In addition, no correlation could be shown between the contents of SO_4^-, NO_3^-, Cl_2^- and PO_4^- and the observed changes in pH. [Abstract reprinted by permission of D. Riedel Publishing Company.]

882
KUCERA, Vladimir, 1976, Effects of sulfur dioxide and acid precipitation on metals and anti-rust painted steel: Ambio, v. 5, no. 5, p. 243-248.

This article surveys damage to building materials caused by airborne sulfur compounds and by acid precipitation. Corrosion of metals and anti-rust painted surfaces occurs more rapidly in polluted, urban environments than in rural environments. High concentrations of airborne sulfur pollutants in urbanized areas are the suspected cause. Increased corrosion rates are resulting in substantial economic losses.

883
KURTZ, J., and SCHEIDER, W. A., 1981, An analysis of acidic precipitation in south-central Ontario using air parcel trajectories: Atmospheric Environment, v. 15, no. 7, p. 1111-1116.

Precipitation samples were collected from the Muskoka-Haliburton region of Ontario and analyzed for pH, sulfate ion (SO_4^{2-}), and nitrate ion (NO_3^-) from April 1976 to April 1979. Analyses of event and composite samples indicate that precipitation most commonly occurrs with trajectories from the south and southwest octants. Most of the H+, SO_4^{2-} and NO_3^- deposited at Muskova-Haliburton was associated with trajectories from the south and southwest octants.

884
KWIATKOWSKI, R. E., and ROFF, J. C., 1976, Effects of acidity on the phytoplankton and primary productivity of selected northern Ontario lakes: Canadian Journal of Botany, v. 54, no. 22, p. 2546-2561.

884 (continued)
This article summarizes the effect of acidity on primary production, species composition, and abundance of phytoplankton in six lakes in the Sudbury region of Ontario. The pH of lake waters ranged from 4.05 to 7.15. A relationship was found between declining pH and increased water transparency and decreases in chlorophyl a. As pH declines, chlorophyta diminish and cyanophyta become dominant. The phytoplankton diversity index (DI) remains mostly unchanged at pH 7.0 to 5.0 but decreases at lower values.

L

885
LaBASTILLE, Anne, 1979, The killing rains: Garden, v. 3, no. 3, p. 8-13.

This article presents a general review of the causes and effects of acid rain. It discusses some short-term remedies such as liming affected lakes, and some long-term approaches to reducing air pollution caused by the burning of fossil fuels.

886
LABEDA, D. P., and ALEXANDER, Martin, 1978, Effects of SO_2 and NO_2 on nitrification in soil: Journal of Environmental Quality, v. 7, no. 4, p. 523-526.

This article describes the effects of continuous fumigation with low concentrations of sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) on the soil nitrification process. Nitrification in lime loam with a pH of 7.2 was not affected by continuous exposure to 0.5 ppm of SO_2 or to brief exposures to SO_2 at higher levels. The soluble levels of K, Mg, Ca, Mn, Fe, and Al were not increased by the treatment. Intermittent exposure to SO_2 decreased the rate of nitrate formation in Hudson silty clay loam (pH 5.0). Continuous fumigation of the acid soil with 10 ppm of SO_2 resulted in decreased nitrification, and fumigation with as little as 1.0 ppm increased the quantity of soluble Mn and Fe. Continuous fumigation of lime loam with 5 ppm of NO_2 inhibited the rate of ammonia disappearance, increased the rate of nitrate formation, and resulted in nitrate accumulation. Results indicate that nitrification in some soils is inhibited in areas having acute SO_2 and NO_2 pollution.

887
LAG, J., 1968, Relationships between the chemical composition of the precipitation and the contents of exchangeable ions in the humus layer of natural soils: Acta Agriculturae Scandinavica, v. 18, p. 148-152.

887 (continued)
This article discusses the relationship between chemical composition of atmospheric precipitation and leaching rates in the soil profile. It also discusses the contribution of trace elements to soils, and the possibilities for adsorption of ions with differing charges. Rain, snow, and humus samples from forests of Nort-Trondelag, Oppland, and Buskerud Counties, Norway, were analyzed for sulfur, calcium, magnesium, potassium, sodium, and pH. Determination of exchangeable metallic cations in 981 humus samples from podzol soils indicates that chemical processes result in an ion exchange equilibrium between the precipitation and raw humus.

888
LAKHANI, K. H., and MILLER, H. G., 1980, Assessing the contribution of crown leaching to the element content of rainwater beneath trees, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 161-172.

889
LANG, D. S., HERZFELD, D., and KRUPA, S. V., 1980, Responses of plants to submicron acid aerosols, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 273-290.

A continuous flow system for exposing vegetation to submicron sulfuric acid aerosols was developed. The aerosols were mechanically produced using a nebulization-impaction-neutralization process. Typical aerosol distributions had a mass mean diameter of about 0.5 μm and a standard geometric deviation near 1.7. Plants were injured during acute exposures to sulfuric acid aerosols. However, the aerosol concentrations required to produce visible injury were significantly higher than the measured ambient concentrations. All species exposed to the acid aerosols exhibited marginal and tip necrosis or interveinal necrosis. However, plant responses to sulfuric acid aerosol did not follow proportional relations to pollutant dose (concentration X time). Lack of proportional dosage relations suggested that active rather than passive mechanisms may be controlling the response. In the exposed tissue no increase in the leaf surface sulfur concentrations could be detected. On the contrary, there was an increase in the internal tissue sulfur levels. [Abstract reprinted by permission of Plenum Press.]

890
LANG, D. S., KRUPA, S. V., and SHRINER, D. S., 1978, Injury to vegetation incited by sulfuric acid aerosols and acidic rain: Air Pollution Control Association, 71st Annual Meeting and Exhibition, Houston, Texas, 1978: Pittsburg, Penn., Air Pollution Control Association, Paper no. 78-7.3, 15 p.

This article summarizes the effect of sulfuric acid (H_2SO_4) from automobiles on vegetation and the overall impact of sulfate aerosols from all sources on vegetation. Possible synergistic effects of sulfate aerosols and other pollutants on vegetation are discussed. A system for exposing vegetation to submicron sulfuric acid aerosol was developed; five plant species were examined after exposure to simulated acid rain; all showed characteristic symptoms of marginal and tip necrosis during acute exposures. When oak leaves were treated with simulated acid rain (pH 3.2), several areas of bifacial necrosis developed.

891
LARSON, G. L., SILSBEE, D. G., and MATHEWS, R. C., Jr., [1978], A brief review of causes and consequences of acid precipitation (rain and snow) in relation to potential effects on the resources of the Great Smoky Mountains National Park: Gatlinburg, Tenn., U.S. National Parks Service, 28 p.

This report gives of acid precipitation and its impact on soil, plants, water quality, and animals in the Great Smoky Mountains Park. The potential impact of acid precipitation on the park is defined. The pH of atmospheric deposition in the park ranges from 3.5 to 4.5. A lengthy bibliography is included.

892
LARSON, T. E., and HETTICK, Irene, 1956, Mineral composition of rainwater: Tellus, v. 8, no. 2, p. 191-201.

Sixty-two rain samples were collected from December 1953 through August 1954 near Savoy, Ill., and analyzed for sodium, potassium, chloride, sulfate, alkalinity, hardness, and nitrate-ammonia. Chloride was equal to the sum of sodium and potassium; sodium levels were three times potassium levels. Calcium plus magnesium was 10 times the amount of choride and equal to the sum of bicarbonate and sulfate. Sulfate was equal to twice the sum of ammonium and nitrate. These results indicate that salt from sea mist constitutes a negligible part of the mineral content of rainwater; the remainder is attributed to combustion of fossil fuels.

893
LARSON, T. V., CHARLSON, R. J., KNUDSON, E. J., CHRISTIAN, G. D., and HARRISON, Halstead, 1975, The influence of a sulfur dioxide point source on the rain chemistry of a single storm in the Puget Sound region: Water, Air, and Soil Pollution, v. 4, no. 3-4, p. 319-328.

This article examines the influence of a major point source of sulfur dioxide (SO_2) on rain chemistry. Rainwater samples collected near a nonferrous iron smelter during a storm indicate a correlation between hydrogen ion and sulfate ion. Arsenic and possibly antimony appear to be good tracers of the smelter plume. A model of the sulfate plume, as defined by rainout and concentrations, is compared with empirical and semiempirical models.

894
LARSON, T. V., and HARRISON, Halstead, 1977, Acidic sulfate aerosols--formation from heterogeneous oxidation by O_3 in clouds: Atmospheric Environment, v. 11, no. 12, p. 1133-1141.

This article presents a mathematical relationship between SO_2 oxidation by O_3 in clouds and the production of acid-sulfate aerosol in the atmosphere. This heterogeneous oxidation reaction is compared with other SO_2 oxidation processes, competing SO_2 removal mechanisms, and with atmospheric measurements to show that the O_3 reaction is a plausible SO_2 oxidation pathway in the atmosphere.

895
LARSON, T. V., HORIKE, N. R., and HARRISON, Halstead, 1978, Oxidation of sulfur dioxide by oxygen and ozone in aqueous solution--a kinetic study with significance to atmospheric rate processes: Atmospheric Environment, v. 12, p. 1597-1611.

This article describes a study of oxidation rates of SO_2 by O_2 and O_3 in buffered aqueous solutions ranging from pH 4 through 12, and at temperatures between 5°C and 25°C, oxygen partial pressures between 0.11 and 1.0 atm, and ozone partial pressures between 0.2 and 1.0 ppm. The O_2 and O_3 rates were nearly equal in neutral or weakly acidic solution, but the O_3 reaction dominated the O_2 reaction in clouds with pH ≤ 5 at typical O_3 mixing fractions that were ≥ 50 ppb.

896
LAUENROTH, W. K., and HEASLEY, J. E., 1980, Impact of atmospheric sulfur deposition on grassland ecosystems, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 417-430.

896 (continued)
We examined impacts of sulfur deposition on grassland ecosystems, focusing upon carbon flow and nutrient cycling. Results from a five-year field experiment with controlled sulfur dioxide (SO_2) concentrations are presented and discussed in terms of their system-level implications. The most important system-level results of this experiment are decreased decomposition rates and increased sulfur concentrations in all system components as a result of exposure to low SO_2 concentrations. A projection of these results to a hypothetical equilibrium state under conditions of substantial sulfur deposition from the atmosphere is presented. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

897
LAWSON, D. R., and WINCHESTER, J. W., 1979, Atmospheric sulfur aerosol concentrations and characteristics from the South American Continent: Science, v. 205, p. 1267-1269.

Aerosol samples were collected from eight geographically distinct locations in South America by six cascade impactors during the winter of 1976 and summer of 1977. Results indicate that the tropospheric sulfur background concentration is about 50 nanograms per cubic meter (ng/m^3) of air >1 micrometer in aerodynamic diameter. Time-sequence filter samples taken concurrently at most sites indicate an average sulfur concentration of 95 ng/m^3 (nonsea spray). The reported concentrations are substantially lower than most published values for nonurban areas in the Northern Hemisphere, and may represent a natural troposphere background level of aerosol sulfur.

898
LAZEREV, K. G., ed., 1971, Khimicheskiy sostav atmosfernykh osadkov i poverkhnostnykh vod: Gidrokhimicheskiye Materialy, v. 56, p. 3-120. [In Russian.]

This special issue of "Gidrokhimicheskiye Materialy" contains 14 papers on the chemical composition of atmospheric precipitation and surface waters, the discharge of solutes, the relationship of mineralization to ionic composition and water regime of rivers, and the content and balance of trace elements in lakes and reservoirs. The articles describe methods for determining individual organic components and complex compounds of heavy metals with organic substances in natural water.

899
LAZRUS, A. L., LORANGE, Elizabeth, and LODGE, J. P., Jr., 1970, Lead and other metal ions in United States precipitation: Environmental Science and Technology, v. 4, no. 1, p. 55-58.

899 (continued)
Precipitation samples were collected at 32 sites from September 1966 to January 1967 throughout the United States and analyzed for lead, copper, iron, manganese, and nickel by atomic absorption. Manmade sources are believed to be the primary sources of these constituents in precipitation. Lead concentrations in precipitation correlate with the amount of gasoline consumed in the sampling area. Mean concentrations of metals in precipitation are compared with analogous values in surface waters and results indicate that lead concentrations in atmospheric precipitation are twice as great as in surface waters.

900
LEADERER, B. P., HOLFORD, T. R., and STOLWIJK, J. A. J., 1979, Relationship between sulfate aerosol and visibility: Journal of the Air Pollution Control Association, v. 29, no. 2, p. 154-157.

Visibility and meteorological data from four airports across the United States are compared with total atmospheric particulate mass, sulfate aerosol mass, and nitrate aerosol mass in samples from sites near the airports. Prevailing visibility observation at the airports, in the absence of local pollutant sources, precipitation, or fog, were strongly associated with local atmospheric sulfate mass and may be used to estimate atmospheric sulfate concentrations.

901
LeBLANC, Fabius, 1969, Epiphytes and air pollution, in Air pollution: European Congress on the Influence of Air Pollution on Plants and Animals, 1st, Wageningen, The Netherlands, 1968, Proceedings: Wageningen, The Netherlands, PUDOC, Center for Agricultural Publishing and Documentation, p. 211-221.

This article describes the effect of two sintering plants on epiphytic vegetation. Epiphytic lichens and mosses are more sensitive to sulfur dioxide (SO_2) than most flowering plants and are good indicators of SO_2 pollution insofar as they are rarely found in the vicinity of emission sources. Epiphytes may be used to determine the long-range effects of SO_2 in a region.

902
LeBLANC, Fabius, and RAO, D. N., 1973, Effects of sulphur dioxide on lichen and moss transplants: Ecology, v. 54, no. 3, p. 612-617.

Injury symptoms in lichens and moss transplants at Sudbury, Ontario, were studied in relation to SO_2 concentrations from May through October 1970. Higher concentrations of SO_2 produced more severe effects to levels of pollution. A quantitative correlation is given between the levels of injuries produced and the levels of SO_2 that they are exposed to in the field. Acute injury occurred when SO_2 were greater than .03 ppm, chronic injury occurred when SO_2 ranged from .006 to .03 ppm, and no injury occurred when SO_2 concentrations were less than .002 ppm.

903
LeBLANC, Fabius, RAO, D. N., and COMEAU, Gilberte, 1972, The epiphytic vegetation of *Populus balsamifera* and its significance as an air pollution indicator in Sudbury, Ontario: Canadian Journal of Botany, v. 50, p. 519-528.

Indices of atmospheric purity (IAP) were determined at 31 sites near Sudbury, Ontario, by assessing the number, frequency-coverage, and resistance factor of *Populus balsamifera*. The investigation area was classified into five zones based on IAP, and these zones are compared with SO_2 levels (ground-level average concentration). Epiphytic vegetation provides an accurate and economical method for assessing and mapping long-range transport of air pollutants.

904
LECHER, D. W., 1974, Acid rain measurements at Trenton, New Jersey and some ecological implications for New Jersey: Bulletin of the New Jersey Academy of Science, v. 19, no. 2, p. 49-51.

Chemical analyses of rain samples collected at Trenton, N.J., during June 1974 indicate the rain to be 10 to 100 times more acid than normal. The pH of rain collected during different storms ranged from 3.69 to 4.10. The weighted mean pH was 3.97. This article includes a discussion of the impact of acid precipitation on the New Jersey environment.

905
LEE, J. J., 1981, Acid rain effects on California crop yield and foliar injury, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 29.

906
LEE, J. J., NEELY, G. E., and PERRIGAN, S. C., 1980, Sulfuric acid rain effects on crop yield and foliar injury: Corvallis, Ore., U.S. Environmental Protection Agency, EPA-600/3-80-016, 20 p.

This article assesses the relative sensitivity of major U.S. crops to sulfuric acid rain. Plants were grown in a controlled environment and exposed to simulated acid rain at pH 3.0, 3.5, and 4.0; the pH of control rain was 5.7. Injury to foliage and decreased yield are common responses to acid rain, but foliar injury is not considered a good indicator of crop yield.

907
LEE, J. J. and WEBER, D. E., 1979, The effect of simulated acid rain on seedling emergence and growth of eleven woody species: Forest Science, v. 25, no. 3, p. 393-398.

This article summarizes the effects of simulated acid rain on seedling emergence and growth of 11 woody species. Seeds were exposed to simulated sulfuric acid rain at pH 3.0, 3.5, and 4.0; pH of control rain was 5.6. Eight of the species were affected, but the magnitude and severity of injury among species varied. Seedling emergence was stimulated in four species by at least one treatment and was inhibited in one species.

908
LEE, J. J., and WEBER, D. E., 1980, Effects of sulfuric acid rain on two model hardwood forests--throughfall, litter leachate, and soil solution: Corvallis, Ore., U.S. Evironmental Protection Agency, EPA-600/3-80-014, 38 p.

Model forests of sugar maple (*Acer saccharum*) and red alder (*Alnus rubra*) were treated with simulated acid rain (pH 3.0, 3.5, 4.5, and 5.6). Water samples were collected from above and below the canopy, below the litter, and from 20 cm and 1 m below the soil surface. Chemical composition of throughfall was not significantly different from that of the rain, but litter leachate had consistently higher concentrations of calcium and magnesium and higher pH. Sulfate concentration in soils from plots receiving the most acidic rain (pH 3.0) became increasingly higher than the in other plots until after three years. After three years sulfate concentrations were approximately equal to sulfate concentrations in the simulated rain.

909
LEE, Ying-Hua, 1979, Linear plot of Brosset's function of the slope of Gran's plot--a useful method for simultaneous determination of concentration and pK-value of a weak acid: Gothenburg, Swedish Water and Air Pollution Institute, 23 p.

This report presents a method for simultaneous determination of the concentration and pK value of a weak acid. The method is based on a linear plot of Brosset's function for the slope of Gran's plot. Use of the method for weak acids (humic acids) in lake water is demonstrated.

910
LEE, Ying-Hua, and BROSSET, Cyrill, 1978, The slope of Gran's plot--a useful function in the examination of precipitation, the water-soluble part of airborne particles, and lake water: Water, Air, and Soil Pollution, v. 10, p. 457-469.

910 (continued)
This article describes a method of applying the slope of Gran's plot to acid base titration curves. The standard titration technique was refined and applied to precipitation, leaching solutions of airborne particles, and lake waters. Results indicate that the dissociation constant and concentration of the acids that are present can often be determined from an accurate measurement of the slope of the plot.

911
LEE, Ying-Hua, and BROSSET, Cyrill, 1979, Interaction of gases with sulphuric acid aerosol in the atmosphere, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 181-192.

912
LEEP, N. W., and FAIRFAX, J. A. W., 1976, The role of acid rain as a regulator of foliar nutrient uptake and loss, in Dickinson, C. H., Preece, T. F., eds., 1976, Microbiology of aerial plant surfaces: New York, Academic Press, p. 107-118.

Hydrogen ion (H^+) concentration is believed to be the major regulator of losses of foliar nutrients. Changes in the H^+ content of a leaching solution result in a change in the quantity of cations lost from foliage. The increased H^+ concentration found in acidic precipitation may change the nutrient balance of foliage. The flow of cations between different components of an ecosystem is affected and the leaf surface, as a habitat for micro-organisms, is altered.

913
LEGGE, A. H., 1980, Primary productivity, sulfur dioxide, and the forest ecosystem--an overview of a case study, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 51-62.

The objective of the West Whitecourt case study was to determine the consequence of chronic long term exposure of a forest ecosystem to low concentrations of sulphur dioxide emissions originating from a "sour gas" processing plant in west-central Alberta, Canada. An interdisciplinary ecological approach was utilized. The vegetation and atmospheric environment were characterized. A concept of ecologically comparable sampling site selection was developed and applied in the West Whitecourt study area. Laboratory and field measurements

913 (continued)
revealed a reduction in photosynthetic rate in lodgepole pine x jack pine (*Pinus contorta* x *Pinus banksiana*) in the field. Reduction of adenosine triphosphate (ATP) concentration in pine tissue during SO_2 fumigation in the field followed by complete recovery after termination of SO_2 fumigation and the disruption of mineral nutrient cycling in the forest ecosystem were observed. Basal area increment measurements of 200 lodgepole x jack pine trees from 5 ecologically comparable sampling sites revealed a decrease in wood production directly related to the presence of sulphur dioxide emissions. It is recommended that the concepts of the assimilatory capacity of the environment for sulphur gas pollutants and irreversible ecological modification be utilized as measures of environmental quality. [Abstract reprinted by permission of U.S. Forest Service.]

914
LEGGE, A. H., JAQUES, D. R., AMUNDSON, R. G., and WALKER, R. B., 1977, Field studies of pine, spruce and aspen periodically subjected to sulfur gas emissions: Water, Air, and Soil Pollution, v. 8, no. 1, p. 105-129.

Field studies of photosynthesis in *Pinus contorta/Pinus banksiana* (lodgepole pine/jack pine) hybrids, *Picae glauca* (white spruce) and *Populus tremuloides* (aspen) subjected to SO_2 and H_2S from a nearby natural gas processing plant were initiated near Whitecourt, Alberta, Canada during the summer of 1974. The site was characterized as a *Pinus-Picea glauca/Arctostaphylos uva-ursi* association (pine-white sprucebearberry). A 15-m high scaffold was used to access to mid-crown foliage in the pines while the spruce and aspen were accessible from the ground. Net assimilation rates, transpiration rates and leaf resistances were calculated and water deficits were monitored. Photosynthetic rates measured were in a low range for the conifers studied, with pine having a maximum of 3.28 mg dm^{-2} h^{-1} and white spruce a maximum value of 2.3 mg dm^{-2} h^{-1}. The low maximum photosynthetic rate determined for aspen is thought to be attributable to the onset of autumn. Chemical analyses for SO_4-sulfur using the methylene blue colorimetric method of Johnson and Nishita (1952) showed levels of 300 to 700 ppm, with the older foliage showing slightly higher values. Visible chronic SO_2 symptoms had a pronounced sun, or upward, orientation. Ambient SO_2, H_2S and total S were measured using a Tracor 270HA Atmospheric Sulfur Analyzer (chromatographic method) and trends in ambient SO_2 concentrations using an Envirometrics SO_2 Analyzer (polarographic method). Concentration was found to be variable for SO_2 and generally below 0.05 ppm. A concentration gradient of SO_2 was found to exist in the lodgepole pine/jack pine stand with the SO_2 values above the canopy generally higher than below the canopy (0.1 ppm above and 0.05 ppm below). This condition was occasionally reversed. The plant canopy is considered to act as a barrier to downward diffusion of the S emissions in the first case and also a barrier to upward diffusion of S emissions present due to advection in the stand in the second case. The vegetative environment surrounding the Windfall Gas Plant is definitely affected by S gas emissions but the extent remains to be determined. [Abstract reprinted by permission of D. Riedel Publishing Company.]

915
LEIVESTAD, H., and MUNIZ, I. P., 1976, Fish kill at low pH in a Norwegian river: Nature, v. 259, p. 391-392.

The decline in freshwater fish populations (particularly salmon and trout) in southern Norway is associated with the increasing acidity in rivers and lakes caused by acid precipitation. The fishkill, which occurred in 1975 in the Tovdal River, supports the hypothesis that the pollutants released in spring snowmelt lowers the total ion content of rivers and lakes and reinforces the pH stress on fish.

916
LEIVESTAD, H., MUNIZ, I. P., and ROSSELAND, B. O., 1980, Acid stress in trout from a dilute mountain stream, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 318-319.

917
LELAND, E. W., 1952, Nitrogen and sulfur in the precipitation at Ithaca, N.Y.: Agronomy Journal, v. 44, p. 172-175.

Precipitation samples were collected from 1931-49 at Ithaca, N.Y. and analyzed for nitrogen and sulfur. Comparison of these data with data collected during 1918-26 indicates that the average amounts of nitrogen and sulfur had increased by 21 percent and 27 percent, respectively. The increase is attributed largely to a 23-percent increase in rainfall.

918
LEONARD, R. L., GOLDMAN, C. R., and LIKENS, G. E., 1981, Some measurements of the pH and chemistry of precipitation at Davis and Lake Tahoe, California: Water, Air, and Soil Pollution, v. 15, p. 153-167.

Precipitation at Davis, Calif. and Lake Tahoe, Calif., is more acidic than water in equilibrium with atmospheric CO_2 (pH <5.6).

918 (continued)
Acidity at Lake Tahoe increased during the 5-year period of the study from 1972-73 and 1977-78. Sulfate is the dominant acid anion; its probable major source is industry in the San Francisco Bay region. Automobile exhaust emissions contribute sulfate and nitrate precursors to the atmosphere.

919
LESLIE, A. C. D., AHLBERG, M. S., WINCHESTER, J. W., and NELSON, J. W., 1978, Aerosol characterization for sulfur oxide health effects assessment, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 729-733.

The mean concentrations of sulfur in six particle size fractions, from <0.25 μm to >4 μm aerodynamic dia. have been determined in Florida during July-August and December, 1976 sampling seasons. A trend of decreasing concentration along the length of Florida, at ten sites from Pensacola to Miami, is found for sulfur in the fine particle mode, <2 μm dia. but not for >2 μm coarse mode sulfur. The trend is most regular for 0.5-1 μm particles, and urban concentrations show no consistent departure from the nonurban trend in this size range. Smaller and larger particle concentrations are more locally variable. The trends are interpreted in terms of a flow of continental air containing a pollution-derived fine particle sulfur component, into Florida during northerly wind regime and of less polluted maritime air with southerly flow. The magnitude of the apparent decrease in average concentration from north to south is dependent on the mix of air flow regimes at various locations in the state during the sample collection periods. The qualitative finding of the decreasing trend, however, may be typical in Florida over much of the year and may be useful for designing epidemiological studies of the relation between fine particle sulfur and public health. [Abstract reprinted by permission of Pergamon Press.]

920
LEWIS, J. E., and HREBENYK, Bohdan, 1979, Summer acid rain events in the Schefferville, Quebec area: Climatological Bulletin, no. 26, p. 1-9.

This article describes the variability of pollutant deposition storms at Schefferville, Nouveau Quebec, in July and August, 1978. Chemical constituents of rain were determined on an event basis, and the data were compared with data collected by the Canadian Network for Sampling Precipitation (CANSAP). Results showed a certain combination of atmospheric conditions produces individual synoptic events that increase the frequency of acid rain in Nouveau Quebec. Specific, infrequent events may yield the above-normal acidity values in Schefferville data.

921
LEWIS, W. M., Jr., 1981, Precipitation chemistry and nutrient loading by precipitation in a tropical watershed: Water Resources Research, v. 17, no. 1, p. 169-181.

Bulk precipitation samples were collected weekly for 2 years at Lake Valencia, Venezuela and were analyzed for total particulates, particulate carbon, hydrogen, nitrogen, and phosphorus, major soluble cations and anions, and soluble nitrogen, phosphorus, and carbon compounds. Striking seasonal peaks in the loading rates of almost all components were noted. Peaks occurred abruptly with the first rains except for soluble inorganic phosphorus and insoluble particulates, which began to peak before the rains began. The total annual loading may occur in a flush lasting 1 or 2 weeks. The removal of nitrogen oxides is dramatic and may result in acidic rainfall (pH <4.0) at this time. The total amount of rainfall in a given week is the most important factor in the variation of loading rates, according to a components of variance analysis. After the first 2 weeks of flushing, a seasonal decline in loading of some components occurs, but the trend is weak.

922
LEWIS, W. M., Jr., and GRANT, M. C., 1978, Sampling and chemical interpretation of precipitation for mass balance studies: Water Resources Research, v. 14, no. 6, p. 1098-1104.

This paper describes techniques and equipment for sampling atmospheric precipitation and methods for interpretation of data. Total dry and wet precipitation consists of the (1) dissolved materials in aqueous precipitation, (2) water-soluble component of dry precipitation, and (3) water-insoluble component of wet or dry precipitation. The methods used in collecting and processing precipitation samples greatly affect the effectiveness of determining the contributions of these components. Chemical interpretation of precipitation samples is controlled by (1) variable leaching of dry fallout, (2) particle formation and chemical repartitioning in aqueous precipitation, (3) height, texture, and composition of the collector surfaces, (4) contamination by birds, insects, and pollen and, (5) method of sample storage. Collectors are discussed and a design is given of a model collector.

923
LEWIS, W. M., Jr., and GRANT, M. C., 1979, Changes in the output of ions from a watershed as a result of the acidification of precipitation: Ecology, v. 6, no. 6, p. 1093-1097.

923 (continued)
The influx of hydrogen ion (H^+) to a high-elevation watershed in Colorado increased by a total of 0.142 (meq/m^2) per week. Outflow of SO_4, NO_4, NH_3, and dissolved organic matter in streams increased significantly. H^+ entering the watershed by acidic precipitation combines with bicarbonate ions in the soil, which may account for the reduction in bicarbonate outflow from the watershed. Because carbonates are not present in the soil, a combination of acid with bicarbonate may lead to the production and release of free CO_2 in amounts equivalent to the acid that is neutralized. Acid precipitation seems to cause a stoichiometric reduction in bicarbonate output and smaller but potentially important shifts in the release of other ions also.

924
LEWIS, W. M., Jr., and GRANT, M. C., 1980, Acid precipitation in the western United States: Science, v. 207, p. 176-177.

Precipitation data collected at a rural area near the Continental Divide in Colorado from 1975-78 indicate surprisingly low pH values for bulk precipitation and a significant downward trend during the 3-year sampling period. An increased amount of nitric acid in precipitation may be a possible cause of this decrease. (See also Kelly, T. J., and Stedman, D. H., 1980, herein.)

925
LI, Ta-Yung, 1975, [Comments on] The long range transport of airborne material and its removal by deposition and washout-I-II: Atmospheric Environment, v. 9, no. 10, p. 946-947.

This is a commentary on a paper by R. A. Scriven and B. E. A. Fisher [1975, herein], which presents a model of atmospheric diffusion of airborne material. Li states that measurement of ground-level sulfur dioxide would be useful to verify the model.

926
LI, Ta-Yung and LANDSBERG, H. E., 1975, Rainwater pH close to a major power plant: Atmospheric Environment, v. 9, p. 81-88.

Rain samples were collected during heavy summer showers in a network of rain gages 0.5 to 5 km from a powerplant in south Maryland. Sample pH ranged from 3.0 to 5.7, with modal values between 3.6 and 4.0. The washout of SO_2 from the plume is affected by wind direction in the ground layer at the time of the shower. The pH values decrease in a concentric pattern from the source in calm conditions.

927
LIBERTI, Arnaldo, BROCCO, D., and POSSANZINI, M., 1978, Adsorption and oxidation of sulfur dioxide on particles, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 255-261.

The role of atmospheric particulate matter is affecting atmospheric SO_2 and its reactions have been investigated. A variety of dusts of various sources (urban particulate matters and stack emissions of industrial plants) have been characterized in terms of their physical and chemical properties and submitted to a SO_2 adsorption process at room temperature and desorption at 175°C.

The interaction between particles and SO_2 can occur through two processes: adsorption and conversion to sulphate. The extent of these processes depends upon the particles, chemical composition and their nature which can be defined in terms of pH, titratable acidity, surface area, humidity and degree of surface coverage by adsorbed components.

SO_2 adsorption by particles is the primary process which occurs in two steps, only the first one being apparently of environmental significance. Humidity has an important role in the adsorption, the higher its value the higher results the amount of adsorbed SO_2. The behaviour of atmospheric dusts collected in different areas and seasons is very similar, the reaction constant of the first order process being 4-5 x 10^{-2} min^{-1}.

Both "fresh" particles coming from stacks, which do not carry SO_2, as well as "aged" atmospheric particles adsorb SO_2, the relative extent of the process being mainly determined by the dust reaction. The former in most cases do not release SO_2 by heating, this behaviour being taken as an example of chemisorption whereas the latter lose SO_2 by heating, SO_2 being retained by only a physical bond.

Conversion to sulphate occurs with a very high rate on particles coming from industrial emissions, the alkaline reaction being the determining factor, whereas it does not take place on urban atmospheric dusts to an appreciable extent.

This mechanism is supported by measurements by differential thermal analysis and by X-ray photo-electron spectroscopy.

Though, in the atmosphere, it is impossible to discriminate various effects due to homogeneous and heterogeneous reactions, the main interaction between SO_2 and particulate matter is adsorption, most catalytic reactions occurring at high temperature and most probably at the chimney outlet. [Abstract reprinted by permission of Pergamon Press.]

928
LIBERTI, Arnaldo, MASSIMILIANO, Possanzini, and VICEDOMINI, Mario, 1972, The determination of the non-volatile acidity of rain water by a coulometric procedure: Analyst, v. 97, p. 352-356.

This article presents a method for determining nonvolatile acidity of rainwater and of any dilute acid solution (10^{-4} to 10^{-6} m). The method is based on the coulometric titration of a sample from which carbon dioxide has been removed by bubbling nitrogen through it. The end point is determined by potentiometry with a glass electrode according to Gran's theory. The acidity of both strong and weak acids may be determined; standard deviation is ±5 percent.

929
LIDDLE, Gerry, 1979, Potential socio-economic impacts of acid rain on the fishing lodge industry of northern Ontario, in, Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 104-111.

930
LIKENS, G. E., 1972, The chemistry of precipitation in the central Finger Lakes region: Ithaca, N.Y., Cornell University, Water Resources and Marine Sciences Center, Technical Report 50, 1 v.

This report discusses the chemistry of precipitation in the central Finger Lakes region during 1970-71. The annual pH of precipitation samples ranged from 3.98 to 4.02. Hydrogen ion was the major cation; sulfate the major anion. It is suggested that sulfur introduced into the atmosphere by combustion of fossil fuels is transported to northeastern United States. The effects of increased acidity of precipitation in the northeast may have significant ecological effects.

931
LIKENS, G. E., 1975, Acid precipitation--our understanding of the phenomenon, in Acid precipitation: Conference on Emerging Environmental Problems, Rensselaerville, N.Y., 1975, Proceedings: New York, U.S. Environmental Protection Agency, p. 45-75.

932
LIKENS, G. E., 1976, Acid precipitation: Chemical and Engineering News, v. 54, no. 48, p. 29-44.

The acidity of rain and snow has increased for more than two decades and the enviromental consequences of these phenomena are far-reaching. Acid precipitation is associated with sharp declines in the number of fish in lakes and streams, and in some cases total extinction of fish. Acid precipitation may also be severely detrimental to terrestrial ecosystems and may increase weathering and corrosion of materials and buildings. Data on the acidity of precipitation are given for the United States and Scandinavia.

933
LIKENS, G. E., 1980, Summing-up and recommendations, in Hendrey, G. R., ed., Limnological aspects of acid precipitation: International Workshop, Sagamore Lake Conference Center, N.Y., 1978, Proceedings: Upton, N.Y. Brookhaven National Laboratory, p. 42-43.

934
LIKENS, G. E., and BORMANN, F. H., 1974, Acid rain--a serious regional environmental problem: Science, v. 184, no. 4142, p. 1176-1179.

Precipitation in the Northeast is significantly more acidic than elsewhere in the United States, and the annual average pH is about 4. Data from individual storms in the Northeast show pH ranges from 2.1 to 5. Increases in acidity are associated with increased use of fossil fuels.

935
LIKENS, G. E., and BORMANN, F. H., 1974, Linkages between terrestrial and aquatic ecosystems: Bioscience, v. 24, no. 8, p. 447-456.

This atricle examines the relationship between terrestrial outflow and aquatic inflow in terms of toxic substances, dissolved nutrients, eutrophication, and atmospheric deposition on terrestrial and aquatic ecosystems. The large quantities of sulfur oxides and nitrogen oxides released into the atmosphere by the combustion of fossil fuels may be oxidized and hydrolyzed to form sulfuric and nitric acids. If the acids are not neutralized by alkaline substances in the atmosphere, they are washed out by precipitation.

936
LIKENS, G. E., BORMANN, F. H., and EATON, J. S., 1980, Variations in precipitation and streamwater chemistry at the Hubbard Brook Experimental Forest during 1964 to 1977, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 443-464.

937
LIKENS, G. E., BORMANN, F. H., EATON, J. S., PIERCE, R. S., and JOHNSON, N. M., 1976, Hydrogen ion input to the Hubbard Brook Experimental Forest, New Hampshire, during the last decade: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 435-445.

937 (continued)
Being downwind of eastern and midwestern industrial centers, the Hubbard Brook Experimental Forest offers a prime location to monitor long-term trends in atmospheric chemistry. Continuous measurements of precipitation chemistry during the last 10 yr provide a measure of recent changes in precipitation inputs of H ion. The weighted average pH of precipitation during 1964-65 to 1973-74 was 4.14, with a minimum annual value of 4.03 in 1970-71 and a maximum annual value of 4.21 in 1973-74. The sum of all cations except H ion decreased from 51 $\mu eq\ L^{-1}$ in 1964-65 to 23 $\mu eq\ L^{-1}$ in 1973-74, providing a significant drop in neutralizing capacity during this period. Based upon regression analysis, the input in equivalents of H ion and nitrate increased by 1.4 fold and 2.3-fold respectively, from 1964-65 to 1973-74. Input of all other ions either decreased or showed no trend. Based upon a stoichiometric formation process in which a sea-salt, anionic component is subtracted from the total anions in precipitation, $SO_4^{=}$ contribution to acidity dropped from 85% to 66%, whereas NO_3^{-} increased from 15% to 30% during 1964-65 to 1973-74. The increased annual input of H ion at Hubbard Brook during the past 10 yr is highly correlated with the increased input of nitrate in precipitation. [Abstract reprinted by permission of D. Riedel Publishing Company.]

938
LIKENS, G. E., BORMANN, F. H., and JOHNSON, N. M., 1972, Acid rain: Environment, v. 14, no. 2, p. 33-40.

Chemical analyses of precipitation in northwestern Europe show a trend toward increased acidity, particularly during the past 15 years. Acidic precipitation is now also affecting large geographic regions of the world. Its effect on ecosystems are manifold and complex. Some of these effects are (1) changes in leaching rates of nutrients from plant foliage, (2) changes in leaching rates of soil nutrients, (3) acidification of lakes and rivers, (4) alteration of plant and animal metabolisms, and (4) corrosion of structures.

939
LIKENS, G. E., BORMANN, F. H., and JOHNSON, N. M., 1981, Interactions between major biogeochemical cycles in terrestrial ecosystems, in Likens, G. E., ed., Some perspectives of the major biogeochemical cycles: New York, John Wiley, p. 93-112.

Global cycles of carbon, sulfur, nitrogen, and phosphorus have been affected by man's activities, yet little quantitative information is available on the interaction between individual biogeochemical cycles of elements in terrestrial ecosystems. Acid precipitation increases the flux of aluminum, phosphorus, and calcium into or out of soils and may decrease the flux of carbon by inhibiting photosynthesis and decomposition of organic matter.

The nitrogen and sulfur contained in acid precipitation, acting as plant nutrients, may stimulate primary productivity and decomposition in some ecosystems, which enhances the flux of the carbon in terrestrial ecosystems.

940
LIKENS, G. E., BORMANN, F. H., PIERCE, R. S., EATON, J. S., and JOHNSON, N. M., 1977, Biogeochemistry of a forested ecosystem: New York, Springer-Verlag, 146 p.

A summary and interpretation of data collected at the Hubbard Brook Experimental Forest, New Hampshire collected since 1963 is presented. The interpretation of data is aimed at determining the response of a forested ecosystem to biochemical conditions. Data on precipitation, hydrology, weathering, and the dynamics of atmospheric gases and water are given. Variations in input-output budgets are discussed. The influence of acid precipitation on the aquatic and terrestrial environment of the Hubbard Brook Experimental Forest is investigated.

941
LIKENS, G. E., and BUTLER, T. J., 1981, Recent acidification of precipitation in North America: Atmospheric Environment, v. 15, p. 1103-1109.

Historical data on the chemistry of precipitation show a widespread increase in acid precipitation in eastern North America during the past 25 years. Precipitation in certain remote areas of eastern North America is as much as 30 to 40 times more acidic than would be expected. Some storms have been several hundred to more than a thousand times more acidic than expected. Both remote and urban areas are affected. Precipitation before 1930 had pH greater than 5.6, according to limited data for this time period. By 1956, pH values were below 5.6, according to analyses of wet-only samples collected monthly. Data from two precipitation monitoring networks operated nationwide during 1965-66 showed results similar to those obtained in 1955-56 with some westward extension of acid precipitation.

942
LIKENS, G. E., EATON, J. S., and GALLOWAY, J. N., 1977, Precipitation as a source of nutrients for terrestrial and aquatic ecosystems, in Precipitation scavenging, Champaign, Ill., 1974, Proceedings: [Oak Ridge, Tenn.], U.S. Energy Research and Development Administration, ERDA Symposium Series 4, p. 552-570.

942 (continued)
Atmospheric deposition of nutrients, heavy metals, acids, and other toxicants may have signficant adverse ecological effects on natural ecosystems. Precipitation is a major source of nutrients for terrestrial ecosystems, and contributions of inorganic nitrogen and phosphorus may exceed losses in drainage waters. Direct precipitation is a major source of nutrients for lakes, particularly where the watershed is undisturbed and the ratio of lake surface area to drainage area is large. Direct precipitation may account for 40 to 55 percent of the phosphorus and 45 to 75 percent of the inorganic nitrogen entering some oligotrophic lakes. Smaller percentages, but significant amounts, of nitrogen and phosphorus are contributed by precipitation to eutrophic lakes. No long-term records of phosphorus in precipitation in the United States are available, but nitrate concentrations in the Northeast have increased 2.5- to 3-fold since 1945.

943
LIKENS, G. E., JOHNSON, N. M., GALLOWAY, J. N., and BORMANN, F. H., 1976, Acid precipitation: Strong and weak acids: Science, v. 194, p. 643-645.

This note comments on a paper on the contribution of weak acids to the acidity of precipitation by J. O. Frohlinger and R. Kane, titled "Precipitation--its acidic nature." Contrary to Frohlinger and Kane's hypothesis, the authors conclude that weak organic acids could contribute to the free and total acidity of precipitation if present in substantial quantities and that the presence of strong acids in precipitation cannot be overlooked. (See Frohlinger, J. O., and Kane, R., 1976, herein.)

944
LIKENS, G. E., WRIGHT, R. F., GALLOWAY, J. N., and BUTLER, T. J., 1979, Acid rain: Scientific American, v. 241, no. 4, p. 43-51.

The acidity of rain and snow is increasing sharply in eastern United States and western Europe. The release of sulfur and nitrogen oxides by burning of fossil fuels is believed to be the principal cause of acidic precipitation. Freshwater ecosystems underlain by siliceous bedrock such as granite, gneisses, quartzite and quartz sandstone are particularly sensitive to acidic deposition because these rock types have a low ability to neutralize acids (buffering capacity).

945
LILJESTRAND, H. M., 1981, Measurement and interpretation of acid rainfall in the Los Angeles basin, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 25.

946
LILJESTRAND, H. M., and MORGAN, J. J., 1978, Chemical composition of acid precipitation in Pasadena, Calif: Environmental Science and Technology, v. 12, no. 12, p. 1271-1273.

Rainfall samples were collected at Pasadena, Calif., from February 1976 to September 1977 in wet-only precipitation samplers and analyzed for major cations and anions. Volume-weighted mean pH was 4.06. Nitric acid was the dominant acid and exceeded the acid contribution of sulfuric acid by 32 percent. The pH is controlled by the interaction of bases (NH_3, metal carbonates, and oxides) and strong acids (HNO_3 and H_2SO_4).

947
LILJESTRAND, H. M., and MORGAN, J. J., 1979, Error analysis applied to indirect methods for precipitation acidity: Tellus, v. 31, no. 5, p. 421-431.

This article evaluates the sensitivity of indirect methods of pH determination to random and systematic errors and provides confidence limits on values derived from historical data used in the indirect methods so that real changes over time can be detected. Conductivity and charge balances and chemical source models were used to verify measured acidities. Indirect methods have been applied to rainwater-chemistry data to quantify acidity values when direct measurements of precipitation acidity are not in historical records. Random uncertainty in the major-ion concentrations is important for rainwaters of high ionic strength. These uncertainties are largest with pH values about 5.65 for the charge balance and source-strength methods and those with pH 6.1 for the conductivity balance method. Estimates of uncertainty in historical mean values of ion concentrations in precipitation are used to calculate upper and lower limits in the acidity of rainwater in the United States before 1970. A trend of increasing acidity of precipitation in the Northeast is found even after applying error analysis.

948
LILJESTRAND, H. M., and MORGAN, J. J., 1980, Modeling the chemical composition of acid rain in southern California, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 109-123.

A variety of techniques to identify and quantify acid and base components in rainwater are applied to data for southern California. Charge balance calculations using major cation and anion concentration data indicate southern California probably had alkaline rain in the 1950's and the 1960's with the exception of the Los Angeles area which probably had acidic precipitation. Measurements

948 (continued)
of the chemical composition of precipitation collected in Pasadena, California, from February 1976 to September 1977 are compared with the charge balance and conductivity balance constraints. A chemical balance is used to determine the relative importances of different sources. The pH is found to be controlled by the interaction of bases and strong acids, with nitric acid being 32% more important on an equivalent basis than sulfuric acid. The uncertainties in the various calculations are discussed. [Abstract reprinted by permission of Plenum Press.]

949
LILJESTRAND, H. M., and MORGAN, J. J., 1981, Spatial variations of acid precipitation in southern California: Environmental Science and Technology, v. 15, p. 333-338.

Wet-only precipitation samplers were used to collect samples at nine sites in the Los Angeles basin from 1978-79; samples were analyzed for major anions and cations and trace elements. The relative importance of natural and anthropogenic sources of NO_x and SO_x are estimated through a chemical balance method. Variations of sea salt, soil dust, NH_4^+, SO_4^{2-}, and NO_3^- contributions agreed with scavenging and advection patterns and source distributions. The ratio of nitrate to sulfate equivalent (non-sea salt) varied from 0.4 near coastal sources to 2.8 in rural mountain areas. The mass-balance calculations show that less than 2 percent of manmade emission of NO_x and SO_x in southern California are scavenged locally.

950
LINDBERG, S. E., 1981, The relationship between manganese and sulfate ions in rain: Atmospheric Environment, v. 15, no. 9, p. 1749-1753.

A significant correlation was found between concentrations of manganese (Mn^{2+}) and sulfate ions (SO_4^{2-}) in incident rain samples (wetfall only) collected at the Walker Branch Experimental Forest in eastern Tennessee. Previous studies have attributed the relationship between Mn^{2+} and SO_4^{2-} to in-cloud catalytic oxidation of SO_2 by manganese. This article presents two alternative explanations of the relationship between Mn^{2+} and SO_4^{2-} in bulk precipitation samples collected weekly or at longer time intervals and in single-event wetfall samples.

951
LINDBERG, S. E., and HARRISS, R. C., 1981, The role of atmospheric deposition in an eastern U.S. deciduous forest: Water, Air, and Soil Pollution, v. 16, p. 13-31.

This article presents deposition rates of Mn, Zn, Cd, Pb, and SO_4 to a forest canopy and underlying soils in Walker Branch watershed, a forested catchment in eastern Tennessee.

951 (continued)
Atmospheric sources contribute significantly to the annual flux of trace metals and sulfate. Measured water solubility of these metals in suspended and deposited particles show that they are mobilized readily after deposition. Interception of rain by the forest canopy results in loss of Cd, Mn, Pb, Zn, and SO^{--} from the canopy; uptake of H^+ by the canopy increases with increasing free acidity of the rain and with increasing residence time of the rain on the leaf surface.

952
LINDBERG, S. E., HARRISS, R. C., TURNER, R. R., SHRINER, D. S., and HUFF, D. D., 1979, Mechanisms and rates of atmospheric deposition of selected trace elements and sulfate to a deciduous forest watershed: Oak Ridge, Tenn., Oak Ridge National Laboratory, ORNL/TM-6674, 550 p.

This report quantifies atmospheric deposition of several trace elements to a deciduous forest canopy at Walker Branch watershed, Tenn., and investigates the major mechanisms of deposition. More than 75 percent of the dilute-acid leachable fraction of Mn, Zn, Cd, and Pb in aerosols were soluble in water. The ratio of water-soluble fraction to total element increased with decreasing particle size and with the duration of atmospheric water-vapor saturation during the sampling period. Atmospheric chemistry at the site may be influenced by regional air-transport phenomena instead of the direct influence from local source emissions. The highest concentrations of H^+, Pb, Mn, and SO_4^{2-} in precipitation occurred during summer storms resulting from synoptic meteorologic conditions.

953
LINDBERG, S. E., TURNER, R. R., FERGUSON, N. M., and MATT, D., 1977, Walker Branch watershed element cycling studies--collection and analysis of wetfall for trace elements and sulfate, in Correll, D. L., ed. 1977, Watershed research in eastern North America--A workshop to compare results: Edgewater, Md., Smithsonian Institute, Chesapeake Bay Center for Environmental Studies, v. 1, p. 125-151.

This article describes a precipitation-sampling network at Walker Branch watershed, Tenn., that is designed to optimize trace-elements analysis. Wetfall is collected by both event and continuous sampling at four throughfall, one ground-level incident, and one above-canopy incident sites. Spatial effect on incident and throughfall rain chemistry during storms are significant within the watershed. Annual temporal changes in chemistry are also significant at some sites. Preliminary data for water year 1975-76 yield weighted mean concentrations for Cd, Mn, Pb, Zn, and SO_4-S in incident precipitation as 0.89, 1.5, 5.5, 7.1, and 840 µg/L, respectively.

954
LINDBERG, S. E., TURNER, R. R., SHRINER, D. S., and HUFF, D. D., 1981, Atmospheric deposition of heavy metals and their interaction with acid precipitation, in International Conference on Heavy Metals in the Environment, Amsterdam, 1981, Proceedings: Edinboro, Scotland, CEP Consultants, Ltd., p. 306-309.

The lead cycle in the environment is con trolled by atmospheric deposition; the cadmium and zinc cycles are significantly affected by atmospheric deposition as well. Atmospheric contribution of manganese to the cycle in a deciduous forest in the eastern United States were minimal. Deposition rates during storms were orders of magnitude greater than dry deposition rates. Dry deposition, however, supplied from 20 to 90 percent of the total annual contribution of heavy metals to the forest. Concentrations of heavy metals and hydrogen ion in the forest canopy were 100 to 1000 times higher than concentrations in rain because of the interactions between dry deposition and acid precipitation.

955
LINTON, R. W., LOH, A., NATUSCH, D. F. S., EVANS, C. A., Jr., and WILLIAMS, P., 1975, Surface predominance of trace elements in airborne particles: Science, v. 191, p. 852-854.

Toxic trace elements such as As, Be, Cd, Cr, Mn, Ni, Pb, Sb, Se, Tl, V, and Zn are mobilized in the atmosphere in association with particles emitted from fossil fuel combustion and conversion. The highest trace-element concentrations are encountered in small particles that pass through pollution-control devices most readily, remain suspended in the atmosphere for long periods, and become deposited in the innermost regions of the respiratory tract when inhaled. Conventional bulk analyses provide a poor measure of the actual concentrations of many airborne toxic trace elements that are in contact with the external environment of a particle.

956
LINZON, S. N., 1966, Damage to eastern white pine by sulfur dioxide, semimature-tissue needle blight, and ozone: Journal of the Air Pollution Control Association, v. 16, no. 3, p. 140-144.

Eastern white pine (*Pinus strobus* L.) forests in the Sudbury mining district of Ontario are severely damaged by atmospheric deposition of sulfur dioxide at distances up to 25 miles northeast of large smelters. Symptoms of sulfur dioxide injury to foliage resemble those caused by semimature-tissue needle blight (SNB), a physiogenic disease. This article describes the differences between sulfur dioxide injury, SNB, and ozone injury to eastern white pine.

957
LINZON, S. N., 1971, Economic effects of sulfur dioxide on forest growth: Journal of the Air Pollution Control Association, v. 21, no. 2, p. 81-86.

This article discusses the long-term chronic effects of sulfur dioxide on plant yield, growth, and survival within a smelting district at Sudbury, Ontario. Eastern white pine is used as the indicator of degree and extent of injury. Tree data are correlated with records of atmospheric sulfur dioxide monitored continuously during the growing season by autometers. The smelting region is divided into three fume zones. An estimate is given on the loss of income by owners of woods or producers of wood products in the area as a result of sulfur dioxide air pollution.

958
LINZON, S. N., 1978, Effects of air-borne sulfur pollutants on plants, in Nriagu, J. O., ed., Sulfur in the environment, part II--Ecological impacts: New York, John Wiley, p. 109-162.

959
LINZON, S. N., McILVEEN, W. D., and TEMPLE, P. J., 1973, Sulphur dioxide injury to vegetation in the vicinity of a sulphite pulp and paper mill: Water, Air, and Soil Pollution, v. 2, no. 1, p. 129-134.

This article discusses the injury to vegetation caused by sulfur dioxide (SO_2) emissions from a sulfite pulp and paper mill in Ontario in July 1971. Acute vegetation injury occurred over several city blocks on the northeast side of the mill. Symptoms of injury were typical of those caused by high concentrations of atmospheric SO_2. The relative sensitivity of 75 plant species to SO_2 is given.

960
LINZON, S. N., and TEMPLE, P. J., 1980, Soil resampling and pH measurements after an 18-year period in Ontario, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 176-177.

961
LION, L. W., and LECKIE, J. O., 1981, Copper in marine microlayers--accumulation, speciation, and transport, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 143-163.

962
LIOY, P. J., 1979, Pollutants and meteorological conditions associated with acid precipitation, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 33-40.

963
LIOY, P. J., WOLFF, G. T., CZACHOR, J. S., COFFEY, P. E., STASIVK, W. N., and ROMANO, David, 1977, Evidence of high atmospheric concentrations of sulfates detected at rural sites in the northeast: Journal of Environmental Science and Health, v. A12, no. 1&2, p. 1-14.

This article describes the relationship between ambient sulfates (SO_4 in the air), total suspended particulates (TSP), ozone, and meteorologic conditions. Data from Whiteface Mountain, N.Y., High Point, N.J., and five other rural sites show that sulfate concentrations have been highest during four distinct meteorologic periods that are defined by anticyclonic stagnation and(or) return flow of maritime air. Some indication of long-range transport of sulfates was noted. The SO_4 and TSP ratio at Whiteface and High Point increases with higher TSP during episode periods. Ozone may be an important reactant in the formation of SO_4.

964
LIPPMANN, Morton, 1980, Health significance of exposure to sulfur oxide air pollutants, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 85-97.

The ambient air in the eastern United States generally contains SO_2 and H_2SO_4 and its ammonium salts at levels well above continental background levels, but also well below levels having demonstrated adverse effects on human health. However, the ambient concentrations are sufficiently high to generate concern about some specific health effects which have been produced in clinical and laboratory studies at concentrations within an order of magnitude of ambient levels. The most significant of these are the studies which demonstrate that H_2SO_4 in the ambient air could (1) contribute to the pathogenesis of chronic bronchitis and (2) cause airway constriction sufficient to affect individuals with reactive airways. Additional concern is generated by animal studies which indicate that (1) SO_2 can act as a cocarcinogen when inhaled with benzo(a)pyrene, (2) SO_2 can inhibit alveolar clearance of mineral dust particles, and (3) H_2SO_4 in combined exposures with ozone can enhance mortality in animals infected with bacterial aerosols. However, the concentrations required to produce these effects were very much higher than anticipated ambient levels. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

965
LIU, B. Y. H., PUI, D. Y. H., WHITBY, K. T., KITTELSON, D. B., KOUSAKA, Y., and McKENZIE, R. L., 1978, The aerosol mobility chromatograph--a new detector for sulfuric acid aerosols, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 99-104.

A new instrument has been developed for measuring sulfuric acid aerosols. The instrument is called an Aerosol Mobility Chromatograph since it is based on the electrical mobility of aerosol particles and operates in a way similar to that of the conventional liquid or gas chromatograph. The particle diameter range of the instrument is from 0.005 to 0.2 μm and the sensitivity (for detecting monodisperse sulfuric acid aerosols), from 0.01 to 10^{-5} μg m^{-3}, depending upon the specific particle detector used. This paper describes the operating principle of the AMC and the performance characteristics of a prototype device developed at the Particle Technology Laboratory, University of Minnesota. [Abstract reprinted by permission of Pergamon Press.]

966
LLOYD, R., and JORDAN, D. H. M., 1964, Some factors affecting the resistance of rainbow trout (*Salmo gairdnerii* Richardson) to acid waters: International Journal of Water and Air Pollution, v. 8, p. 393-403.

Acclimation of rainbow trout to acidity affects the level at which the acidity will be lethal. Fifty percent of the fish tested died after 4 days in waters with pH 4.18, 4.22, and 4.25. The relation between log survival time and pH is linear and is affected by the presence of up to 50 ppm free carbon dioxide. Exposure to pH below 5.0 for about 3 months might be harmful to rainbow trout when little free carbon dioxide is present in water. Exposure to pH 6.0 for 3 months or less might be lethal if an acid discharge were to raise the free carbon dioxide content to 20 ppm.

967
LOCKHART, W. L., and LUTZ, Andrew, 1977, Preliminary biochemical observations of fishes inhabiting an acidified lake in Ontario, Canada: Water, Air, and Soil Pollution, v. 7, no. 3, p. 317-332.

Blood serum and other tissues of white suckers (*Catostomus commersoni*) and other

967 (continued)
species of fish have been examined in a preliminary effort to understand losses of fish from acid lakes. Maturing females of highly acid George Lake failed to show the normal degree of increase in serum Ca over males captured in the same location. Elevated serum Ca was always observed in females, relative to males, from non-acid locations when maturation stages were similar. A number of body tissues were examined to determine whether the distributions of Ca or other elements were altered and the only striking change evident in fish from George Lake was their high Mn content. Bone in particular was examined for N, Na, Mg, P, K, and Ca and no evidence of demineralization was found. Other tests such as hemoglobin indicated that an anticipated adaptive response to asphyxia was absent. Our results indicate that potential mechanisms of fish losses such as asphyxia and starvation are unlikely to have been significant, however, they do not firmly establish any alternate mechanism. As a working hypothesis we suggest that Ca dynamics may limit ovarian development and that adsorption of this metal at exchange surfaces may be impaired. [Abstract reprinted by permission of D. Riedel Publishing Company.]

968
LOCKYER, D. R., COWLING, D. W., and FENLON, J. S., 1978, Laboratory measurements of dry deposition of sulphur dioxide on to several soils from England and Wales: Journal of the Science of Food and Agriculture, v. 29, p. 739-746.

This article presents a laboratory method for measuring dry deposition of sulfur dioxide (SO_2) onto soils. The effect of soil type on deposition velocity is examined through comparison of soil samples from 16 sites in England and Wales. Deposition velocity on most soils did not vary significantly, but was correlated with soil pH. Deposited SO_2 was recovered from the soil as sulfate S.

969
LODGE, J. P., Jr., PATE, J. B., BASBERGILL, W., SWANSON, G. S., HILL, K. C., LORANGE, Elizabeth, and LAZRUS, A. L., 1968, Chemistry of United States precipitation--final report on the national precipitation sampling network: Boulder, Colo., National Center for Atmospheric Research, 66 p.

This report presents mean benchmark concentrations of airborne contaminants throughout the United States and describes the possible long-term trends. It also compares seasonal fluctuations and geographic distributions of contaminants and evaluates precipitation-sampling techniques.

970
LOGAN, John, 1961, Estimation of electrical conductivity from chemical analyses of natural waters: Journal of Geophysical Research, v. 66, no. 8, p. 2479-2483.

An empirical method of estimating the electrical conductivity of natural waters from their chemical analyses is tested statistically with six existing methods. Standard errors of estimate for the empirical method are less than 7 percent.

971
LOGAN, J. A., McELROY, M. B., WOFSY, S. C., and PRATHER, M. J., 1979, Oxidation of CS_2 and COS--sources for atmospheric SO_2: Nature, v. 281, p. 185-188.

Atmsopheric SO_2 in remote regions of the marine troposphere may result from the oxidation of CS_2 and COS initiated by reaction with OH. The relatively uniform distribution of SO_2 observed in the upper marine troposphere requires a diffuse atmospheric source for this gas.

972
LOHM, Ulrik, 1980, Effects of experimental acidifiction on soil organism populations and decomposition, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 178-179.

973
LOO, B. W., FRENCH, W. R., GATTI, R. C., GOULDING, F. S., JAKLVIC, J. M., LLACER, J., and THOMPSON, A. C., 1978, Large-scale measurement of airborne particulate sulfur, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 759-771.

We describe an aerosol sampling and analysis system which represents an integral approach to large-scale monitoring of airborne particulate matter. During our two-year participation in the St. Louis, Missouri, Regional Air Pollution Study (RAPs), 34,000 size-fractionated samples were collected by automated dichotomous samplers characterized by a particle size cutpoint of 2.4 μm. The total mass of the particulate matter was measured by beta-particle attenuation and the elemental composition, including sulfur was determined by photon-excited X-ray fluorescence. The long-term performance of the system will be reported. Potential systematic effects related to the sampling and analysis of sulfur particles are treated here in detail. Both the accuracy and precision of sulfur measurement are estimated to be 2%. While the X-ray attenuation correction

973 (continued)
required is typically only a few percent, a larger correction is required for a small fraction of the samples due to the migration of the sulfur into the filter. This correction is derived from the ratio of sulfur determinations made on the front and back surfaces of the membrane filter. Laboratory and field experiments have shown insignificant gaseous SO_2 conversion on the type of filters employed in the study. Preliminary data on the composition and the temporal and spatial distribution of the St. Louis aerosol are presented. About 90% of the sulfur was found in the fine-particle fraction. Sulfur variations were significantly slower than those of the trace elements. Sulfates usually constitute about 35% of the total fine-particle mass, but may rise to 41% during an "episode". The long-term (4 month average) sulfur data indicate that the background air masses arriving at St. Louis from the west and north were about 30% lower in particulate sulfur than those from the east and south. Also, an urban station may experience local increases in sulfur level up to a factor of two greater than the general background. Short-term (6 h average) data indicate that the effects of stationary SO_2 sources extend for long distances (at least 40 km) and are highly directional in character. [Abstract reprinted by permission of Pergamon Press.]

974
LOUCKS, O. L., 1981, The emerging socio-economic concerns related to acid rain, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 21-27.

975
LOUCKS, O. L., 1981, Technical options, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 157-159.

976
LUCK, R. F., 1980, Impact of oxidant air pollution on Ponderosa and Jeffrey pine cone production, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 240.

977
LUDWIG, F. L., 1978, Siting air monitoring stations: Environmental Science and Technology, v. 12, no. 7, p. 774-778.

977 (continued)
This article gives criteria for siting stations to monitor carbon monoxide, sulfur dioxide, total suspended particulates, and photochemical pollutants. Monitoring sites should be classified and uniform physical criteria should be developed for each type of site to allow comparisons among sites and to provide guidance for the proper use of the data that are collected.

978
LULMAN, P. D., FESSENDEN, R. J., and McKINNON, S. A., 1980, Lichens as air quality monitors, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 241.

979
LUNDHOLM, Bengt, 1970, Interactions between oceans and terrestrial ecosystems, in Singer, S. F., ed., 1980, Global effects of environmental pollution: New York, Springer-Verlag, p. 195-201.

Pollutants may be transported from the sea to the air even though the oceans are the sink for many pollutants. Pollutants may later be washed out over the continents. Sulfur leaves the marine environment, and by forming sulfuric acid, contributes to the acidity of precipitation. Pollutants move freely between air, water, soil, and living organisms. There is also some indication that mercury contamination of the environment and acid precipitation are interrelated.

980
LUOMA, J. L., 1980, Troubled skies, troubled waters: Audubon, v. 82, no. 6, p. 88-110.

This article describes the effects of acid precipitation on the lakes in Minnesota's Boundary Waters Canoe area and the Adirondack Mountains. Included are interviews with scientists and with officials of the smelting industry at Sudbury, Ontario, regarding SO_2 emissions, and a description of air-quality monitoring networks in the U.S.

981
LUSIS, M. A., and PHILLIPS, C. R., 1977, The oxidation of SO_2 to sulfates in dispersing plumes: Atmospheric Environment, v. 11, p. 239-241.

This article presents a mathematical model of sulfur dioxide oxidation to sulfates in chimney plumes and compares model predictions with oxidation rates observed in a nickel smelter plume.

982

LUXMOORE, R. J., 1980, Modeling pollutant uptake and effects on the soil-plant-litter system, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 174-180.

Five coupled models of water, carbon, and chemical dynamics in a soil-plant-litter system are outlined. Algorithms defining gaseous and particulate pollutant uptake are described along with functions for chemical effects on plant growth and litter decomposition. Some simulation results of a deciduous forest illustrate the importance of diurnal and annual cycles of environmental conditions on pollutant movement in vegetation. This modeling approach has provided (1) insights into plant physiological processes and their interactions, (2) indentification of plant properties important in pollutant uptake, (3) alternative hypotheses about pollutant effects, and (4) a unified basis for assessment of diurnal and long-term pollutant impacts on plant communities. [Abstract reprinted by permission of U.S. Forest Service.]

983

LYKKE, Erik, 1980, Pollution problems across international boundaries, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 477-488.

On the basis of available data which indicated that airborne pollutants were transported distances of hundreds of kilometers, the Nordic countries decided in 1970 to propose the OECD conduct a study of the transport of air pollutants. The OECD in 1972 adopted a "Co-operative Technical Programme to Measure the Long Range Transport of Air Pollutants." This programme covering northwest Europe focused primarily on sulphur dioxide and sulphur compounds and was concluded in 1977 after confirming that these compounds do travel hundreds of kilometers across international borders. [Abstract reprinted by permission of Plenum Press.]

984

LYNCH, J. A., and CORBETT, E. S., 1980, Acid precipitation--a threat to aquatic ecosystems: Fisheries, v. 5, no. 3, p. 8-12.

Concentrations of strong acids and heavy metals in precipitation over the northeastern United States, Scandinavia, and western Europe can cause significant damage to many organisms inhabiting lakes and streams. Fish populations in about 75 percent of the high-elevation lakes in the Adirondack Mountains of New York are adversely affected by acidic waters. Some of the effects are decreases in weight, size, structure, and growth rates. In Norway, 741 of 2,083 lakes surveyed are devoid of fish. Data for 516 of these lakes indicate that at pH levels below 5.5, fish are either absent or present only in reduced numbers. This article discusses the causes and patterns of acidity, and its impact on forest-stream ecosystems.

985

LYONS, W. A., DOOLEY, J. C., Jr., and WHITBY, K. T., 1978, Satellite detection of long-range pollution transport and sulfate aerosol hazes, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 621-631.

While not designed for such a task, meteorological satellites now play a growing role in our understanding of long range transport of secondary pollutants. This paper reports on a demonstration project showing that currently available synchronous satellite data can detect the areal extent and motion of large-scale "hazy" air masses associated with sulfate and ozone episodes. An interactive computer graphics system is utilized showing that digital satellite data can obtain precise measurements of upward scattered solar radiation which is correlated to aerosol optical thickness and therefore to sulfate concentrations. Measurements over Lake Michigan, for instance, reveal over-water image brightness enhanced fully 60-70% as visibility estimates of b_{scat} increased from $1.8 \times 10^{4}\ m^{-1}$ to $5.7 \times 10^{-4}\ m^{-1}$. Digital satellite data is shown to have great promise in mapping sulfate haze areas, especially over water. [Abstract reprinted by permission of Pergamon Press.]

M

986

MacCRACKEN, M. C., 1978, MAP3S: An investigation of atmospheric energy related pollutants in the northeastern United States, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 649-659.

The Multi-State Atmospheric Power Production Pollution Study (MAP3S) is a major new atmospheric research program of the U.S. Energy Research and Development Administration. The goal of the MAP3S program is to develop and demonstrate an improved, verified capability to simulate the present and potential future changes in pollutant concentration,

986 (continued)
atmospheric behavior and precipitation chemistry as a result of pollutant releases to the atmosphere from large-scale power production processes, primarily coal combustion. A major motivation of this program is to be able to provide those agencies charged with the task of meeting the nation's energy needs with the knowledge required to assess alternative strategies for generating power while ensuring ample protection of human health and adequate preservation of the natural environment. Since coal is the most abundant domestic fossil energy resource and since electric power production is a major and growing sector of our energy economy, this study focuses on the effects of emissions from coal fired electric power plants, particularly sulfur oxide emissions. The study domain is the high population, energy intensive northeastern quadrant of the United States. Research projects are underway to measure present sulfur oxide concentrations and composition, to assess the potential for long range transport, to investigate transformation processes in plumes from point and urban sources, to sample precipitation chemistry and improve understanding of scavenging mechanisms, and to develop numerical models that can simulte future air quality in subcontinental scales given patterns of anticipated combustion emissions. [Abstract reprinted by permission of University of California, Lawrence Livermore National Laboratory, U.S. Department of Energy, and Pergamon Press.]

987
MacCRACKEN, M. C., comp., 1979, The Multistate Atmospheric Power Production Pollution Study--MAP3S; progress report for FY 1977 and FY 1978: Washington, D.C., U.S. Department of Environment, DOE/EV-0040, 404 p.

The Multistate Atmospheric Power Production Pollution Study (MAP3S) was established in 1976 to investigate the atmospheric effects of emissions from fossil fuel power-generating plants. The northeastern quadrant of the United States was selected as a study area because it has a high population density and intensive industry. The objective of phase I (1977-78) was to investigate transport and fate of sulfur compounds, especially sulfate particulate matter, because of its effect on human health and the role of sulfur compounds in acid atmospheric deposition on the environment.

988
MacINTIRE, W. H., and YOUNG, J. B., 1923, Sulfur, calcium, magnesium and potassium content and reaction of rainfall at different points in Tennessee: Soil Science, v. 15, p. 205-227.

988 (continued)
Rain samples were collected at 10 sites in Tennessee and analyzed for sulfur, calcium, magnesium, and potassium. Most of the soluble sulfates in rainwater were dissolved from solid matter, and the volume of solid matter discharged into the atmosphere is the primary factor governing the concentration of sulfates in rain water. The authors conclude that rain carrying sulfurous materials was not more active than pure water in producing acidic soils.

989
MacKAY, D., and YUEN, A. T. K., 1981, Transfer rates of gaseous pollutants between the atmosphere and natural waters, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 55-65.

990
MADGWICK, H. A. I., and OVINGTON, J. D., 1959, The chemical composition of precipitation in adjacent forest and open plots: Forestry, v. 32, no. 1, p. 14-22.

This article presents the chemical composition of precipitation collected in three open plots and under 13 types of forest canopies at sites in southeast England. Analyses show that deposition rates of sodium, potassium, calcium, and magnesium in samples from the open plots are 19, 3, 11, and less than 4 (Kg/ha)/yr respectively, as compared to 33, 24, 24, and less than 10 under forest canopies. The article also discusses nutrient cycles of forest stands, removal of nutrients by logging, and the maintenance of soil fertility.

991
MADSEN, B. C., 1981, Acid rain at Kennedy Space Center, Florida--recent observations: Atmospheric Environment, v. 15, no. 5, p. 853-862.

Rainwater samples were collected near Kennedy Space Center Florida from July 1977 to September 1979 and were analyzed for major chemical constituents and acidity. The pH ranged from 5.1 in November 1977 to 4.3 in July 1978 and 1979. Weighted average pH for the duration of the study was 4.55. Sulfuric and nitric acids caused the acidity. The mole ratio of excess SO_4^{-2} to NO_3^- was typically greater than 1. Monthly chloride concentrations ranged from 20-240 µmoles/L and the Cl^- to Na^+ was slightly lower than in seawater.

992
MAHARA, Yasunori, and KUDO, Akira, 1981, Interaction and mobility of cobalt-60 between water and sediments in marine environments--possible effects by acid rain: Water research, v. 15, p. 413-419.

992 (continued)
This article examines the behavior of ^{60}Co, one of the radionuclides produced by nuclear reactors, in terms of its interaction between water and sediments. Emphasis is on the quantitative difference between cobalt behavior in marine and freshwater environments. Cobalt is generally mobile in marine environments, and mobility depends on the pH of water. Acid rain is, therefore, expected to strongly influence the mobility of ^{60}Co in aquatic environments.

993
MALMER, Nils, 1976, Acid precipitation--chemical changes in the soil: Ambio, v. 5, no. 5-6, p. 231-234.

This article discusses the effects of acid precipitation on soil chemistry with emphasis on soil conditions in the Scandinavian countries. Several other airborne pollutants that are associated with acid precipitation may have synergistic effects on soils. Acid precipitation may shorten the time required for the decomposition of organic compounds, and acidification may cause heavy metals to become more mobile and accessible to living organisms. The release of toxic elements in the soil has an adverse effect on organisms in these soils.

994
MAMANE, Yaacov, and DE PENA, R. G., 1978, A quantitative method for the detection of individual submicrometer size sulfate particles, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 69-82.

A quantitative method for the analysis of individual submicrometer size sulfate particles has been developed. It is based on the reaction of the sulfate ion with barium chloride and can be applied only to soluble sulfates. The method is specific for sulfates. Carbonates, sulfites and nitrates can be distinguished from sulfates. The size of the halo depends on the size of the particle, the thickness of the barium chloride film and the relative humidity at which the reaction takes place. By fixing the values of the last two parameters, a single correlation can be established between the halo and the particle size. The method requires sampling time on the order of minutes for clean air to seconds for very polluted areas. An example of the application of the method to atmospheric aerosol is shown. [Abstract reprinted by permission of Pergamon Press.]

995
MANDELKER, D. R., 1980, Emission quotas for maintaining air quality, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 449-462.

995 (continued)
In order to control the air pollution, the Environmental Protection Agency (EPA) has adopted the National Ambient Air Quality Standards (NAAQS) as required by the Clean Air Act. The emission quota is applied to major industrial pollutants and particularly to the sulfur oxides in an attempt to maintain the standards over an air quality control region. It is a regionalized and not an interstate control. The scientists at Argonne have put together a book which tells how to put together an emission control quota in a local region.

Regions may be categorized as those where the NAAQS are already violated, where the standards are met and finally where the air is much cleaner than required. The actions to be taken in the various categories are discussed. Of special interest is the situation where additional pollution is allowable--the problems being those of an equitable and wise apportionment of the increased pollution. Four emission quota strategies are considered. [Abstract reprinted by permission of Plenum Press.]

996
MANSFIELD, T. A., ed., 1976, Effects of air pollutants on plants: Cambridge, England, Cambridge University Press, 209 p.

This book contains a series of chapters based on a seminar sponsored by the Society for Experimental Biology and held at the University of Liverpool in 1975. Topics include the gaseous exchange between plants and polluted atmospheres, sulfur dioxide resistance in plants, biochemical effects, and pollution and evolution. Also included are appendices on chemistry of atmospheric pollutants and metabolic and biochemical effects of air pollutants on higher plants. Increasing evidence suggests that mixtures of pollutants interact chemically in the atmosphere and physiologically at the plant level. The responses of differing species to pollutants varies greatly, and many species contain highly resistant genotypes.

997
MARSH, A. R. W., 1978, Sulphur and nitrogen contributions to the acidity of rain: Atmospheric Environment, v. 12, p. 401-406.

Sulfate, nitrate, and ammonium are the dominant ions contributing to the acidity of precipitation. In remote areas with low sulfur dioxide SO_2 concentrations washout of gas is unlikely to produce significant changes in the pH of rain, although the presence of NH_3 enhances the final sulfate concentration. The washout of SO_2 gas and sulfate aerosol is also unlikely to contribute more than 50 percent to the final concentration of sulfate ion (SO_4--) in precipitation in remote areas.

997 (continued)
The ions SO_4^{--}, NO_3^-, and NH_4^+ in precipitation seem to be correlated through chemical mechanisms. Nitrate is formed after sulfate production.

998
MARSH, A. R. W., 1978, Sulphur and nitrogen contributions to the acidity of rain, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 401-406.

The dominant ions contributing to the acidity of precipitation are usually SO_4^{2-}, NO_3^-, and NH_4^+ after allowance for sea salts.

In remote areas with low concentrations of SO_2 theoretical estimates suggest that the washout of the gas is unlikely to produce marked changes in the pH of rain although the presence of NH_3 enhances the final sulphate concentration.

The contribution of washout of SO_2 gas and sulphate aerosol is unlikely to contribute more than 50% to the final concentration of SO_4^{2-} in precipitation in remote areas.

The chemical composition of precipitation in remote areas shows a correlation between the ions SO_4^{2-}, NO_3^- and NH_4^+. Some physical mechanisms such as the variation in composition with rain density clearly contribute to the correlation but it appears that there are chemical mechanisms correlating these ions. A similar correlation is also found in aerosols nearer source areas. The role of NH_3 is straight forward acid neutralization but the relationship between NO_3^- and SO_4^{2-} is more difficult to define. It appears that the nitrate is formed after sulphate production. [Abstract reprinted by permission of Pergamon Press.]

999
MARTENS, C. S., and HARRISS, R. C., 1973, Chemistry of aerosols, cloud droplets, and rain in the Puerto Rican marine atmosphere: Journal of Geophysical Research, v. 78, no. 6, p. 949-957.

The chemical transformation of aerosols to cloud droplets and rain has been observed in orographic clouds in the eastern part of Puerto Rico. Element ratios in particles and rain compared with particle-size distributions in and out of the clouds show that scavenging efficiencies of iodine, bromine, and chlorine exceed those of sodium by more than 100 percent and that scavenging efficiencies of aluminum, manganese, and vanadium exceed that of sodium by less than 25 percent.

1000
MARTIN, A., 1975, Rainwater pH close to a major power plant: Atmospheric Environment, v. 9, p. 945-949.

This article comments on a paper by the above title by Ta-Yung Li and H. E. Landsberg, which appeared in Atmospheric Environment, v. 9, p. 81-88, 1975. The authors' response is also given. (See also Li, Ta Yung and Landsberg, H. E., 1975, herein.)

1001
MARTIN, A., 1979, A survey of the acidity of rainwater over large areas of Great Britain: Science of the Total Environment, v. 13, p. 119-130.

Rainwater samples were collected from dustfall monitoring gages at 100 sites in the United Kingdom and analyzed for pH. The greatest acidity occurred during winter at the outskirts of cities in the center of England; the lowest acidity occurred in areas having contamination from local sources of alkalinity such as soil, fly ash, or ammonia. Acidity of precipitation in the U.K. during the past 50 years shows only small changes except at the outskirts of towns, where sharp increases in acidity might be related to fuel uses.

1002
MARTIN, A., and BARBER, F. R., 1978, Some observations of acidity and sulphur in rainwater from rural sites in central England and Wales: Atmospheric Environment, v. 12, p. 1481-1487.

Rainwater samples were collected from 10 rural sites in eastern England and analyzed for acidity and other ions in solution. The quantities of material attributed to sea and land sources are given. Significant amounts of sea salts are deposited as far as 80 km inland. In the absence of rain, rain gages collect significant amounts of salt from seawater aerosols and sulfates from soils. Dry deposition of SO_2 gas to the gages can be significant if the humidity is high or if dewfall occurs. Highly acidic rain has been recorded in a Welsh valley, but the increase in amount of acidity is believed to result from large amounts of rainfall.

1003
MARTIN, H. C., 1979, Acid rain--the environment, current stress and a prognosis, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 173-177.

1004
MARTIN, H. C., 1979, The Canadian long-range transport of air pollution programme, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 77-78.

1005
MASARU, Nakada, KATSUHISA, Fukaya, SANKICHI, Takeshita and YUTAKA, Wada, 1980, Effects of inorganic components in acid rain on tube elongation of *Camellia* pollen: Environmental Pollution, series A, v. 21, p. 51-57.

Pollen grains of *Camellia japonica* were cultivated in culture plates with inorganic components of acid rain, for example, SO_4^{2-}, NO_3^-, Cl^-, H^+, Pb^{2+}, Mg^{2+}, or Mn^{2+}. Nitric acid, hydrochloric acid, and sulfuric acid promoted pollen tube elongation. Concentrations of nitric acid and hydrochloric acid greater than 0.6 mmol/L (pH <3.2) caused significant inhibition. Sulfuric acid promoted tube elongation in the range 0 to 0.2 mmol/L and significantly inhibited tube elongation above 0.3 mmol/L. Nitric acid promoted tube elongation more than hydrochloric acid and sulfuric acid.

1006
MATZIRIS, D. I., and NAKOS, George, 1977 [1978], Effect of simulated "Acid Rain" on juvenile characteristics of aleppo pine (*Pinus halepensis* Mill.): Forest Ecology and Management, v. 1, no. 3, p. 267-272.

Seedlings from 1-year-old, half sib families of Aleppo pine were irrigated with simulated acid rain (pH 3.1 and 3.5; control was 5.1) for one growing season. Seedlings treated with pH 3.1 had a mean height of 22.6 cm at the end of the test, which was 8.2 percent less than the control. The acid treatments hindered the formation of terminal buds, increased seedling mortality, and dissolved and leached considerable amounts of calcium carbonate from the soil.

1007
MAUGH, T. H., II, 1979, SO_2 pollution may be good for plants: Science, v. 205, p. 383.

Sulfur from the atmosphere may be increasing the productivity of many common agricultural species, according to J. C. Noggle of the Tennessee Valley Authority. Although atmospheric sulfur dioxide above certain concentrations is toxic to plants, it can be beneficial at lower concentrations. Sulfur is a plant nutrient and it has a major role in the synthesis of proteins and chlorophyll.

1008
MAYER, Robert, and ULRICH, Bernard, 1977, Acidity of precipitation as influenced by the filtering of atmospheric sulfur and nitrogen compounds--its role in the element balance and effect on soil: Water, Air, and Soil Pollution, v. 7, no. 3, p. 409-416.

Acidity of throughfall precipitation is increased by the filtering of S and N from the atmosphere by trees. An element balance for a beech forest is given. As a consequence of acidification the soil chemical conditions are changed in a way that plants rooting close to the soil surface are affected. Losses of nutrients may pose a problem in forest plant nutrition in the near future in central European forests on light or medium textured acid soils. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1009
MAYER, Robert, and ULRICH, Bernard, 1978, Input of atmospheric sulfur by dry and wet deposition to two central European forest ecosystems, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 375-377.

The total input of atmospheric sulfur to a beech and a spruce forest in the Federal Republic of Germany has been measured over a period of 6 years. The contribution of dry deposition to the total input was determined indirectly by comparing seasonal changes in the sulfur flux coupled with precipitation beneath the canopy of the deciduous beech forest. As a result of these investigations seasonal and annual sulfur fluxes are reported corresponding to removal rates of atmospheric sulfur. The experimental data show clearly that the removal rates depend upon the quality of the atmosphere/land interface, in forested areas from the tree species forming the canopy. The 6-years average of total deposition on bare soil is 23 kg S ha^{-1}, on a beech forest 47-51 kg S ha^{-1} y^{-1}. Based upon the experimental results the role of the forest vegetation in the removal of sulfur from the atmosphere in the area of the Federal Republic of Germany is considered. The figures indicate, that at least 50% of the total sulfur deposition takes place on forested areas which cover only 28% of the total land surface. [Abstract reprinted by permission of Pergamon Press.]

1010
MAYER, Robert, and ULRICH, Bernard, 1980, Input to soil, especially the influence of vegetation in intercepting and modifying inputs--a review, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 173-182.

1011
MAZUMDAR, Sati, and REDMOND, Carol, 1980, An overview of epidemiologic evidence on effects of atmospheric sulfur, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 109-117.

The present review of the epidemiologic studies on effects of atmospheric sulfur shows the findings, problems, and limitations of existing studies in delineating adverse health effects of sulfur compounds from other confounding factors, especially cigarette smoking, in the investigation of long-term effects. The need for subjecting all studies, old and new, to critical evaluation as their methodology and validity is stressed. In investigating the short-term effects, the surrogating behavior of SO_2 has been pointed out, and the need for proper adjustment for the confounding health effects of weather variables has been discussed. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

1012
McBEAN, G. A., 1979, Emissions, atmospheric transport, transformation and depositions, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 9-14.

1013
McBRIDE, M. B., and BLASIAK, J. J., 1979, Zinc and copper solubility as a function of pH in an acid soil: Soil Science Society of America Journal, v. 43, no. 5, p. 866-870.

This article discusses the influence of soil pH on the adsorption, solubility, and solution complexation of Cu^{2+} and Zn^{2+} in an acid soil. Hydrous oxides of iron, aluminum, or manganese are probably involved in the adsorption process. Adsorption on permanent charge sites of clays, or complexation with organic matter cannot account for the apparent fixation of Zn^{2+} in a nonexchangeable form in the pH range of 5 to 7. Nucleation of Zn hydroxide on clay mineral surfaces may produce the strongly pH-dependent retention in the soil. Cu^{+}, however, is more controlled by organic complexation mechanisms than Zn^{2+}. Results suggest that chemical precipitation is not involved in metal-retention capacity of the soil.

1014
McCOLL, J. G., 1972, Dynamics of ion transport during moisture flow from a Douglas-fir forest floor: Soil Science Society of America, Proceedings, v. 36, p. 668-674.

The dynamics of ion transport during periods of moisture flow from the forest floor was studied during 1974-75 in a Douglas-fir forest (*Pseudotsuga menziesii*) in western Washington. This article discusses the transport process in relation to temperature of the forest floor, length of time before flow, and the amount of moisture flow and also describes seasonal climatic changes in relation to the ion-transport process and changes in solution concentration during some wetting cycles. Changes in ion additions to the soil system may result from atmospheric sources. Nitrate and sulfate ions accompanied by hydrogen ions often make up a large part of total ions in rainwater near industrial areas. Ion inputs from the atmosphere are reflected in measurable increases in nutrient cation concentrations in the drainage water from the forest ecosystem studied.

1015
McCOLL, J. G., 1973, Environmental factors influencing ion transport in a Douglas-fir forest soil in western Washington: Journal of Ecology, v. 61, p. 71-83.

An automated tension-lysimeter system was used to collect data from a second-growth Douglas-fir forest in western Washington. Solutions from natural precipitation were studied as they passed downward through the tree canopy, the forest floor, and the soil at depths of 8 cm, 50 cm, and 120 cm. Total ion transport, mean solution conductivity change, mean solution pH, and maximum pH change of solution were determined for each horizon and wetting front. Multiple linear regression and principal component analyses show that the independent variable that contribute most to the accountable variance in ion characteristics of solution are total volume of flow through a specific horizon and the duration and temperature of a dry period preceding flow. Characteristics of solutions from a given horizon are conditioned by the corresponding characteristics of the horizon above it.

1016
McCOLL, J. G., 1973, A model of ion transport during moisture flow from a Douglas-fir forest floor: Ecology, v. 54, no. 1, p. 181-187.

1016 (continued)
This article describes a mathematical model of the ion-transport process within a second growth, Douglas-fir forest on glacial outwash soil in western Washington. The model verifies the relationship between temperature and moisture flow and the transport of ions from the forest floor. The model is based on field and laboratory data.

1017
McCOLL, J. G., 1980, Acid precipitation and ecological effects in northern California, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 122-123.

1018
McCOLL, J. G., 1980, A survey of acid precipitation in northern California: Sacramento, California Air Resources Board, 94 p.

Wet and dry deposition were monitored on an event basis at eight sites in northern California from November 1978 through May 1979. Acid precipitation (pH <5.6) was common at all sites. The mean pH of storms varied from 4.42 at San Jose to 5.20 at Davis. The lowest recorded pH (3.71) occurred at San Jose. The major causes of acidity are probably NO_x and SO_x after their dissolution in wet precipitation. Nitrate ion is the anion that correlates best with hydrogen ion in precipitation samples; nitrogen generally occurred in greater amounts than sulfur. Adverse effects of acid precipitation may occur in pollution-source areas as well as the coast ranges, Napa Valley, and Sierras.

1019
McCOLL, J. G., 1981, Acid rain in northern California: Fremontia, v. 8, no. 4, p. 3-5.

Wet and dry atmospheric precipitation samples were collected at eight sites in northern California during the wet season of 1978-79 and analyzed for inorganic constituents. Results of analyses show that acid precipitation is common and is widely distributed in northern California. The mean pH of storms at eight sampling sites ranged from 4.42 at San Jose to 5.20 at Davis. The lowest pH value during the study was 3.7, recorded at San Jose. Nitric acid appears to be the primary cause of acidity; sulfuric acid appears to be the secondary cause. Nitrogen compounds in California originate almost entirely from automobile exhaust.

1020
McCOLL, J. G., 1981, Effects of acid rain on plants and soils in California: Sacramento, California Air Resources Board, 111 p.

Agronomic and forest tree species growing in differing soils were treated with simulated rain of varying acidity. Plant productivity, interactions between plant and soils, and soil leaching was studied. Direct damage to foliage was not apparent except under extreme conditions. Sugar beet was the most sensitive agronomic species that was tested. Under severe acid conditions, the germination of Douglas-fir seed was inhibited. Growth of 2-year old conifer seedlings was not seriously affected except after severe treatments. Plant productivity was both negatively and positively affected by simulated acid rain, and effects were usually predicted by the type of soil in which the plants were growing. A laboratory method was developed for determining potential sensitivity of soils to leaching by acid rain. The most sensitive soils were shallow, silicic soils with low cation-exchange capacity and base saturation.

1021
McCOLL, J. G., 1981, Increasing hydrogen ion activity of water in two reservoirs supplying the San Francisco Bay area, California: Water Resources Research, v. 17, no. 5, p. 1510-1516.

Hydrogen ion (H^+) activity in two reservoirs in the Sierra Nevada that supply drinking water to the San Francisco Bay area has been increasing during 1954-79. The rate of H^+ increase is the same at both reservoirs, and H^+ concentration at both has varied from year to year which suggest a common, general source. The mean monthly variation in H^+ correlates with mean monthly variation in atmospheric pollution from the San Francisco Bay area. This article suggests that NO_x from automobile exhaust is the primary cause of the increasing H^+ of the reservoir waters.

1022
McCOLL, J. G., 1981, A survey of acid precipitation in northern California, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 23.

1023
McCOLL, J. G., 1981, Trace elements in the hydrologic cycle of a forest ecosystem: Plant and Soil, v. 62, no. 3, p. 337-349.

Bulk precipitation, throughfall, stemflow, and soil solutions at 10-, 15-, 25-, and 30-cm depths in a *Eucalyptus globulus* forest near Berkeley, Calif. were analyzed for concentrations of copper (Cu), manganese (Mn), iron (Fe), and zinc (Zn). Samples were collected during the 1974-75 wet season after each significant storm; litter and plant samples were also collected and analyzed. Mn and Zn are mostly deposited on the forest canopy by impaction during episodes of dry

1023 (continued)
deposition; Cu and Fe are deposited mostly by precipitation. Concentrations of Cu and Fe increase in the following order: precipitation, throughfall, stemflow, and soil solutions. Concentrations of Zn increase in the following order: precipitation, stemflow, throughfall, and soil solutions. Concentrations of Mn increase in the following order: precipitation, soil solutions, throughfall, and stemflow. Concentrations of Cu, Zn, Mn, and Fe in the soil solution are negatively correlated with pH.

1024
McCOLL, J. G., and BUSH, D. S., 1978, Precipitation and throughfall chemistry in the San Francisco Bay area: Journal of Environmental Quality, v. 7, no. 3, p. 352-357.

The major ionic constituents of bulk precipitation collected at Berkeley, Calif. during the wet season of 1974-75 were sulfate ion (SO_4^{2-}), chloride ion (Cl^-), bicarbonate (HCO_3^-), sodium ion (Na^+), and calcium ion (Ca^+). Mean hydrogen ion concentration (H^+) was 10.7 ± 1.5 μeq/L (pH 5.0). SO_4^{2-} constituted 50 percent of the anions in bulk precipitation; however, H^+ had the highest correlation with NO_3^-. Impacted air pollutants accumulated on tree leaves between major rainstorms. Atmospheric nitrogen and sulfur correlate with NO_3^- and SO_4^{2-} in bulk precipitation and leafwash in a *Eucalyptus globulus* forest. Ionic composition of bulk precipitation resembles that of surface soil solutions in an adjoining clearcut area.

1025
McCOLL, J. G., and FIRESTONE, M. K., 1980, Acid precipitation in California and some ecological effects, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, River side, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 242.

1026
McCOLL, J. G., and FIRESTONE, M. K., 1981, Some effects of acid rain on plants and soils, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 31.

1027
McFEE, W. W., 1980, Effects of atmospheric pollutants on soils, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 307-323.

The effects of two types of atmospheric pollutants on soils, acid precipitation and metals, are considered. Potential acid precipitation effects include soil acidification, increased loss of plant nutrients, accelerated weathering of mineral components, decreased rates of organic matter decay, changes in soil organism populations, mobilization of aluminum ions, and reduction in cation exchange capacity. Soils that are poorly buffered, i.e., have low cation exchange capacity due to low clay and organic matter contents, are most likely to undergo appreciable change due to acid inputs. Acid precipitation inputs experienced thus far are generally low compared to the effects of agricultural fertilization and liming practices on soil pH.

Results of field experimentation have not shown serious delterious effects of acid precipitation on productivity or soil biota. The reaction of soils to acid inputs is complex and dependent on numerous soil parameters, such as type of clay present, base saturation, presence of easily weatherable minerals, and upon the ionic composition of the precipitation.

Soils are efficient collectors of metallic ions. Damaging levels of metal contamination of soils reported thus far are confined to urban areas and regions around point sources, such as smelters. Since metals are retained over long periods, recovery from metal contamination is slow. [Abstract reprinted by permission of Plenum Press.]

1028
McFEE, W. W., 1980, Sensitivity of soil regions to acid precipitation: Corvallis, Oregon, U.S. Environmental Protection Agency, EPA-600/3-80-013, 78 p.

This report presents a series of maps of the eastern United States delineating soil areas according to their sensitivity to acid preciptation. Four criteria used in estimating soil sensitivity to acid precipitation are (1) total buffering capacity or cation-exchange capacity; (2) base saturation; (3) soil-management system; and (4) presence or absence of carbonates in the soil profile. Cation-exchange capacity is the primary criterion for classification of areas as nonsensitive, slightly sensitive, and sensitive. North-central states contain generally nonsensitive to slightly sensitive soils; the northeastern states contain large regions of slightly sensitive to sensitive soils.

1029
McFEE, W. W., 1980, Sensitivity of soil regions to long-term acid precipitation, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 495-505.

1029 (continued)

Criteria for ranking soil sensitivity to the effects of acid precipitation are discussed. A ranking scheme based on cation exchange capacity and presence or absence of carbonate in the top 25 cm of soil and presence or absence of flooding was devised. Five map units varying in potential sensitivity and percentage of the area considered sensitive were used to map the eastern United States. Maps of New York, North Carolina, West Virginia, Pennsylvania, and Indiana are presented. It is recognized that other factors could be considered to improve the ranking scheme and that land use, which is ignored in these maps, has an effect overshadowing that of acid precipitation. The maps should be useful in research planning and in selecting areas for intensive study. The ranking of sensitivities is not intended to predict severity of effects but to guide the selection of terrestrial and aquatic sites to areas where the potential for adverse impacts of long-term atmospheric deposition are the greatest. The need for field testing of the system is obvious. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

1030

McFEE, W. W., KELLY, J. M., and BECK, R. H., 1977, Acid precipitation effects on soil pH and base saturation of exchange sites: Water, Air, and Soil Pollution, v. 7, no. 3, p. 401-408.

The typical values and probable ranges of acid-precipitation are evaluated in terms of their theoretical effects on pH and cation exchange equilibrium of soils characteristic of the humid temperature region. The extent of probable change in soil pH and the time required to cause such a change are calculated for a range of common soils. Hydrogen ion input by acid precipitation is compared to cation inputs from nutrient cycling and other sources. For example it can be calculated that 100 yr of acid precipitation (10,000 cm at pH 4.0) could be expected to shift the percentage base saturation in the top 20 cm of a typical midwestern forest soil (cation exchange capacity of 20 meq 100 g^{-1}) downward 20%, thus lowering the pH of the Al horizon by approximately 0.6 units, if there are no countering inputs of basic materials. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1031

McILVEEN, W. D., 1980, Leaf litter decomposition in the vicinity of a zinc refinery, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 243.

1032

McKAY, H. A. C., 1971, The atmospheric oxidation of sulphur dioxide in water droplets in presence of ammonia: Atmospheric Environment, v. 5, p. 7-14.

This article discusses the kinetics of the conversion of ammonia and sulfur dioxide to ammonium sulfate in water droplets in the atmosphere in the absence of metal ion catalysts. The reaction is an order of magnitude faster than previously believed, and lowering of temperature increases the rate by a large factor. Appreciable amounts of ammonium sulfate may be formed in a cloud or a thick mist in a few minutes. A substantial part of the unreacted ammonia may persist for hours despite excess sulfur dioxide and a fast initial reaction.

1033

McKIM, J. M., and BENOIT, D. A., 1971, Effects of long-term exposures to copper on survival, growth, and reproduction of brook trout (*Salvelinus fontinalis*): Journal Fisheries Research Board of Canada, v. 28, no. 5, p. 655-662.

The developmental stages of brook trout (*Salvelinus fontinalis*) exposed to copper concentrations ranging from 32.5 to 1.9 µg/L were monitored for 22 months. The highest concentration decreased survival and growth in adult fish and reduced the number of viable eggs produced and hatchability. Survival, growth, and reproductive success of adults exposed to concentrations of 17.4 to 3.4 µg/L did not differ from those of the control group (1.9 µg/L). Concentrations of 32.5 and 17.4 µg/L decreased survival and growth of alevins and juvenile fish, respectively.

1034

McKIM, J. M., CRISTENSEN, G. M., TUCKER, J. H., and LEWIS, M. J., 1973, Effects of pollution on freshwater fish: Journal of the Water Pollution Control Federation, v. 45, p. 1370-1407.

This article summarizes significant literature from 1971-72 on the effects of metals, pH, pesticides, and industrial and radioactive wastes on freshwater fish. The section that discusses the effect of pH on fish includes information on the lethal effects of acidity and metals on white sucker, brook trout, carp, and several others.

1035

McLAREN, Eugene, YENCHA, A. J., KUSHNIR, J. M., and MOHNEN, V. A., 1974, Some new thermal data and interpretations for the system SO_2-NH_3-H_2O-O_2: Tellus, v. 26, no. 1-2, p. 291-294.

1035 (continued)
Thermal data are presented on gas-phase reactions in systems consisting of NH_3 and SO_2; NH_3, SO_2, and O_2; NH_3, SO_2, and H_2O (vapor); and NH_3, SO_2, O_2, and H_2O (vapor). The data are interpreted in relation to previously published data and are applied to knowledge of the atmospheric SO_2 cycle and formation of particulates.

1036
McLAUGHLIN, S. B., McCONATHY, R. K., and DUVICK, D., 1980, Effects of chronic air pollution stress on allocation of photosynthate by white pine, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 244.

1037
McLEAN, R. A. N., 1981, The relative contributions of sulfuric and nitric acids in acid rain to the acidification of the ecosystem: Journal of the Air Pollution Control Association, v. 31, no. 11, p. 1184-1187.

Much of the nitric acid from rain is decomposed in the soils and waterways. Unlike sulfuric acid in acid rain, nitric acid does not significantly contribute to the long-term acidification of soils and waters. Overall, nitric acid in atmospheric deposition is not likely to be contributing to the acidification of the environment except during the spring snowmelt, especially in areas that have been heavily subjected to acid precipitation for many years.

1038
McLEAN, R. A. N., FARKAS, M. O., and FINDLAY, D. M., 1982, Determination of mercury in natural waters--sampling and analysis problems, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 151-173.

Many studies have been carried out on the factors involved in the collection of water and precipitation samples for the later determination of trace heavy metal concentrations. Problems which have been identified in the use of sampling vessels for mercury determinations include (a) contamination from the vessels and from the atmosphere, (b) loss of mercury to the vessel walls, and (c) loss from solution to the air due to chemical or microbiological reduction. An assessment of some earlier data on mercury in natural waters and precipitation will be given. In our initial studies on mercury transport in natural waters, we encountered a number of problems in sampling, principally contamination. Fortunately, the automatic method used for the determination of total mercury in water could be adapted to carry out determinations without the intermediate use of sampling vessels. The equipment can be used on site and the water to be analyzed is pumped directly into the analytical system. It was originally used to evaluate different sampling techniques, sampling vessels and storage methods. Some data is shown to illustrate resultant improvements in the sampling methods. The method has also been used as a continuous monitor for determining total mercury concentrations. A number of measurements of mercury in precipitation have also been carried out. The method is sufficiently versatile to be adapted for speciation of mercury in natural waters and some results are shown to illustrate this use. [Abstract reprinted by permission of Plenum Press.]

1039
McMAHON, T. A., and DENISON, P. J., 1979, Empirical atmospheric deposition parameters--a survey: Atmospheric Environment, v. 13, p. 571-585.

This article discusses generalized values as determined from several studies on deposition velocity of atmospheric particles and gases, surface resistance to gaseous deposition, scavenging coefficient of particles and gases, and scavenging ratio of gases. The data are tabulated. About 128 references to published papers are listed.

1040
McMAHON, T. A., DENISON, P. J., and FLEMING, R., 1976, A long-distance air pollution transportation model incorporating washout and dry deposition components: Atmospheric Environment, v. 10, p. 751-761.

This article describes a long-distance air pollution model of washout and dry deposition that operates on a daily time scale. The parameters used for the model are based on values from published literature. The model was tested by comparing computed results with field measurements for specific precipitation events during a 1-year period. Analysis showed that the model is sensitive to the washout coefficient and deposition velocity of dry loading and to species change as well. Errors in the model result from sources such as emission strengths, wind-field specification, mixing depth, uniform dispersion, and species change.

1041
McMURRY, P. H., 1980, The dynamics of secondary sulfur aerosols, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 153-161.

1041 (continued)
Significant amounts of sulfur-containing aerosol are formed in the atmosphere by gas-to-particle conversion of SO_2. The distribution of such secondary aerosols with respect to particle size is important in determining their environmental effects. In this paper, factors which determine the size distributions of evolving secondary aerosols are discussed. Evidence is presented which shows that growth mechanisms and hence size distributions of secondary sulfur aerosols vary in the atmosphere. Also, a theoretical analysis which quantitatively predicts the dynamic behavior of sulfur aerosols formed by gas-phase reactions is outlined. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

1042
McNAUGHTON, D. J., 1979, Emission source specification in a regional pollutant transport model, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 3-8.

1043
McNAUGHTON, D. J., 1981, Relationships between sulfate and nitrate ion concentrations and rainfall pH for use in modeling applications: Atmospheric Environment, v. 15, no. 6, p. 1075-1079.

This article analyzes precipitation chemistry data for the northeastern United States used to define the relationship between anthropogenic sulfate and nitrate ion contributions to pH of rain. A derived regression equation to estimate rainfall pH from predictions made by a long-range transport model is included.

1044
McWILLIAMS, P. G., BROWN, D. J. A., HOWELLS, G. D., and POTTS, W. T. W., 1980, Physiology of fish in acid waters, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 282-283.

1045
MEGONNELL, W. H., 1975, Atmospheric sulfur dioxide in the United States--can the standards be justified or afforded?: Journal of the Air Pollution Control Association, v. 25, no. 1, p. 9-16.

When the national ambient air-quality standards were adopted by EPA in 1971, data were insufficient to establish a quantifiable, scientific definition of clean air. Analysis of recent ambient air-quality data indicate that the U.S. does not contain excessive sulfur dioxide. Government reports indicate a few areas in which national standards are exceeded, but scrutiny of data gathered by inaccurate monitoring techniques reveals that such conclusions may be incorrect.

1046
MEHLICH, A., 1964, Influence of sorbed hydroxyl and sulfate on neutralization of soil acidity: Soil Science Society of America Proceedings, v. 28, p. 496-496.

Soils of varying clay-mineral characteristics were treated with anion-exchange resin to obtain systems containing either sorbed OH^- or SO_4^{2-}. They were then equilibrated with $Ca(OH)_2$. This article evaluates the neutralization of acidity consisting of permanent charge (Hp), variable charge (Hv) and anion-exchange (Han, principally SO_4^{2-} absorbed). The order of neutralization is Hp first (consisting mostly Al^{3+} except for muck), followed almost simultaneously by Hv and Han. Sorbed SO_4^{2-} results in more strongly acidic systems. The magnitude of Han, the soil acidity due to sorbed acid radical ions, may be a large part of the total acidity of red-yellow podzolic and reddish-brown lateritic soils.

1047
MENENDEZ, Raymond, 1976, Chronic effects of reduced pH on brook trout (*Salvelinus fontinalis*): Journal of the Fisheries Research Board of Canada, v. 33, no. 1, p. 118-123.

Brook trout (*Salvelinus fontinalis*) at all developmental stages were continuously exposed to pH levels of 4.5, 5.0, 6.0, 6.5 (control 7.1) for 11 months, and all stages of the trout were monitored. The number of viable eggs was reduced significantly at pH 5.0 and to a lesser extent at the higher pH values. Embryo hatchability was significantly decreased at all pH levels below 6.5, and the growth and survival of alevins was likewise reduced. Continual exposure to pH below 6.5 resulted in significant reductions in egg hatchability and growth.

1048
MENZIES, W. J. M., 1927, River pollution and the acidity of natural waters: Nature, v. 119, no. 3000, p. 638-639.

In this commentary a discussion is given on a paper by H. W. Harvey titled "Fundamental Problems Relating to River Pollution." The author discusses Harvey's theory on the probability effect of the hydrogen ion concentration on river flora and fauna. He suggests that acid conditions that are typical in peatlands may affect the population distribution of the flora and may possibly restrict the fauna, but both trout and salmon parr thrive in waters of pH 4.6 to 6. (See also Harvey, H. W., 1927, herein.)

1049
MESSER, J., and BREZONIK, P. L., 1981, Importance of atmospheric fluxes to the nitrogen balance of lakes in the Florida peninsula, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 217-236.

1050
MESZAROS, E., 1978, Concentration of sulfur compounds in remote continental and oceanic areas, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 699-705.

The results of concentration measurements of atmospheric sulfur dioxide and sulfate particles carried out near the Earth's surface under background conditions are compiled. The data for continental (mainly Europe and North America) and oceanic (mainly Atlantic Ocean) areas are discussed. On the basis of the available information the sulfur quantities in an air column and in the whole atmosphere over continents and oceans are calculated. Some data on the H_2S concentration in the air are also presented. [Abstract reprinted by permission of Pergamon Press.]

1051
MEYERS, P. A., OWEN, R. M., and MACKIN, J. E., 1981, Organic matter and heavy metal concentrations in the particulate phase of Lake Michigan surface microlayers, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 129-141.

1052
MIDDLETON, Paulette, and KIANG, C. S., 1978, Experimental and theoretical examination of the formation of sulfuric acid particles, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 179-185.

Previous experimental and theoretical studies of sulfuric acid aerosol formation for the SO_2^- air system in smog chambers are discussed. Shortcomings in both theory and experiments are outlined. The effects of these uncertainties on calculated and measured nucleation rates are illustrated with numerical kinetic aerosol model calculations. From this examination recommendations for future experimental and theoretical nucleation studies are made. [Abstract reprinted by permission of Pergamon Press.]

1053
MILLER, D. F., 1978, Precursor effects on SO_2 oxidation, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 273-280.

1053 (continued)
Smog chamber experiments were conducted to determine the relationships between SO_2 oxidation and the gaseous precursors common in polluted air: NO_x, NMHC (a mixture of 17 hydrocarbons) and SO_2-SO_2 oxidation to sulfate aerosols was first-order in SO_2. The maximum rate of oxidation was strongly related to initial MNHC/NO_x ratios, but over 6-h irradiation intervals, the conversion of SO_2 to sulfate aerosol was only weakly related to initial MNHC/NO_x concentrations. Typical SO_2 oxidation rates for polluted air ranged from 2-8%/h, but the higher rates were sustained for only a few hours. SO_2 lifetimes > 100 h are predicted from these experiments, in accord with kinetic simulations of photochemical smog and lifetimes derived from tropospheric data. [Abstract reprinted by permission of Pergamon Press.]

1054
MILLER, H. G., and MILLER, J. D., 1980, Collection and retention of atmospheric pollutants by vegetation, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 33-40.

1055
MILLER, J. E., and XERIKOS, P. B., 1979, Residence time of sulphite in SO_2 "sensitive" and "tolerant" soybean cultivars: Environmental Pollution, v. 18, no. 4, p. 259-264.

Species as well as varieties or cultivars of a single species vary in the severity of their response to air pollutants such as sulfur dioxide. Leaves from eight soybean cultivars with varying sensitivity to sulfur dioxide injury were treated with sulfite (dissolved SO_2). Differences among responses of cultivars may reflect differing physiological tolerances and differential gas uptake by plant tissues.

1056
MILLER, J. M., 1979, The acidity of Hawaiian precipitation as evidence of long-range transport of pollutants, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 231-238.

1057
MILLER, J. M., 1979, The monitoring of acid rain, in Gunnerson, C. G., and Willard, B. E., eds., Acid rain: ASCE National Convention, Boston, Mass., 1979, Proceedings: New York American Society of Civil Engineers, p. 111-119.

1058
MILLER, J. M., 1980, National atmospheric deposition program--analysis of data from the first year, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 469-476.

The National Atmospheric Deposition Program (NADP) is an interagency project sponsored by the state agricultural experiment stations, U.S. Department of Agriculture, the Environmental Protection Agency, and others. Originally designated NC-141, one of its major goals is to determine spatial and temporal trends in the deposition of chemicals, both harmful and beneficial, on the land and surface waters. The first precipitation samples for chemical analysis were taken in July 1978. A year later, over 30 sites were part of the program, and their weekly collected rain samples were shipped to a central laboratory for the analysis of all the major ions.

This paper presents data from the first year (July 1978-June 1979), which were taken during a period of atypical meteorological conditions: a very dry period in the fall of 1978 and an extremely wet period in the winter of 1979.

Selected sulfate deposition data that were available from the network were compared with values from other networks, both active and inactive. The comparison showed that precipitation amounts and sulfate concentrations collected simultaneously at the same site by two different networks varied enough to cause disagreement in sulfate depositions. Though there are not enough data to make comprehensive evaluation, this preliminary review points out the need for long-term commitment for continuing the network, for a continuous data review process, and for a vigorous quality assurance program. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

1059
MILLER, J. M., 1980, Special session on precipitation chemistry at the GMCC Annual Meeting, 6 March 1980, Boulder, Colo.: Bulletin of the American Meteorological Society, v. 61, no. 12, p. 1622-1627.

This article is a reprint of a summary of a session on regional and global chemistry of precipitation, held at the 1966 meeting on Geophysical Monitoring for Climatic Change (GMCC). A discussion is given on plans for acid precipitation research to be conducted by the National Oceanic and Atmospheric Administration (NOAA) during fiscal year 1982.

1060
MILLER, J. M., ed., 1981, The potential atmospheric impact of chemicals released to the environment--proceedings of four workshops: Washington, D.C., U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances, 229 p.

This book contains reports on the following workshops held at Jekyll Island, Georgia: (1) toxic substances in atmospheric deposition, (2) screening chemicals for inadvertent modification of the stratosphere, (3) impact of chemicals on the radiative transfer imbalance, and (4) anthropogenic chemicals as modifiers of clouds and precipitation. The workshops were held in November 1979 to study the impact of toxic chemicals on the atmosphere and to assess the feasibility of screening chemicals to diminish these impacts and to develop a screening strategy.

1061
MILLER, J. M., COTTON, G. F., PACK, D. H., MITCHELL, J. M., and SMITH, M. E., 1976, An evaluation of precipitation pH data from the Washington, D.C. area collected during 1975: Silver Springs, Md., U.S. National Oceanic and Atmospheric Administration, Environmental Research Laboratories, NOAA Technical Memorandum ERL ARL-57, 23 p.

This report describes a 1-year study to obtain data on the chemistry of precipitation in Washington, D.C. Precipitation samples were collected at six sites in the Washington, D.C. area during 1974-74 and analyzed for pH. Samples were collected in plastic rain gages with 4-inch diameter. pH measurements were usually made within 12 to 48 hours of collection with an electrode and a pH meter. Median pH ranged between 4.0 and 4.1, within the same order of magnitude as observed elsewhere in the northeastern United States.

1062
MILLER, J. M., and DE PENA, R. G., 1972, Contribution of scavenged sulfur dioxide to the sulfate content of rain water: Journal of Geophysical Research, v. 77, no. 30, p. 5905-5916.

The rate of formation of sulfate ion in raindrop-size, distilled water drops was measured for partial pressures of sulfur dioxide ranging from 10^{-6} to 4×10^{-3} atm. A model was developed from results and on the assumption that the rate of formation of sulfate is determined by the rate of the first dissociation of sulfurous acid and by the rate of oxidation of sulfite to sulfate. Results of the model agree with published data for the rate of solution of SO_2 at low partial pressures. The model was applied to rainout and washout of SO_2 by clouds and raindrops.

1063
MILLER, J. M., GALLOWAY, J. N., and LIKENS, G. E., 1978, Origin of air masses producing acid precipitation at Ithaca, New York--a preliminary report: Geophysical Research Letters, v. 5, no. 9, p. 757-760.

Precipitation data collected on an event basis at Ithaca, N.Y. from August 1974 to June 1976 are interpreted through meteorological maps and a trajectory model developed by the Air Resources Laboratory of NOAA. Acid precipitation (pH <5.6) comes mostly from the southwest sector, where the largest manmade sources of acid-forming gases are found. The northwest sector also contributes acid forming gases. This article describes a method for determining the origin of air masses that produce acid precipitation. The method is useful for identifying general sources of acid precipitation as increased amounts of fossil fuels are burned.

1064
MILLER, J. M., and YOSHINAGA, A. M., 1978, Use of a standard raingage as a precipitation chemistry collector: Journal of Applied Meteorology, v. 17, no. 11, p. 1747-1748.

This article comments on a paper by R. C. Dalal, titled "The effect of some meteorological parameters on the chemical composition of precipitation at the University Field Station, Trinidad, West Indies." The authors point out that the use of standard metal rain gages may alter the chemical composition of precipitation samples.

1065
MILLER, R. B., 1961, The chemical composition of rainwater at Taita, New Zealand, 1956-1958: New Zealand Journal of Science, v. 4, p. 844-853.

Rainwater samples were collected monthly for 3 years at Taita near Wellington, New Zealand and analyzed for major constituents. Salt, sulfate, magnesium, potassium, and calcium concentrations in the samples decreased in the order listed. Phosphate was low. Total nitrogen, measured during only part of the 3-yr data collection period, was double the inorganic nitrogen plus albuminoid nitrogen.

1066
MILLS, E. L., MURPHY, C. B., Jr., and BLOOMFIELD, J. A., 1980, Oxidants in precipitation, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 367-390.

Large quantities of chlorine are produced in the United States each year. A by-product of industrial use and manufacture is that some chlorine gas escapes into the atmosphere. However, a general lack of information exists on precipitation washout of these oxidant residuals despite recognized emissions into the atmosphere. It is hypothesized that acid precipitation is only an indicator of other less obvious phenomena, and the pH of precipitation may well serve as an index of a variety of atmospheric pollutant problems.

Significant inputs of chlorine gas are emitted into the atmosphere in New York State; the major source of chlorine emissions occurs in Niagara County, New York. Oxidant residuals have been measured in rainfall from central New York. Maximum residuals in rainfall coincided with depressed pH values and maximum rainwater temperature. The observed chlorine residuals and dominance of NH_3 ions in rainfall suggest the residual may be a combined form of the type NH_xCl_y. One hypothesis is that industrial emissions of this gas combine with NH_3 in the atmosphere to form NH_xCl_y compounds or chloramines which are later removed by atmospheric washout.

Laboratory and field studies reported in the literature suggest that oxidant residuals are toxic to biological organisms and the impact is highly dependent on concentration and duration of exposure. In dilute aquatic systems of low buffering capacity, measured oxidant residuals can potentially affect biological organisms and may pose a new element of concern. [Abstract reprinted by permission of Plenum Press.]

1067
MINNIS, M. M., 1981, Signature assignment to industrial coal flyash emissions, in American Chemical Society, Division of Environmental Chemistry, 182nd National Meeting, New York, N.Y., Preprints, v. 21, no. 2: Washington, D.C., American Chemical Society, p. 31-33.

1068
MISSOURI BOTANICAL GARDEN, 1975, Sulfur in the environment: St. Louis, Missouri Botanical Garden, 189 p.

This report describes the natural sulfur cycle. A chapter on acid precipitation explains the formation and deposition of airborne acids and the effects of acid precipitation on the ecosystem. Other chapters discuss the microbial sulfur system; lichens as bioindicators; and the effects of sulfur on aquatic and forest ecosystems, grasslands, and agriculture. The text is illustated and includes a glossary. A bibliography is given at the end of each chapter.

1069
MITCHELL, G. J., 1981, Legislative action--an American status report, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 137-139.

1070
MITCHELL, M. J., LANDERS, D. H., and BRODOWSKI, D. F., 1981, Sulfur constituents of sediments and their relationship to lake acidification: Water, Air, and Soil Pollution, v. 16, p. 351-359.

This article describes major organic and inorganic sulfur (S) fractions in the sediment of Oneida Lake (Onondaga County), Deer Lake (Essex County), and South Lake (Herkimer County), N.Y. These lakes differ in buffering capacity, pH, and biological productivity. Total S in Deer and South Lakes is highest near their major inlets. Sulfide was highest in Oneida sediment, which has a lower redox potential. A major portion of the S in the three lakes is ester sulfate. Oxygen consumption was greatest in Oneida Lake and lowest in South Lake. Low ester sulfate and elevated carbon/nitrogen ratio in South Lake sediment suggest that acidification inhibits decomposition of organic matter.

1071
MIYAMOTO, Seiichi, BOHN, H. L., RYAN, J., and YEE, M. S., 1974, Effect of sulfuric acid and sulfur dioxide on the aggregate stability of calcareous soils: Soil Science, v. 118, no. 5, p. 299-303.

The effects of sulfuric acid (H_2SO_4) and sulfur dioxide (SO_2) on water-stable, soil aggregates were determined for two noncalcareous, two sodic-calcareous, and six calcareous soils in southern Arizona. Aggregate stability, the percentage of silt and clay remaining as a >50-μ aggregate, decreased with increasing amounts of H_2SO_4 and SO_2. The relative aggregate stability, the ratio of the destroyed portion of the aggregate to its total, decreased with relative acidification in all calcareous soils. Sorption of SO_2 from most streams also reduced aggregate stability, but the reduction was less than equivalent amounts of H_2SO_4 solutions.

1072
MOHN, E., JORANGER, E., KALVENES, S., SOLLIE, B., and WRIGHT, R. F., 1980, Regional surveys of the chemistry of small Norwegian lakes--a statistical analysis of the data from 1974-1978, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 234-235.

1073
MOLDAN, B., 1980, The analysis of atmospheric precipitation in Czechoslovakia, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 124-125.

1074
MORDY, W. A., 1957, Report on the Third Annual Conference on Atmospheric Chemistry, May 28-30, 1956: Tellus, v. 9, no. 1, p. 127-134.

This article summarizes reports from the Third Conference on Atmospheric Chemistry, Stockholm, Sweden, 1956, sponsored by the International Union of Geodesy and Geophysics. It discusses some proposed recommendations for improving the European atmospheric chemistry observation network and presents results of investigations of (1) atmospheric chemistry, (2) chemical composition of rivers, and (3) sampling techniques. [See also Tellus, v. 6, no. 3, 1954 and v. 6, no. 3, 1955 for summaries of the two previous conferences.]

1075
MORRISON, I. K., 1981, Effect of simulated acid precipitation on composition of percolate from reconstructed profiles of two northern Ontario forest soils: Canadian Forestry Service Research notes, v. 1, no. 2, p. 6-8.

This article compares the hydrogen ion (H^+) and sulfate (SO_4^{2-}) leaching products from soil columns from two northern Ontario forests subjected to differing regimes of artificial acid loading under greenhouse conditions. Results suggest that element loss is a stage by stage process. Initially soils exhibited considerable resistance to acid input, which in some soils is probably related to SO_4^{2-} retention. The second stage is characterized by cation removal under the influence of freely moving SO_4^{2-}. The author suggests that a similar process occurs under natural conditions and resistance in the soils is a function of SO_4^{2-} adsorptive capacity.

1076
MORSE, H., 1966, Measurements of pH, and chemical analyses of rain-, snow-, and fog-water: Tellus, v. 18, no. 2, p. 266-270.

Rain samples were collected at Dresden, Germany, from 1957-65, and fog-water samples were collected at four mountain summit stations and one coastal station in Germany. Yearly mean pH of samples (mean value 4.5) remained constant after 1958, and no pH differences between winter and summer rain were found. The concentations of elements did not differ among storms, and the season differences were not noteworthy.

1077
MOSELLO, R., 1980, Chemical characteristics and buffer capacity of fifty alpine lakes (Italy, Pennine-Lepontine Alps), in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 236-237.

1078
MOSS, Brian, 1973, The influence of environmental factors on the distribution of freshwater algae--an experimental study--the role of pH and the carbon dioxide-bicarbonate system: Journal of Ecology, v. 61, p. 157-177.

Algae were tested to determine the effects of pH, carbon dioxide (CO_2), and bicarbonate on growth. Species found in oligotrophic waters did not grow at pH 8.5 or higher, but species in eutrophic waters grew at pH values above 9 and at considerably higher bicarbonate levels than in oligotrophic waters. Oligotrophic species are probably limited to free CO_2 as a source of inorganic carbon for photosynthesis and may be unable to absorb CO_2 below concentrations of 0.011 m moles. Eutrophic species use bicarbonate directly for photosynthesis or may be able to use free CO_2 at low concentrations. The lack of free CO_2 prevents growth of oligotrophic species in hard waters.

1079
MOSS, Brian, 1973, The influence of environmental factors on the distribution of freshwater algae--an experimental study--growth of test species in natural lake waters, and conclusions: Journal of Ecology, v. 61, p. 193-211.

Experiments were done to investigate the effect of free CO_2 and pH on growth of algae eutrophic and oligotrophic in lake waters. Bioassays using the natural algal flora of lake waters were conducted to identify nutrients that may be limited to algal growth in general and to compare similar assays using test species. Results indicate increasing productivity in lakes with increasing flux (annual load) of nutrients, particularly phosphorus, which is related to intrinsic growth rate of the algae species in eutrophic lakes. A summary is given of the overall project results.

1080
MOSS, M. R., 1975, Spatial patterns of precipitation reaction: Environmental Pollution, v. 8, p. 301-315.

The spatial pattern of acid precipitation effects is attributed to gaseous pollutants from industrial areas. Precipitation samples from two urban industrial sites in Great Britain differed considerably in acidity, and precipitation at both sites was less acidic than at some rural sites. Spatial patterns of acidic deposition are affected by many chemical and meteorological factors, some of which are unique to each site.

1081
MOSS, M. R., 1978, Sources of sulfur in the environment; the global sulfur cycle, in Nriagu, J. O., ed., Sulfur in the environment, part 1--The atmospheric cycle: New York, John Wiley, p. 23-50.

1082
MOSS, T. H., 1980, Environmental versus emission control costs--a legislative perspective, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 21-30.

1083
MOUNT, D. I., 1973, Chronic effect of low pH on fathead minnow survival, growth and reproduction: Water Research, v. 7, p. 987-993.

Fathead minnows (*Pimephales promelas* R.) were continuously exposed to waters of pH 4.5, 5.2, 5.9, 6.6, and 7.5 (control) for 13 months. Survival rate was not affected even at the lowest pH, but behavior became abnormal at pH 4.5 and deformities occurred at 5.2. Egg production and hatchability were reduced at pH 5.9 and below, and all eggs were abnormal.

1084
MULLER, E. F., and KRAMER, J. R., 1977, Precipitation scavenging in central and northern Ontario, in Precipitation scavenging, Champaign, Ill., 1974, Proceedings: [Oak Ridge, Tenn.], U.S. Energy Research and Development Administration, ERDA Symposium Series 4, p. 590-601.

Time-averaged deposition of SO_4, Fe, Ni, and Cu during 1970-74 are presented and discussed in view of the industrial mining and smelting activities and associated atmospheric emissions in central Ontario. Deposition after the installation of a 381-m stack at the main smelter complex in Sudbury increased in extent, but the amount of deposition near the source decreased.

Deposition rates are shown to be highest in the Sudbury area and decrease with distance therefrom. Deposition rates decrease in the following order: $Fe > Ni > Cu \gg SO_4$; material balance of emitted vs. deposited materials shows removals ranging from 100 percent to 0.5 percent.

1085
MULLER, Peter, 1980, Effects of artificial acidification on the growth of periphyton: Canadian Journal of Fisheries and Aquatic Sciences, v. 37, p. 355-363.

An increase in periphyton growth in large enclosures in the littoral zone of Lake 223 in the Experimental Lakes Area of Ontario is attributed to lake acidification. The genus *Mougeotia*, which is dominant in many acidified lakes in Scandinavia, is the most tolerant of high acidity. Fewer species and less diversity are observed at higher acidity. Increases in standing crop are observed; however, no corresponding increased in production has been noted. The abundance of invertebrates and microbiota appear to be unaffected by increased acidity.

1086
MULLER, Stanton, 1981, SURE air quality data: Environmental Science & Technology, v. 15, no. 9, p. 989-990.

This article describes the Sulfate Regional Experiment (SURE) program, funded by Electric Power Research Institute (EPRI), that was begun in the mid-1970's to monitor the distribution of air pollutants, especially hazes in the northeastern U.S. that contain sulfate particles. The program, is designed to (1) establish an adequate data base with seasonal, diurnal, and three-dimensional resolution; (2) acquire a three-dimensional emissions inventory; and (3) develop transport models. The first two objectives of the program have been met but the modeling needs to be further developed. The SURE acronym has been changed to RAQS (Regional Air Quality Studies) program.

1087
MULLIN, R. E., 1969, Soil acidification with sulphur in a forest tree nursery: The Sulphur Institute Journal, v. 5, no. 1, p. 2-3.

Soil pH of a tree nursery near Toronto, Ontario has risen above that recommended for production of coniferous seedlings. Soil pH was lowered by the following methods: (1) acidification of irrigation water to pH 6.0 with sulfuric acid, (2) addition of acid peat at the rate of 60 cubic yards per acre, and (3) addition of powdered sulfur at the rate of 750, 1500, and 2250 pounds per acre. The soil pH was effectively and safely lowered to the required level (pH 5.0-6.0) for coniferous production with powdered sulfur treatments.

1088
MUNIZ, I. P., 1981, Acidification and the Norwegian salmon, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 65-72.

1089
MUNIZ, I. P., and LEIVESTAD, H., 1980, Acidification--effects on freshwater fish, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 84-92.

1090
MUNIZ, I. P., and LEIVESTAD, H., 1980, Toxic effects of aluminum on the brown trout, *Salmo trutta*, L., in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 320-321.

1091
MUNN, R. E., 1977, The greenhouse effect: Mazingira, v. 2, p. 78-86.

This article describes the effects of fossil fuels on air quality. Increasing use of fossil fuels is causing a rise in CO_2 emissions, and since 1955 the rate of increase has been nearly exponential. As the level of carbon dioxide (CO_2) rises, so does the temperature in the lower atmosphere because CO_2 absorbs infrared radiation. CO_2 is not the only gas that causes this "greenhouse" effect. The halocarbons and trace gases such as N_2O, CH_4, NH_3, HNO_3, C_2H_4, SO_2, CCl_2F_2, CCl_3F, CH_3Cl, and CCl_4 also absorb infrared radiation in some wave bands. Suspended particulate matter also affects climate. This article gives special attention to sulfate particles, the precursors of acid precipitation.

1092
MUNN, R. E., and RODHE, Henning, 1971, On the meteorological interpretation of the chemical composition of monthly precipitation samples: Tellus, v. 23, no. 1, p. 1-13.

This article presents a method for determining the influence of synoptic weather patterns on the chemical composition of precipitation samples collected monthly. The method is described in relation to data on the deposition of sulfur and chloride at two stations in southern Sweden from 1951-69. Long-term trends in regional pollution may result from changes in emissions, changes in the general circulation patterns in the atmosphere, or both. The data used in this article indicate (1) a curvilinear relationship between deposition and precipitation rates and (2) that temporal or local variation in precipitation amount is not a major cause of local variations in deposition rate.

1093
MURPHY, T. J., SCHINSKY, A., PAOLUCCI, G., and RZESZUTKO, C. P., 1981, Inputs of polychlorinated biphenyls from the atmosphere to Lakes Huron and Michigan, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 445-458.

N

1094
NADER, J. S., 1980, Primary sulfate emissions from stationary industrial sources, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 123-130.

The genesis of sulfur emissions impacting on ambient sulfate levels includes both natural and anthropogenic sources. Sulfate salts and sulfuric acid emitted as such directly from anthropogenic sources are called primary sulfates to distinguish them from secondary sulfates resulting from atmospheric transformations. Studies of sulfate emissions from various combustion sources are reviewed. Current experimental data on physical and chemical properties, emission factors, operating parameters, and fuel composition affecting the emissions are briefly summarized. Oil-fired combustion sources were found to have sulfate emissions that ranged from 5% to 10% of the SO_x emissions, about a factor of 5 times the historical values. The sulfate emissions are calculated for a New Jersey area which utilizes large amounts of oil in its combustion sources. Oil combustion alone accounted for 97% of the sulfate emissions in the combustion source category. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

1095
NAGOURNEY, S. J., and BOGEN, D. C., 1981, Trace metals in atmospheric deposition at American Samoa, in American Chemical Society, Division of Environmental Chemistry, 182nd National Meeting, New York, N.Y., Preprints, v. 21, no. 2: Washington, D.C., American Chemical Society, p. 38-40.

1096
NASH, T. H., III, and SIGAL, L. L., 1980, Sensitivity of lichens to air pollution with an emphasis on oxidant air pollutants, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 117-124.

1096 (continued)
The hypothesis that lichens are sensitive indicators of air pollution is now well established for oxidants, sulfur dioxide, hydrogen fluoride and trace elements. From field studies differential sensitivity of different lichen species around pollution sources is evident. Laboratory studies with the particular air pollutant generally confirm the same degree of differential sensitivity. [Abstract reprinted by permission of U.S. Forest Service.]

1097
NATIONAL RESEARCH COUNCIL OF CANADA, 1939, Effect of sulphur dioxide on vegetation: Ottawa, Canada, National Research Council of Canada, Report no. 815, 1 v.

A study was initiated to investigate effects of sulfur dioxide fumes emitted from smokestacks of a smelting company at Train, British Columbia. This report discusses sulfur dioxide in the atmosphere of industrial areas, symptoms of injury to forests and crops, and pH and sulfate content of soils and water. Fumigation experiments are also described. Results indicate that sulfur dioxide produces characteristic symptoms on leaves and plants that may constitute acute and chronic injury. If sulfur dioxide is absorbed directly into soils it is oxidized to sulfuric acid, and the acid then reacts with bases in the soil to decrease the base saturation, which may involve a gradual loss of calcium, magnesium, and other alkali metals.

1098
NATIONAL RESEARCH COUNCIL OF CANADA, 1981, Acidification in the Canadian aquatic environment--scientific criteria for assessing the effects of acidic deposition on aquatic ecosystems: National Research Council of Canada Publication no. 18475, 369 p.

This publication is a state-of-the-art review of research, modeling, and monitoring of the acidification of the Canadian aquatic environment. It addresses the relationships among components of the hydrologic cycle, including atmosphere, vegetation, and lithology, and gives recommendations. It is concluded that acidic atmospheric deposition poses an environmental problem in Canada, but its geographic extent and severity cannot be accurately determined from available data. Substances produced from oxides of sulfur and nitrogen are the primary agents causing acidification of the aquatic environment. Acidification affects the distribution, chemical composition, and availability of many elements in soils, water, and sediments, particularly metals. Short-term changes in surface-water chemistry may occur prior to observable long-term changes.

1099
NATIONAL WILDLIFE FEDERATION, 1981, Acid rain vulnerability of the 27 states east of the Mississippi River: Washington, D.C., National Wildlife Federation, 13 p.

This article gives a qualitative assessment of the vulnerability of the eastern states to acid precipitation on the basis of data from published studies, precipitation monitoring stations, and from communications with researchers. The 27 eastern states are ranked according to their vulnerability to fishery, soil, crop foliage, and masonry damage. Fifteen states are extremely susceptible to adverse impacts of acid precipitation, 10 states are moderately vulnerable, and one state (Florida) is classified as having low vulnerability.

1100
NEVILLE, C. M., 1979, Sublethal effects of environmental acidification on rainbow trout (*Salmo gairdneri*): Journal of Fisheries Research Board of Canada, v. 36, p. 84-87.

Cannulated rainbow trout (*Salmo gairdneri*) were exposed to water acidified to pH of 4.0 (acid group); the control group was in water at pH 7.0. Dorsal aorta blood samples were taken from both groups; results over a 5-day period showed a gradual decrease in blood pH and total CO_2 in the acid group, but no significant change in pO_2 and lactate. When exposed to the same conditions for 12 days, the acid group showed significant increases in hemoglobin, hematocrit, and erythrocyte levels in caudal vein samples.

1101
NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION, 1981, Preliminary report of stream sampling for acidification studies: Albany, N.Y., New York State Department of Environmental Conservaton, Technical Report 81-2, 116 p.

Stream samples were collected at 100 sites in the Adirondack and Catskill Mountains of New York from 1979 through the spring of 1980. Some streams in the Adirondack Mountains were affected by low pH and alkalinity. Some streams remained acidified during most of the summer; and many never had pH values above 5.0. Of streams sampled in the Catskill Mountains, none had critically low pH during the same period. Fish-population statistics correlate well with stream pH. Both Catskills and Adirondacks were classified in terms of sensitivity. Those with pH below 5.0 were classified as "critical," those ranging between pH 5.0 and pH 6.0 as "endangered," and those with pH above 6.0 as "satisfactory." About 15 percent of the sampled streams were in the "critical" classification.

1102
NEWMAN, J. R., 1980, Air pollutants and their effects on wildlife with particular reference to the house wren (*Delichon urbica*), in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 131-135.

Injury and death to wildlife from air emissions have been recorded since before the turn of the century. Air pollution can directly affect wildlife (i.e., cause death), or can indirectly affect wildlife (i.e., cause habitat loss). A recent investigation on the chronic and sublethal effects of air pollution on the house martin (*Delichon urbica*) has shown that air emissions can significantly affect the nesting ecology of this species. [Abstract reprinted by permission of U.S. Forest Service.]

1103
NEWMAN, Leonard, 1975, Acidity in rainwater--has an explanation been presented?: Science, v. 188, p. 957-958.

This article comments on a paper by G. E. Likens, and F. H. Bormann on the regional environmental effects of acid precipitation. Newman disputes Likens' and Bormann's theory on the conversion of SO_2 to sulfuric acid and the effect of particulate-removing devices in tall stacks on this process. A reply by Likens and Bormann is included. (See Likens, G. E., and Bormann, F. H., 1974, herein.)

1104
NEWMAN, Leonard, 1978, Techniques for determining the chemical composition of aerosol sulfur compounds, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 113-125.

An extensive critical review is given of the methods presently available for the determination of the chemical composition of aerosol sulfur compounds. Some recent typical results employing the methods are presented. The advantages, limitations and future promises of the techniques are discussed. Potential problems associated with the alteration of chemical composition during sampling are illustrated. The utility of general analytical and wet chemical identification techniques are demonstrated. A sequential selective solvent separation scheme and the use of thermal volatilization for the determination of verious sulfates are described and illustative results given. The application of thermometric titrimetry and electron spectroscopy for the identification of oxidation states is presented and evaluated. A discussion is given for the use of

1104 (continued)
utility of i.r. and lasar Raman spectroscopic techniques for the identification of sulfate species. A diffusion battery processor technique for sampling suboptical particles is described and its utility in conjunction with chemical analysis of these size separated particles evaluated. [Abstract reprinted by permission of Pergamon Press.]

1105
NEWMAN, Leonard, 1980, Atmospheric oxidation of sulfur dioxide, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 131-143.

An overview is presented of significant historical, recent, and new power plant and smelter plume studies which have been directed at understanding the atmospheric oxidation of sulfur dioxide. It can be concluded that the average rate of oxidation of sulfur dioxide in plumes entering into clean air is generally less than 1% per hour but that in polluted urban air the rate can be at least twice as fast. In addition, there is a diurnal variation in the rate, being near zero at night and approximately 3% per hour during midday. Although there is a tendency to select homogeneous over heterogeneous as the dominant pathway, there is no basis for a definitive choice, and most likely both mechanisms are at times operative. The suggestion is made that important and definitive new studies can be performed with technologies just becoming available. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

1106
NGUYEN, B. C., GAUDRY, Andre, BONSANG, Bernard, and LAMBERT, Gerard, 1978, Reevaluation of the role of dimethyl sulphide in the sulphur budget: Nature, v. 275, p. 637-639.

This article discusses the possiblity of an oceanic source of atmospheric sulfur dioxide (SO_2). Biogenically produced dimethyl sulfide (DMS) may escape from the oceans to the atmosphere, where it is oxidized to SO_2. A method for measuring DMS in seawater has been developed. Measurements obtained by this method indicate that the oceans could contribute more than 30 percent of the sulfur required to balance the global sulfur budget.

1107
NICHOLLS, K. H., and COX, C. M., 1978, Atmospheric nitrogen and phosphorus loading in Harp Lake, Ontario, Canada: Water Resources Research, v. 14, no. 4, p. 589-592.

1107 (continued)
Precipitation and dry fallout samples were collected at Harp Lake, Ontario, during 1974 and analyzed for nitrogen (N), phosphorus (P), and pH. Weighted mean concentrations of total N and P during the ice-free period of collection were 1.91 mg/L N and 0.105 mg/L P; winter concentrations of N were similar; P were considerably lower. Total atmospheric loading of N to the lake was 1600 (mg/M^2)yr, and dissolved inorganic N loading formed about 63 percent of the total N loading from the atmosphere. Rain pH of 14 samples ranged from 3.2 to 5.1; the median value was 3.9.

1108
NICHOLSON, I. A., CAPE, J. N., FOWLER, David, KINNAIRD, J. W., and PATERSON, I. S., 1980, pH and sulphate content of precipitation over northern Britain, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 142-143.

1109
NICHOLSON, I. A., CAPE, J. N., FOWLER, David, KINNAIRD, J. W., and PATERSON, I. S., 1980, Effects of a Scots pine (*Pinus sylvestris* L.) canopy on the chemical composition and deposition pattern of precipitation, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 148-149.

1110
NICHLOSON, I. A., FOWLER, David, PATERSON, I. S., CAPE, J. N., and KINNAIRD, J. W., 1980, Continuous monitoring of airborne pollutants, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 144-145.

1111
NIEBOER, E., and RICHARDSON, D. H. S., 1981, Lichens as monitors of atmospheric deposition, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 339-388.

1112
NIEMANN, Brand, HIRATA, Allan, and SMITH, Lowell, 1979, Application of a regional transport model to the simulation of regional sulphate episodes over the eastern United States and Canada, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 337-346.

1113
NIHLGARD, Bengt, 1970, Precipitation, its chemical composition and effect on soil water in a beech and spruce forest in south Sweden: Oikos, v. 21, no. 2, p. 208-217.

This article presents data on the distribution and chemical composition of rain in a beech and a spruce forest in southern Sweden. Extrapolated annual values of nutrients in the throughfall and stemflow amount to 107 kg/ha and 215 kg/ha in the beech and spruce forests, respectively. The soil of the spruce forest is about 19 percent drier than that of the beech forest. A high percentage of nutrients may be derived from dry deposited aerosols, particularly Na, Mg, Cl, and Ca. No indication is given that the spruce forest adsorbs more aerosols than the beech forest; hence the greater amount of nutrients in the rainfall in the spruce forest is probably derived from stronger leaching processes of the canopy.

1114
NILSSEN, J. P., 1980, Acidification of a small watershed in southern Norway and some characteristics of acidic aquatic environments: International Revue der Gesamten Hydrogiologie [Norway], v. 65, no. 2, p. 177-207.

The pH of lakes in a small watershed in southern Norway has decreased by nearly half a unit (from pH 5.9 to pH 5.4), and conductivity has increased from 23 to 29 μS/cm from 1965-75. Sediment analyses show that *Daphnia* and *Chaoborus* are found deeper than 4 cm. Forest clearing has accelerated the acidification process. The solute content of acidic lakes is below 0.4 meq/L and the bicarbonate buffer system may no longer be efficient. Spring snowmelt and autumn rains significantly alter the chemistry of lake environments by causing a decrease in Ph and an increase in conductivity and sulfate. The planktonic community changes from a system governed by fish predation to one governed by invertebrate predation. Pelagic zooplankton are composed mostly of littoral species: *Bosimina logispina*, *Diaphanosoma brachyurum*, *Eudiaptomus gracilis*, and *Heterocope saliens*.

1115
NILSSEN, J. P., 1980, Acidification of freshwater and limnetic organisms—complex biotic interactions or statistics? [abstract], in Drablos, D., and Tollan, A., eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 344.

1116
NILSSEN, J. P., 1980, Early warning signals of acidification [abstract], in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 344.

1117
NILSSON, Ingvar, 1977, The acidification sensitivity of some Swedish forest soils: Meddelanden fran Avdelningen for Ekologisk Botanik 32, Lunds Universitet, 81 p.

Soil samples were collected at 21 sites in a forest in southern Sweden and analyzed for humus and clay content, base saturation (pH 7.0), and cation-exchange capacity (pH 7.0). Some samples were used to determine the acid buffer capacity and ion-adsorption isotherms. Acid buffer capacity showed strong correlations with base saturation and the sum of base cations.

1118
NILSSON, S. I., 1980, Ion adsorption isotherms in predicting leaching losses from soils due to increased inputs of "hydrogen" ions—a case study, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 537-551.

1119
NISBET, I. C. T., 1974, Acid rain—fossil sulfur returned to earth: Technology Review (Massachusetts Institute of Technology), v. 76, no. 4, p. 8-9.

This article discusses the effectiveness of tall stacks in easing the pollution problem caused by sulfur dioxide emissions. SO_2 emissions from manmade sources throughout the world are estimated to range from 100 to 150 million tons per year, which could yield 200 million tons of sulfuric acid. Acid precipitation is severely affecting salmon and trout populations. Fishkills are occurring in acid lakes in Northern Ontario, rural New Hampshire, and throughout Scandinavia. Another effect is the leaching of essential nutrients such as calcium, magnesium, and potassium from soils. This article also discusses some of the economic impacts of acid precipitation.

1120
NOBLE, R. D., and JENSEN, K. F., 1980, Effects of SO_2 and ozone on photosynthesis and leaf growth in hybrid poplar, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 245.

1121
NOCHUMSON, D. H., 1979, Comment on "Gaseous sulfur pollutants from urban and natural sources": Journal of the Air Pollution Control Association, v. 29, no. 2, p. 164-165.

This commentary suggests that errors in a global atmospheric sulfur budget by Robinson and Robbins may be due to misinterpretation of the input values used to calculate the amount of sulfur removed by precipitation scavenging. Suggestions for correcting the budget are given. (See also Robinson, E., and Robbins, R. C., 1970, herein.)

1122
NOGGLE, J. C., 1980, Sulfur accumulation by plants; the role of gaseous sulfur in crop nutrition, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 289-297.

Sulfur (S) requirements to maintain high crop production range from 10 to 40 kg/ha year. The relationship between soil S supply and crop yield is presented, and the need for supplemental S to maintain high crop yields is discussed. A decline in the use of fertilizers that contain S has placed a greater dependency on the atmosphere as a source of supplemental S to meet the needs of plants.

A technique was developed and used to measure the amount of atmospheric S accumulated by crops grown in the field. Amounts of atmospheric-derived S in cotton grown 3 km and 16 km from a coal-fired power plant were 44 and 26 percent, respectively, of the total S content in the plant tissue. Results from this study and from collection of wet and dry deposition of atmospheric S provide evidence that a significant quantity of S is transferred from the atmosphere to the agroecosystem. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

1123
NORDO, Jack, 1974, Quantitative estimates of long range transport of sulphur pollutants in Europe: Annalen der Meteorologie, v. 9, p. 71-77.

1123 (continued)
Long-range transport of sulfur compounds in Europe is estimated from data on regional emissions of sulfur in Scandinavia and the instantaneous wind field. A mathematical model is developed based on Eulerian and Lagrangian integration schemes; applications of the model are demonstrated. Dry deposition rate and conversion rate of sulfur dioxide to sulfate are critical factors in estimating long-range transport. The model computations of concentration are within a factor of 2 of the measured concentrations at representative field sites.

1124
NORDO, Jack, 1976, Long range transport of air pollutants in Europe and acid precipitation in Norway: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 199-217.

Observations show that pollutants from large emission sources may cause significiant air concentrations 500 to 1000 mi away. Very acid precipitation occurs in such periods. The scavenging is often intensified by the topography. Case studies will be presented with special emphasis on acid precipitation in Scandinavia.

Large scale dispersion models have been develloped recently in order to estimate the long range transport of air pollutants. The models take into account chemical transformations as well as deposition of pollutants. The calculations will be compared with observations from airplanes and surface stations.

A simple model has been integrated over a long period of time in order to derive the best value for the decay rate of SO_2. This best values is based on a day-by-day comparison with surface observations. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1125
NORLUND, G. G., 1979, On the contribution of meteorological factors to the seasonal variations in atmospheric sulphur concentrations, in WMO Symposium on the Long-Range Transport of Pollutants and Its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 53-64.

1126
NORTON, S. A., 1980, Geologic factors controlling the sensitivity of aquatic ecosystems to acidic precipitation, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 521-531.

1126 (continued)
Minerals, when dissolved, are capable of neutralizing excess acid in precipitation according to the number of positive charges released in excess of negative charges released into solution. However, the kinetics of solution are important in the effectiveness of a particular mineral's capability of neutralizing acid. Thus quartz,

$$SiO_2 + 2H_2O \rightarrow H_4SiO_4,$$

has no buffering capacity; albite,

$$2NaAlSi_3O_8 + 2H^+ + 9H_2O \rightarrow 2Na^+ + Al_2Si_2O_3(OH)_4 + 4H_4SiO_4,$$

and calcite,

$$CaCO_3 + H^+ \rightarrow Ca^{2+} + HCO_3^-,$$

$$HCO_3^- + H^+ \rightarrow H_2CO_3,$$

have similar ultimate acid-neutralizing capacities. However, $CaCO_3$ dissolves rapidly and consequently is highly effective at neutralizing excess acid.

Rocks have been classified from type 1 (yield no or little buffering capacity) to type 4 ("infinite" buffering capacity). Maps, based on bedrock geology, have been produced which predict vulnerability of aquatic ecosystems to impact from acidic precipitation. Field checks of areas underlain by rock types 1 and 2 verify that acidification of surface waters and impact on biological systems due to acidic precipitation are occurring. The lack of discrimination by these maps for rock types 1 and 2 is due to the generalization of large-scale maps, the local hydrology and neutralization by soils of precipitation acidity. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

1127
NORTON, S. A., 1981, Changing processes in soils caused by atmospheric deposition of pollutants, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 15.

1128
NORTON, S. A., DAVIS, R. B., BRAKKE, D. F., HANSON, D. W., and KENLAN, K. H., 1981, Responses of northern New England lakes to atmospheric inputs of acid and heavy metals: Washington, D.C., U.S. Department of the Interior, Office of Water Research and Technology, Research Technical Completion Report, 90 p.

The effects of pH changes on 94 low-humic lakes in mostly noncalcareous terrain of northern New England were studied. Most (85 percent) of the lakes are more acidic now than in previous years, according to a comparison of historical calorimetric measurements to modern electrode pH measurements. Among the lakes studied, Fe, Mn, Pb, Zn, and Al concentrations increased as pH decreased. Whereas Na, K, Ca, and Mg concentrations and alkalinity increased as pH increased. Analyses of upper sediments show that concentrations of Na_2O, K_2O, MgO, and organic compounds were higher at higher pH values, that Cu increased as pH decreased, and that CaO, FeO, MnO, Al_2O_3, TiO_2, Pb, and Zn did not correlate with pH. The relative abundance of taxa of diatom remains in profundal surface sediments from 25 of the lakes was related to surface-water pH 4.4 to 7.0. Greatest taxonomic diversity occurred at pH 5.8.

1129
NORTON, S. A., DUBIEL, R. F., SASSEVILLE, D. R., and DAVIS, R. B., 1978, Paleolimnologic evidence for increased zinc loading in lakes of New England, U.S.A.: International Association of Theoretical Applied Limnology, Proceedings, v. 20, p. 538-545.

A study of sediments in 12 lakes in New England was conducted to determine the relationship of sediment chemistry, flora, and fauna to land-use practices in the drainage basins. Results indicated that increased zinc loadings in the lakes cannot always be attributed to land-use practices. The article discusses the affect of acid precipitation on fluxes of zinc and other heavy metals.

1130
NORTON, S. A., HANSON, D. W., and CAMPANA, R. J., 1980, The impact of acidic precipitation and heavy metals on soils in relation to forest ecosystems, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 152-157.

Normal terrestrial cycling of metals in eastern North America and the Pacific Coast states has been altered by the increasing acidity of precipitation, and associated heavy metal deposition and mobilization. Pb and chemically similar metals are accumulating in soils. Al, Ca, K, Mg, and Mn are being leached from soils. The mobilities of Fe, Zn, and P vary with site characteristics. Biological recycling of nutrients by decomposition and uptake is impeded by lowered pH and elevated levels of toxic metals in soils. Increased leaching of nutrients in the O and A horizons, caused by increased H^+ inputs, decreases percent base saturation and thus decreases nutrient pools for shallow rooted plants, especially seedlings. Deeper rooted plants are subjected to elevated, potentially toxic, concentrations of dissolved metals (e.g., Al and Mn).

1130 (continued)
In many contemporary forest ecosystems, nutrient availability is barely adequate for sustained yield with bole harvesting techniques. Our work indicates that nutrient pools are diminishing in the northeastern United States, suggesting that decreases in forest productivity will occur. [Abstract reprinted by permission of U.S. Forest Service.]

1131
NORTON, S. A., and HESS, C. T., 1980, Atmospheric deposition in Norway during the last 300 years as recorded in SNSF lake sediments, U.S.A. and Norway. I. Sediment dating and chemical stratigraphy, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 268-269.

1132
NORTON, S. A., HESS, C. T., and DAVIS, R. B., 1981, Rates of accumulation of heavy metals in pre- and post-European sediments in New England lakes, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 409-421.

1133
NOVAKOV, T., CHANG, S. G., and HARKER, A. B., 1974, Sulfates as pollution particulates--catalytic formation on carbon (soot) particles: Science, v. 186, p. 259-261.

Finely divided carbon (soot) particles may be significant in the catalytic oxidation of sulfur dioxide to sulfate in polluted atmosphere. Data on the properties and behavior of sulfates produced in a laboratory by the oxidation of sulfur dioxide on graphite particles and combustion-produced soot particles are compared with those of ambient sulfates. Laboratory experiments indicate (1) graphite and soot particles oxidize SO_2 in the air, (2) SO_2 catalyzed by soot plays a major role, in the presence of flames and gases produced by combustion, and (3) soot-catalyzed oxidation shows a prominent saturation effect. Results of the experiment are quantitatively consistent with field observations.

1134
NRIAGU, J. O., 1978, Deteriorative effects of sulfur pollution on materials, in Nriagu, J. O., ed., Sulfur in the environment, part II--ecological impacts: New York, John Wiley, p. 1-59.

1135
NRIAGU, J. O., 1978, Production and uses of sulfur, in Nriagu, J. O., ed., Sulfur in the environment, part 1--The atmospheric cycle: New York, John Wiley, p. 1-21.

1136
NRIAGU, J. O., and COKER, R. D., 1978, Isotopic composition of sulfur in precipitation within the Great Lakes Basin: Tellus, v. 30, p. 365-375.

Seasonal changes in the relative contributions of airborne sulfur from bacteriogenic and anthropogenic sources were assessed by monitoring isotope ratios and concentrations of sulfur (S) in bulk precipitation samples at urban and rural sites on the Canadian side of the Great Lakes basin. Average sulfur dioxide (SO_2) concentrations at urban sites were higher during winter than summer. Precipitation samples from the urban sites had higher S concentrations and were enriched in 34S compared to samples from rural sites. Bacteriogenic sulfur emissions within the Great Lakes basin may account for 10 to 30 percent of the total sulfur emitted from the basin. Biogenic release of sulfur from land areas may be smaller than has been assumed in many models of the global sulfur cycle.

1137
NRIAGU, J. O., and HARVEY, H. H., 1978, Isotopic variation as an index of sulphur pollution in lakes around Sudbury, Ontario: Nature, v. 273, p. 223-224.

This article describes the distribution and isotopic composition of sulfur in lakes at various distances from smelter stacks near Sudbury, Ontario and assesses the point-source contributions in terms of isotopic composition of sulfur. Measurements of 34S in polluted lakes, especially when pH and sulfate concentrations are known, is an effective means of diagnosing sulfur contamination.

1138
NRIAGU, J. O., and HEM, J. D., 1978, Chemistry of pollutant sulfur in natural waters, in Nriagu, J. O., ed., Sulfur in the environment, part II--Ecological impacts: New York, John Wiley, p. 211-270.

1139
NUR, Ramin, and BATES, M. H., 1979, The effects of pH on the aluminum, iron, and calcium phosphate fractions of lake sediments: Water Research, v. 13, no. 8, p. 813-815.

The effect of sediment pH on the amount of phosphorus bound in the aluminum, iron, calcium, and saloid-bound fractions of sediments from Lake Carl Blackwell, Oklahoma was studied. The pH of lake sediment samples were experimentally altered by mixing with distilled water acidified to a pH range from 1 to 12. When the pH of the sediment and overlying water was equilibrated, a 1-g sample was fractionated to determine the phosphorus bound in each fraction. The point

1139 (continued)
of minimum fixation within the sediment occurred at pH 7.33. Aluminum and iron phosphate fractions were predominant in an acidic environment. Thus, more phosphorus was found in the aluminum and iron fractions than in the calcium fraction. The amount of saloid-bound phosphorus was minimal at every pH used in the study.

1140
NYBORG, Marvin, 1978, Sulfur pollution and soil, in Nriagu, J. O., ed., Sulfur in the environment, part II--Ecological impacts: New York, John Wiley, p. 359-390.

1141
NYBORG, Marvin, CREPIN, J., HOCKING, Drake, and BAKER, J. P., 1977, Effect of sulphur dioxide on precipitation and on the sulphur content and acidity of soils in Alberta, Canada: Water, Air, and Soil Pollution, v. 7, no. 4, p. 439-448.

Rain and snow in Alberta are seldom acid. The S content of snow is so low that the snow pack gives a deposition of less than 1 kg S ha^{-1}, even downwind from large SO_2 emission sources. Rainfall contributes at the most 4 kg S ha^{-1} yearly near SO_2 sources, and only about 1 kg S ha^{-1} in clean areas. However, rain intercepted by forest trees exposed to SO_2 emission becomes acid (pH 3.5 to 4.5) and has a S content 3 to 4 times greater than rain. Soils absorb large amounts of S from emissions (up to 50 kg S ha^{-1} annually) but much of the S is found in non-sulphate form. Soils are slowly acidified by the SO_2 at a rate estimated at 1 pH unit in 10 to 20 yr. Water surfaces will absorb SO_2 emissions at a rate of about 4 to 15 kg S ha^{-1} annually. Particulates deposit 3 to 4 times as much S as is deposited by rainfall. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1142
NYBORG, Marvin, PARKER, R. W., HODGINS, L. W., LAVERTY, D. H., and TAKYI, S., 1980, Soil acidification by SO_2 emissions in Alberta, Canada, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 180-181.

O

1143
OATIS, J. W., 1977, The acid precipitation problem in New York State: Albany, New York State Assembly, 14 p.

The principal sources of fossil-fuel emissions, which are causing acidic precipitation in New York, are from the Ohio River Valley and, to a lesser extent, the Sudbury smelting region in Ontario, Canada. Acidic rain and snow lower the pH of poorly buffered lakes in the Adirondack Mountains. The acidification of lakes and ponds in New York is not confined to high-elevation watersheds. The most significant effect of the acidification of lakes is the disappearance of some fish species in these lakes. Acid precipitation is also associated with potential health problems, for example, aggravation of respiratory and cardiopulmonary illnesses, and heavy-metal contamination of municipal drinking water systems.

1144
ODDIE, B. C. V., 1962, The chemical composition of precipitation at cloud levels: Royal Meteorological Society Quarterly Journal, v. 88, p. 535-538.

Precipitation samples were collected by aircraft over southern England in an attempt to obtain samples uncontaminated by industrial sources or sea spray. Most samples were found to be contaminated by industrial pollution. Some samples were collected under synoptic conditions, and pollution seemed improbable. The amount of dissolved matter in these samples was smaller than in the remainder, and their composition showed a close similarity to samples collected at ground-level at remote, unpolluted sites. The solute did not appear to contain matter derived from land. Differences in chemical composition seemed to arise from a reaction occurring either at the sea surface or in the atmosphere.

1145
ODEN, Svante, 1968, The acidification of air and precipitation and its consequences on the natural environment, translated by Translation Consultants, Ltd.: Stockholm, Sweden, National Science Research Council, Bulletin no. 1, 117 p.

This report discusses trends of atmospheric chemistry as determined from 15 years of data collected by a European monitoring network. The S content of air and precipitation show a characteristic pattern that correlates with air pollution from industrial areas. Increasing S content in the atmosphere with time is related to the increasing use of sulfurous fuels as a substitute for coke and coal. A series of maps shows geographic patterns of decreased pH of precipitation. Data on the acidity of yearly precipitation in Europe show that in 1958, values below pH 5 were found only in a limited area of the Netherlands. By 1965, precipitation of pH 4.5 had spread to southern Sweden, and by 1967, pH of precipitation in central Sweden had decreased to 4.3.

1146
ODEN, Svante, 1975, Acid precipitation--a world concern, in Acid precipitation: Conference on Emerging Environmental Problems, Rensselaerville, N.Y., 1975, Proceedings: New York, U.S. Environmental Protection Agency, p. 5-44.

1147
ODEN, Svante, 1976, The acidity problem--an outline of concepts: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 137-166.

The nature and extent of acid precipitation is reviewed. Studies have shown that significant decreases in the pH of rain have occurred in Scandinavia and the northeastern United States during the last two decades. This increased acidity correlated well with anthropogenic activities that emit acidifying substances into the atmosphere. Problems of measurement and interpretation are discussed. Finally, a review of acid precipitation's impact on surface waters and on soils is presented. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1148
ODEN, Svante and AHL, Thorsten, 1980, The sulfur budget of Sweden, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 111-122.

1149
OGDEN, J. G., III, 1977, Watershed research in Nova Scotia, in Correll, D. L., ed., Watershed research in eastern North America--A workshop to compare results: Edgewater, Md., Chesapeake Bay Center for Environmental Studies, Smithsonian Institute, v. 1, p. 67-82.

Bulk precipitation and specific-storm samples were collected from three watersheds in Nova Scotia, Canada, and outlet waters were quantitatively sampled for major ions to determine their input and output from each watershed. This article discusses the effects of decreases in average pH of precipitation (4.7 to 3.5) on nutrient loss from the ecosystems, methods of precipitation sampling, and results of heavy metals analyses.

1150
OGDEN, J. G., III, 1980, Comparative composition of continental and maritime precipitation and acidification of Nova Scotian lakes, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 82.

1151
OGDEN, J. G., III, 1980, Comparative composition of continental and Nova Scotian precipitation, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 126-127.

1152
OGILVIE, D. M., 1981, Acid precipitation in North America--"A Hard Rain is Gonna Fall": Ambio, v. 10, no. 2-3, p. 148-149.

This article comments on the 1981 annual meeting of the American Association for the Advancement of Science in Toronto, Canada, specifically the sessions on documentation of atmospheric events and ecological effects associated with acid precipitation, emission control technologies, and government intervention. A part of the Synfuels Bill signed into law in 1980 known as the Federal Acid Precipitation Act of 1980 addresses the environmental effects of acid precipitation. A task force will be preparing a comprehensive 10-year plan designed to answer pertinent questions about acid precipitation. Acid precipitation is a significant environmental problem in Canada and a major issue to be resolved with the United States.

1153
OGNER, G., 1980, Effects of acid precipitation on soil and forest, 10. The effect of growth of Norway spruce on soil acidity by acid irrigation, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 208-209.

1154
OKLAND, J., 1980, Acidification in 50 Norwegian lakes: Nordic Hydrology, v. 11, no. 4, p. 25-32.

Fifty lakes in southeastern Norway were studied during 1953-57 and 1963-70. The average pH decreased from 7.0 to 6.8; total hardness showed no statistically significant change. The pH of lakes with low total hardness ($\leq$ 1 degree dH) decreased from 6.6 to 6.3, and average hydrogen ion concentration increased by 4.33×10^{-7} mol per liter, which is equivalent to a 233-percent increase. No significant statistical change in acidity was observed in lakes with high total hardness (>1 degree dH). Lakes with low total hardness are probably vulnerable to acidification.

1155
OKLAND, J., 1980, Environment and snails (Gastropoda)--studies of 1000 lakes in Norway, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 322-323.

1156
OKLAND, J., and OKLAND, K. A., 1980, pH level and food organisms for fish--studies of 1000 lakes in Norway, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 326-327.

1157
OKLAND, K. A., 1980, Mussels and crustaceans--studies of 1000 lakes in Norway, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 324-325.

1158
OLSEN, R. A., 1957, Absorption of sulfur dioxide from the atmosphere by cotton plants: Soil Science, v. 84, p. 107-111.

This article gives a quantitative estimate of the amount of sulfur dioxide (SO_2) from the atmosphere that may pass directly into the leaf tissue of cotton plants. Results show that the amount of SO_2 that plants absorb is proportional to the size of the plant and is a function of the effective leaf surface. Absorption of atmospheric SO_2 provides an important supplementary source of sulfur to growing plants despite the potential for serious injury and defoliation of plants when concentrations exceed 0.5 ppm for extended periods of time.

1159
OMSTEDT, Gunnar, and RODHE, Henning, 1978, Transformation and removal processes for sulfur compounds in the atmosphere as described by a one-dimensional time-dependent diffusion model, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 503-509.

The model is used to simulate vertical profiles of H_2S, SO_2, and SO_4^{2-} in the atmosphere up to about 8 km. Transformation and wet removal processes are treated as first order reactions with constant rate coefficients and the dry deposition is estimated using deposition velocity parameters. From a systematic study of the sensitivity of the model to variations in some of the key parameters and from a comparison with aircraft measurements of SO_2, and SO_4^{2-} over Scandinavia the following results are derived. An increase in the value of the deposition velocity in long range transport models beyond about 1 cm s^{-1} has little effect on the estimated dry deposition. As the rate coefficient for the transformation of H_2S to SO_2 varies from 10 to 0.01 h^{-1} the scale height of H_2S varies from 40 to 1400 m and that of SO_2 (applicable to background air) from 1300 to 3400 m. An average value for the first 30 hours of the rate of transformation of man-made SO_2 to SO_4^{2-} is probably in the range 0.007 to 0.04 h^{-1} for European conditions. It is difficult to simulate the observed pattern of wet deposition of sulfur over northern Europe if the wet removal of SO_2 is neglected. [Abstract reprinted by permission of Pergamon Press.]

1160
ONO, Akira, 1978, Sulfuric acid particles in subsiding air over Japan, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 753-757.

Direct investigations were made of physical and chemical properties of aerosol particles, collected at the summit of Mt. Fuji (3776 m) in subsiding air, based on the appearance and chemical tests of individual particles under the electron microscope.

From electron microscopy of aerosol particles collected on a carbon film and that on a thin film of reacting materials by vacuum deposition, it is found that most of the aerosol particles in subsiding air are present in the form of free sulfuric acid droplets. They are predominantly small, the common radius of the equivalent sphere being smaller than 0.1 μm and their concentrations are on the order of 300 cm^{-3}.

Some of the implications of the present findings in relation to sources of sulfuric acid particles are discussed. [Abstract reprinted by permission of Pergamon Press.]

1161
ONTARIO. MINISTRY OF THE ENVIRONMENT, 1979, Determination of the susceptibility to acidification of poorly buffered surface waters: Rexdale, Ontario, Ministry of the Environment, Water Resources Branch, 21 p.

The report discusses sampling and analytical methods used in lake and stream surveys to determine the sensitivity of freshwaters to acidic deposition. Geochemistry of a watershed is the most important factor governing acid sensitivity. Methods for determining total alkalinity, pH, and equipment used in the sampling are described.

1162
ONTARIO. MINISTRY OF THE ENVIRONMENT, LIMNOLOGY AND TOXICITY SECTION, 1981, Acid sensitivity survey of lakes in Ontario: Rexdale, Ontario Ministry of the Environment, Acidic Precipitation in Ontario Study APIOS Report no. 002/81, 1 v.

This report tabulates lake data collected for the Acidic Precipitation in Ontario study, conducted by the Ontario Ministry of the Environment. The lakes are grouped by county or district and listed alphabetically. The following information is given for each lake: location (township, latitude, and longitude); documents providing data; sampling dates; and alkalinity, conductivity, and calcium concentration.

1163
ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT, 1971, Ad hoc meeting on acidity and concentration of sulphate in rain, May 1969: Paris, Organization for Economic Cooperation and Development, 19 p.

Scientists from Finland, France, Germany, Netherlands, Norway, Sweden, and Great Britain met in 1969 to review a "Swedish report on the acidity and the concentration of sulphate in precipitation over Europe." The Swedish report discusses long-term trends of the acidity and the concentration of sulfate in precipitation. An overall increase in the acidity of precipitation in Scandinavia and central Europe has been documented, but such a trend has not been observed in Great Britain or Ireland. This article cummarizes the reviewing committee's recommendations for expanding the precipitation monitoring network based on the data presented in the Swedish report.

1164
OTTAR, Brynjulf, 1976, Organization of long range transport of air pollution monitoring in Europe: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 219-229.

In the 1950s a network of stations for observation of the chemical composition of air and precipitation was established in Europe. Analyzing these data, Oden (1968) was able to show that a central area in Europe with highly acid precipitation was expanding from year to year. This was further substantiated by Granat (1972), and the explanation is the increasing use of fossil fuels in Europe. In 1969, the problem was examined by OECD [Organization for Economic Cooperation and Development], and on the inititative of the Scandinavian countries, a joint research program to study the long range transport of air pollutants was started in 1972. The program will be completed with a final report in 1976.

1164 (continued)
In this program, atmospheric dispersion models are used to describe emission, dispersion and deposition of SO_2 and sulphate with particular emphasis on the acidification of the precipitation. An emission field has been constructed for Europe, and data from the European weather forecasting system are used for the dispersion calculations. Calculated concentrations and deposition are compared with data from about 70 ground stations and measurements from aircraft.

Results show that the main cause for acidification of precipitation is the increasing use of fossil fuels. Large amounts of H_2SO_4 can be transported over distances up to a few thousand kilometers.

In southern Scandinavia where the soil is highly acid (podsol), this has caused severe damage to life in rivers and lakes, and it is feared that in the future, there will be serious damage to forestry. In the Alps, where the soil has a high carbonate content, such effects are not expected. The long range transport of air pollutants has also been shown to increase the corrosion of materials.

Work is now in progress to establish a more permanent system for the monitoring of air pollutants in Europe. The first plans for such a system were presented at the meeting in Oslo in December 1974, where countries from both eastern and western Europe participated. The work is supported by the Economic Commission for Europe, UN, in cooperation with other international organizations such as the World Meteorological Organization and the GEMS program of the United Nations Environment Programme.

In this connection, studies have also been taken up in several countries concerning the effects of the long range transport of air pollutants. In the future monitoring system, a coordination of these efforts is envisaged. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1165
OTTAR, Brynjulf, 1977, International agreement needed to reduce long-range transport of air pollutants in Europe: Ambio, v. 6, no. 5, p. 276-270.

Sulfur dioxide emissions have doubled in Europe since 1950. Countries such as Norway, Sweden, and Finland in Scandinavia, and Switzerland and Austria in the alpine region, receive larger contributions of air pollution from abroad than from their own sources. Data from an air-quality monitoring program involving the eastern European countries show that an international agreement to reduce sulfur dioxide emissions is needed.

1166
OTTAR, Brynjulf, 1978, An assessment of the OECD study on long range transport of air pollutants (LRTAP), in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnki, Yugoslavia, 1977: New York, Pergamon Press, p. 445-454.

Based on a survey of the sulphur emissions in Europe, and measurements at about 70 ground stations and by aircraft, atmospheric dispersion models have been used to evaluate the long range transfer of sulphur pollutants in Europe. The annual mean sulphur dioxide concentrations range from .20 $\mu g\ m^{-3}$ in rural areas close to the major source regions to .2 $\mu g\ m^{-3}$ in remote areas of the northern and western Europe. The annual mean aerosol sulphate concentrations are lower, ~10 $\mu g\ m^{-3}$, and fall off more gently to ~0.5 $\mu g\ m^{-3}$ in remote areas. The pattern of wet deposition shows enhanced values in areas exposed to polluted air masses and locally increased precipitation. Qualitatively the main features of the concentration fields are reproduced by the model calculations, but full quantitative agreement cannot be expected because of the many approximations made. However, on an annual basis a correlation coefficient of 0.9 was obtained between observed and calculated values.

Estimates of the annual transfer of pollutants from one country to other countries are given for 1974. These amounts are, however, dependent on variations in the annual weather pattern. Future plans for monitoring and evaluation of the long range transport of air pollutants in Europe are outlined. Experience indicates that considerable improvements could probably be obtained by introducing more detailed formulations of the chemical reactions and deposition processes in the atmospheric dispersion models. [Abstract reprinted by permission of Pergamon Press.]

1167
OTTAR, Brynjulf, 1979, Long-range transport of air pollutants which are reemitted to the atmosphere by sublimation, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/ Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 125-126.

1168
OTTAR, Brynjulf, 1980, The long range transport of air pollution and acid rain formation, in International Symposium on Inland Waters and Lake Restoration, Portland, Maine, 1980, Restoration of lakes and inland waters: Washington, D.C., U.S. Environmental Protection Agency, EPA-440/5-81-010, p. 432-437.

1168 (continued)
The increase in acidity of precipitation in Europe was first documented in 1968 by Svante Oden, who related the phenomenon to increasing use of fossil fuels containing a high sulfur content. Later an extensive exchange of air pollutants between the European countries was shown, and acid precipitation was observed in areas frequently exposed to polluted air masses. Additional studies indicate that air pollutants from Europe are found in the Artic, particularly in winter. Sulfuric acid is the main acid component of acid precipitation.

1169
OUELLET, Marcel, 1981, Some paleolimnological aspects of the most recent sediments of Lac LaFlamme (Laurentides Provincial Park, Quebec) in relation to atmospheric transportation of pollutants: Quebec, Canada Inland Waters Directorate, Water Planning and Management Branch, 37 p.

Quantities of Cs^{137}, Na, Cu, S, Ca, Hg, Ni, Pb, and Zn released into the atmosphere by man's activities are reflected by stratigraphic increases of these sediments beginning primarily in the levels corresponding to the 1940's. A slight decline in Al and Ca levels in the sediments of Lac LaFlamme is noted within the same interval; this may be attributed to the greater mobility of the elements as a result of acid precipitation. The high capacity of loose sediments in the lake for ion exchange may prevent acidification of the lake water, which is pH 6.1.

1170
OVERREIN, L. N., 1972, Sulphur pollution patterns observed; leaching of calcium in forest soil determined: Ambio, v. 1, no. 4, p. 145-147.

This article reports a pattern of sulfur deposition around a Norwegian industrial center and describes experiments to determine the effect of acid precipitation on calcium levels in nearby forest soils. The largest deposition of calcium, magnesium, iron, manganese, potassium, sodium, and sulfate was confined to urban districts near the source of pollution. Leaching of calcium increases significantly in a variety of soils as acidity of precipitation increases. The acidification rate of soils is affected by the (1) concentration of excess acid in precipitation, (2) amount of acid water penetating the soil profile, (3) susceptibility of the nutrient elements available to leaching, and (4) buffering capacity of the soil. The gradual acidification of soils is accompanied by increasing acidity of ground water.

1171
OVERREIN, L. N., 1976, A presentation of the Norwegian project "Acid Precipitation--Effects on forest and fish": Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 167-172.

The joint research project, "Acid Precipitation--Effects on Forest and Fish" (the SNSF project) of the Agricultural Research Council of Norway and the Norwegian Council for Scientific and Industrial Research was started in 1972. The objectives of the project are to: (1) establish as precisely as possible the effects of acid precipitation on forest and freshwater fish; and (2) investigate the effects of air pollutants on soil, vegetation, and water, required to satisfy point 1.

Research activities on the project are organized and carried out mainly at four institutes. Within and between these institutes groups are formed carrying out investigations in fields including atmospheric transport and chemistry, dry deposition and leaching of foliage, forest growth, soil biology and soil chemistry, hydrological relationships of peatland, hydrobiology with special stress on fish, and hydrochemistry including snow chemistry. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1172
OVERREIN, L. N., 1980, Acid precipitation impact on terrestrial and aquatic systems in Norway, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 145-151.

In recent decades the acidity of rain and snow has increased sharply over wide areas. The principal cause is the release of sulphur and nitrogen oxides by the burning of fossil fuels. The air quality in any one European country is measurably affected by emissions in other European countries. Strong acids have lowered the annual mean pH of precipitation in much of northern Europe to between 4 and 5. In southern coastal areas of Norway, the annual mean acidity in precipitation is now 4.3 pH-units, or even more acidic.

Acid precipitation has increased leaching of nutrients from the uppermost soil layers. These losses of nutrients may be expected to decrease plant growth, but field evidence in Norway and elsewhere has not yet been obtained. It is possible that polluted air and precipitation over a period of years can influence plant production.

Atmospheric transport of sulphur and other acidifying components has led to extensive regional acidification of water courses in areas with very little neutralization capacity. Acidification of watercourses has had major effects on life in rivers and lakes. Lakes in an area of 13,000 km^2 in southern Norway have become empty of fish in recent decades, and a further area of approximately 20,000 km^2 contains lakes with significantly reduced fish stocks. [Abstract reprinted by permission of U.S. Forest Service.]

1173
OVERREIN, L. N., 1981, Acid precipitation as an environmental problem in Europe, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 9.

1174
OVERREIN, L. N., SEIP, H. M., TOLLAN, ARNE, 1980, Acid precipitation--effects on forest and fish; final report of the SNSF Project, 1972-80: Oslo-As, Norway, SNSF Project, Research Report FR 19/80, 175 p.

The Norwegian Interdisciplinary Research Program, titled "Acid precipitation--effects on forest and fish," began in 1972 to study the effects of acid precipitation on the natural environment. This final report is based on nearly 300 SNSF reports and other published papers. Some of the topics discussed are (1) emissions, transport, and deposition; (2) acidification of freshwaters; (3) influence of terrestrial ecosystem on the chemical composition of runoff; (4) land-use changes and acidification of water; (5) conceptual models of the acidification of water; (6) effects on soil productivity and plant growth; and (7) effects on aquatic life. (See also Tollan, Arne, 1981, herein.)

1175
OVERTON, J. H., Jr., ANEJA, V. P., and DURHAM, J. L., 1979, Production of sulfate in rain and raindrops in polluted atmospheres: Atmospheric Environment, v. 13, p. 355-367.

This article describes a chemical model of the accumulation of sulfur species in raindrops. The model accounts for the mass transfer of SO_2, O_3, NH_3, and CO_2 into ideal droplets containing the catalyst Fe(III). Sulfur accumulation in the droplets is calculated as a function of fall distance. The model predicts the formation of sulfate due to the oxidation of dissolved SO_2 by O_3 and catalytic ions in the presence of NH_3 and CO_2. Results of the model conform to experimentally measured values of rain (pH 3-9) and sulfate concentrations (20 to 150 µmol/L) as reported in the literature.

P

1176
PACK, D. H., ed., 1979, Advisory workshop to identify research needs on the formation of acid preciptation, Alta, Utah, 1978, Proceedings: Palo Alto, California, Electric Power Research Institute, EPRI-EA-1074, 1 v.

This is a collection of papers presented at a workshop sponsored by the Electric Power Research Institute (EPRI) on instrumentation and sampling, atmospheric chemistry, cloud processes, meteorological transport, and mathematical modeling. Thirty-eight research projects are summarized by representatives from government, utilities, universities, and private research organizations.

1177
PACK, D. H., 1980, Precipitation chemistry patterns: A two-network data set: Science, v. 208, p. 1143-1145.

A comparison of precipitation chemistry data from two networks in the United States shows that the two networks yield comparable data. The two networks are the Multi-State Atmospheric Power Production Study (MAP3S) and Electric Power Research Institute (EPRI) Network. This body of data can be used to examine the chemistry of precipitation from individual storms as they pass across the eastern part of the country. Data from the two networks can be used to study patterns and trends of anions and cations that control acidity of precipitation.

1178
PACK, D. H., GERBER, G. J., HEFFTER, J. L., TELEGADAS, K., ANGELL, J. K., HOECKER, W. H., and MACHTA, L., 1978, Meteorology of long-range transport, in Sulfur in the Atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 425-444.

The increasing attention to regional-scale transport of pollution has resulted in numerous air quality networks, models and large scale field studies to relate the sources of pollution to subsequent air quality measurements and thence to the effects of pollution. We compare observed air quality and trajectory data to calculations to quantitatively evaluate the differences. Methods of preparing air trajectories are described with emphasis on the Air Resources Laboratories' trajectory model and an accompanying diffusion model. The comparison of observed atmospheric transport with calculated trajectories shows that large computational errors can occur, and more importantly that these may be systematic, but different, depending on the type of advection (cold vs warm) and whether the transport is over land or over the sea. We describe the use of tetroon recovery locations in trajectory analysis and show that such data can be obtained over distances up to 4000 km. Computed trajectories based on the geographic assumption and on the observed wind field are compared to observations to determine the adjustments required to obtain the best comparisons. Directional adjustments of up to 40° and changes in speed by a factor of two are sometimes necessary. We make suggestions for studies to improve the capability of calculating trajectories, including experiments using balloons and controlled tracer releases. Both of these techniques are applicable over regional scales. Finally we show the global distribution of sulfur from the industrial areas of the Northern Hemisphere, as calculated by an efficient computer model, as a step in the determination of the global sulfur budget. [Abstract reprinted by permission of Pergamon Press.]

1179
PACK, D. H., and PACK, D. W., 1980, Seasonal and annual behavior of different ions in acidic preciptation, in WMO Technical Conference on Regional and Global Observation of Atmospheric Pollution: Geneva, Switzerland, World Meteorological Organization, WMO no. 549, p. 303-313.

This article defines spatial and temporal trends in the acidity of precipitation in the eastern United States from 1975-78. Sulfate concentration data show a significant annual cycle with a strong peak in warmer months. The pH cycle parallels the SO_4 cycle, with the lowest pH during the warmer months.

1180
PACK, D. W., 1978, Sulfate behavior in eastern U.S. precipitation: Geophysical Research Letters, v. 5, no. 8, p. 673-674.

Analyses of precipitation samples for H^+, SO_4^{2-}, and NO_3^- collected from 1976-77 at five sites in eastern United States show that monthly weighted concentrations of SO_4^{2-} correlate significantly among the sites up to a distance of 750 km. NO_3^- concentrations correlate significantly among sites to only 150 km. The H^+ is significantly correlated among sites to 600 km. Results of the study show that SO_2 and(or) SO_4^{2-} are well mixed over eastern United States. A sulfur reservoir fluctuates uniformly in the region, but NO_3 does not show the same tendency for consistent fluctuation over large separation distances.

1181
PACKER, R. K., and DUNSON, W. A., 1972, Anoxia and sodium loss associated with the death of brook trout at low pH: Comparative Biochemistry and Physiology, pt. A, v. 41A, p. 17-26.

Brook trout exposed to waters with pH 2.0 to 3.50 show a considerable decrease in or a complete inhibition of O_2 consumption before death. Death from anoxia due to KCN occurs in about the same time as death due to very low pH. Trout lose large amounts of Na before death when exposed to water of low pH. H_2SO_4 (pH 3.25) is less toxic than HCl of the same pH. The lethal effects of these acids may be due to inhibition of O_2 uptake and a large increase in net loss of Na.

1182
PAEHLKE, R. C., 1979, Canada--acid rain: Environment, v. 21, no. 7, p. 4-5, 42.

Lakes in northern Ontario, Quebec, and the eastern provinces are slowly becoming acidic. At least 140 lakes in Ontario are acidified to the point of having severe reductions in fish populations, and as many as 48,000 lakes could be expected to do so. Most of the lake acidification results from airborne sulfur dioxide and oxides of nitrogen that are picked up by water vapor in the air and fall as acid precipitation. Forest growth is also affected by acid precipitation in many regions of Ontario, New England, and the Adirondack Mountains of New York State.

1183
PAHLICH, E., 1975, Effect of SO_2--pollution on cellular regulation, a general concept of the mode of action of gaseous air contamination: Atmospheric Environment, v. 9, p. 261-263.

This article describes the effect of SO_2 and its derivatives on regulatory enzymes of amino acid metabolism in pea seedlings. The ratio of the inorganic to organic fraction of SO_2 derivatives determines whether the effect will be nutritional or damaging to plants.

1184
PARENT, S., and CHEETHAM, R. D., 1980, Effects of acid precipitation on *Daphnia magna*: Bulletin of Environmental Contamination and Toxicology, v. 25, p. 298-304.

Experiments show that adult *Daphnia magna* (14 days) tolerate low pH for short periods of time (24 h) but that continued survival is unlikely at or below pH 5.0. At pH 5.5, younger organisms (4 days) are unable to survive whereas those 7 days old show a 40-percent survival rate after 3 weeks. Reproduction does not occur below pH 5.5 with 4-day *D. magna* nor below 5.0 with 7-day *D. magna*. Normal reproduction rates are unlikely in adults at pH 5.0 or less.

1185
PARKER, G. G., LINDBERG, S. E., and KELLY, J. M., 1980, Atmosphere-canopy interactions of sulfur in the southeastern United States, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 477-493.

Throughfall sulfate-sulfur enrichment in five southeastern forests was found to be related to the proximity of sulfur sources, though not all of the differences between stands could be ascribed to dry-deposition inputs. Both net throughfall deposition and throughfall concentrations as sulfate sulfur exhibited maxima in the warmer months, suggesting rapid cycling as well as enhanced dry deposition. Plots of the relationship between throughfall sulfate concentrations and precipitation amounts are suggested as possible indicators of net throughfall sources. From indications in the literature and observations in these studies, it is suggested that, depending on the forest type and proximity to sulfur sources, on the order of 50% of net throughfall sulfate is due to precipitation-dissolved dry deposition. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

1186
PARMANN, Georg, 1981, The acidification of Norway: Ambio, v. 10, no. 2-3, p. 150-151.

The effects of acid precipitation on the forest ecosystem remains uncertain. The Norwegian Interdisciplinary Research Program, titled "Acid Precipitation--Effects on Forest and Fish" (SNSF project) began in 1972 and ended in 1981. Although acidic deposition alters soil components, the SNSF project did not conclude that it retards forest growth. Long-term adverse effects are likely--specifically leaching of nutrients and trace metals from forest soils and vegetation, and decreases in litter decomposition. The acidification of Norway's freshwater lakes and streams has severely reduced aquatic plant and fish populations.

1187
PARSONS, J. D., 1977, Effects of acid mine wastes on aquatic ecosystems: Water, Air, and Soil Pollution, v. 7, no. 3, p. 333-354.

The Cedar Creek Basin (39th N parallel 92nd W meridian) was studied for the period June 1952 through August 1954 to observe the effects of both continuous and periodic acid effluent flows on aquatic communities. The acid strip-mine effluent contained ferric and ferrous Fe, Cu, Pb, Zn, Al, Mb, titratable acid, and elevated H ion concentration, and was toxic to many of the aquatic organisms. In the areas of Cedar Creek subjected to

1187 (continued)
continuous acid flow, planktonic and benthic species had become adapted to the severe conditions and varied in abundance and diversity. No fishes were observed in the continuous acid effluents area. Downstream, where periodic mineral acid conditions changed drastically during an excessive effluent flow, planktonic and benthic communities had high diversity but low density. The populations of fishes were variable in this stream reach. The chemical basis of water quality variability was shown to be time-related, and statistically related to the aquatic communities.

Physical, chemical and biological conditions of acid lakes formed by surface mining were reviewed. In addition to apparent physical and chemical differences in lakes, due in part to variable solar absorbance due to suspended oxides of Fe, chemical variability related to organic composition was reviewed. It is quite probable that degradation of such lakes can be reversed. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1188
PATRICK, Ruth, BINETTI, V. P., and HALTERMAN, S. G., 1981, Acid lakes from natural and anthropogenic causes: Science, v. 211, p. 446-448.

Naturally acidic lakes occur in several parts of the United States, typically in areas of igneous rock or where the substrate is largely sand. Most are small and are characterized by water with low conductivity and a weak carbonate-bicarbonate buffering capacity. Another type of naturally acidic lake is those occupying a geologic substrate similar to those described above and that have accumulated large amounts of organic matter. Many lakes in the northeastern United States have increased in acidity in the last 2 decades. Some naturally acidic lakes are more acidic today than formerly. Factors that may contribute to acidification of lakes are (1) industrial use of precipitators, sulfur scrubbers, and tall stacks, and (2) combustion fossil fuels.

1189
PATTERSON, D. E., HUSAR, R. B., and HAKKARINEN, C., 1980, Monte Carlo simulation in the eastern United States--comparison with SURE data and visibility observations, <u>in</u> Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 163-177.

A long-range transport model is presented and applied to simulate daily sulfate concentrations over the eastern United States during August 1977. The model uses a Monte Carlo random-sampling technique to simulate horizontal dispersion as well as transformation and removal kinetics of individual sulfur emission quanta. On a daily basis, the spatial distribution of simulated SO_4^{2-} compares well with measured SO_4^{2-} on 12 days, with fair agreement on another 12 days. However, on 7 days there was a major disagreement. The measured sulfate data from the Sulfate Regional Experiment (SURE) and light extinction coefficients derived from routine visibility measurements show remarkable spatial and temporal agreement throughout the month. This suggests that the extensive visibility data base collected by the National Weather Service may be useful as a semiquantitative surrogate for sulfate measurements over the eastern United States. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

1190
PEAKALL, D. B., 1979, Acid precipitation and wildlife, <u>in</u> Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 91-96.

1191
PEARSON, F. H., and McDONNELL, A. J., 1975, Limestone barriers to neutralize acidic streams: American Society of Civil Engineers, Journal of the Environmental Engineering Division, EE3, p. 425-440.

Onsite neutralization from streams in Pennsylvania was done by feeding hydrated lime directly into the water. Acidic streams also can be neutralized on site by placing crushed limestone in a stream bed and allowing water to percolate through. Water-sample analyses and field measurements collected for 9 months in 1972-73 at four prototype limestone barriers at Huntingdon County, Pennsylvania demonstrate the capability of properly designed barriers to renovate acidic streams for economic uses and to support normal aquatic life. A mathematical model of barrier performance is presented based on hydraulic laws and the chemical kinetics of the rate-limiting reactions.

1192
PEARSON, F. J., Jr., and FISHER, D. W., 1971, Chemical composition of atmospheric precipitation in the northeastern United States: U.S. Geological Survey Water-Supply Paper 1535-P, 23 p.

Bulk precipitation samples were collected monthly from 18 sites in New York, Pennsylvania, and New England for 12 to 36 months. Samples were analyzed for calcium, magnesium, sodium, potassium, ammonium, hydrogen ion, bicarbonate, sulfate, chloride, nitrate, and phosphate. Hydrogen ion and sulfate loads varied with precipitation quantity in both inland and coastal areas. Data from one station showed higher calcium,

1192 (continued)
nitate, and sulfate loads near industrial areas. Species with loads that did not vary with precipitation entered bulk precipitation samples mostly as dry fallout; those loads that varied with precipitation were dissolved. Chemical loads in precipitation falling on several basins in the Northeast are compared with loads carried by unpolluted streams draining the same basins. Total nitrogen loads in precipitation entering the basins were greater than total nitrogen output by streams. Sulfate present in dilute streams is derived from precipitation. Precipitation chemistry affects the chemistry of ground water, as suggested by data collected from the Magothy aquifer on Long Island, N.Y.

1193
PEARSON, M. J., PITCHFORD, Marc, and SNELLING, Robert, 1979, Western energy sulfate/nitrate monitoring network progress report: Las Vegas, Nevada, U.S. Environmental Protection Agency EPA-600/7-79-074, 42 p.

The U.S. Environmental Monitoring and Support Laboratory at Las Vegas initiated a program to increase the number of location sites for monitoring particulate sulfate and nitrate in the Western Energy Resource Development Area. The sulfate-nitrate monitoring network became fully operational in late 1978. Results of data analysis for January 1975 to December 1977 indicate generally low values in this area. Sulfate concentrations were less than 6 micrograms per cubic meter ($\mu g/m^3$), and nitrate concentrations less than 3 $\mu g/m^3$.

1194
PECACHE, G. A., 1979, A comparison between two methods of measuring the concentration of suspended particulates, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 193-198.

1195
PEDEN, M. E., and SKOWRON, L. M., 1978, Ionic stability of precipitation samples: Atmospheric Environment, v. 12, p. 2343-2349.

Precipitation samples were collected on a weekly and by event basis at Champaign, Illinois by three types of collectors. Samples were stored under different conditions and analyzed over a 6-week period for nine inorganic constituents. A comparison is given of the three collector designs, sampling durations, and six storage procedures to determine optimal handling methods for obtaining accurate data. Marked variations in the concentrations of some species are caused by particulate loading. Cooling of samples retards changes in ionic composition; however, immediate filtering after wet-only collection is the most effective method of retaining sample integrity and preventing adsorption-desorption reactions.

1196
PENKETT, S. A., JONES, B. M. R., BRICE, K. A., and EGGLETON, A. E. J., 1979, The importance of atmospheric ozone and hydrogen peroxide in oxidizing sulphur dioxide in cloud and rainwater: Atmospheric Environment, v. 13, p. 123-137.

The process of sulfur dioxide oxidation in atmospheric droplets was studied in laboratory experiments designed to collect a large amount of chemical data pertinent to the atmospheric conditions. This article presents data on the oxidation of sodium sulfite solutions by oxygen, ozone, and hydrogen peroxide at differing pH values and temperatures and gives estimates of the rate of sulfate formation in water droplets under atmospheric conditions for each of the three oxidants.

1197
PENKETT, S. A., JONES, B. M. R., and EGGLETON, A. E. J., 1979, A study of SO_2 oxidation in stored rainwater samples: Atmospheric Environment, v. 13, p. 139-147.

The rate of oxidation of SO_2 in stored rainwater samples is directly proportional to the manganese content of the sample. The oxidation rate is also proportional to the initial SO_2 concentration and this largely determines the effectiveness of SO_2 oxidation in rainwater in producing sulfate in atmospheric droplets such as rain and fog water. In rural areas, where the manganese and SO_2 concentrations in rain clouds are low, the reaction is too slow to compete with other sulfate producing reactions such as oxidation by ozone and hydrogen peroxide. In urban areas, particularly with fog, both the manganese and SO_2 concentrations are at high enough levels that the reaction can produce enough sulfuric acid within the lifetime of the fog to account for published observations.

1198
PERHAC, R. M., 1978, Sulfate regional experiment in northeastern United States--the "SURE" program, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 641-647.

The Electric Power Research Institute (EPRI) is supporting a research program to define the relation between emitted primary pollutants (e.g. SO_2) and regional, ambient

1198 (continued)
concentrations of secondary products (e.g. sulfates). Emphasis will be on identifying the contribution of the electric power industry to ambient sulfate levels in the northeastern United States. This project, the Sulfate Regional Experiment (SURE) will be conducted over three years at a cost of about $6 m. Part of the stimulus for SURE is the concern that utilities may be required to reduce SO_2 emissions in order to meet an ambient sulfate standard. The relationship, however, between SO_2 emissions and ambient sulfate concentrations is obscure, at best. Present studies seem to indicate that the formation of sulfates is a regional problem, tied not just to SO_2, hence no simple relation exists between SO_2 emissions and regional sulfate levels. If so, a control on SO_2 emissions may not be a realistic means of effecting sulfate reduction. The SURE program comprises four main elements: (1) a ground monitoring network of 54 randomly distributed stations throughout northeastern United States; (2) a program of measurements of air quality using airplanes; (3) a detailed emissions inventory; and (4) a modeling program. Nine ground stations will operate continuously over a 19-month period. The remaining 45 will operate continuously for one month out of each of the four seasons of the year. At all ground stations, a wide range of chemical and meteorological parameters will be measured. Emphasis is on sulfur compounds; however, measurements will also include nitrogen species, ozone, hydrocarbons and some trace metals. The airborne work will serve as a limited supplement to the ground network in an attempt to give a 3-dimensional validity to any conclusions drawn from the measurements made on the ground. The emissions inventory will include SO_x, NO_x, suspended particles and hydrocarbons from power plants, other industry, homes and surface transportation. Emissions will be reported as daily averages for each season. The modeling effort will develop a simulation system which predicts regional concentations of primary and secondary pollutants in terms of: (1) multiple sources; (2) pollutant transport and chemical reaction; and (3) meteorological parameters, viz., temperature and humidity. Data for the model will be drawn from other studies as well as from SURE. The program is closely coordinated with activities of U.S. government agencies. Field measurements began in July 1977. [Abstract reprinted by permission of Pergamon Press.]

1199
PERHAC, R. M., 1981, Acid rain--uncertainties in scientific knowledge, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 11.

1200
PERSSON, G. A., 1976, Control of sulfur dioxide emissions in Europe: Ambio, v. 5, no. 5-6, p. 249-252.

Technical methods for reducing sulfur dioxide (SO_2) emissions in Europe to any level are available. The obstacles involved in reducing SO_2 emissions are economic limitations. To reduce SO_2 emissions from 60 million tons to 25 million tons per year by desulfurization of fuels and stack gases would cost at least $250 per ton of sulfur.

1201
PERSSON, G. A., 1981, Socio-economic impacts of the effects of man on biogeochemical cycles--sulfur, in Likens, G. E., Some perspectives on the major biogeochemical cycles: New York, John Wiley, p. 145-156.

Large regions of the northeastern United States and northern Europe are affected by acidification of freshwaters and subsequent losses in fish stocks. The regions most sensitive to acid precipitation are generally underlain by granitic or similar bedrock with thin or patchy soils. Losses in commercial fishing and income from tourism, including sport fishing, are among the socioeconomic effects of acid precipitation. Some of the costs for restoring damaged ecosystems (such as liming), and costs of fuel oil and flue gas desulfurization are given. It is estimated that about $10 billion is needed annually to reduce sulfur dioxide emissions in Europe from the present level of 60 million tons to 25 million tons per year.

1202
PETERS, L. K., 1976, Some considerations on the washout of sulfate from stack plumes: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 303-319.

A theoretical analysis of the contribution to rainwater sulfate concentration by precipitation scavenging of gaseous SO_2 and sulfate containing aerosols is presented. Aspects, such as the proper choice of mean raindrop diameter, are discussed in detail, and guidelines for their use are explored. Sample calculations are provided in which emissions from a hypothetical stack are considered as the source of the gaseous SO_2 and sulfate aerosol. The basic assumption of irreversible sorption behavior is discussed and utilized to obtain an upper limit to the resulting sulfate concentration.

The effect of raindrop diameter on the sulfate concentration is not consistent. However, for a given drop diameter the sulfate concentration decreases as the precipitation rate increases. The sulfate concentration resulting from aerosol scavenging depends on the particle diameter and the precipitation rate. The sulfate concentration shows a maximum with respect to particle size; at

1202 (continued)
moderate distances from the source, it is maximum for particles having aerodynamic equivalent diameter of about 5 to 10 μm. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1203
PETERSEN, Leif, 1980, Podsolization--mechanisms and possible effects of acid precipitation, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 223-237.

1204
PETERSEN, Leif, 1980, Sensitivity of different soils to acid precipitation, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 573-577.

1205
PETERSON, R. H., 1980, LRTAP--Effects of fishes, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 83-85.

1206
PETERSON, R. H., 1980, Water chemistry of ten lakes in southern New Brunswick: Canada, Department of Fisheries and Oceans, Canadian Technical Report of Fisheries and Aquatic Sciences, no. 962, 25 p.

Water samples were collected from ten lakes in southern New Brunswick, Canada from May to September, 1978, and analyzed for major ions. The lakes showed differing buffering capacities. This report discusses and presents data on the relationship of rain pH, weather vectors, rainfall patterns during sampling, and local geology to concentration of selected ions.

1207
PETERSON, R. H., 1981, Canadian fisheries research related to acid precipitation, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 113-117.

1208
PETERSON, R. H., DAYE, P. G., and METCALFE, J. L., 1980, The effects of pH on hatching of Atlantic salmon eggs, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 328-329.

1209
PETERSON, R. H., DAYE, P. G., and METCALFE, J. L., 1980, Inhibition of Atlantic Salmon (*Salmo salar*) hatching at low pH: Canadian Journal of Fisheries and Aquatic Science, v. 37, p. 770-774.

This article describes the effects of low pH on hatching of Atlantic Salmon (*Salmo salar*) eggs. Hatching was delayed or prevented if eggs were exposed to water with pH 4.0 to 5.5 after eye pigmentation had developed, but hatching could be induced by returning eggs to water of pH 6.6 to 6.8. When eggs were exposed to low pH, perivitelline pH decreased rapidly to near ambient levels.

1210
PETIT, C., LEDOUX, M., AND TRINITE, M., 1977, Transfer resistance to SO_2 capture by some plane surfaces, water and leaves: Atmospheric Environment, v. 11, p. 1123-1126.

This article discusses the transfer of sulfur dioxide (SO_2) across boundary layers that are developed over plane surfaces of water and leaves and are able to adsorb or absorb SO_2 through a chemical reaction on the surface. The article gives kinetic constants of SO_2 and surface resistance over water at different pH values.

1211
PETRENCHUK, O. P., 1977, Atmospheric precipitation sampling procedures and application of cloud water chemical composition data to the estimation of background aerosol chemical composition, in World Meteorological Organization, Air pollution measurement techniques: Geneva, Switzerland, World Meteorological Organization, Special Environmental Report no. 10, WMO-no. 460, p. 50-57.

1212
PETRENCHUK, O. P., and SELEZNEVA, E. S., 1970, Chemical composition of precipitation in regions of the Soviet Union: Journal of Geophysical Research, v. 75, no. 18, p. 3629-3634.

The chemical composition of precipitation is largely affected by the (1) formation of droplets on condensation nuclei, and (2) washout of contaminants by cloud and precipitation elements in atmospheric layers. This article evaluates the effect of each of these processes on precipitation chemistry.

1212 (continued)
Results of analyses of cloud-water samples and aerosol collected from the European Territory of the USSR show that in the unpolluted, northern regions of the USSR, clouds contribute 55 percent of the total mineralization of precipitation. In the southern regions of the USSR, where heavy pollution of the atmospheric boundary layer is prevalent, the washout of pollutants in the subcloud layer is the predominant process. Precipitation is significant in the "self-cleaning" of the atmosphere.

1213
PFEIFFER, M. H., and FESTA, P. J., 1980, Acidity status of lakes in the Adirondack region of New York in relation to fish resources: Albany, New York State Department of Environmental Conservation, 1 v.

Alkalinity and pH measurements were made on 849 lakes in the Adirondack Mountains of New York to determine the impact of acidic atmospheric deposition on water quality. Twenty-five percent of the lakes had pH below 5.0. This article discusses changes in fish-species diversity and sport fishing yields in acidic waters and describes the relationships between meter pH, colorimetric pH, alkalinity, conductivity, calcium, lake-surface area, lake-surface evaluation, and geographic location.

1214
PIERRARD, J. M., 1969, Environmental appraisal--particulate matter, oxides of sulfur, and sulfuric acid: Journal of the Air Pollution Control Association, v. 19, no. 9, p. 632-637.

This article discusses the contribution of particulate matter and oxides of sulfur to the degradation of the atmosphere and describes the relationship between pollution by particulate matter and cloud formation. Some general observations are made on the persistence of fog in urban areas and sources of particulate pollution that indroduce ice nuclei.

1215
PINKERTON, J. E., 1981, Acidic deposition and its effects on forest productivity--a review of the present state of knowledge, research activities, and information needs: New York, National Council of the Paper Industry for Air and Stream Improvement, Atmospheric Quality Improvement Technical Bulletin, no. 110, 92 p.

This article presents conclusions drawn from a detailed review of literature on the effects of acidic atmospheric deposition on forest productivity. Acid substances are deposited on surfaces by wet and dry processes. Data on wet deposition indicate that acid precipitation (pH <5.6) occurs over most of the region east of the Mississippi River, over isolated areas on the west coast, eastern Canada, and over much of northern Europe. Wet-deposition data indicate that the chemical composition of precipitation varies significantly with time and is altered as it passes through a forest canopy. No definitive conclusions are reached on the effects of acidic deposition on forest productivity. Direct effects on trees and forests include (1) physical damage to leaf tissues, (2) leaching of materials from exposed leaf surfaces, (3) changes in microbial populations that inhabit exposed tree surfaces, and (4) alteration of the composition of ground flora species.

1216
PITBLADO, J. R., KELLER, W., and CONROY, N. I., 1980, A classification and description of some northeastern Ontario lakes influenced by acid precipitation: Journal of Great Lakes Resarch, v. 6, no. 3, p. 247-257.

Water-quality data of 187 lakes in the Sudbury, Ontario region are used to evaluate the influence of atmospherically derived contaminants. A multivariate statistical method is used to classify the lakes. Principal components of the lake-classification system are (1) nutrient status, (2) buffering capacity, (3) atmospheric deposition, and (4) sodium chloride status. Lake groups are mapped and their distinguishing features given.

1217
PLATT, U., 1978, Dry deposition of SO_2, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 363-367.

SO_2 concentration gradient measurements are reported, which have been carried out between May 1975 and September 1976 at the Kernforschungsanlage Julich. Most of the measurements were made with differential optical absorption spectroscopy.

Mirrors at various heights (30, 80, 120 m) on the meterological tower were used to reflect the light beam back to the laboratory placed at the ground. In this way absorption paths of about 600 m were obtained. In some cases, the optical data were compared with chemical measured concentration profiles (after West & Gaeke, 1976) showing an agreement within ±20%. From simultaneously measured temperature and wind profiles the transfer resistance of the turbulent boundary layer was calculated.

Average values of the vertical SO_2-flux obtained from SO_2 concentration gradient and atmospheric transfer resistance varied from about 0.6 $\mu g\ m^{-2}s^{-1}$ in winter and 0.1 to 0.4 $\mu g\ m^{-2}s^{-1}$ in summer, corresponding to a lifetime for SO_2, if dry deposition is taken as

1217 (continued)
the only sink mechanism, of half a day up to several days, respectively. [Abstract reprinted by permission of Pergamon Press.]

1218
PLONKA, A. C., MITCHELL, R. B., and ANTHONY, Adam, 1971, Quantitative cytophotometry of PAS positive material in Stannius corpuscles of brook trout (*Salvelinus fontinalis*) exposed to acidic water: Pennsylvania Academy of Science Proceedings, v. 45, p. 78-81.

Cytophotometric analyses of PAS positive material were conducted on Stannius corpusles of brook trout (*Salvelinus fontinalis*) exposed to varying severeties of acid water for 3-5 days (acute) and 28 days (subacute). This article evaluates PAS staining of selected fish for its usefulness as a bioindicator of acid pollution. A quantitative increase in PAS material in Stannius corpuscles occurs with acute exposures but not with subacute exposures to pH values of 4.0-6.5. The PAS reaction of the Stannius corpuscle may provide a useful short-term bioassay of acidified streams.

1219
PLONKA, A. C., and NEFF, W. H., 1969, Mucopolysaccharide histochemistry of gill epithelial secretions in brook trout exposed to acid pH: Pennsylvania Academy of Science Proceedings, v. 43, p. 53-55.

Gills of trout exposed to water of low pH were analyzed. Colloidal iron, mucicarmine, and alcian blue stains were evaluated for their effectiveness in detecting changes in mucin content and distribution in fish exposed to acidic water. Colloidal iron was shown superior to other stains. Gills of trout exposed to acidic water showed an increase in mucin content and a proliferation of cells between gill lamellae such that individual lamellae were indistinguishable.

1220
POLOMSKI, Janina, FLUHLER, Hannes, and BLASER, Peter, 1980, Behavior of airborne fluorides in soils, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 246.

1221
POPOVIC, B., 1980, Acidification effect of urea and sulphur application on the forest soil in a percolation experiment, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 182-183.

1222
POPP, C. J., 1981, Atmospheric particulates in New Mexico, in American Chemical Society, Division of Environmental Chemistry, 182nd National Meeting, New York, N.Y., Preprints, v. 21, no. 2: Washington, D.C., American Chemical Society, p. 61-63.

1223
POTTER, S. W., Jr., 1979, Precipitation monitoring at Pack Demonstration Forest, Warrensburg, New York, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 84-85.

1224
POTZL, Karl, 1974, New trace analysis methods for sulfate, chloride and nitrate anions in the scope of a long-term investigation on the nature and composition of atmospheric aerosols: Staub Reinhaltung der Luft, v. 34, no. 2, p. 48-52. [In English.]

Increases in air pollution were investigated by continuous analysis of the composition and transport of aerosol in the free atmosphere at a mountain station 1780 meters above sea level at Wankgipfel, West Germany. Samples were analyzed for seven water-soluble ions and six mineral components. This article describes photometric methods of determining concentrations of atmospheric anions Cl^-, $SO_4{}^{2-}$, and $NO_3{}^-$.

1225
POUGH, F. H., 1976, Acid precipitation and embryonic mortality of spotted salamanders, *Ambystoma maculatum*: Science, v. 192, p. 68-70.

Temporary ponds that are formed by accumulation of melted snow or rain are frequently breeding sites for salamanders (*Ambystoma maculatum*). Many such ponds in the northeastern United States are extremely vulnerable to alterations of pH because precipitation entering them has little or no contact with buffering systems. Egg mortality is low (<1 percent) in pools with near neutral pH but is high (>60 percent) in pools with pH lower than 6.0.

1226
POUGH, F. H., 1981, Mechanisms by which acid precipitation produces embryonic death in aquatic vertebrates: Washington, D.C., U.S. Department of the Interior, Office of Water Research and Technology, Research Project Technical Completion Report, 10 p.

In a study of embryonic death, 14 species of amphibians were similar in their tolerance to acid conditions during embryonic development. An 85-percent mortality rate was observed

1226 (continued)
when species were subjected to water of pH 3.7 to 3.9, and more than 50 percent mortality occurred at pH 4.0 or less. Sensitivity of amphibian embryos to acidity was greater during late stages of their development than during the intitial cleavage. Teratogenic effects of acidity seem to be the result of damage to the superficial tissues of the embryo.

1227
POUGH, F. H., and WILSON, R. E., 1977, Acid precipitation and reproductive success of *Ambystoma* salamanders: Water, Air, and Soil Pollution, v. 7, no. 3, p. 307-316.

The two species of mole salamander that occur in the Ithaca, New York, region (*Ambystoma maculatum* and *A. jeffersonianum*) breed in temporary ponds that are formed by accumulation of melted snow and spring rains. Water in many of these pools during the breeding season is acid; pH values as low as 3.5 have been measured. In laboratory experiments *A. maculatum* tolerated pHs from 6 to 10 and had greatest hatching success at pH 7 to 9. *Ambystoma jeffersonianum* tolerated pH 4 to 8 and was most successful at pH 5 to 6. Mortality rose abruptly beyond the tolerance limits. The pH optimum shifted upward with increasing temperature for *A. jeffersonianum* and downward for *A. maculatum*.

Judging from our laboratory studies, the acidity measured in breeding ponds should cause mortality in *A. maculatum* and permit normal development in *A. jeffersonianum*. In a 4-yr study of a large, acidic vernal pond, 938 adult *A. maculatum* produced 486 metamorphosed juveniles (0.52 juvenile/adult), while 686 adult *A. jeffersonianum* produced 2157 juveniles (3.14 juveniles/adult). Because the effects of acid precipitation on the salamanders' breeding ponds are cumulative from year to year, profound changes in the salamander populations can be anticipated. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1228
POUNDSTONE, W. N., 1980, Let's get the facts on acid rain: Mining Congress Journal, v. 66, no. 7, p. 45-48.

Acidity of rainfall is caused by both manmade and natural sources. More is unknown about the phenomenon of "acid rain" than is known, and the reported trends in increasing acidity of precipitation in the Northeast are questionable. The burning of fossil fuels should not be considered as the only cause of acid precipitation.

1229
POWERS, E. B., 1929, Fresh water studies. I. The relative temperature, oxygen content, alkali reserve, the carbon dioxide tension and pH of the waters of certain mountain streams at different altitudes in the Smoky Mountain National Park: Ecology, v. 10, p. 97-111.

Water samples were collected and analyzed during the summers of 1925 and 1926 from two streams in the Smoky Mountain National Park, Tennessee, to determine the effect of streamwater quality on the migration of speckled trout from the lower reaches of both streams sampled. Results indicate that temperature, pH, and alkalinity of waters in mountain streams decrease with increasing altitude. Oxygen content increases and carbon dioxide tensions decrease with increasing altitude.

1230
PRAHM, L. P., CONRADSEN, K., NIELSEN, L. B., and ELIASSEN, Anton, 1979, Regional source quantification model for sulphur oxides in Europe, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 37-44.

1231
PRATT, Richard, 1981, Canadian political options, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 163-165.

1232
PRATT, Richard, 1981, Public action in Canada, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 133-136.

1233
PRATT, Richard, and FALCONER, P., 1979, Circumpolar measurements of ozone, particles and carbon monoxide from the 50th anniversary flight of a Pan American airliner, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 385-392.

1234
PROKOP, Mojmir, 1979, Some results of airborne air pollution monitoring from cross-section flights over Czechoslovakia, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 11-17.

1235
PUCKETT, K. J., 1980, Effects of LRTAP on vegetation, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 46.

1236
PUESCHEL, R. F., and MAMANE, Yaacov, 1979, Mechanisms and rates of formation of sulphur aerosols in power plant plumes, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 141-148.

1237
PUESCHEL, R. F., and VAN VALIN, C. C., 1978, Cloud nucleus formation in a power plant plume, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 307-312.

A rate of production of *ca* 10^{16} particles s^{-1} of H_2SO_4 aerosol that acts as cloud condensation nuclei at 1% supersaturation has been estimated to take place in the emission plume from the Four Corners power plant near Farmington, N.M. This generating plant produces about 2175 MW at full capacity, and emits about 3.7 kg s^{-1} of SO_2, 2.2 kg s^{-1} of NO_x, and 0.9 kg s^{-1} of particulates. The site area is desert; annual precipitation averages around 15 cm, daytime relative humidity is typically 10-20%, and annual sunshine is 75% of possible.

An instrumented aircraft was utilized during five investigative periods over a 2-year span to measure plume parameters and to collect plume aerosol samples.

The estimated production rate of 10^{16} particles s^{-1} in the plume is equivalent to a gas phase oxidation of SO_2 and homogeneous nucleation-condensation of about 5 μg $m^{-3}h^{-1}$ of H_2SO_4, and is consistent with this mechanism being the primary route for removal of SO_2. [Abstract reprinted by permission of Pergamon Press.]

1238
PYATT, F. B., 1970, Lichens as indicators of air pollution in a steel producing town in south Wales: Environmental Pollution, v. 1, p. 45-56.

Lichens were used as indicators of air pollution at Port Talbot, Wales, a steel-producing town. The number of lichen species increased with distance from Port Talbot, and a change was also observed in the proportion of various growth forms. A "lichen desert" zone is defined as an area where only *Parmelia sulcata*, *P. saxatilis*, *Cladonia conioraea*, and *C. fimbriata* grow. This article describes three zones and the lichen species that dominate them.

R

1239
RADDUM, G. G., 1980, Comparison of benthic invertebrates in lakes with different acidity, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 330-331.

1240
RADDUM, G. G., 1980, Invertebrates--quality and quantity as fish food, in Hendrey, G. R., ed., Limnological aspects of acid precipitation: International Workshop, Sagamore Lake Conference Center, N.Y., 1978, Proceedings: Upton, N.Y. Brookhaven National Laboratory, p. 17-24.

1241
RADDUM, G. G., HOBAEK, A., LOMSLAND, E. R., and JOHNSEN, T., 1980, Phytoplankton and zooplankton in acidified lakes in south Norway, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 332-333.

1242
RAHEL, F. J., and MAGNUSON, J. J., 1980, Fish in naturally acidic lakes of northern Wisconsin, U.S.A., in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 334-335.

1243
RAHN, K. A., and McCAFFREY, R. J., 1979, Long-range transport of pollution aerosol to the Arctic--a problem without borders, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 25-36.

1244
RASMUSSEN, K. H., TAHERI, Mansoor, and KABEL, R. L., 1975, Global emissions and natural processes for removal of gaseous pollutants: Water, Air, and Soil Pollution, v. 4, no. 1, p. 33-64.

This article presents a review of research on sources and natural sinks of gaseous pollutants. Removal mechanisms of gaseous pollutants are vegetation, soil, stone, water bodies, precipitation scavenging, and chemical reactions within the atmosphere. Discussed are (1) the nature and magnitude of anthropogenic and natural emissions of gases (H_2S, SO_2, N_2O, NO, NO_2, NH_3, CO, O_3, and hydrocarbons) and (2) ambient background concentrations of these gases. About 150 references are cited.

1245
RAUCH, R. J., 1979, Major studies show need for tighter control of SO_2 emissions: Chemical and Engineering News, v. 57, no. 17, p. 47-48.

This article discusses results of recent research on health and environmental effects of sulfur dioxide emissions. Long-range transport of sulfur dioxide (SO_2) and constituents produced by the SO_2 oxidation process are causing serious acid precipitation problems, particularly for aquatic ecosystems. Tall stacks and intermittent controls may only aggravate the problem. Reducing SO_2 emissions is recommended to protect human health and environmental systems.

1246
RAYNOR, G. S., and HAYES, J. V., 1981, Acidity and conductivity of precipitation on central Long Island, New York in relation to meteorological variables: Water, Air, and Soil Pollution, v. 15, p. 229-245.

Hourly precipitation samples were collected at central Long Island, New York, for 3 years and analyzed for sulfate, nitrate plus nitate, nitrogen and ammonium, sodium, and chloride ions. This article discusses the relationships between sample acidity and conductivity and between precipitation acidity and meteorological conditions. Hydrogen ion (H+) concentrations were similar to those found elsewhere in the northeastern United States and were correlated most closely with sulfate concentrations, but were also correlated with nitrogen in nitrate plus nitrite and nitrogen in ammonium ion. H+ concentrations were highest in summer, during cold-front and squall-line precipitation, and rain showers. H+ contributed most to sample conductivity.

1247
RAYNOR, G. S., and McNEIL, J. P., 1979, An automatic sequential precipitation sampler: Atmospheric Environment, v. 13, p. 149-155.

1247 (continued)
Described is an automatic, sequential precipitation sampler that was designed at Brookhaven National Laboratory. The sampler collects wet and frozen precipitation and excludes dry fallout between precipitation events. The sampler consists of a large box containing a turntable that holds 30 bottles; precipitation enters through a funnel on top of the box. The funnel is opened by a movable cover that is activated by a rain sensor when precipitation starts.

1248
REBSDORF, Aa, 1980, Acidification of Danish soft-water lakes, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 238-239.

1249
REED, L. E., 1976, The long-range transport of air pollutants: Ambio, v. 5, no. 5-6, p. 202.

This article gives an overview of the history of research on long-range transport of air pollutants in Europe. The Organization for Economic Cooperation and Development (OECD) is sponsoring a study on the long-range transport of air pollutants that involves a group of industrialized nations. The objective is to determine the contributions of sulfur compounds from distant sources to the air pollution of a region. A forthcoming conclusion as determined by the OECD study is that pollution travels from one country to another. In most countries this is not significant but in others, the incoming sulfur, which may only represent a fraction of the total sulfur emissions in western Europe, might be enough to cause serious adverse effects on the ecological balance of an entire country.

1250
REICH, P. B., AMUNDSON, R. G., and LASSOIE, J. P., 1980, Multiple pollutant fumigations under near ambient environmental conditions using a linear gradient technique, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 247.

1251
REIMANN, Brunon, MICHAJLUK, Leon, and BOROWICZ, Anna, 1968, Toxicity of some forms of sulfur compounds on soils in close vicinity to the sulfur chemical factory at Poznan-Zegrze [Poland]: Roczniki Gleboznawcze, v. 18, p. 537-545. [In Polish.]

1251 (continued)
This article gives data on concentrations of various forms of sulfur in soils near a sulfur chemical factory at Poznan-Zegrze. Soil samples were analyzed for total sulfur, sulfates, organic sulfur, free sulfur, sulfides, free sulfuric acid, and sulfite. The concentration of total sulfur decreased from 398 mg to 77 mg per 100 g of soil with increased distance from the factory. A higher concentration of free sulfur acid was observed close to the factory.

1252
REINERS, W. A., MARKS, R. H., and VITOUSEK, P. M., 1975, Heavy metals in subalpine and alpine soils of New Hampshire: Oikos, v. 26, no. 2-3, p. 265-275.

This article gives concentrations and total quantities of lead (Pb) and zinc (Zn) in organic horizons of soils distributed over an elevational gradient of Mt. Moosilauke, New Hampshire. Pb concentrations are higher than expected for a remote area; Zn concentrations were within a broad range assumed to represent natural conditions. High-elevation ecosystems are exposed to larger extremes of all airborne pollutants. Flux of hydrogen, sulfate, and nitrate ions associated with acid precipitation, may be more than double the fluxes at low elevations. High-elevation ecosystems may be particularly vulnerable to airborne pollutants.

1253
REINERT, R. A., 1975, Monitoring, detecting, and effects of air pollutants on horticultural crops--sensitivity of genera and species: Hortscience, v. 10, no. 5, p. 495-500.

This article describes the effects of major gaseous pollutants (SO_2, O_3, NO_2, NO, HF, and H_2C) on plant yield and growth of crops and evaluates the relative sensitivity of various species and cultivars to these substances. A summary of research needs is included.

1254
REITER, E. R., 1979, Tropospheric-stratospheric transport processes--indications of their interannual variability, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 393-400.

1255
RENNIE, P. J., 1979, Dangers to soils and vegetation, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 24-29.

1256
RENNIE, P. J., 1980, Long range pollution and acid rain--factors in the terrestrial environment, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 35-44.

1257
RENZETTI, N. A., and DOYLE, G. J., 1960, Photochemical aerosol formation in sulfur dioxide-hydrocarbon systems: International Journal of Air Pollution, v. 2, p. 327-345.

Photochemical experiments were conducted to study aerosol formation from various hydrocarbons in the presence of nitrogen oxides and sulfur dioxide. Photolysis of sulfur dioxides proceeds at a rate of 0.4 percent per minute. High sulfate content of particulate matter and low gaseous sulfur dioxide concentrations observed in Los Angeles smog are consistent with the results of the study.

1258
RESHETNIKOV, A. I., 1979, Determination of the mean concentrations of methane in the atmosphere with spectral instruments of mid-resolution, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 133-134.

1259
REUSS, J. O., 1975, Chemical/biological relationships relevant to ecological effects of acid rainfall: Corvallis, Oregon, U.S. Environmental Protection Agency, EPA-660/3-75-032, 53 p.

This report examines problems in measuring and interpreting the effect of rainfall acidity on the soil-plant system. Results from acation-anion balance model of acidity of rainfall indicate that calculating average H+ concentration from pH measurements may not be a satisfactory method of determining H+ loading from rainfall if the rain is not consistently acidic. The flux of H+ in soil systems, which is caused by plant uptake processes and sulfur and nitrogen cycling, is considered. Soil acidifying potential due to the oxidation of NH_4+ in rain is of similar magnitude to the direct H^+ acidity inputs in rain.

1260
REUSS, J. O., 1977, Chemical and biological relationships relevant to the effect of acid rainfall on the soil-plant system: Water, Air, and Soil Pollution, v. 7, no. 4, p. 461-478.

1260 (continued)
This paper deals with problems concerning measurements of rainfall acidity and interpretation in terms of possible effects on the soil-plant system.

The theory of acidity relationships of the carbon dioxide-bicarbonate equilibria and its effect on rainfall acidity measurements is given. The relationship of a cation-anion balance model of acidity in rainfall to plant nutrient uptake processes is discussed, along with the relationship of this model to a rainfall acidity model previously proposed in the literature. These considerations lead to the conclusion that average H^+ concentration calculated from pH measurements is not a satisfactory method of determining H^+ loading from rainfall if the rain is not consistently acid. Calculating loading from H^+ minus HCO_3^-, strong acid anions minus basic cations or net titratable acidity is suggested.

The flux of H^+ ions in soil systems due to plant uptake processes and sulfur and nitrogen cycling is considered. H^+ is produced by oxidation of reduced sulfur and nitrogen compounds mineralized during decomposition of organic matter. Plant uptake processes may result in production of either H^+ or OH^- ions. Fluxes of H^+ from these processes are much greater than rainfall H^+ inputs, complicating measurement and interpretation of rainfall effects. The soil acidifying potential due to the oxidation of the NH_4^+ in rainfall is examined, with the conclusion that acidity from this source is of a similar magnitude to direct H^+ inputs common in rainfall. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1261
REUSS, J. O., 1978, Simulation of nutrient loss from soils due to rainfall acidity: Corvallis, Oregon, U.S. Environmental Protection Agency, EPA 600/3-76-053, 56 p.

This report describes a mathematical model that simulates a quantitative system through established soil-chemistry relationships to predict the most likely effect of rainfall acidity on the leaching of cations from noncalcareous soils. The model uses the relationship between lime potential and base saturation. Ionic composition of leachates in response to rainfall composition can be calculated.

1262
REUSS, J. O., 1980, Simulation of soil nutrient losses resulting from rainfall acidity: Ecological Modeling, v. 11, p. 15-38.

A simulation model is described that simulates a quantitative system on the basis of established soil chemistry relationships to predict the effect of rainfall acidity on cation leaching from noncalcareous soils. The model predicts nearly exact chemical equivalence between basic cations removed in the leachate and strong acid anions entering the system in the rainfall if the lime potential is above 3.0, at which point base saturation will not generally exceed 20 percent.

1263
RICE, Harbert, NOCHUMSON, D. H., and HIDY, G. M., 1981, Contribution of anthropogenic and natural sources to atmospheric sulfur in parts of the United States: Atmospheric Environment, v. 15, p. 1-9.

Presented is an estimate of the contributions to atmospheric sulfur of natural versus anthropogenic processes in areas of the United States. Areas used in the study were selected on the basis of population density, industrialization, and potential for different kinds of geographically unique natural emissions. Emissions are estimated in part from land-use practice and from the relationship of sulfur to biological carbon cycling. Emissions seem to be heavily influenced by contributions from sulfate reduction in freshwater sediments and intertidal mud flats and from acid mine drainage. If 10 percent of the available biogenic sulfur is released to the atmosphere, natural emissions may be a significant contributor in air over Minnesota, Wisconsin, Florida, rural areas of Virginia, and remote parts of Arizona and Utah.

1264
RICHARDSON, C. J., and MERVA, G. E., 1976, The chemical composition of atmospheric precipitation from selected stations in Michigan: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 385-393.

The pH and amount of rainfall from over 60 selected stations throughout northern and lower Michigan were determined from September 1972 to December 1974. Precipitation pH was determined for each station by calibrated electrode meters.

The seasonal weighted average and median pH from all stations in the study was 5.0 and 6.3, respectively. Daily readings from stations throughout Michigan indicate that pH is dependent on the amount of rainfall and that variations in it are often locally controlled. Collectively the pH values suggest carbonic acid control for most of the state.

Annual median pH varied from a high of 8.45 at Dimondale, a station located 1.5 km from a concrete tile plant in central Michigan to 4.65 at Vassar, a small town located east of several industrial centers in the thumb region of the state.

1264 (continued)
A comparison of annual nutrient loading for NO_3^-, $SO_4^=$, Cl^-, $PO_4^{\equiv}$, Ca^{++}, Mg^{++}, Na^+, K^+, and pH of rainwater from selected stations revealed that the eastern U.S. stations reporting pHs <4.02 have similar loadings for NO_3 but twice the SO_4 input found for rural areas of Michigan. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1265
RICHTER, Andreas, and GRANAT, Lennart, 1978, Pine forest canopy throughfall measurements: Stockholm, Sweden, University of Stockholm, Department of Meteorology Report AC-20, 25 p.

Rainwater samples were collected beneath the canopy in a pine forest in Sweden and at an open field and analyzed for nine major constituents. Analyses indicate a considerable enrichment in hydrogen ion, sulfate, potassium, magnesium, calcium, sodium, chloride; nitrate was partly enriched but ammonia was not. Areal average pH of throughfall per event ranged from 3.4 to 4.0, compared with rainfall pH of 4.2 to 4.4. The lower pH of throughfall is due to the increase in strong mineral acids, particularly sulfuric acid. The concentration of sulfuric acid in the throughfall did not decrease significantly even during extended periods of rain but remained constant throughout the event. It is suggested that a mechanism exists whereby material from the interior of the needles is leached through a rate-determining restriction, which may be the stomata.

1266
RIPPON, J. E., 1980, Studies of acid rain on soils and catchments, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 499-524.

1267
RIPPON, J. E., SKEFFINGTON, R. A., WOOD, M. J., BROWN, K. A., and BROWN, D. J. A., 1980, Hydrogen, sulphur and nitrogen budgets in soils and catchments, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 276-277.

1268
RITTER, J. R., and BROWN, A. E., 1981, An evaluation of the effects of acid rain on low conductivity headwater streams in Pennsylvania: U.S. Geological Survey Open-File Report 81-1025, 53 p.

Water samples were collected at 32 sites on headwater streams in Pennsylvania during low-flow periods of 1979-80. Samples were analyzed for specific conductance, pH, alkalinity, and several other constituents including sulfate, nitrogen and phosphorus species, chloride, sodium, and potassium. These data were compared to data collected before 1971 to assess the impact of acidic atmospheric deposition on stream-water chemistry. Results indicate that pH, alkalinity, and sulfate in 1979-80 samples were within the same range as those before 1971. From the limited data, it is concluded that pH may have increased with time, whereas alkalinity and sulfate may have decreased with time.

1269
RIVERS, Martin, 1981, Government programs in Canada, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 127-130.

1270
ROBERTS, T. M., CLARKE, T. A., INESON, P., and GRAY, T. R., 1980, Effects of sulphur deposition on litter decomposition and nutrient leaching in coniferous forest soils, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 381-434.

1271
ROBERTSON, J. K., DOLZINE, T. W., and GRAHAM, R. C., 1980, Chemistry of precipitation from sequentially sampled storms: Research Triangle Park, N.C., U.S. Environmental Protection Agency, Environmental Sciences Research Laboratory, 116 p.

This report reviews several techniques for sequential sampling of precipitation. Presented are chemical data of samples collected by an intensity-weighted sequential sampling device operated at the U.S. Military Academy, West Point, N.Y., from October 1976 to April 1978. Intensity-weighted sequential sampling is considered a useful method for monitoring rapid changes in chemistry of precipitation during a storm. A description of a sampler that excludes dry deposition is given.

1272
ROBINSON, Elmer, and ROBBINS, R. C., 1970, Gaseous sulfur pollutants from urban and natural sources: Journal of the Air Pollution Control Association, v. 20, no. 4, p. 233-235.

This article gives estimates of the rate of sulfur movement through the atmosphere. About one-third of the sulfur reaching the

1272 (continued)
atmosphere is contributed as sulfur dioxide (SO_2) from pollution sources. There is also a net transfer of sulfur from land to ocean areas within the atmosphere. More than two thirds of the world's natural and manmade sulfur emissions occur in the northern hemisphere. (See also Nochumson, David, 1979, herein.)

1273
ROBINSON, G. D., DUNSON, W. A., WRIGHT, J. E., and MAMOLITO, G. E., 1976, Differences in low pH tolerance among strains of brook trout (*Salvelinus fontinalis*): Journal of Fish Biology, v. 8, p. 5-17.

Survival time of brook trout (*Salvelinus fontinalis*) in low pH ranges is directly related to fish size and inversely related to temperature. An increase in pH increments of 0.25 units leads to a two-to three-fold increase in survival time at pH 2.50 to 3.25. Between pH 3.25 and 3.75, increases in pH by the same increments produce a 3- to 5-fold increase. Brook trout tested at pH 3.35 and 3.50 show maximum survival times in June, July, and August. Members of seven inbred lines of brook trout were tested for acid tolerance; the lines differed significantly, which suggests that acid tolerance is hereditary.

1274
ROBINSON, R. M., 1980, Acid rain, Canada, and the coal conversion program: Journal of the Air Pollution Control Association, v. 30, no. 5, p. 456458.

The Canadian Government has expressed concern that the conversion of a large number of powerplants in the United States from oil to coal will, in the absence of stringent emission controls, significantly increase the amount of acidic atmospheric deposition that afflicts eastern Canada. Conversion to coal-fired plants could increase load factors to 75 percent, which would result in emissions 2.5 times greater than those currently estimated. Major reduction in the acid-causing emissions in Canada and the U.S. are needed to rectify the acid precipitation problem that is afflicting both countries.

1275
ROBINSON, R. M., 1980, Acid rain--the crossroads for decision making: Journal of the Air Pollution Control Association, v. 30, p. 106-108.

Acid precipitation is an environmental problem in the northeastern United States and eastern Canada. Policy decisions by both countries regarding emissions of sulfur oxides and nitrogen oxides need to be made. This article discusses some scientific activities being conducted by both countries to investigate sources and effects of acid precipitation.

1276
RODHE, Henning, 1970, On the residence time of antropogenic sulfur in the atmosphere: Tellus, v. 22, no. 1, p. 137-139.

The deposition of sulfur (S) in snow samples collected during 12 days in February 1969 at Uppsala, Sweden, showed significant spatial variations, but a pattern of decreasing S content at a distance of 1 kilometer from the center of Uppsala was indicated.

1277
RODHE, Henning, 1972, A study of the sulfur budget for the atmosphere over northern Europe: Tellus, v. 24, no. 2, p. 128-138.

An atmospheric sulfur budget for northern Europe is compared with global averages. Anthropogenic sulfur sources contribute more to the sulfur budget than natural sources. A comparison of emission and deposition of sulfur in various regions of northern Europe indicates that sulfur is transported more than 1,000 km before it is deposited. A mathematical model of the variation in deposition rates with distance from a source is presented. The model estimates turnover time for anthropogenic sulfur to be 2 to 4 days. About half of the sulfur deposited in Sweden originated from foreign emissions.

1278
RODHE, Henning, 1980, Estimate of wet deposition of pollutants around a point source: Atmospheric Environment, v. 14, p. 1197-1199.

Three mathematical models are used to estimate long-term, average deposition of pollutants by precipitation at a continuously emitting point source. The spatial scales that are considered range from a few km up to about 100 km. Some of the simplified models, which correspond to parameterizations commonly applied to diffusion transport models, give results that differ significantly from the one believed to be most accurate.

1279
RODHE, Henning, CRUTZEN, P., and VANDERPOL, A. H., 1979, Formation of sulphuric and nitric acid in the atmosphere during long-range transport, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 165-172.

RODHE, Henning, PERSSON, Christer, and AKESSON, Ove, 1972, An investigation into regional transport of soot and sulfate aerosols: Atmospheric Environment, v. 6, p. 675-693.

1280 (continued)

Daily measurements of soot and sulfate aerosols at urban and nonurban sites in southern Sweden show that an appreciable long-distance transport of these substances from source regions takes place in southeast and southwest directions. Sources more than 1,000 km away contribute significantly to total emissions. The rate of formation of sulfate aerosols from oxidation of sulfur dioxide (SO_2) is discussed, and total aerosol concentration is estimated from visibility observations.

1281

RODHE, Wilhelm, 1981, Reviving acidified lakes: Ambio, v. 10, no. 4, p. 195-196.

Progressive acidification of lakes has caused excessive damage during the past 2 decades, particularly in northwestern Europe and eastern North America. The most vulnerable lakes are those with low calcium and bicarbonate levels. In many lakes, the pH has decreased to levels that destroy the original ecosystem. There is some evidence that acidified lakes devoid of life may eventually become naturally colonized by acid-tolerant algae and invertebrates. Several species of plankton and benthic algae with optimum growth at pH from 3 to 7 may be recruited from naturally acidic waters.

1282

ROFF, J. C., and KWIATKOWSKI, R. E., 1977, Zooplankton and zoobenthos communities of selected northern Ontario lakes of different acidities: Canadian Journal of Zoology, v. 55, p. 899-911.

Zooplankton and zoobenthos were studied in six lakes in the Sudbury region of Ontario; pH of the lakes ranged from 4.05 to 7.15. Zooplankton were signficantly reduced in species and numbers at lower pH levels; Rotifera showed the greatest decrease. The zooplankton diversity index declined sharply below pH 5.3; the zoobenthos diversity index decrease slightly below pH 4.9.

1283

ROFFMAN, Ariel, 1980, Acid precipitation in the Pittsburgh, Pennsylvania area: The Journal of Environmental Sciences, v. 23, no. 2, p. 33-38.

Precipitation samples were collected at three sites in the Pittsburgh, Penn. area and analyzed for pH. One site was within the city limits near several industrial mills, one was 5 miles east of the city near a shopping mall, and one was 12 miles east of the city in a rural area. All samples had low pH. Industrial mills along the Allegheny, Monongahela, and Ohio Rivers seem to have little effect on pH at the closest (rural) station. Long-range transport of pollutants from the Ohio River Valley basin seems to contribute to the acidity of precipitation at the three stations.

1284

ROOT, J., McCOLL, J. G., and NIEMANN, B. L., 1980, Map of areas potentially sensitive to wet and dry acid deposition in United States, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 128-129.

1285

RORISON, I. H., 1980, The effects of soil acidity on nutrient availability and plant response, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 283-304.

1286

ROSENBERG, C. R., HUTNIK, R. J., and DAVIS, D. D., 1979, Forest composition at varying distances from a coal-burning power plant: Environmental Pollution, v. 19, no. 4, p. 307-317.

This article reports the effects of sulfur emissions from a coal-burning power plant on the vegetation of a mixed oak forest of white pine (*Pinus strobus* L.) and hemlock (*Tsuga canadensis*) in central Pennsylvania. Species diversity and importance values for some species was inversely related to distance from the emission. Diversity of white pine and sweet birch increased with distance, whereas the importance of white oak and red maple decreased. Species richness and diversity were more sensitive indicators of pollution damage than growth assessments of individual overstory species or groups of species.

1287

ROSENCRANZ, Armin, 1980, The problem of transboundary pollution: Environment, v. 22, no. 5, p. 15-20.

Long-range transport of air pollutants is a serious problem in Europe. The Organization for Economic Cooperation and Development (OECD) estimates that 63 percent of all sulfur emissions represent national depositions, 17 percent represent reciprocal depositions, and 20 percent represent one-way depositions. An OECD study shows that sulfur emissions have transnational significance, especially for Norway and Sweden. In 1979, members of the Economic Commission for Europe, a United Nations organization containing 34 member states including the U.S., Canada, and European countries, signed an international accord to address the problem of transboundary air pollution. If countries undertake collective action to resolve problems associated with long-range transport of air pollutants, they must agree on maximum acceptable levels of transboundary flow of air pollutants.

1288
ROSENQUIST, I. T., 1978, Alternative sources for acidification of river water in Norway: Science of the Total Environment, v. 10, p. 39-49.

This article presents a theory that acid precipitation contributes only a minor part of the acidity of surface waters and that most the acidity is the result of ion-exchange reactions in raw humus in the soil profiles of the catchment areas. The article presents data on increases in the amount of biomass and subfossil humus due to changes in southern Norway in agriculture, cattle farming, and forestry practices.

1289
ROSENQUIST, I. T., JORGENSEN, P., and RUESLATTEN, H., 1980, The importance of natural H^+ production for acidity in soil and water, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 240-241.

1290
ROSS, F. F., 1971, What sulphur dioxide problem? *with a preamble* by T. T. Frankenberg: Combustion, v. 43, no. 3, p. 6-11.

This article discusses the extent of air pollution by sulfur dioxide (SO_2) emissions in the United States and Great Britain. The author recommends monitoring SO_2 effects on vegetation rather than animals or people to determine the hazards of SO_2. SO_2 emissions from tall stacks have only a minor effect on ground-level concentrations and result in uniform distribution over large areas.

1291
ROSSELAND, B. O., 1980, Physiological responses to acid water in fish, SNSF project, 2. Effects of acid water on metabolism and gill ventilation in brown trout, *Salmo trutta* L., and brook trout, *Salvelinus fontinalis* Mitchill, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 348-349.

1292
ROSSELAND, B. O., SEVALDRUD, I. H., SVALASTOG, D., and MUNIZ, I. P., 1980, Studies on freshwater fish populations--effects of acidification on reproduction, population structure, growth, and food selection, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 336-337.

1293
ROSSOTTI, F. J. C., and ROSSOTTI, Hazel, 1965, Potentiometric titrations using Gran plots: Journal of Chemical Education, v. 42, no. 7, p. 375378.

This article describes the advantages of using Gran's plots in the analysis of potentiometric acid-base titrations. Calculations from Gran's plots are easy, and the method may be used when only part of the pH range is accessible to measurement. End points obtained by a linear Gran extrapolation are more precise than those obtained by the differential method, particularly if the titration curve is not symmetric.

1294
ROVINSKY, F. Ya, KOLOSKV, I. A., and CHERCHANOV, Yu. P., 1979, The use of background stations for monitoring long-range transport of atmospheric pollutants, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 239-240.

1295
ROWE, R. D., 1976, A sulphur budget for sour gas plants: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 321-327.

The principal aim of this project is to produce a mass balance for the SO_2 that is emitted into the atmosphere from sour gas plants in various localities in Alberta. Partial S budgets for two plants at dissimilar locations are shown to exhibit major differences.

The rise and dispersion of sour gas plant plumes have been investigated in detail. In order to investigate the chemical transformation of SO_2 within these plumes, the use of a conservative tracer that can be detected by neutron activation is discussed. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1296
RUBEC, C. D. A., 1981, Characteristics of terrestrial ecosystems impinged by acid precipitation across Canada: Ottawa, Ontario, Environment Canada, Lands Directorate Working Paper no. 19, 30 p.

Acid precipitation falls on about 28 percent, or 2.5 million km^2, of Canada's land area. A computerized environmental data base of geographic information was used to quantify information on the types of soils, vegetation, and surficial geology of land receiving precipitation with a mean annual acidity of less than pH 5.6; annual precipitation data for these areas are reported. More than 79

1296 (continued)
percent of the affected areas have surficial, morainal, and glaciofluvial deposits frequently associated with poorly buffered, acidified podzolic or brunisolic soils or almost bare rock. Analyses of data are given for regions in eastern and western Canada with terrain having potential sensitivity to acid precipitation, including Podzols, Brunisols, and rocklands having moraine and glaciofluvial deposits. About 37 percent of the area north of 60° latitude and about 31 percent of western Canada may be highly sensitive to acid precipitation.

1297
RUBY, S. M., ACZEL, J., and CRAIG, G. R., 1977, The effects of depressed pH on oogenesis in flagfish *Jordanella floridae*: Water Research, v. 11, p. 757-762.

Female flagfish (*Jordanella floridae*) were continuously exposed for 20 days to waters with pH 6.7, 6.0, 5.0, and 4.5. Quantitative histological analysis of oocytes during six arbitrarily assigned stages of development shows that the ability of oocytes to form mature eggs is reduced at all tested pH values. The reduction in egg formation is caused by the inability of oocytes to deposit secondary yolk within the cytoplasm. At pH 4.5, primary and secondary yolk deposition is severely inhibited.

1298
RUBY, S. M., ACZEL, J., and CRAIG, G. R., 1978, The effects of depressed pH on spermatogenesis in flagfish *Jordanella floridae*: Water Research, v. 12, p. 621-626.

Male flagfish (*Jordanella floridae*) were continuously exposed for 20 days to water at 25°C with pH values of 6.7 (control), 6.0, 5.5, and 4.5. Quantitative histological analysis of the final stage of spermatogenesis prior to sperm formation shows that the production of mature sperm at the respective pH values was reduced by 24.03, 27.03, 37.28 and 35.29 percent below the control at pH 6.7. The overall decline in spermatogenesis was confirmed by increased occurrence of tubules devoid of sperm and was particularly evident at pH 4.5. Comparison of these results with data on oogenesis indicates a greater sensitivity among developing eggs than among sperm to pH levels.

1299
RUTHERFORD, G. K., 1967, A preliminary study of the composition of precipitation in S.E. Ontario: Canadian Journal of Earth Sciences, v. 4, p. 1151-1160.

Bulk precipitation samples were collected at 12 sites in southeast Ontario from 1965-66 and analyzed for 12 constituents. Snow samples showed high concentrations of sulfate, which are probably caused by industrial emissions. The high chloride concentrations found at inland sites are not explained.

1300
RYAN, P. M., and HARVEY, H. H., 1977, Growth of rock bass, *Ambloplites rupestris*, in relation to the morphoedaphic index as an indicator of an environmental stress: Journal of the Fisheries Research Board of Canada, v. 34, no. 11, p. 2079-2088.

Acidification of lakes in the La Cloche Mountains by acidic atmospheric deposition has resulted in reduced population densities of fishes. Surviving rock bass (*Ambloplites rupestris*) responded to decreased abundance with an increase in growth rate. Results show that growth rate of fishes, in conjunction with the morphoedaphic index, may be used as an indicator of levels of environmental stress in lake ecosystems.

1301
RYAN, P. M., and HARVEY, H. H., 1980, Growth responses of yellow perch, *Perca flavescens* (Mitchill), to lake acidification in the La Cloche Mountain Lakes of Ontario: Environmental Biology of Fishes, v. 5, no. 2, p. 97-108.

The article describes the effects of lake acidification on growth rates of yellow perch (*Perca flavescens*) in lakes in the La Cloche Mountains. Yellow perch of ages 1 to 3 years responded to lake acidification with increased growth rates; those of ages 4 to 9 responded with reduced growth rates. The growth rates of yellow perch may be used as an indicator of environmental stress levels.

1302
RYAN, P. M., and HARVEY, H. H., 1981, Factors accounting for variation in the growth of rock bass (*Ambloplites rupestris*) and yellow perch (*Perca flavescens*) in the acidifying La Cloche Mountain Lakes of Ontario, Canada: International Association of Theoretical and Applied Limnology, Proceedings, v. 21, p. 1231-1237.

Variations in the growth rate of rock bass and yellow perch, two relatively acid-tolerant species, were studied to determine the first stages of acid-induced stress. Increased growth rates in both species were observed and may be attributed to recruitment failures, which result in less competition for food in those lakes. However, a reversal in growth response to acidification was noted at a size of about 140 mm. At a constant mean depth, the growth statistic of rock bass relates more closely to chemical factors than to physical factors, whereas growth statistic of perch relate more closely to physical factors. This may be because physical factors are more important than chemical factors. As stress increases, the relationship of growth to chemical factors becomes more pronounced.

S

1303
SADASIVAN, S., 1979, Trace elements in monsoon rains at Bombay and over the Arabian Sea: Mausam, v. 30, no. 4, p. 449-456.

Rainwater samples were collected at three sites in Bombay, India and analyzed for trace elements. Results show that sea-salt aerosols predominate the trace-element composition of rainwater. The effect of industrial pollution on the chemical composition of rain is localized.

1304
SAGE, Bryan, 1980, Acid drops from fossil fuels: New Scientist, v. 85, no. 1197, p. 743-746.

This article briefly discusses the ecological impacts of acid precipitation and gives an overview of the problem of long-range transport of air pollutants. Some of the economic, political, and social aspects of the acid rain problem are also considered.

1305
SANDBERG, J. S., LEVAGGI, D. A., DeMANDEL, R. E., and SIU, W., 1976, Sulfate and nitrate particulates as related to SO_2 and NO_x gases and emissions: Journal of the Air Pollution Control Association, v. 26, no. 6, p. 559-564.

Sulfate and nitrate data from eight air-quality stations in the San Francisco Bay area collected from 1969-73 were analyzed from high-volume particulate samples. These data are compared with simultaneous SO_2 and NO_x gas data and emission inventory data. Sulfate and nitrate particulates closely track the emission inventory data, but the gas data vary more widely in response to local sources and meteorological factors. The 5-year mean for sulfates is only slightly above the remote, nonurban background level, but the 5-year mean for nitrate is well above the national urban average. The low sulfate levels indicate the effectiveness of a regional SO_x control program. The relatively high nitrate levels suggest that greater control of NO_x emissions is needed. Sulfate and nitrate data seem to be better indicators of air quality than total suspended particulate data.

1306
SANDERSON, Marie, and LaVALLE, P. D., 1979, Surface loading from pollutants in precipitation in southern Ontario: Some climatic and statistical aspects: Journal of Great Lakes Research, v. 5, no. 1, p. 52-60.

Bulk precipitation samples were collected monthly during 1975-77 at six watersheds in southern Ontario and analyzed for sulfate, nitrogen, phosphate, chloride, calcium, sodium, potassium, magnesium, heavy metals, and PCB's. The relationship between constituent loading in the precipitation and the amount of precipitation was studied, and a significant relationship at the 0.05 level was observed for all constituents except sodium. Loadings were tested statistically for spatial and temporal trends. All constituent loadings showed a decreasing trend over time, which may be attributable to a decrease in precipitation during the second year of observations. Although some sampling sites were near major sources of industrial pollutants, and others hundreds of kilometers away, no significant differences in monthly loadings were observed except for magnesium and calcium.

1307
SANTROCH, Jaroslav, and ZAVODSKY, Dusan, 1979, Sulphur compounds in background air pollution in Czechoslovakia, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 45-52.

1308
SATAKE, Ken'ichi, 1980, Limnological studies on inorganic acid lakes in Japan: Japanese Journal of Limnology, v. 41, no. 1, p. 41-50. [In Japanese.]

This article summarizes recent studies on the chemical composition of inorganic acid lakes in Japan and presents results of biological studies of fish, insects, algae, and zooplankton.

1309
SAUNDERS, P. J. W., 1970, Air pollution in relation to lichens and fungi: Lichenologist, v. 4, p. 337-349.

This article discusses the effects of air pollution on lichens and fungi. The ecology and survival of lichens and fungi are significantly influenced by atmospheric pollutants, especially sulfur dioxide (SO_2). The principal factors in the degree of damage are (1) type of pollutant, (2) concentration and duration of exposure, (3) inherent resistance of the affected organism, and (4) nature of substrate. Humidity, surface water, growth rate, and shelter are also important factors. SO_2 concentration and pH are not independent factors because they are considered critical to each other. Lichens and fungi can be used as indicators of atmospheric pollution; however, many factors can alter ecological patterns in polluted areas.

1310

SCALE, P. R., 1980, Changes in plant communities with distance from an O_2 source, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 248.

1311

SCHEIDER, W. A., ADAMSKI, J., and PAYLOR, M., 1975, Reclamation of acidified lakes near Sudbury, Ontario: Rexdale, Ontario, Ontario Ministry of the Environment, 129 p.

Two lakes with low pH near Sudbury, Ontario, were treated with calcium hydroxide ($Ca(OH)_2$) and calcium carbonate ($CaCO_3$) to change acidic conditions, re-establish buffering system, and reduce levels of heavy metals. The treated lakes and those upstream from the treated lakes were monitored from 1973-75. Treatment of $CaCO_3$ and $Ca(OH)_2$ was more effective than $Ca(OH)_2$ only because it provided a more stable buffering system and maintained improved water quality for a longer period of time. Microbial and phytoplankton populations responded positively to treatment. Zooplanktonic and zoobenthic populations declined, however, which may have been caused by the rapid increase in pH.

1312

SCHEIDER, W. A., CAVE, B., and JONES, J. D., 1975, Reclamation of acidified lakes near Sudbury, Ontario by neutralization and fertilization: Rexdale, Ontario, Ontario Ministry of the Environment, 48 p.

This report presents additional results of a 1973-75 study on the use of calcium hydroxide ($Ca(OH)_2$) and calcium carbonate ($CaCO_3$) to neutralize acidic lakes near Sudbury, Ontario. Initially, neutralization caused a decline in phytoplankton, but in all cases biomass recovered to pretreatment levels in a few months. Zoobenthos and zooplankton have shown no similar recovery. The taxonomic composition of phytoplankton became more typical of nonacidic lakes; however, zooplankton and zoobenthic composition did not change. An experiment in nutrient enrichment of the acidified study resulted in a rapid recovery of the phytoplankton. (See also Scheider, W. A., Adamski, J., and Paylor, M., 1975, herein.)

1313

SCHEIDER, W. A., and DILLON, P. J., 1976, Neutralization and fertilization of acidified lakes near Sudbury, Ontario: Water Pollution Research in Canada, Proceedings 11th Canadian Symposium on Water Pollution Research, p. 93-100.

Two pairs of acidified lakes near Sudbury, Ontario, were treated with calcium carbonate ($CaCO_3$) and calcium hydroxide ($Ca(OH)_2$). Before treatment, the lakes were soft (hardness 21-47 mg/L as $CaCO_3$), poorly buffered (alkalinity 0.04-2.6 mg/L as $CaCO_3$), and had low pH (4.4-4.5). Sulfur was the dominant ionic constituent; copper and nickel were among the highest recorded in the region. After treatment, pH increased to about 7.0, and heavy metal concentrations decreased. Rapid increase of pH caused an initial decline in standing stock of phytoplankton, zooplankton, and zoobenthos; however, phytoplankton soon increased, and taxonomic composition changed during the summer after treatment. Numbers of zooplankton and zoobenthos did not increase the year after treatment, probably because of the relative difficulty in recolonization and their slow reproduction rate. (See also Scheider, W. A., Cave, B., and Jones, J., 1975, herein.)

1314

SCHEIDER, W. A., JEFFRIES, D. S., and DILLON, P. J., 1979, Effects of acid precipitation on Precambrian freshwaters in southern Ontario: Journal of Great Lakes Research, v. 5, no. 1, p. 45-51.

The pH of precipitation on the Precambrian Shield of south-central Ontario is about 4.0 to 4.2. The region is underlain by noncalcareous bedrock of low solubility with a thin glacial overburden; consequently many of the lakes have a low buffering capacity. The pH of some lakes and streams has been reduced by acidic precipitation, particularly during spring runoff and after storms.

1315

SCHEIDER, W. A., JEFFRIES, D. S., and DILLON, P. J., 1981, Bulk-deposition in the Sudbury and Muskoka-Haliburton areas of Ontario during the shutdown of Inco Ltd. in Sudbury: Atmospheric Environment, v. 15, no. 6, p. 945-956.

The contribution of a smelter in Sudbury, Ontario, to bulk deposition of free hydrogen ion, sulfate, total copper, and total nickel at eight collectors near Muskoka-Haliburton was monitored between September 1978 and June 1979 during the shutdown of the smelter. Bulk deposition of total copper and total nickel up to 50 km from Sudbury was significantly lower when the smelter was not in operation. The deposition of sulfate decreased significantly (5 to 50 percent) at stations within 12 km of Sudbury during the shutdown, but no decrease in free hydrogen ion occurred. No significant decrease in deposition of sulfate, free hydrogen ion or total copper was detected at Muskoka-Haliburton during the shutdown.

1316
SCHEIDER, W. A., JONES, J. D., and CAVE, B., 1976, A preliminary report on the neutralization of Nelson Lake near Sudbury, Ontario: Rexdale, Ontario, Ontario Ministry of the Environment, 36 p.

Nelson Lake, near Sudbury, was treated with calcium hydroxide ($Ca(OH)_2$) and calcium carbonate ($CaCO_3$). Although the lake had received considerable amounts of acidic material before treatment, standing stocks and taxonomic composition of the biota after treatment were similar to those of nonacidic lakes. The addition of calcium hydroxide and calcium carbonate resulted in an increase in pH range from 5.7-5.8 to 6.4-6.8. The treatments did not affect the standing stocks or taxonomic composition of the biota.

1317
SCHEIDER, W. A., SNYDER, W. R., and CLARK, B., 1979, Deposition of nutrients and major ions by precipitation in south-central Ontario: Water, Air, and Soil Pollution, v. 12, p. 171-185.

Precipitation samples (bulk and wet only) were collected at sites in south-central Ontario from 1976-78 and analyzed for nutrients and major ions. The dominant anion in both bulk and wet-only precipitation samples was SO_4^{2-}; the dominant cation was H^+. Precipitation in this area was more acidic than recorded at any other location in the Canadian Shield. Ion concentrations varied by one to three orders of magnitude between individual precipitation events; annual deposition varied twofold.

1318
SCHINDLER, D. W., 1979, Effects of acid deposition on Canadian lakes and fisheries, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 61-64.

1319
SCHINDLER, D. W., 1980, Chemical budgets and watershed acidification, in Hendrey, G. R., ed., Limnological aspects of acid precipitation: International Workshop, Sagamore Lake Conference Center, N.Y., 1978, Proceedings: Upton, N.Y. Brookhaven National Laboratory, p. 13-14.

1320
SCHINDLER, D. W., 1980, Ecological effects of experimental whole-lake acidification, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 453-468.

1320 (continued)
Experimental acidification of an oligotrophic lake in the Canadian Precambrian Shield has been attempted to examine aspects of the acidification process that are impossible to study in areas with long previous history of acidification. It is apparent that several dramatic changes occur in the aquatic ecosystem before pH decreases to levels that are toxic to fish. More attention must be given to the effects of acidification on organisms other than fish if ecosystems are to be maintained in their present state.

1321
SCHINDLER, D. W., 1980, Experimental acidification of a whole lake--a test of the oligotrophication hypothesis, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 370-374.

1322
SCHINDLER, D. W., 1980, Implications of regional-scale lake acidification, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 533-538.

Lakes in large areas of the Canadian Shield are being affected by acid deposition. Although data from which to analyze trends are scanty, evidence suggests that fish populations may be seriously affected in the region with little or no additional acidification. Loss of sport fisheries or of migration of the impact are causing severe economic losses.

1323
SCHINDLER, D. W., HESSLEIN, R. H., WAGEMANN, R., and BROECKER, W. S., 1980, Effects of acidification on mobilization of heavy metals and radionuclides from the sediments of a freshwater lake: Canadian Journal of Fisheries and Aquatic Sciences, v. 37, no. 3, p. 373-377.

Increased concentrations of heavy metals have been observed in many of the acidified lakes of Scandinavia and eastern Northern America. These increases are attributed to industrial contamination of precipitation and(or) the leaching of heavy metals from soils in the drainage basins. Much of the observed increase in heavy metals could also result from the leaching of lake sediments at low pH. Results of a study by the Ontario Ministry of the Environment to determine the extent to which acidification mobilizes heavy metals and radionuclides from lake sediments in the Experimental Lakes Area of Ontario show that acidification caused several metals, including FE-59, Co-60, Mn-54, and Zn-65, to become more soluble.

1324
SCHINDLER, D. W., NEWBURY, R. W., BEATY, K. G., and CAMPBELL, P., 1976, Natural water and chemical budgets for a small Precambrian lake basin in central Canada: Journal of Fisheries Research Board of Canada, v. 33, p. 2526-2543.

This article presents a hydrochemical budget for Rawson Lake, Ontario. Inputs of water and most chemicals varied nearly two-fold from one year to the next, which suggests that several years of hydrologic data are necessary to determine average nutrient contribution and losses from an ecosystem. Precipitation seemed to be the sole source of P and N to the lake and terrestrial ecosystems, with N_2 fixation contributing to N. The pH of precipitation averaged less than 5 even though the collection sites were far from major industrial sources of SO_2.

1325
SCHINDLER, D. W., WAGEMANN, R., COOK, R. B., RUSZCZYNSKI, T., and PROKOPOWICH, J., 1980, Experimental acidification of lake 223, experimental lakes area--background data and the first three years of acidification: Canadian Journal of Fisheries and Aquatic Sciences, v. 37, no. 3, p. 342-354.

Sulfuric acid was added to Lake 223 in the Experimental Lakes Area of northwestern Ontario for 3 years to simulate the chemical and biological effects of acid precipitation. The pH of epilimnion water ranged from 6.7 to 7.0 in 1976, 6.0 to 6.2 in 1977, and 5.7 to 5.9 in 1978. The acid treatments depleted alkalinity from the water column by 31 to 38 percent and, as a result, the pH of the lake did not decrease as much as predicted. Sulfate reduction increased as the addition of sulfuric acid caused an increase of sulfate concentration. Concentrations of ammonia, iron, manganese, zinc, and aluminum increased, and the transparency of the lake increased, but, no change in chlorophyll, dissolved color, dissolved organic carbon, or primary production was noted.

1326
SCHINDLER, P. W., 1976, The regulation of trace metal concentrations in natural water systems--a chemical approach: Journal of Great Lakes Research, v. 2, supplement no. 1, p. 132-145.

This article presents equations for calculating residence times and steady-state concentrations of trace metals in aquatic systems. It also assesses the effect of pH and the influence of ligands that form complexes with metal ions. A model is applied to trace metals that are removed from aquatic systems by adsorption on sedimenting particulate matter. Results are compared with field data on concentrations of copper and zinc in Lake Biel, Switzerland.

1327
SCHLESINGER, W. H. and REINERS, W. A., 1974, Deposition of water and cations on artificial foliar collectors in fir Krummholz of New England mountains: Ecology, v. 55, p. 378-386.

Atmospheric deposition of water, calcium, magnesium, sodium, potassium, and lead was measured in a fir (*Abies balsamea*) Krummholz on Mt. Moosilauke, New Hampshire. Water catchment was about 4.5 times greater in foliar collectors than in open buckets, and deposition of calcium, magnesium, sodium, potassium, and lead averaged 8.3, 6.0, 4.9, 5.7, and 5.5 times greater, respectively, in foliar collectors. Most of the cation increases in foliar collectors were due to higher volume catchment, but some concentration enrichment through interception may have contributed. In areas of high wind and frequent exposure to clouds or fog, measurement of total elemental deposition requires an evaluation of interception and bulk precipitation.

1328
SCHNEIDER, T., 1979, Aerial determination of long-range transport, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 17-24.

1329
SCHNITZER, Morris, 1980, Effect of low pH on the chemical structure and reactions of humic substances, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 203-222.

1330
SCHOFIELD, C. L., 1975, Acid precipitation--our understanding of the ecological effects, in Acid precipitation: Conference on Emerging Environmental Problems, Rensselaerville, N.Y., 1975, Proceedings: New York, U.S. Environmental Protection Agency, p. 76-87.

1331
SCHOFIELD, C. L., 1976, Acid precipitation--effects on fish: Ambio, v. 5, no. 5-6, p. 228-230.

This article summarizes information on the effects of acidification on fish. Most of the studies discussed were conducted in Norway and Sweden. Extinction of fish is often a result of chronic reproductive failure because of acidification during

1331 (continued)
sensitive stages of the life cycle. Mortality is usually greatest in newly hatched larvae, but, disruption of reproductive physiology in maturing female fish has been observed.

1332
SCHOFIELD, C. L., 1976, Acidification of Adirondack lakes by atmospheric precipitation--extent and magnitude of the problem: Albany, New York State Department of Environmental Conservation, 1 v.

A synoptic survey of the water chemistry of 214 in the Adirondack Mountains of New York was conducted in June 1975 to study the distribution and characteristics of acidified lakes in high-elevation watersheds. About 52 percent of the lakes in the survey had pH less than 5, and 7 percent had pH ranging from 5.5 to 6.0. Regional variation in pH may be due to the interaction of acid precipitation with the terrain. Lakes in the vicinity of calcitic rock or drift generally had pH levels above 6, whereas those in granitic terrain, primarily in the western Adirondacks were acid (pH <5). Elevated concentrations of zinc, manganese, and aluminum were observed in the acid lakes. The role of aluminum as a possible acid buffer is discussed.

1333
SCHOFIELD, C. L., 1977, Acid snow-melt effects on water quality and fish survival in the Adirondack Mountains of New York State: Washington, D.C., U.S. Department of the Interior, Office of Water Research and Technology, Research Project Technical Completion Report, 27 p.

This report summarizes the effects of acidic snowmelt episodes on water quality and fish survival in Adirondack lakes. High NO_3/SO_4 ratios in precipitation during winter and in snowmelt runoff indicate that nitric acid may be a major strong acid component. Snowpack storage of strong acids, concentration by ion separation during thaws, and release of acids in snowmelt results in severe changes in quality of lake and stream waters. Decreased pH and high concentrations of aluminum in runoff are lethal to captive brook trout populations. Aluminum is identified as the major toxic component in acidic snowmelt.

1334
SCHOFIELD, C. L., 1979, The acid precipitation phenomenon and its impact in the Adirondack Mountains of New York State, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 86-91.

1335
SCHOFIELD, C. L., 1979, Effects on acid rain on lakes, in Gunnerson, C. G., and Willard, B. E., eds., Acid rain: American Society of Civil Engineers National Convention, Boston, Mass., 1979, Proceedings: New York American Society of Civil Engineers, p. 55-69.

1336
SCHOFIELD, C. L., 1980, Processes limiting fish populations in acidified lakes, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 345-356.

Acidified lakes that have lost bicarbonate buffering and maintain chronically depressed pH levels are generally devoid of fish. Less acidic but poorly buffered waters experience episodic acidification during snowmelt and periods of increased surface runoff. Fish mortalities, which occur during these episodes, are a result of stresses associated with the extreme temporal variations in pH and metallic cation concentrations. These stresses can lead to recruitment failure and alterations in population structure. Aluminum was identified as a primary toxicant present in acidified runoff entering streams and lakes during snowmelt. The mobilization of toxic species of aluminum from the edaphic to the aquatic environment is an integral part of the acidification process that affects fish populations.

1337
SCHOFIELD, C. L., 1980, Toxicity of metals, in Hendrey, G. R., ed., Limnological aspects of acid precipitation: International Workshop, Sagamore Lake Conference Center, N.Y., 1978, Proceedings: Upton, N.Y. Brookhaven National Laboratory, p. 31-36.

1338
SCHOFIELD, C. L., 1981, Acid precipitation effects on aquatic ecosystems, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 17.

1339
SCHOFIELD, C. L., 1981, Acid rain and Adirondack trout, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 93-96.

1340
SCHOFIELD, C. L., 1981, Aquatic effects of acid rain, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 17-19.

1341
SCHOFIELD, C. L., and GALLOWAY, J. N., 1977, The utility of paleolimnological analyses of lake sediments for evaluating acid precipitation effects on dilute lakes: Washington, D.C., U.S. Department of the Interior, Office of Water Research and Technology, Research Project Technical Completion Report, 23 p.

Sediment cores were collected from three lakes of widely differing pH in the Adirondack Mountains of New York in July 1975. Diatom microfossils in the sediment cores were examined for pH preference, and an index was developed from the ratio of acidophilous to alkaliphilous units. Sediments from one lake showed a significant increase in acidophilous taxa in the uppermost centimeters of sediment and a decrease in pH from the range 5.5-6.0 in historical sediments to pH 5.0 in recent sediments. Results show that pH indices based on diatom microfossils may be used as indicators of lake acidification.

1342
SCHOFIELD, C. L., and TROJNAR, J. R., 1980, Aluminum toxicity to brook trout (*Salvelinus fontinalis*) in acidified waters, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 341-366.

Aluminum was identified as a primary toxicant in acidic, snowmelt runoff and lakes in the Adirondack Mountain region of New York. Covariance analysis of water quality data from 53 Adirondack lakes suggests that survival of stocked brook trout is determined primarily by aluminum concentrations rather than pH or calcium levels. Lakes not supporting brook trout had a mean aluminum concentration of 0.29 mg/L, as compared to 0.11 mg/L in lakes where stocked brook trout survived. Comparisons of mortality and gill pathology of brook trout exposed to acidic synthetic solutions and natural Adirondack waters with aluminum levels above 0.2 mg/L, indicated a specific toxic response to aluminum at pH down to 4.4. An apparent increase in toxicity of fixed total aluminum levels with increasing pH suggested that changes in speciation involving hydroxyl complexing enhances the toxicity of the aluminum cation.

1343
SCHOFIELD, Edmund, and HAMILTON, W. L., 1970, Probable damage to tundra biota through sulphur dioxide destruction of lichens: Biological Conservation, v. 2, no. 4, p. 278-281.

Lichens are extremely sensitive to SO_2. Studies conducted in arctic North America show that recent oilfield development has resulted in the elimination of lichens through a combination of biological and meteorological factors. SO_2 pollution from industrial sources is an increasing threat to arctic ecosystems.

1344
SCHOFIELD, R. K., and TAYLOR, A. W., 1955, The measurement of soil pH: Soil Science Society of America Proceedings, v. 19, p. 164-167.

Soil samples were shaken with solutions of $CaCl_2$ of differing concentrations to determine the effect on pH. Results were interpreted through ratio law based on the Gouy theory of electrical double layer, and the pH values and electrolyte concentrations showed the expected relationship. This article discusses the relationship between pH and electrolyte concentration in the routine measurement of soil pH. Such measurements must be made in an electrolyte solution of known composition to obtain comparable results from different soils.

1345
SCHOLZ, F., and RECK, S., 1977, Effects of acids on forest trees as measured by titration *in vitro*, inheritance of buffering capacity in *Picea abies*: Water, Air, and Soil Pollution, v. 8, no. 1, p. 41-45.

The effect of acid precipitation on vegetation is the result of an interaction between acid and plant. The metabolism of plants is dependent on optimal pH-values, which are maintained by regulation. There are differences in the effectiveness of regulation under such exogenous influences as acidic precipitation. These differences can be related to the resistance of plants to acidic precipitation. Such differences were measured as buffering capacity of homegenized leaves during titration with acid. There are significant differences in buffering capacity between clones in *Pinus* spp. and *Picea abies*. A highly significant variance in buffering capacity also was found among families of *P. abies*. Calculations of genetical parameters show that the phenotypical variance of buffering capacity is governed mainly by genetical factors. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1346
SCHREIBER, R. K., 1980, Acid rain--industrial fallout in the north woods: Fish and Wildlife News, August/September 1980, p. 8-10.

This article discusses acid precipitation with emphasis on research conducted by the U.S. Fish and Wildlife Service, National Power Plant Team. The research program emphasizes (1) collecting new data and analyzing existing data on the effects of acid rain on aquatic and terrestrial ecosystems, (2) assessing methods of mitigation, (3) evaluating techniques for management and reclamation of coal-combustion wastes, and (4) developing methods for research on the biological effects of acid rain on fish and wildlife and their habitats.

1347
SCHRIMPFF, E., 1980, The relationship between relief and deposition of some organic and inorganic contaminants in snow of northern Bavaria, FRG., in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 130-131.

1348
SCHUMAN, G. E., and BURWELL, R. E., 1974, Precipitation nitrogen contribution relative to surface runoff discharges: Journal of Environmental Quality, v. 3, no. 4, p. 366-368.

An investigation was conducted to determine the amount of nitrogen (N) in surface runoff that originated from the soil (commercial fertilizer, crop residue, or soil organic matter) and what fraction orginated from N in precipitation. Results indicate that 69 percent of the N discharged by surface runoff from sampled events could be attributed to precipitation-originated N.

1349
SCOTT, B. C., 1978, Parameterization of sulfate removal by precipitation: Journal of Applied Meteorology, v. 17, no. 9, p. 1375-1389.

This article presents a mathematical model that predicts concentrations of sulfate in the air and in precipitation. The model assumes that incloud oxidation of SO_2 is negligible, and that the sulfate deposited on the ground results from the scavenging of pre-existing sulfate during the lifetimes of individual cloud elements. For light to moderate precipitation rates, the removal of airborne sulfate by precipitation is predicted to be strongly dependent on the mechanism of precipitation formation. Analyses used to predict washout ratios are also used to forecast the mean oxidation rate of SO_2.

1350
SCOTT, B. C., 1981, Modeling of atmospheric wet deposition, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 3-21.

1351
SCOTT, B. C., and LAULAINEN, N. S., 1979, On the concentration of sulfate in precipitation: Journal of Applied Meteorology, v. 18, p. 138-147.

Data from two storms that occurred in March 1977 at Muskegon, Mich. are evaluated to determine the relationship of sulfate concentration in surface precipitation to microphysical characteristics of the precipitating cloud systems. Data from the first storm support the hypothesis that sulfate aerosol is incorporated into cloud water by the nucleation process and accounts for most of the sulfate concentration in cloud and precipitation water. Activated sulfate particles accumulate water through the condensation process and are then deposited on land after accretion on large snowflakes. Data from the second storm are inconclusive.

1352
SCOTT, W. D., 1978, The pH of cloud water and the production of sulfate: Atmospheric Environment, v. 12, p. 917-921.

The acidity of cloud water near Sidney, Australia, was measured upwind and downwind of the city. Although urban pollution may lower pH to less than 5.0, unpolluted samples tend to be more alkaline than expected from samples in equilibrium with atmospheric levels of carbon dioxide. Large concentrations of sulfate ion may be produced within clouds at the sampling area.

1353
SCOTT, W. D., and HOBBS, P. V., 1967, The formation of sulfate in water droplets: Journal of the Atmospheric Sciences, v. 24, p. 54-57.

The formation of sulfate in the SO_2-NH_3 liquid H_2O system was studied to determine the catalytic action of ammonia in the formation of sulfate. Assuming that the limiting mechanism in the rate of sulfate production is the oxidation of sulfite ion explains catalysis of the oxidation by ammonia. The theory predicts that when NH_3 and SO_2 are present in water droplets in concentrations similar to those in the atmosphere, the concentration of sulfate produced after 24 hours is about two orders of magnitude greater than that which would be produced in the absence of NH_3.

1354
SCRIVEN, R. A., and FISHER, B. E. A., 1975, The long range transport of airborne material and its removal by deposition and washout--1. General considerations: Atmospheric Environment, v. 9, p. 49-58.

This article examines the fate of airborne material that is confined between the ground and an elevated inversion, which is assumed impenetrable, when deposition at either surface and washout by rain can occur. It describes a mathematical model of the lifetime and decay distance of airborne pollution downwind of a large source area. Rainout and chemical reactions are not included in this paper. Detailed effects of turbulent diffusion on concentration profiles are discussed in part II [below]. (See also Li, Ta-Yung, 1975, herein.)

1355
SCRIVEN, R. A., and FISHER, B. E. A., 1975, The long range transport of airborne material and its removal by deposition and washout--II. The effect of turbulent diffusion: Atmospheric Environment, v. 9, p. 5968.

The effect of turbulent diffusion in increasing travel distances estimated by a model described in part I is further examined with emphasis on characteristics of the low turbulence region adjacent to the absorbing surface. The effective deposition rate for long-distance travel is governed mostly by the diffusive resistance of the low-turbulence region adjacent to the land surface. (See also Li, Ta-Yung, 1975, herein.)

1356
SEHMEL, G. A., 1980, Model predictions and a summary of dry deposition velocity data, <u>in</u> Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 223-235.

This article discusses previously published data on dry deposition velocities as a function of particle diameter and gas speciation. Most experiments reported in the literature, encountered uncertainties that hindered the development of general predictive deposition velocity models. However, one model (Sehmel and Hodgson, 1978, herein) offers a satisfactory approach for predicting dry deposition velocities as a function of particle diameter, friction velocity, aerodynamic surface roughness, and particle density.

1357
SEIP, H. M., 1980, Acid snow--snowpack chemistry and snowmelt, <u>in</u> Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 77-94.

1358
SEIP, H. M., 1980, Acidification of freshwater--sources and mechanisms, <u>in</u> Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 358-366.

1359
SEIP, H. M., and TOLLAN, Arne, 1978, Acid precipitation and other possible sources for acidification of rivers and lakes: Science for the Total Environment, v. 10, p. 253-270.

This article describes trends in acidity of rivers and lakes in southern Norway and reviews evidence for a causal relationship between acid precipitation and acidification of surface water. A regional survey indicates that several sources may contribute to the acidification. Acidification of rivers and lakes seems to be caused mainly by changes in the chemical composition of precipitation due to increased combustion of fossil fuels during recent years.

1360
SELEZNEVA, E. S., 1972, Estimation of the background contamination of the atmosphere from the chemical composition of precipitation: Tellus, v. 24, no. 2, p. 122-126.

This article describes the relationship of marine and continental constituents in precipitation and gives background concentrations of selected constituents for different geographical regions in the USSR, central Europe, and central Asia. Background levels constitute 30 to 40 percent of the total contamination over the continental USSR. Local sources contribute 60 to 70 percent, of which 20 to 30 percent can be attributed to natural sources and the rest to contamination from anthropogenic sources.

1361
SEMB, Arne, 1976, Measurement of acid precipitation in Norway: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 231-240.

Since January 1972, chemical analysis of daily precipitation samples from about 20

1361 (continued)
background stations in Norway has been carried out on a routine basis. Air monitoring is carried out at six stations.

The chemical analysis program is: sulphate, pH and acidity in precipitation, sulphates and SO_2 in the air. In addition, more detailed chemical analysis of aerosol and precipitation has been carried out at selected stations. Some results for the measurement period 1972 to 1974 are presented. Comparison of air and precipitation concentrations of S compounds show that the precipitation scavenging efficiency is very high under the conditions in southern Norway. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1362
SEMB, Arne, 1978, Sulphur emissions in Europe, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 455-460.

Natural and man-made emissions of sulphur to the atmosphere are discussed. Within Europe the man-made emissions, which are closely associated with the consumption of fossil fuels, are overwhelmingly dominant. Emissions from the 11 countries participating in the OECD study were 8.8 M tonnes S in 1973, and have been estimated at about 25 M tonnes for the whole of Europe. Based on information from the participating countries, and from various other sources, an emission survey has been worked out. This gives the emissions in 1/2° latitude x 1° longitude geographical reference system which has been transferred to a 127 x 127 km grid used in dispersion model calculations. [Abstract reprinted by permission of Pergamon Press.]

1363
SEMB, Arne, 1979, Emission of gaseous and particulate matter in relation to long-range transport of air pollutants, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 1-2.

1364
SEMONIN, R. G., 1976, The variability of pH in convective storms: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 395-406.

The rainwater pH was measured in a total of 22 storms which occurred in 1972 and 1974 in the METROMEX (Metropolitan Meteorological Experiment) rainwater sampling network. The network consists of 81 collectors in an area of 1800 km^2 over and east of St. Louis, Missouri.

1364 (continued)
The data set is composed of dry fallout samples as well as precipitation samples which have been analyzed independently. An analysis of the frequency distribution of these data shows the rainfall samples form a bimodal distribution of pH with relative frequency maxima at pH 7.0 and 4.0 while the dry samples are unimodal with the maximum frequency at pH 7.0.

The areal distribution of precipitation weighted mean pH indicates a variability unrelated to total precipitation. However, the derived deposition of H^+ is more similar to the areal rainfall pattern than to the pH. The dH is defined which incorporates both the rainfall and pH which is useful for climatological trend studies of acid rainfall.

Examples of two individual storm events illustrate an inexplicable area-wide variation from nearly an all acid rain pH ≤ 4.5 to an all alkaline rain (pH ≥ 5.5). These case studies indicate some of the meteorological as well as chemical problems which must be considered when attempting to characterize convective storm rainfall pH. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1365
SEQUEIRA, R., 1981, Acid rain—some preliminary results from global data analysis: Geophysical Research Letters, v. 8, no. 2, p. 147-150.

Preliminary results from a global precipitation network maintained by the World Meteorological Organization indicate that remote, maritime baseline stations could become predisposed to acid precipitation if there is a deficiency of nonmaritime calcium relative to nonmaritime sulfate. Results suggest that not all nonmaritime sulfate and nitrate in precipitation are present as acid.

1366
SEVALDRUD, I. H., MUNIZ, I. P., and KALVENES, S., 1980, Loss of fish populations in southern Norway—dynamics and magnitude of the problem, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 350-351.

1367
SEYMOUR, M. D., SCHUBERT, S. A., CLAYTON, J. W., Jr., and FERNANDO, Quintus, 1978, Variations in the acid content of rain water in the course of a single precipitation: Water, Air, and Soil Pollution, v. 10, p. 147-161.

Strong acid, weak acid, ammonium ion (NH_4^+), and dissolved carbon dioxide (CO_2) were the major acid components in rainwater collected

1367 (continued)
during five storms in July and August 1977. Variations in their concentration were determined as a function of time in each of the events. The most significant result showed that strong acid concentration increased from very low to a maximum and then decreased in the course of a single storm.

1368
SHAPIRO, M. A., 1979, The exchange of chemical constituents between the stratosphere and troposphere through turbulent mixing processes within tropopause folds, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 377-384.

1369
SHARMA, G. K., 1977, Cuticular features as indicators of enviromental pollution: Water, Air, and Soil Pollution, v. 8, no. 1, p. 15-19.

Several leaf cuticular features such as stomatal frequency, stomatal size, trichome length, type, and frequency, and subsidiary cell complex respond to environmental pollution in different ways and hence can be used as indicators of environmental pollution in an area. Several modifications in cuticular features under polluted environments seem to indicate ecotypic or survival significance for the plant species under investigation. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1370
SHARMA, Vinaya, and REISINGER, L. M., 1978, Tennessee regional atmospheric transport study: Journal of the Air Pollution Control Association, v. 28, no. 1, p. 63-65.

This article summarizes the characteristics and mechanisms affecting the long-range transport of emissions from coal-fired powerplants in the southeastern United States. It also discusses regional effects of these emissions, specifically the Tennessee River watershed and surrounding areas. Results of the investigation indicate that for the three days for which Lagrangian measurements were made, the average sulfate flux entering the study area was 31 μg m^{-2} sec^{-1} and the average sulfate flux leaving the area was 47 μg m^{-2} sec^{-1}. Outflow fluxes were higher than inflow fluxes.

1371
SHAW, R. W., 1979, Acid precipitation in Atlantic Canada: Environmental Science and Technology, v. 13, no. 4, p. 406-411.

1371 (continued)
A portion of the deposition of SO_x and NO_x from the atmosphere to freshwater, soil, and vegetation in the Atlantic region of Canada may be transported from the eastern United States and central Canada. Some fraction of these materials is being imported from areas outside the region, possibly central Canada and eastern U.S. The effects of emissions can be diminished only by reducing the quantities of materials being emitted in the source region. Consequently emissions control on an international scale may be necessary.

1372
SHAW, R. W., 1980, Atmospheric transport and deposition of pollutants in the Atlantic provinces, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 19-24.

1373
SHAW, R. W., 1980, Estimated contributions of Swedish and outside sources to background aerosol concentrations in Sweden: Stockholm, Sweden, University of Stockholm, Department of Meteorology Report CM-50, 31 p.

This report describes an atmospheric dispersion model to determine sources of sulfur, vanadium, nickel, iron, manganese, and lead in background atmospheric aerosols measured in the absence of precipitation at Velen, a rural site in south-central Sweden. Observed concentrations could be accounted for by Swedish and Finnish sources within a factor of $\underline{+}2$ for atmospheric flow from the northeast gradient. A substantial fraction (50 to 90 percent) of the measured concentrations cannot be accounted for by Swedish sources for atmospheric flow with a southerly component. Sources outside Sweden seem to have a significant influence on background concentrations of the six substances studied.

1374
SHAW, R. W., 1980, Monitoring and modelling of the long range atmospheric transport and deposition of pollution--an overview with respect to the Atlantic region, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 94-103.

1375
SHAW, R. W., and RODHE, Henning, 1981, Non-photochemical oxidation of SO_2 in regionally polluted air during winter: Stockholm, Sweden, University of Stockholm, Department of Meteorology Report CM-53, 26 p.

Concentrations of airborne sulfur dioxide (SO_2) and sulfate (SO_4) transported from the United Kingdom and continental Europe to southern Scandinavia in the absence of precipitation show an increase of SO_4 with traveltime during winter. An additional oxidation mechanism of SO_2 20 times the rate of OH^- and H_2O_2 oxidation by ozone is considered as a possible process resulting in the estimated production of SO_4. However, ozone may not be an effective oxidant of sulfur in winter.

1376
SHAW, R. W., and WHELPDALE, D. M., 1973, Sulphate deposition by precipitation into Lake Ontario: Water, Air, and Soil Pollution, v. 2, no. 1, p. 125-128.

Precipitation samples were collected during individual snowstorms of several hours duration in the western Lake Ontario region. Sulfate analyses ($SO_4{}^{2-}$) show that about 9 to 66 mg/m^{-2} of $SO_4{}^{2-}$ is deposited onto the lake per storm. From a mean $SO_4{}^{2-}$ concentration of 4 mg/L and an annual accumulation of precipitation of 760 mm, the yearly $SO_4{}^{2-}$ deposition by precipitation is about 0.1 percent of the total mass of $SO_2{}^{4-}$ in the lake. It is also the same order of magnitude as the $SO_4{}^{2-}$ discharged directly into the lake by industry.

1377
SHEIH, C. M., HESS, G. D., and HICKS, B. B., 1978, Design of network experiments for regional-scale atmospheric pollutant transport and transformation: Atmospheric Environment, v. 12, p. 1745-1753.

This article discusses site-selection criteria sampling schedules, and sampling intervals for a regional air-quality monitoring network to obtain verification requirements for various numerical models. Network experiments are classified into tracer experiments to test the physical and chemical mechanisms of atmospheric pollutant transformation and transport, and air quality experiments to determine the extent of air pollution. Two lines of five stations are recommended for tracer experiments, and the lines should be 400 km apart; stations should be 170 km apart for the upstream line and 200 km for the downstream line. More than 13 stations are needed to define the annual pattern of the pollutant concentration.

1378
SHEIH, C. M., WESELY, M. L., and HICKS, B. B., 1979, Estimated dry deposition velocities of sulfur over the eastern United States and surrounding regions: Atmospheric Environment, v. 13, p. 1361-1368.

This article presents surface-deposition velocities of sulfur dioxide and sulfate particles over the eastern United States, southern Ontario, and nearby oceanic regions for use in studies of regional-scale atmospheric pollution. Surface roughness and resistance to pollutant uptake can be estimated from land-use characteristics and biological status of vegetation.

1379
SHELLITO, G. A., and DeCOSTA, John, 1981, Primary production in a eutrophic acid lake: Water, Air, and Soil Pollution, v. 16, p. 415-431.

Total phosphorus (P) and chlorophyll concentrations and phytoplankton production were measured biweekly in Tibbs Run Lake, West Virgina, from March 1977 to March 1978. Mean hydrogen ion (H^+) concentration was 25.1 µeq/L (pH 4.6). The acidity of the lake is attributed to acid precipitation and the low buffering capacity of the watershed. This article presents nutrient budgets and a H^+ budget for the lake and describes its trophic status in terms of chlorophyll concentrations and primary production.

1380
SHEN-MILLER, J., HUNTER, M. B., and MILLER, J., 1976, Simulated acid rain on growth and cadmium uptake by soybean [abstract]: Plant Physiology, v. 57, p. 50.

Soybean plants were treated with simulated acid rain with pH ranging from near neutral to 2.1. Several plant injury symptoms correlated positively to increasing acidity. Increased acidity of rain significantly increased the uptake of cadmium by the treated plant. Plants subjected to acid rain may be more susceptible to injuries from other pollutants.

1381
SHERIDAN, R. P., 1979, Effects of airborne particulates on nitrogen fixation in legumes and algae: Phytopathology, v. 69, no. 9, p. 1011-1018.

This article reports the effects of sulfur compounds and phytotoxic elements from stack emissions from coal-fired electrical facilities and diazotrophic processes on nitrogen fixation in legumes and algae. Inhibition of nitrogen fixation by sulfur dioxide (SO_2) or its oxidation products involves a direct effect on nitrogenase or on photosynthesis. In either case the result is an increased

1381 (continued)
dependence on combined soil nitrogen for growth. Data given for blue-green algae (*Anabaena azolla*) indicate that nitrogenase is more sensitive to acid rain than the photosynthetic mechanism. Because soil cyanophytes and piokilohydric lichens grow only on the surface soil, they are exposed directly to SO_2 and H_2SO_4 without the benefit of an intervening soil structure to act as a buffer.

1382
SHERIDAN, R. P., and ROSENSTRETER, R., 1973, The effect of hydrogen ion concentrations in simulated rain on the moss *Tortula ruralis* (Hedw.) Sm.: Bryologist, v. 76, no. 1, p. 168-173.

Gametophores of moss (*Tortula ruralis*) were treated with solutions of sulfuric acid with pH 1.0 to 6.0. Concentations of chlorophyllus a and b decreased at pH values between 6 and 3 then decreased more rapidly between pH 3 and pH 1. Chlorophyll a was more sensitive to acid than chlorophyll b. Oxygen production was relatively unaffected between pH 6 and pH 2, and photosynthesis based on dry weight decreased uniformly in relation to decrease in pH. Simulated acid rain seemed to reduce photosynthesis through acid hydrolysis of chlorophyll a.

1383
SHREFFLER, J. H., 1978, Factors affecting dry deposition of SO_2 on forests and grasslands: Atmospheric Environment, v. 12, p. 1497-1503.

Deposition velocities of sulfur dioxide (SO_2) over forests and grasslands were determined by a mass conservation approach that uses established empirical relations characteristic of atmospheric transport of a gaseous contaminant above and within a vegetational canopy. The investigation emphasized situations when surface resistance to uptake is relatively small and does not overwhelm atmospheric transport in the determination of deposition. This applies specifically to situations when the vegetation surface is a perfect sink or has resistance approximating stomatal resistance. Deposition velocity is largely insensitive to canopy height, shape, roughness, length, and extinction coefficients. However, it is sensitive to atmospheric stability, zero-plane displacement, surface resistance, leaf area index, and friction velocity. Deposition velocities are two or three times greater over forests than over grasslands or other low-set vegetation.

1384
SHRINER, D. S., 1977, Effects of simulated rain acidified with sulfuric acid on host-parasite interactions: Water, Air, and Soil Pollution, v. 8, no. 1, p. 9-14.

Wind-blown rain, rain splash, and films of free moisture play important roles in the epidemiology of many plant diseases. The effects of simulated rain acidified with sulfuric acid were studied on several host-parasite systems. Plants were exposed in greenhouse or field to simulated rain of pH 3.2 ± 0.1 or pH 6.0 ± 0.2. Simulated "rain" of pH 3.2 resulted in: (1) an 86% inhibition in telia production of *Cronartium fusiforme* on *Quercus phellos*; (2) a 66% inhibition of reproduction of *Meloidogyne halpa* on field-grown *Phaseolus vulgaris*; (3) a 10% decrease in the severity of *Uromyces phaseoli* on field-grown *Phaseolus vulgaris*; and (4) an inhibition of Rhizobium nodulation of *Phaseolus vulgaris* and *Glycine max* by an average of 73%. Effects on halo blight of kidney bean (caused by *Pseudomonas phaseolicola*) depended upon the segment of the disease cycle in which the "rain" occurred: (1) simulated rain of pH 3.2 applied to plants before inoculation simulated disease development; (b) suspension of inoculum in "rain" of pH 3.2 decreased inoculum potential; and (c) "rain" of pH 3.2 applied to plants after infection inhibited disease development. Scanning electron microscopy of epicuticular waxes on leaves of *Quercus phelos* and *Phaseolus vulgaris* showed marked erosion of those surfaces by "rain" of pH 3.2, indicating possible influences on the structure and function of plant cuticles. These results suggest that the acidity of rain is a new parameter of environmental concern, and underline the need for study of the consequences of prolonged exposure of both agronomic and natural ecosystems to this stress factor. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1385
SHRINER, D. S., 1978, Effects of simulated acidic rain on host-parasite interactions in plant diseases: Ecology and Epidemiology, v. 68, no. 2, p. 213-219.

The influence of simulated rain acidified with sulfuric acid on disease development in parasite systems in plants was investigated. When simulated acid rain was applied to plants before inoculation, disease severity increased by 42 percent; however, suspension of bacteria in acidic rain resulted in no infection. When acidic rain was applied to plants after infection, disease development was inhibited by 22 percent.

1386
SHRINER, D. S., 1980, Vegetation surfaces--a platform for pollutant/parasite interactions, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 259-272.

Above-ground surfaces of higher plants are the site of deposition of a variety of air-

1386 (continued)
borne biological materials and atmospheric pollutants. These biological materials (pollen, fungal spores, bacterial cells, waste from insect feeding) and the pollutants (as aerosols gases, or dissolved in rain) may interact to influence the host plant, the pathogen, or the host/pathogen association. The conditions of the plant's surface environments can affect the behavior of a pathogen and alter the chemical characteristics of behavior of a pathogen and alter the chemical characteristics of throughfall or stemflow originating at those surfaces. Host/pathogen interactions represent a sensitive indicator of plant stress, since the changes in balance between host and parasite may reveal a subtle abiotic stress long before the response would be detectable in the healthy plant alone. The impact of wet and dry deposition of pollutant materials on the plant surface alone, and on potentially pathogenic organisms, is necessary in order to fully interpret many plant/parasite interactions. This paper discusses examples of pollutant-parasite interactions at the leaf surface to illustrate the role that pollutants can play in the relationship of susceptible host and virulent pathogen. [Abstract reprinted by permission of Plenum Press.]

1387
SHRINER, D. S., and COWLING, E. B., 1980, Effects of rainfall acidification on plant pathogens, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 435-442.

1388
SHRINER, D. S., and HENDERSON, G. S., 1978, Sulfur distribution and cycling in a deciduous forest watershed: Journal of Environmental Quality, v. 7, no. 3, p. 392-397.

This article describes sulfate concentrations and pH of precipitation and streamwater, and sulfur concentrations of biomass and soil components in a mixed deciduous forest in eastern Tennessee. The amount of sulfur (S) added by precipitation and lost by streamflow is compared to fluxes of S between biomass pools. Seasonal variations in S inputs exported from the watershed are related to precipitation events. Sulfate accounts for 80 percent of the anions that are contributed to the watershed. The data indicate that the southeastern United States is adversely affected by atmospheric sulfate pollution, which is commonly associated with the northeastern United States.

1389
SHUGART, H. H., McLAUGHLIN, S. B., and WEST, D. C., 1980, Forest models--their development and potential applications for air pollution effects research, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 203-214.

As research tools for evaluating the effects of chronic air pollution stress, forest simulation models offer one means of integrating forest growth and development data with generalized indices of pollution stress. This approach permits consideration of both the competitive interactions of trees in the forest stand and the influences of the stage of stand development on sensitivity of component species. A review of forest growth models, including tree, stand, and gap models, is provided as a means of evaluating relative strengths, weaknesses, and limits of applicability of representative examples of each type. Data from recent simulations with a gap model of eastern deciduous forest responses to air pollution stress are presented to emphasize the potential importance of competition in modifying individual species' responses in a forest stand. Recent developments in dendroecology are discussed as a potential mechanism for model validation and extended application. [Abstract reprinted by permission of U.S. Forest Service.]

1390
SHY, C. M., 1978, Health consequences of human exposure, in Nriagu, J. O., ed., Sulfur in the environment, part II--ecological impacts: New York, John Wiley, p. 75-108.

1391
SIDHU, S. S., 1980, LRTAP--susceptibility of terrestrial systems in the Atlantic provinces, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 47-52.

1392
SIEGAL, D. I., 1981, Effect of snowmelt on the quality of Filson Creek and Omaday Lake, northeastern Minnesota, *with a section on* Preliminary evaluation of methods for determination of sulfate concentration in precipitation and other dilute solutions by D. I. Siegel, L. E. Anderson, and J. A. Rogalla: U.S. Geological Survey Water-Resources Investigations 81-66, 81 p.

1392 (continued)
Major constituents of surface water, ground water, and precipitation in Filson Creek watershed were determined to assess the effects of acid precipitation on surface-water quality during snowmelt. Sulfate concentrations increased in Filson Creek and Omaday lake during snowmelt from less than 2 to 12 milligrams per liter in 1977 and from less than 2 to 4 milligrams per liter in 1979. An increase in hydrogen ion concentration from $10^{-6.0}$ to $10^{-5.0}$ occurred during snowmelt in 1977 and from $10^{-6.5}$ to $10^{-6.0}$ in 1979. Factors affecting the increases of sulfate and hydrogen ion concentration are (1) antecedent soil-moisture conditions, (2) timing of snowmelt, and (3) concurrent precipitation. Dilution of streamflow with more dilute precipitation during snowmelt affect alkalinity and concentrations of total calcium, sodium, and magnesium. A quality-assurance analysis is presented on the accuracy and precision of the turbidimetric, complexometric (methylthymol blue), and ion-chromatographic methods used to determine sulfate concentrations.

1393
SIEGEL, D. I., 1981, The effect of snowmelt on the water quality of Filson Creek and Omaday Lake, northeastern Minnesota: Water Resources Research, v. 17, no. 1, p. 238-242.

Surface-water, ground water, and precipitation samples were collected at the Filson Creek watershed in Minnesota and analyzed for sulfate and pH. Sulfate concentration increased from 2 to 14 mg/L during and immediately after snowmelt; pH decreased from 6.6 to 5.5 during snowmelt. It is suggested that sulfate acidity is concentrated in the snowpack at snowmelt. Mass balance calculations show that the sulfate contribution from ground water during snowmelt was minimal compared to that from snow.

1394
SIEVERING, Herman, DAVE, Mehul, DOLSKE, D. A., HUGHES, R. L., and McCOY, Patric, 1979, An experimental study of lake loading by aerosol transport and dry deposition in the southern Lake Michigan basin: Chicago, Ill., Environmental Protection Agency, EPA-905/4-79-016, 197 p.

The contribution to Great Lakes loading by atmospheric transport and dry deposition of aerosol was determined. Trace-element and nutrient data were collected during 1977 and 1978. A linear dependence upon atmospheric thermal stability in the variability of the aerosol constituents was observed, but no linear dependence on wind speed was found. Bulk deposition velocities, as a function of overlake climatology, were used to calculate dry deposition atmospheric loadings to Lake Michigan.

1395
SIEVERING, Herman, DAVE, Mehul, DOLSKE, D. A., and McCOY, Patric, 1981, Transport and dry deposition of trace metals over southern Lake Michigan, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 285-325.

1396
SIGAL, L. L., and NASH, T. H., III, 1980, Lichens as ecological indicators of photochemical oxidant air pollution, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 249.

1397
SIMMONS, Roger, 1981, Legislative action--a Canadian status report, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 141-144.

1398
SINGH, B. R., 1980, Effects of acid precipitation on soil and forest, 3. Sulfate sorption by acid forest soils, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 194-195.

1399
SINGH, B. R., ABRAHAMSEN, G., and STUANES, A. O., 1980, Effect of simulated acid rain on sulfate movement in acid forest soils: Soil Science Society of America Journal, v. 44, no. 1, p. 75-80.

Investigated is the effect of simulated acid rain on sulfate movement and leaching of other nutrients in two acid forest soils of southern Norway. Sulfate mobility was higher in the semipodzol soil than in the iron-podzol soil and was dependent on their sulfate adsorption capacities, which were dependent on aluminum (Al) content of these soils. Sulfate losses from applied ^{35}S increased with increased precipitation volume and decreased pH. Element losses were also higher in the semipodzol, which is an indication of greater mobility of sulfate in this soil.

1400
SKARTVEIT, A., 1980, Observed relationships between ionic composition of precipitation and runoff, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 242-243.

1401
SKELLY, J. M., 1980, Photochemical oxidant impact on Mediterranean and temperate forest ecosystems--real and potential effects, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 38-50.

Photochemical oxidants (primarily ozone) as air pollutants pose a more serious problem to forests of the United States than any other single air pollutant. Temperate and Mediterraean forests elsewhere have most likely been similarly impacted and current investigations of such effects are being pursued. Ozone (and its photochemically reactive precursors) has been demonstrated to occur at considerable distances downwind of major urban sources. Ozone has induced perturbations to vegetation over large areas and has therefore impacted innumerable and diverse forest ecosystems. Direct injury due to ozone has been documented to occur on numerous individual forest vegetation species but direct alterations of forest ecosystems as related to ozone induced effects have only been extensively documented in the San Bernardino Mountains of California; to a lesser degree similar studies have been done in the Blue Ridge Mountains of Virginia. Due to the current sulfur dioxide (SO_2) problems confronting European forests and due to the planned increased utilization of fossil fuels in much of the North American Continent, the influence of ozone in combination with SO_2 must be fully considered. The influence of other photochemical oxidants such as nitrogen oxides and peroxyacetyl nitrate on forest vegetation has remained relatively unknown. [Abstract reprinted by permission of U.S. Forest Service.]

1402
SKINNER, R. G., 1980, Geological considerations related to acid rain, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 53.

1403
SKYE, Erik, 1979, Lichens as biological indicators of air pollution: Annual Review of Phytopathology, v. 17, p. 325-341.

This article describes a study at Stockholm, Sweden to evaluate the effectiveness of lichens as biological indicators of air pollution. Their effectiveness as bioindicators is shown, however there is some difficulty in translating lichen distribution to exact pollution values. The degree of change in the lichen substrate and in the general appearance provides an indication of the extent of air pollution.

1404
SLANINA, Jakob, and ASMAN, W. A. H., 1980, Detection of compounds in the atmosphere by careful sampling and analysis of rainwater, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 138-139.

1405
SLANINA, Jakob, VAN RAAPHORST, J. G., ZIJP, W. L., VERMEULEN, A. J., and ROET, C. A., 1979, An evaluation of the chemical composition of precipitation sampled with 21 identical collectors on a limited area, in Frei, R. W., ed., Recent advances in environmental analysis: New York, Gordon and Breach, p. 53-67.

Twenty-one precipitation collectors were installed in a pasture in the province of Noord-Holland, The Netherlands. Eleven collectors were emptied every day if precipitation exceeded 0.3 mm; samples from ten collectors were collected each month for four months. Analyses for SO_4^{2-}, Cl^-, NO_3^-, NH_3^+, Pb^{2+}, and pH of the samples collected daily showed good agreement; but those samples collected monthly were less satisfactory. Analyses from the monthly and daily samples differed as much as 50 percent.

1406
SLINN, S. A., and SLINN, W. G. N., 1981, Modeling of atmospheric particulate deposition to natural waters, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 23-53.

1407
SLINN, W. G. N., 1977, Some approximations for the wet and dry removal of particles and gases from the atmosphere: Water, Air, and Soil Pollution, v. 7, no. 4, p. 513-543.

Semi-empirical formulae are presented which can be used to estimate precipitation scavenging and dry deposition of particles and gases. The precipitation scavenging formulae are appropriate both for in- and below-cloud scavenging and comparisons with data indicate the importance of accounting for aerosol particle growth by water vapor condensation and attachment of the pollutant to plume or cloud particles. It is suggested that both wet and dry removal of gases is usually dictated by other than atmospheric processes. Dry deposition of particles to a canopy is shown to depend on canopy height, biomass, vegetative type and mean wind. Two large-scale practical

1407 (continued)
problems are addressed dealing with the relative importance of wet and dry deposition and with the sources which contribute to deposition in a specific location. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1408
SMITH, E. D., 1981, Water characteristics: Journal of the Water Pollution Control Federation, v. 53, no. 6, p. 649-659.

This article presents a literature survey on water characteristics; about half the 154 references cited are on acid precipitation, including analytical techniques for determining the acidity of precipitation. The article also describes current research on the cause and effects of acid precipitation.

1409
SMITH, F. B., 1979, The character and importance of plume lateral spread affecting the concentration downwind of isolated sources of hazardous airborne material, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 241-252.

1410
SMITH, F. B., and HUNT, R. D., 1978, Meteorological aspects of the transport of pollution over long distances, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 461-477.

Since sulphur pollution is carried by the atmosphere over considerable distances it is important to have an adequate understanding of those aspects of the atmosphere's structure which are important in this process and to know not only the mean conditions but also have a good feel for the statistical variations and their significance to both wet and dry depositions to the ground. This paper discusses several aspects of the role of the atmosphere and starts by considering the nature of the mixing layer and gives statistics of its depth from measurements made at Cardington, England.

It goes on to summarize conclusions reached from aircraft sampling flights over the North Sea (1971-75) in terms of the velocity of deposition of SO_2 (0.8 cm s^{-1} over land, 0.5 cm s^{-1} over sea) and the conversion rate of SO_2 to sulphate (roughly 1% h^{-1}). The next section considers particular states of the atmosphere which can lead to episodes of very high deposition of sulphate in precipitation. Such episodes are given a formal definition and their cause and geographical distribution in western Europe are investigated. Two case-studies of notable episodes are presented and tentative conclusion reached that average statistics of the state of the atmosphere should be used only with caution when modelling long-term pollution transport in view of the relative dominance of episodes and their own rather distinctive meteorology.

Finally the paper reviews some of the rather more important aspects of meteorology which have a direct bearing on transport and require further theoretical and experimental study. [Abstract reprinted by permission of Pergamon Press.]

1411
SMITH, Lowell, 1980, The acidity problem--its nature, causes, and possible solutions, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 136-144.

Interest within the scientific community in North America and Europe about the nature, effects, and causes of atmospheric acid deposition has grown rapidly over the past decade. This interest has recently intensified because of the explosion in public awareness of, and concern over, the acid deposition problem, and a growing political will to address the problem within appropriate national and international forums. This paper sketches the nature of the acid deposition problem; describes the atmospheric processes that convert precursor emissions into acidic compounds as these are transported over distances ranging from a few to more than a thousand kilometers; discusses past and possible future trends in geographical distribution and rate of acid deposition; and summarizes the governmental activities which have been initiated to address the problem. [Abstract reprinted by permission of U.S. Forest Service.]

1412
SMITH, Lowell, 1981, Recent developments in government programs on transboundary air pollution, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 119-125.

1413
SMITH, R. A., 1852, On the air and rain of Manchester: Memoirs of the Manchester Literary and Philosophical Society, series 1, v. 10, p. 207-217.

1414
SMITH, R. A., 1872, Air and rain--the beginnings of chemical climatology: London, Logmans, Green, and Co., 600 p.

This book summarizes results of a study of the chemical quality of the atmosphere and rain done in England and Scotland. Methods of analyses are stated. Data on the chemical composition of rain at sites in Great Britain, Scotland, Ireland, and Germany are presented. The acidity of rain at Liverpool, Manchester, and Glasgow is attributed almost entirely to sulfuric acid, which is associated with the burning of coal or the oxidation of sulfur compounds from decomposition.

1415
SMITH, R. J., 1980, Acid rain agreement: Science, v. 209, no. 4459, p. 890.

A discussion is given on the U.S. and Canada agreement made in 1980 to enforce emission standards as a step to ameliorate the acid precipitation problem. The agreement establishes a scientific work group to collect air-quality samples and estimate the impact of acid precipitation on each country's environment.

1416
SMITH, R. J., 1981, Administration views on acid rain assailed: Science, v. 214, p. 38.

This commentary disputes conclusions of a 1980 report by the National Research Council on the ecological consequences of fossil fuel combustion. Continued emissions of sulfur and nitrogen oxides at current or accelerated rates will be extremely risky. The commentary also discusses the relationship of coal burning to the release of toxic metals into the environment.

1417
SMITH, S. B., and SANDHU, H. S., 1980, The Alberta oil sands environmental research program--an overview, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 132-133.

1418
SMITH, T. B., BLUMENTHAL, D. L., ANDERSON, J. A., and VANDERPOL, A. H., 1978, Transport of SO_2 in power plant plumes--day and night, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 605-611.

As part of the July 1976 Midwest Interstate Sulfur Transformation and Transport experiment (MISTT) in St. Louis, Missouri, U.S.A., the long-range transport of SO_2 and other pollutants emitted from the 216 m stack of a 2000 Mw coal-fired power plant have been documented during both day and night summer conditions.

1418 (continued)

Aircraft measurements and trajectory analyses show that SO_2 emitted during the late morning hours of 18 July, 1976, underwent rapid mixing near the plant. Once mixed through the mixing layer, however, the plume maintained its identity. In the evening, a surface radiation inversion formed, thermally driven mixing ceased, and the lapse rate aloft became more stable. Although winds less than 4 m s^{-1} existed at the surface, from 300 to 800 m msl, the winds were 8-15 m s^{-1} for most of the night. SO_2 emitted during the day became decoupled from the ground and was shown to be transported more than 300 km by midnight in the high wind speed region aloft. The SO_2 emitted at night remained decoupled from the ground and experienced much less dilution. At 75 km in the night-emitted plume, the peak SO_2 concentration was greater than 0.85 ppm.

The high wind speeds seen aloft in stable air on the night of 18 July are a common occurrence in the U.S. and presumably in other parts of the world during the summer months. In July 1976, conditions were favorable for the long-range transport of SO_2 in layers aloft on at least 18 out of 31 nights. The stable night regime is important for the long-range transport of sulfur compounds in the air. Without the ground as a sink, or solar heating to drive mixing, the SO_2 can be transported hundreds of kilometers. Accumulation and transport of SO_2 and its reaction products is a synoptic scale, multiday problem. [Abstract reprinted by permission of Pergamon Press.]

1419
SMITH, W. H., 1980, Air pollution--a 20th century allogenic influence on forest ecosystems, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 79-87.

Chronic doses of ozone, sulfur dioxide, nitrogen oxides, hydrogen fluoride and other primary or secondary gaseous air contaminants may cause subtle effects on forest ecosystems. Air pollutants may influence reproduction, nutrient cycling, photosynthesis, predisposition to entomological or pathological stress or quantity of health foliar tissue. Forest ecosystem response to chronic air pollution may include alterations in growth rates and successional patterns. The establishment of comprehensive field and laboratory investigations to systematically

1419 (continued)
examine chronic air pollution stress on forest ecosystems in those parts of the world subject to atmospheric contamination is concluded to be of top priority. In the United States, forest ecosystems judged to be at particular risk and in need of more intensive investigation include the Northern Hardwood forest, Central Hardwood forest and Western Montane forest. [Abstract reprinted by permission of U.S. Forest Service.]

1420
SNEKVIK, Einar, SELMER-OLSEN, A. R., NJOS, A., and BAERUG, R., 1973, Investigations on precipitation from various locations in Norway 1965-71: Meldinger fra Norges Landbrukshegskole, v. 52, no. 13, p. 1-19.

This paper describes the quality of precipitation in Norway during 1965-71. The pH of samples was lower during 1969-71 than in 1965-68. Average pH did not exceed pH 5.5 in any of the small regions used to classify the data collected for the study. Precipitation from coastal areas had higher concentrations of Cl, Mg, Na, K, and a higher conductivity than precipitation from Southern Island. The NO_3-N concentration was about twice as high in snow as in rain, but total hardness, Cl, and SO_4^{--} were higher in rain.

1421
SODERLUND, Rolf, 1977, NO_x pollutants and ammonia emissions--a mass balance for the atmosphere over NW Europe: Ambio, v. 6, no. 2-3, p. 118-122.

A regional budget for ammonium compounds and compounds of nitrogen oxides indicates that human activities are responsible for the dominant part of the total fluxes of nitrogen oxides in northwestern Europe. A sharp increase in the deposition of nitrates from precipitation during the last 20 years is probably due to increased use of fossil fuels.

1422
SOLAR, Marjan, 1980, The effects of air pollutants on forest ecosystems in S.R. Slovenia, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 250-251.

1423
SPARLING, J. H., and NALEWAJKO, C., 1970, Chemical composition and phytoplankton of lakes in southern Ontario: Journal of the Fisheries Research Board of Canada, v. 27, no. 8, p. 1405-1428.

Results of an investigation of the water chemistry of lakes in southern Ontario indicate four main lake types: (1) base-poor lakes, frequently systrophic and found on the Precambrian Shield; (2) moderately base-rich lakes in the Bancroft-Rideau Lakes region; (3) base-rich lakes in the limestone region of the Shield; and (4) base-rich lakes with high levels of magnesium, draining from Silurian dolomitic limestone bedrock and dolomite-rich tills. Phytoplankton populations are related in part to the chemical composition of lake waters. Certain species such as *Tabellaria flocculosa* and to a lesser extent *Asterionella formosa* and *Dinobryon divergens* are associated with base-poor lakes. A much larger number of species is characteristic of base-rich lake conditions.

1424
SPENCER, P. S., and EDGERTON, E. S., 1976, Micro-analysis of selected classes of organic compounds in natural waters, in Literature reviews on acid precipitation: Ithaca, N.Y., Cornell University, paper 2, p. 1-27.

This article describes analytical methods for determining organic microcontaminants in streamwater, throughfall, and precipitation. Knowledge of the occurrence of organic species in water is useful in determining their effect on the acidity of rainfall, interaction of organic compounds in adjacent water bodies, and the chemical and biochemical influence of organic compounds on the metabolic processes in an ecosystem. Gas chromatographic methods are selected because they provide sensitivity with selectivity over a broad range of organic compounds and provide rapid and reliable qualitative and quantitative results.

1425
SPETH, Gus, 1979, The Sisyphus syndrome--air pollution, acid rain and public responsibility, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 163-171.

1426
SPOSITO, Garrison, PAGE, A. L., and FRINK, M. E., 1980, Effects of acid precipitation on soil leachate quality--computer calculations: Corvallis, Oregon, U.S. Evironmental Protection Agency, Environmental Research Laboratory, EPA-600/3-80-015, 38 p.

GEOCHEM, a multipurpose computer program, was used to calculate equilibrium speciation in 23 samples of acid precipitation from New Hampshire, New York, and Maine, and in 23 examples containing mixtures of acid precipitation with minerals characteristic of soils in the three states. In each speciation calculation, between 100 to 200 soluble inorganic and organic complexes were considered.

1426 (continued)
Calculations from the acid precipitation samples indicate that metals and the sulfate, chloride, and nitrate ligands are almost entirely in their free ionic forms; however, phosphate, carbonate, ammonia, and organic ligands are in their protonated forms. Speciation calculations from the precipitation-soil-mineral mixtures show that aluminum and iron levels in a soil solution affected by acid precipitation are significantly higher than in a soil solution dominated by carbonic acid. The higher levels may be caused by the lower pH of acid precipitation and by complexes formed with inorganic and organic ligands. Soil cation exchangers also seem to preferentially absorb heavy metals.

1427
SPRULES, W. G., 1975, Midsummer crustacean zooplankton communities in acid-stressed lakes: Journal of the Fisheries Research Board of Canada, v. 32, no. 3, p. 389-395.

This article examines the distribution of limnetic crustacean zooplankton species and species associations in 47 lakes in the La Cloche Mountains of Ontario. The pH of the lakes, which ranges from 3.8 to 7.0, and to a lesser extent, lake area and depth, were the major components that determine the structure of these communities. Complexity of zooplankton communities increased with increased pH. The La Cloche lakes have unusually simple zooplankton associations, particularly the very acid lakes, in relation to relatively unspoiled lakes of similar morphometry in northwestern Ontario. Lake pH has a significant effect on zooplankton communities, primarily in lakes with pH below 5.0, where many species have been eliminated and tolerant species become progressiveley rarer until in some lakes only a single species remains.

1428
STAATS, David, ed., 1979, Acid rain, nothing to sing in: Great Lakes Communicator, v. 10, no. 3, p. 1-8.

This article summarizes the effects of acid precipitation on the terrestrial and aquatic ecosystems of the Great Lakes basin. Included are brief summaries of (1) damages caused by acidity, (2) the need for emissions standards, (3) long-range transport of SO_2 emissions, (4) acid precipitation research, (5) a case study of the effects of acid rain on the ecosystems of Isle Royale, in the northern part of Lake Superior, and (6) political aspects of the acid precipitation problem.

1429
STENSLAND, G. J., 1976, Precipitation chemistry studies at Lake George--acid rains: Rensselaer Fresh Water Institute at Lake George, Newsletter, v. 6, no. 1, p. 1-4.

1429 (continued)
During the summer of 1975, a field study was conducted at the Fresh Water Institute at Lake George to investigate the precipitation scavenging of acids. Precipitation samples were collected and analyzed for concentrations of SO_4, NO_3, NH_4, PO_4, Na, K, Mg, and Ca. The pH of samples was measured manually for each sequential sample. Some data on sulfate and pH of rain samples are given.

1430
STENSLAND, G. J., 1980, Precipitation chemistry trends in the northeastern United States, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 87-108.

Gases and particles injected into the atmosphere by natural or anthropogenic sources are returned to the earth's surface through wet and dry removal processes. Therefore historical trends of the concentrations of the various trace substances in precipitation can serve as an indication of the changes in the levels of these substances in the air.

This paper will examine three topics related to the precipitation chemistry data base for the United States. First, since the pH of precipitation is of major interest, techniques to calculate this quantity will be considered. This calculation is necessary when the pH was not reported, as is frequently the case for the older data sets. Next, the changes in the precipitation chemistry for a central Illinois site will be discussed. This site is at the western edge of present high atmospheric sulfate levels, and thus it is interesting to examine changes in the precipitation pH at this site and the reasons for them. The third and final topic will be to consider changes in the sulfate and nitrate at this central Illinois site and other sites further east, and to compare these changes to the time trends in the anthropogenic source emissions. [Abstract reprinted by permission of Plenum Press.]

1431
STEVENS, R. K., DZUBAY, T. G., RUSSWURM, G., and RICKEL, Dwight, 1978, Sampling and analysis of atmospheric sulfates and related species, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977, New York, Pergamon Press, p. 55-68.

Sampling and analytical methods to measure atmospheric concentrations of sulfur, sulfates and related species are compared for aerosols collected in New York City; Philadelphia, PA; South Charleston, WV; St. Louis, MO; Glendora, CA; and Portland, OR. Dichotomous samplers equipped with virtual impactors were used to separately collect fine (<3.5 µm) and coarse (>3.5 µm) particles on membrane filters. Both size fractions

1431 (continued)
were analyzed by energy-dispersive X-ray fluorescence spectroscopy to determine the total amounts of sulfur and other elements, and the samples were analyzed by an ion chromatograph and by the Thorin spectrophotometric method to determine sulfate. These analyses reveal that more than 70% of the sulfur occurs in the fine particle fraction for at least 90% of the samples. Sulfate typically accounts for about 40% of the mass of the fine particle fraction; the ratio of the sulfate and the sulfur mass concentrations is 2.96 ± 0.15, which is in excellent agreement with the value of 3.00 for sulfate.

To test for the existence of sulfite ions in the samples, a cold extraction procedure was developed, which minimizes the conversion of sulfite to sulfate. Analysis for sulfite using the Ion Chromatograph indicates that less than 2% of the sulfur collected in South Charleston, WV, and Philadelphia, PA is in the form of sulfite.

A procedure was developed to preserve the acidity of aerosols collected with an automated dichotomous sampler and was recently used to sample aerosols in Research Triangle Park, NC. Analysis of the samples for H^+, NH_4^+, and SO_4^{2-} ions revealed that the sulfate concentrations were typically 10 to 14 μg^{-3} and that H^+ ions accounted for 5% to 60% of the cations associated with sulfate. In addition the sum of NH_4^+ and H^+ equaled the SO_4^{2-} concentration expressed in nanoequivalents.

In the network of stations that was part of the Regional Air Pollution Study (RAPS) the hi-volume sampler gave mass and sulfate concentrations that were consistently higher than values obtained for the automated dichotomous sampler. For samples collected at eight RAPS stations at St. Louis, MO, between September and December 1975, the ratio for sulfate determined for the two types of samplers was 1.32. [Abstract reprinted by permission of Pergamon Press.]

1432
STEVENSON, C. M., 1968, An analysis of the chemical composition of rainwater and air over the British Isles and Eire for the years 1959-1964: Quarterly Journal of the Royal Meteorological Society, v. 94, p. 56-70.

Rainwater and air samples were collected monthly from 10 stations in Great Britain and Ireland and analyzed for concentrations of S, Cl, Na, K, Ca, and nitrogen in ammonia and nitrate. Maps showing variations in sources of various chemicals are given. Problems with sampling techniques are discussed.

1433
STOLPMAN, Paul, 1981, Acid deposition--regulatory control options, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 13.

1434
STOREBO, P. B., and DINGLE, A. N., 1974, Removal of pollution by rain in a shallow air flow: Journal of the Atmospheric Sciences, v. 31, p. 533-542.

This article presents a theoretical examination of particle removal in a heavily polluted air flow through which rain falls from above. The development and growth of the droplets formed on the particles were observed. The article gives data on droplet temperatures, equilibrium humidities, and removal rates. Dissipation of kinetic fall energy of droplets affects droplet behavior, and removal of pollution from low-level air by rain, seem to be efficient.

1435
STRAND, L., 1980, The effect of acid precipitation on tree growth, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 64-67.

1436
STROUD, R. H., 1979, Acid rain: Sport Fishing Institute Bulletin, v. 304, p. 5-6.

A description is given of a study conducted by the Corvallis Environmental Research Laboratory of the U.S. Environmental Protection Agency to evaluate the effects of acid rain on forest and agricultural systems. Simulated acid rain experiments were conducted on plots of model forest ecosystems, that contained a reconstructed forest soil and a litter layer, a water-extraction system, and tree seedlings of sugar maple or red alder. Forest productivity and nutrient cycling were monitored. Some changes observed in sugar maple ecosystems were increased in (1) leaching of calcium, magnesium, and sulfate ions from soil; (2) the input of hydrogen and sulfate ions from water passing through the forest litter to soil; and (3) removal of calcium from leaf litter.

1437
STUANES, A. O., 1980, Effects of acid precipitation on soil and forest, 5. Release and loss of nutrients from a Norwegian forest soil due to artificial rain of varying acidity, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 198-199.

1438
SUMMERS, P. W., and HITCHON, Brian, 1973, Source and budget of sulfate in precipitation from central Alberta, Canada: Journal of the Air Pollution Control Association, v. 23, no. 3, p. 194-199.

Rain, hail, and snow samples were collected in central Alberta and analyzed for sulfate and chloride by a conductometric titration method. This article discusses the efficiency with which SO_2 is removed from the atmosphere by precipitation processes. Most of the sulfate in precipitation in central Alberta is from local industrial sources. An atmospheric sulfur budget is derived by comparing sulfate deposition in precipitation around an isolated gas plant with a known SO_2 emission rate. The budget shows that summertime convection storms are very efficient at removing SO_2 from the atmosphere. From 32 to 46 percent of the sulfur emitted as SO_2 arrives on the ground as sulfate sulfur within a radius of 25 miles of the source. Snow, however, is inefficient as a removal mechanism.

1439
SUMMERS, P. W., and WHELPDALE, D. M., 1976, Acid precipitation in Canada: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 447-455.

The total annual emissions of sulfur oxides and nitrogen oxides in Canada are estimated to be 7.2×10^6 t, respectively. These figures represent 5% and 2%, respectively, of the estimated worldwide anthropogenic emissions. Nearly two-thirds of the Canadian SO_2 emissions come from primary smelters located in low population areas. The remainder originate from natural gas processing, pulp mills, fuel combustion and transportation in the more heavily populated areas. Transportation is the major source of oxides of nitrogen.

No coordinated precipitation sampling has been carried out on a national basis prior to the establishment of the World Meteorological Organization regional stations in 1974, but several local projects in problem areas have been conducted over the last 20 yr. These data are reviewed with respect to sulphate and nitrate content and, when available, the pH.

The geographical distribution of acid rain in Canada is discussed in relation to main source areas of pollutants, prevailing meteorological conditions and precipitation type.

Finally, the extent of current and potential problems associated with acid rain is discussed, and current and recommended future monitoring and research programs are outlined. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1440
SUNDSTROM, Karl-Ragnar, and HALLGREN, Jan-Erik, 1973, Using lichens as physiological indicators of sulfurous pollutants: Ambio, v. 2, no. 1-2, p. 13-21.

Lichens and bryophytes were studied to ascertain their sensitivity and usefulness as indicators of sulfurous pollution. A discussion is given on physiological bioassays that are fast and specific for sulfur dioxide (SO_2) and may be used quantitatively.

1441
SUTCLIFFE, D. W., and CARRICK, T. R., 1973, Studies on mountain streams in the English Lake District. I. pH, calcium and the distribution of invertebrates in the River Duddon: Freshwater Biology, v. 3, p. 437-462.

This article is the first of a series of three articles on the English Lake District. The pH of the River Duddon and its tributaries rarely exceed 7.0. A close relationship has been noted between the pH regime of stream water and benthic fauna. Calcium concentration is less important than the pH-bicarbonate concentrations in limiting the qualitative distribution of benthic invertebrates. The limiting effects of low pH on insects may operate indirectly through changes in food supply.

1442
SUTCLIFFE, D. W., and CARRICK, T. R., 1973, Studies on mountain streams in the English Lake District. II. Aspects of water chemistry in the River Duddon: Freshwater Biology, v. 3, p. 543-560.

Concentrations of sodium, potassium and other major ions were monitored in streamwater and rainwater. A hydrologic budget is given for annual inflow and outflow of sodium, potassium, and calcium in the Duddon catchment.

1443
SUTCLIFFE, D. W., and CARRICK, T. R., 1978, Studies on mountain streams in the English Lake District. III. Aspects of water chemistry in Brownrigg Well Whelpside Ghyll: Freshwater Biology, v. 3, p. 561-567.

The pH and concentrations of major ions in streamwater from Brownrigg Well and the River Duddon are compared. The pH of Brownrigg Well usually exceeds 5.7, but concentrations of sodium, potassium, and possibly calcium are close to the maximum required to support the amphipod, *Gammarus pulex*. Most insect taxa are not affected by low H^+ ionic concentrations. It is suggested that insects in mountain streams had wider distribution before acidification by acid rain.

1444
SWANK, W. T., and HENDERSON, G. S., 1976, Atmospheric input of some cations and anions to forest ecosystems in North Carolina and Tennessee: Water Resources Research, v. 12, no. 3, p. 541-546.

Atmospheric contributions of ions in precipitation and dry fallout to forest ecosystems were investigated at two sites in the southern Appalachian Mountains. Dry fallout associated with local land-use activities influenced seasonal concentrations of bulk precipitation at both sites, except for Na^+, which seemed to be partly derived from marine sources. The total ionic input values for both ecosystems are considered to be low estimates as a result of sampling and analytical methods.

1445
SWANSON, K. A., and JOHNSON, A. H., 1980, Trace metal budgets for a forested watershed in the New Jersey pine barrens: Water Resources Research, v. 16, no. 2, p. 373-376.

This article presents data on the deposition of Pb, Cu, Ni, Fe, Mn, and Cd in bulk precipitation on the McDonalds Branch basin in southern New Jersey, the output in streamflow, and the loss to deep ground water. Mobilization of the trace metals studied is accelerated by highly acidic conditions and the presence of mobile organic matter except for Pb and probably Cu, Ni, and Cd. Biogeochemical processes that retain the elements in the landscape are dominant for these metals.

1446
SWARTS, F. A., DUNSON, W. A., and WRIGHT, J. E., 1978, Genetic and environmental factors involved in increased resistance of brook trout to sulfuric acid solutions and mine acid polluted waters: Transactions of the American Fisheries Society, v. 107, no. 5, p. 651-677.

Twenty-three strains of brook trout (*Salvelinus fontinalis*) were exposed to low pH in the laboratory and in the field. Pronounced strain differences in survival rates were observed among embryonic, juvenile, and adult brook trout in laboratory tests. Juvenile brook trout showed the same effects in field tests. Embryonic development of brook trout was delayed in solutions of sulfuric acid at low pH. There appeared to be no difference between sexes in survival time at low pH. Enhancement of acid resistance in hatchery brook trout was mostly affected by hereditary resistance of a strain and the acclimation of fish to nonacidic stream conditions before exposure to acidified water.

1447
SWYNNERTON, G. H., and WORTHINGTON, E. B., 1939, Brown-trout growth in the lake district [Britain]; a study of the conditions in "acid" lakes and tarns: Salmon and Trout Magazine, v. 97, p. 337-354.

This article discusses the factors affecting growth of trout and other freshwater fish and gives data on the number of fish observed and their size at different growth intervals. It is concluded that trout grow rapidly in alkaline waters and slowly in acidic waters (low pH).

1448
SYRAKOV, Eugeni, 1979, On the basic dependences of the relative eddy diffusion in synoptic scales for rotating atmosphere, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 371-376.

1449
SYRAKOV, Eugeni, 1979, On the Gaussian and non-Gaussian models of turbulent diffusion in synoptic and global scales in atmosphere, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 315-320.

1450
SYRAKOV, Eugeni, and YORDANOV, D., 1979, On the Lagrangian characteristics of turbulence and diffusion in the planetary boundary layer, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 307-314.

1451
SZEPESI, D. J., 1978, Transmission of sulfur dioxide on local, regional, and continental scale, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 529-535.

The transport, dispersion, transformation and removal, i.e. the transmission of sulfur dioxide, depends on the scale of the pollution process and on the type of the source, too. To take these considerations into account, working formulas were developed to simulate the transmission on different scales. The overall decay and transformation rates were separated into terms of dry deposition,

1451 (continued)
transformation during low (r.h. less than 90%) and high (r.h. more than 90%) humidity conditions and wet deposition, together with the respective time intervals during which the separate mechanisms were effective. The intervals were evaluated along the trajectories on surface and upper air charts.

To simulate the transmission for continental scale pollution processes, 72 h, 850 mb, isobaric, backward trajectories were constructed. For regional and local scale pollution processes trajectories were constructed on the basis of the surface wind pattern. The dispersion of the sulfur dioxide for the larger scale processes was taken into account by air trajectory box models, for the local process by Gaussian model.

The removal processes were taken into account by using scale-dependent rate constants from the available current literature.

By applying the transmission model presented here, four case studies showed good agreement between the measured (63 and 1 $\mu g\ m^{-3}$) and calculated 63 and 7 $\mu g\ m^{-3}$) sulfur dioxide concentrations, respectively and between measured turbidity parameters (B = 0.308 and 0.072) and calculated particulate sulfate concentrations (22 and 4 $\mu g\ m^{-3}$) respectively. [Abstract reprinted by permission of Pergamon Press.]

T

1452
TABATABAI, M. A., 1974, Determination of sulphate in water samples: Sulphur Institute Journal, v. 10, no. 2, p. 11-13.

This article presents a simple method for determining sulfate concentration in water samples, including rainwater and snowmelt. The method is based on measuring turbidity when a mixture of barium chloride and gelatin are added to the sample. Results are comparable to those obtained by a methylene blue reduction method.

1453
TABATABAI, M. A., and LAFLEN, J. M., 1976, Nitrogen and sulfur content and pH of precipitation in Iowa: Journal of Environmental Quality, v. 5, no. 1, p. 108-112.

Precipitation samples were collected at six sites in Iowa from September 1971 through December 1973 and analyzed for pH and ammonium-N (NH_4-N), nitrate-N (NO_3-N), sulfate-S (SO_4-S) and phosphate-P ($PO_4{}^{3-}$) concentrations. The addition of nutrient constituents by precipitation was determined. The amounts of NH_4-N and NO_3-N added annually by precipitation were about equal at each site. Average annual pH of rainfall and snowfall at each site was about 6.0; sample pH was rarely as low as 4.

1454
TABATABAI, M. A., and LAFLEN, J. M., 1976, Nutrient content of precipitation over Iowa: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 361-373.

Nutrient content and pH of precipitation samples collected at six sites during 1971-1973 were studied to determine the fraction of rainfall and snowmelt and the amounts of N, S, and P added by precipitation over Iowa. The amount of NH_4-N ha^{-1} added by precipitation annually to each site was about equal to that added as NO_3-N. The amounts of inorganic N ha^{-1} yr^{-1} added ranged from 10 kg in north-central to 14 kg in west-central Iowa, and the annual amounts of SO_4-S ha^{-1} added ranged from 13 kg in northeastern to 17 kg in north-central Iowa. It is estimated that, on the average, precipitation adds about 0.6 kg of NH_4-N, 0.6 kg of NO_3-N, and 1.5 kg of SO_4-S ha^{-1} monthly in Iowa. However, the data indicated that, on an annual basis, the contribution of precipitation to P in soil is very small; at the most, about 0.1 kg of water-soluble PO_4-P ha^{-1} was added annually in Iowa. No NO_2-N could be detected in any of the precipitation samples analyzed.

Average pH values of the rainfall and snowmelt samples collected at each site during each year was about 6, individual samples seldom reached as low as pH 4. The data indicate that the concentration of SO_4-S in precipitation in this region is seasonal, high during fall and winter and low during spring and summer. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1455
TAMM, C. O., 1976, Acid precipitation--biological effects in soil and on forest vegetation: Ambio, v. 5, no. 5-6, p. 235-238.

This article summarizes the effects of acid precipitation on biological processes in the forest ecosystem in Scandinavia. The study concludes that it is difficult to predict long-term effects of acidification. Soil processes, such as nitrogen turnover, are affected by acidification, and productivity of Scandinavian forests has declined as a result of acid precipitation.

1456
TAMM, C. O., 1977, Acid precipitation and forest soils: Water, Air, and Soil Pollution, v. 7, no. 3, p. 367-369.

1456 (continued)
The impact of acidifying substances on soils is examined and related to soil properties such as the amount of exchangeable cations in the soil and the proportion of those cations which are other than hydrogen ions. The importance and influence of differential soil horizons and the transport of water through the soil profile are also discussed. Differences between how agricultural and forest ecosystems affect nutrient cycling in soil systems are outlined. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1457
TAMM, C. O., and COWLING, E. B., 1977, Acidic precipitation and forest vegetation: Water, Air, and Soil Pollution, v. 7, no. 4, p. 503-511.

Effects of acidic precipitation on forest vegetation may be classified as being either direct or indirect. Among the most important direct effects are damage to protective cuticular layers, interference with normal functioning of guard cells, poisoning of plant cells after diffusion of acidic substances through stomata or cuticle and interference with reproductive processes. Indirect effects include accelerated leaching of substances from foliar organs, increased susceptibility to drought and other environmental stress factors, and alteration of symbiotic associations and host-parasite interactions. The potential importance of nutrient uptake through foliage and the need to understand atmosphere-plant-soil interactions are stressed. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1458
TAMM, C. O., and WIKLANDER, G., 1980, Effects of artificial acidification with sulphuric acid on the growth in Scots pine forest, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 188-189.

1459
TAMM, C. O., WIKLANDER, G., and POPOVIC, B., 1977, Effects of application of sulphuric acid to poor pine forests: Water, Air, and Soil Pollution, v. 8, no. 1, p. 75-87.

Results of field experiments designed to determine effects of acid treatment on pine forests are reported. Sites were located at Lisselbo and Norrliden, Sweden. Acid treatments of sulphuric acid were combined with fertilizer treatments in order to identify possible effects of acidification on the forests. At both sites N was found to be a factor limiting forest growth. The application of sulphuric acid resulted in a loss of much of the ground vegetation. No negative effects on the growth of the trees have been detected thus far. Results of lysimeter and soil incubation experiments indicate that even moderate additions of H_2SO_4 or S on the soil affect soil biological processes, particularly N turnover. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1460
TANAKA, Hirofumi, TAKANASHI, Toshiharu, and YATAZAWA, Michihiko, 1972, Experimental studies on sulfur dioxide injuries in higher plants: Water, Air, and Soil Pollution, v. 1, no. 2, p. 205-211.

Studied are the formation of glyoxylate bisulfite, the most probable form of a hydroxy sulfonate present in plants exposed to sulfur dioxide (SO_2), and the identification of the compound by radiochemical analyses. Results suggest that the formation of sulfide additives of aldehyde in plants exposed to SO_2 may result in a decrease in photosynthesis.

1461
TANAKA, Kiyoshi, 1980, Studies on relationship between air pollutants and microorganisms in Japan, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 110-116.

A review of the literature on the interaction of air pollutants with parasitic and epiphytic microorganisms is presented with a brief outline of air pollution problems in Japan. Some fungi such as *Cercospora sequoiae*, *Pucciniastrum styracinum*, *Puccinia kusanoi*, *Melampsora coleosporioides*, *Trichoroma matsutake*, and some epiphytic bacteria disappeared in the areas affected by air pollutants, and *Rhizosphaera kalkhoffii* inreased its activity due to SO_2 in the air. [Abstract reprinted by permission of U.S. Forest Service.]

1462
TANAKA, Shigeru, DARZI, Michael, and WINCHESTER, J. W., 1980, Sulfur and associated elements and acidity in continental and marine rain from north Florida: Journal of Geophysical Research, v. 85, no. C8, p. 4519-4526.

Rainwater samples were collected from November 1978 through January 1979 at Tallahassee, and analyzed for 12 constituents. The chemical composition of the samples varied with northerly and southerly air-flow regimes. Concentrations of lead, sulfur, and iron were higher in air-flow rains that originated from northern (continental) areas with more pollution. The

1462 (continued)
average pH of northern rain was 4.4 with a minimum of 3.7, whereas the average pH of southern (marine-derived) rain was 5.3 with a low of 4.6. A significant correlation between pH and of sulfur concentration was observed in northern rain only.

1463
TANNER, R. L., 1980, Sulfur and nitrogen compounds in urban aerosols: Annals of the New York Academy of Sciences, v. 338, p. 39-49.

Aerosol sampling was conducted at an urban site in New York State and a background site at High Point, N.J. from 1976-78; in 1977 the sampling program was expanded to Brookhaven, N.Y. and New Haven, Conn. in 1977. Samples were analyzed for ammonium, sulfate, nitrate, and sulfuric acid. Discussed are some experimental advances in sampling and analysis of aerosol sulfur and nitrogen compounds and related gases that may be used for measuring all components of the atmospheric sulfate-nitrate-SO_2-NO_x-NH_3 system.

1464
TANNER, R. L., 1981, Phase equilibrium in the mixed aerosol-gaseous ammonia, nitric acid system--relevance to considerations of ion incorporated into rainfall, in American Chemical Society, Division of Environmental Chemistry, 182nd National Meeting, New York, N.Y., Preprints, v. 21, no. 2: Washington, D.C., American Chemical Society, p. 20-24.

1465
TANNER, R. L., D'OTTAVIO, T., GARBER, R., and NEWMAN, Leonard, 1980, Determination of ambient aerosol sulfur using a continuous flame photometric detection system. I. Sampling system for aerosol sulfate and sulfuric acid: Atmospheric Environment, v. 14, p. 121-127.

This article presents a technique for measuring ambient levels of aerosol sulfur by flame photometric sulfur analyzer (FPD) with a heated denuder for SO_2 removal. Sulfuric acid and other sulfate aerosols are identified by cyclic addition of ammonia. This article evaluates the effects of changes in ambient water vapor concentration and barometric pressure on the FPD sulfur response are quantitatively evaluated and presentes data and calibration plots that demonstrate the specificity and sensitivity of the system to <1.0 ppb aerosol sulfur.

1466
TANNER, R. L., FORREST, Joseph, and NEWMAN, Leonard, 1978, Determination of atmospheric gaseous and particulate sulfur compounds, in Nriagu, J. O., ed., Sulfur in the environment, part 1--The atmospheric cycle: New York, John Wiley, p. 371-452.

1467
TANNER, R. L., LEADERER, B. P., and SPENGLER, J. D., 1981, Acidity of atmospheric aerosols: Environmental Science & Technology, v. 15, no. 10, p. 1150-1153.

This article summarizes the chemical characteristics of acid atmospheric aerosols. Most of the strong acid in atmospheric aerosols results from oxidation of sulfur dioxide (SO_2) to sulfate by homogeneous and heterogeneous processes. Atmospheric aerosols contain varying quantities of weak and strong acids, and strong acid concentrations equivalent to as much as 20 $\mu g/m^3$ of sulfuric acid may be found in ambient aerosols for several hours. Strong acids are more frequently present (and in larger amounts) in rural samples than in urban samples. The principal deleterious effects of acidic aerosol particles are (1) potential health effects of acid sulfates, (2) reduction of visibility, (3) corrosion of physical structures, and (4) acidification of precipitation.

1468
TANNER, R. L., and NEWMAN, Leonard, 1976, The analysis of airborne sulfate, a critical review: Journal of the Air Pollution Control Association, v. 26, no. 8, p. 737-747.

This article discusses analytical methods for sulfate in airborne particles and methods for determining total aerosol sulfate and total soluble sulfate. A technique for quantitative speciation of airborne sulfate is described.

1469
TARRANT, R. F., LU, K. C., CHEN, C. S., and BOLLEN, W. B., 1968, Nitrogen content of precipitation in a coastal Oregon forest opening: Tellus, v. 20, no. 3, p. 554-556.

Precipitation samples were collected at monthly and bimonthly intervals from June 1963 through May 1964 at the Cascade Head Experimental Forest, Ore. Litterfall was also measured and analyzed. Chemical composition of precipitation was influenced mostly by oceanic rather than terrestrial sources. Very little NO_2-N or NO_3-N and no NH_4-N was found in precipitation at any time during the sampling period. About 87 percent of the total N estimated as deposition by precipitation was in the organic form.

1470
TARRANT, R. F., LU, K. C., BOLLEN, W. B., and CHEN, C. S., 1968, Nutrient cycling by throughfall and stemflow precipitation in three coastal Oregon forest types: U.S. Forest Service, Research Paper PNW-54, 7 p.

1470 (continued)
This report describes the alteration of some chemical constituents of rainfall by its passage through the forest canopy. The role of precipitation in N-cycling in three coastal forests in Oregon seems to be minor compared to the greater amounts of N cycled in litterfall. Concentration of nitrate ion was greater in stemflow from conifers than in other precipitation-forest combinations. Although stemflow generally contains more nutrient ions than throughfall, stemfall seems to be of little importance in nutrient cycling by precipitation because of its small volume per area. Acidity of throughfall precipitation did not differ from that of precipitation collected in open plots.

1471
TARTARELLI, R., DAVINI, P., MORELLI, F., and CORSI, P., 1978, Interactions between SO_2 and carbonaceous particulates, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnki, Yugoslavia, 1977: New York, Pergamon Press, p. 289-293.

Interactions between SO_2 at low concentrations and carbonaceous particulates have been investigated. The amount of SO_2 adsorbed by the solid has been related to its surface area and valued at different compositions of the gaseous mixture in the temperature range 20-150°C. A distinction between two types of adsorption has been made: a part of the adsorbed SO_2 is weakly adsorbed, SO_2(a) and the residual part is strongly bound to the solid SO_2(b). The fraction of SO_2(b) is enhanced by the presence of O_2 and H_2O. Evolution of SO_2(a) to SO_2(b) on the solid occurs and its rate appears to be increased by the presence of adsorbed O_2 and H_2O. By contracting the particulate containing SO_2 with a flux of air at room temperature, the SO_2(a) desorbs into the gaseous stream, but a part of it may be also transformed to SO_2(b). [Abstract reprinted by permission of Pergamon Press.]

1472
TAYLOR, G. E., Jr., and TINGEY, D. T., 1980, Population differences in response to sulfur dioxide--a physiological analysis, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 252.

1473
TAYLOR, J. K., DEARDORFF, E. R., and RAINS, T. C., 1977, Simulated precipitation reference materials II: Washington, D.C., National Bureau of Standards, NBSIR 77-1315, 27 p.

1473 (continued)
This report describes a series of reference materials to be used for the intercalibration of precipitation measurement stations. The materials consist of ampoules of concentrates that can be diluted to simulate natural rainwater. A separate reference sample, which is used undiluted, is provided for evaluating acidity measurements. The report also describes methods of analytical measurements.

1474
TENNESSEE VALLEY AUTHORITY, 1980, The acid connection: Impact, v. 3, no. 4, p. 2-10.

This article gives a general discussion of the chemistry of acid precipitation, its effects, and remedial actions to protect air quality. The Tennessee Valley Authority (TVA) is actively engaged in a program to assess the effects of acid precipitation by monitoring (1) rainfall to determine present conditions and trends, (2) atmospheric movement and chemical reaction of pollutants to determine the relationship between emissions and rainfall acidity, and (3) changes in vegetation, soils, and surface waters to define present conditions and future trends in acidity.

1475
TETRA TECH INC., 1981, The Integrated Lake-Watershed Acidification Study (ILWAS)--contributions to the International Conference on the Ecological Impact of Acid Precipitation: Palo Alto, Calif., Electric Power Research Institute, Report EA-1825, 1 v.

This report is a compilation of seven research papers presented at the International Conference on the Ecological Impact of Acid Precipitation, Sandefjord, Norway, in 1980. The report examines the qualitative relationship between acidic atmospheric deposition and acidity of surface water in three forested watersheds in the Adirondack Mountains of New York.

1476
THOMPSON, M. E., 1978, Major ion loadings to Lake Superior: Journal of the Great Lakes Research, v. 4, no. 3-4, p. 361-369.

This article presents a method for predicting loadings of major ions to Lake Superior based on a water budget, water-quality data for Lake Superior, and data on the chemistry of atmospheric precipitation on or around the lake. Predicted tributary loadings are compared with water chemistry, and basic assumptions of the procedure are confirmed. Calcium, magnesium, and bicarbonate ions are supplied to the lake mostly by chemical weathering in the basin. The atmosphere is a major source of sulfate and chloride to the lake basin. An excess loading of chloride and sulfate, mostly atmospheric in origin,

1476 (continued)
has been observed, but increases in their concentration in the open waters of the lake will not be detectable for several decades owing to the large volume of lake water.

1477
THOMPSON, M. E., and BENNETT, E. B., 1980, Variations in the degree of acidification of river waters observed in Atlantic Canada, in International Symposium on Inland Waters and Lake Restoration, Portland, Maine, 1980, Restoration of lakes and inland waters: Washington, D.C., U.S. Environmental Protection Agency, EPA-440/5-81-010, p. 453-456.

Temporal and spatial variations in river water chemistry observed in the eastern region of Canada are attributed to variations in acidic deposition on the watersheds, independent of the rate of fossil fuel emissions at the sources. Data on water quality of Rocky River in easternmost Newfoundland show an increasing trend in both acidity and sulfate concentrations, and simultaneous occurrences of relative maxima and minima of pH and sulfate concentration. The data illustrate the geochemical response to acid loading in a basin.

1478
THOMPSON, M. E., ELDER, F. C., DAVIS, A. R., and WHITLOW, S., 1980, Evidence of acidification of rivers of Eastern Canada, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 244-245.

1479
THOMPSON, R. J., 1977, The sampling and analysis techniques in current use in the EPA/NOAA/WMO precipitation network, in World Meteorological Organization, Air pollution measurement techniques: Geneva, Switzerland, World Meteorological Organization, Special Environmental Report no. 10, WMO-no. 460, p. 40-49.

1480
THORNTON, J. D., EISENREICH, S. J., MUNGER, J. W., and GORHAM, Eville, 1981, Trace metal and strong acid composition of rain and snow in northern Minnesota, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 261-284.

1481
TIMBERLID, J. A., 1980, Have changes in use of land influenced the regional lake acidification?, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 352-353.

1482
TINGEY, D. T., and BURNS, W. F., 1980, Hydrocarbon emissions from vegetation, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 24-30.

A wide range of volatile organic compounds may be emitted by vegetation. The identified emittants, however, are mainly terpenoid in nature. Their emission rates are controlled primarily by the physical/chemical processes that regulate hydrocarbon vapor pressure. Emission rates vary between species and are influenced by environmental factors such as light and temperature. Regional emission estimates indicate that vegetation may emit as much as 30 kg of hydrocarbons km^{-2} day^{-1}. The measured atmospheric concentrations are in reasonable agreement with the estimated emission rates. Within the atmosphere, these hydrocarbons may participate in photochemical reactions leading to aerosol production and the consumption or formation of ozone. [Abstract reprinted by permission of U.S. Forest Service.]

1483
TINGEY, D. T., REINERT, R. A., DUNNING, J. A., and HECK, W. W., 1971, Vegetation injury from the interaction of nitrogen dioxide and sulfur dioxide: Phytopathology, v. 61, p. 1506-1511.

Six plant species were exposed to nitrogen dioxide and (or) sulfur dioxide for 4 hours in greenhouse exposure chambers. Concentrations of nitrogen dioxide below 200 parts per hundred million and sulfur dioxide below 50 pphm caused no leaf injury. Leaf injury developed, however, when plants were exposed to mixtures of 5 to 25 pphm of each of the two gases. Concentrations of nitrogen dioxide and sulfur dioxide that caused plant injury were similar to those found in urban areas. Yield losses for plants grown in field conditions are likely to result.

1484
TISUE, G. T., and KACOYANNAKIS, J., 1974, Acidity in rainfall: Argonne, Ill., Argonne National Laboratory, Radiological and Environmental Research Division, Annual Report, ANL-75-60, Part III, p. 45-50.

Rainwater samples were collected at Argonne, Ill., during October and November 1975 and analyzed for pH, acid and base-neutralizing properties, and ammonia, nitrate, chloride, sulfate, and calcium ions. The pH of samples ranged from 3.79 to 4.99, and the base-neutralizing capacities between 5.01 and 18.9 x 10^{-5} equiv./L. The overall excess of base neutralizing capacity in many of the samples

1484 (continued)
may be due to a weak acid whose pK_a is not significantly different from that of H_2CO_3 (6.5). There are many other acids, in addition to carbonic acids, with pK_a's in the range 6 to 7, which could be present in rainwater and could contribute to excess base neutralizing capacity. Phosphoric and sulfurous acids are most likely to be present in the samples collected for this study because of high concentration of SO_2 in local air.

1485
TOKOS, Joseph, 1980, Water analysis methods at the Integrated Lake-Watershed Acidification Study Laboratory, Raquette Lake, N.Y.: Upton, N.Y., Brookhaven National Laboratory, BNL-51396, 14 p.

This report summarizes the materials, equipment, and methods used by Brookhaven National Laboratory staff for chemical and biological analyses for the Integrated Lake-Watershed Acidifiction Study (ILWAS). It also describes procedures used to analyze pelagic samples from Panther, Sagamore, and Woods Lakes and methods used for determining benthic primary production.

1486
TOLLAN, Arne, 1977, Deterioration of water quality due to long range transport of air pollution (air precipitation etc.), in United Nations Water Conference, Argentina, 1977, Proceedings, Water Development and Management: N.Y., Pergamon Press, v. 1, pt. 4, p. 2059-2070.

Background information on the origin of sulfur and nitrogen compounds in the atmosphere and the deposition of air pollutants in Scandinavia are discussed. Wet deposition of pollutants may be large during limited time periods or "episodes," and the occurrence of episodes is mostly determined by wind direction. Acidification of lakes depends on three principal sources of chemical components: (1) atmospheric inputs of sea-water salts, (2) atmospheric inputs of acid precipitation, and (3) terrestrial inputs of chemical weathering products. Some of the biological effects of acid precipitation and emission standards are also discussed. [Abstract reprinted by permission of Pergamon Press.]

1487
TOLLAN, Arne, 1980, Effects of acid precipitation on aquatic and terrestrial ecosystems, in International Symposium on Inland Waters and Lake Restoration, Portland, Maine, 1980, Restoration of lakes and inland waters: Washington, D.C., U.S. Environmental Protection Agency, EPA-440/5-81-010, p. 438-445.

Acid precipitation, which occurs over large regions in Europe and eastern North America, causes acidification of natural waters in areas having a sparse soil cover and underlain by noncalcareous bedrock. Acidification occurs in lakes when the normal bicarbonate buffering system breaks down and sulfate becomes the dominant anion. Leaching of aluminum from soils to lakes may increase, which affects aquatic life. The structure of aquatic ecosystems of acidified lakes becomes simplified and dominated by a few tolerant species.

1488
TOLLAN, Arne, 1981, Annotated bibliography, 1974-1980, SNSF Project, Acid Precipitation--effects on forest and fish: Oslo-As, Norway, SNSF Project, 42 p.

This annotated bibliography lists reports resulting from the Norwegian research project titled "Acid Precipitation-Effects on Forest and Fish" (SNSF Project), which was conducted from 1972-80. The reports are published in the following SNSF series: Research reports (FR), Internal reports (IR), Technical notes (TN), and Scientific papers (FA) that are published in journals and conference proceedings. Copies of the bibliography and most of the reports may be obtained for free from:

Norwegian Institute for Water Research
P.O. Box 333, Blindern
Oslo 3, Norway

1489
TOMLINSON, G. H., 1979, Acidic precipitation and mercury in Canadian lakes and fish, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 104-118.

1490
TOMLINSON, G. H., BROUZES, R. J. P., McLEAN, R. A. N., and KADLECEK, J. S., 1980, The role of clouds in atmospheric transport of mercury and other pollutants, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 134-137.

1491
TONG, E. Y., MILLS, M. T., NIEMANN, B. L., and SMITH, Lowell, 1979, Characterization of regional episodes of particulate sulfates and ozone over the eastern United States and Canada, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 85-94.

1492
TONNESSEN, Kathy, and HARTE, John, 1980, The potential for acid precipitation damage to aquatic ecosystems of the Sierra Nevada, California (U.S.A.), in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 338-339.

1493
TONNESSEN, Kathy and HARTE, John, 1981, The potential for acid precipitation damage to aquatic ecosystems of the Sierra Nevada, California, in California Symposium on Acid Precipitation, San Francisco, 1981, Agenda and Abstracts: Sacramento, California Air Resources Board, p. 27.

1494
TOWNE, R. E., 1973, Acid rain: Journal of the New Hampshire Water Works Association, v. 34, no. 5, p. 13-16.

Lake-surface samples collected at Kezar Lake, N.H., in 1972 showed a pH range of 3.6 to 3.9. The acidity of the samples may have been affected by rain that occurred at the time of the sampling. Ice cover prevented the usual buffering capacity; hence the lake-surface samples reflected the acidity of the rain. Precipitation samples from pH 3.54 to pH 6.60, with a mean of 4.3

1495
TRAAEN, T. S., 1980, Effects of acidity on decomposition on organic matter in aquatic environments, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 340-341.

1496
TRESHOW, Michael, 1980, Interactions of air pollutants and plant disease, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 103-109.

Each interaction between an air pollutant and disease is unique. Pollutants may mitigate disease response or intensify it; and the presence of certain diseases can modify the plant's response to a pollutant. Air pollutants can act directly on a fungus or bacteria inhibiting parasitism. They may also act most strongly on the host, modifying its physiology and rendering it either more or less sensitive to weak pathogens, but less sensitive to obligate parasites. Where the pollutant physically injures the host, infection may be facilitated. Pollutant interactions have been demonstrated both in the laboratory and the field at ambient pollutant concentrations. Interactions between pollutants and abiotic stress are particularly critical. Water regime, temperature relations, mineral nutrition and other parameters of the physical environment play a major role in the expression of air pollution injury. [Abstract reprinted by permission of U.S. Forest Service.]

1497
TROEDSSON, T., 1980, Ten years acidification of Swedish forest soils [abstract], in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 184.

1498
TROJNAR, J. R., 1977, Egg and larval survival of white suckers (*Catostomus commersoni*) at low pH: Journal of the Fisheries Research Board of Canada, v. 34, p. 262-266.

The eggs of white sucker (*Catostomus commersoni*) were incubated in water of high conductivity with pH ranging from 4.2 to 8.0. At pH 4.5 and below, a few prolarvae hatched but were deformed and died shortly thereafter. At pH 5.0, the total hatch was the same at either high (250 μmho/cm) or low (20 μmho/cm) conductivity level. Body deformities and abnormalities in the vascular system were observed at pH 5.0; none of the prolarvae survived to the swim-up stage at pH 5.0.

1499
TROJNAR, J. R., 1977, Egg hatchability and tolerance of brook trout (*Salvelinus fontinalis*) fry at low pH: Journal of the Fisheries Research Board of Canada, v. 34, p. 574-579.

Hatchability of brook trout (*Salvelinus fontinalis*) eggs at pH 4.6, 5.0, 5.6, and 8.0 ranged from 76 to 96 percent. When swim-up fry were exposed to a different pH, differential mortality occurred, which suggests an accumulation effect. Brook trout fry incubated at lower, sublethal pH levels were less likely to experience death induced by acidity upon emergence than those incubated in spring upwellings.

1500
TROUTMAN, D. E., and PETERS, N. E., 1980, Comparison of lead, manganese and zinc transport in three Adirondack lake watersheds, New York, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 262-263.

1501
TU, K. W., and KANAPILLY, G. M., 1978, Generation and characterization of submicron ammonium sulfate and ammonium hydrogen sulfate aerosols: Atmospheric Environment, v. 12, p. 1623-1629.

Ammonium sulfate condensation aerosols with particle diameters of 0.01 to 0.3 μm were produced by two methods. This paper discusses the effects of vaporization temperature, condensation temperature, and relative humidity on particle size distribution and particle shape. Submicron $(NH_4)_2SO_4$ and NH_4HSO_4 aerosols can be produced with relatively constant mass and number concentrations and narrow size distributions. The aerosols are suitable for inhalation toxicological studies and physiochemical evaluations.

1502
TUKEY, H. B., Jr., 1980, Some effects of rain and mist on plants, with implications for acid precipitation, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 141-150.

1503
TUNDERMANN, D. W., 1980, Environmental economic, and energy balancing in fossil energy regulation, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition--environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 5-11.

1504
TUOMI, A. W. L., 1981, Socio-economic impacts of acid rain on Canada's Atlantic salmon, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 47-55.

1505
TURK, J. T., and PETERS, N. E., 1977, Acid-rain weathering of a metasedimentary rock basin, Herkimer County, New York: U.S. Geological Survey Open-File Report 77-538, 10 p.

Major chemical constituents in precipitation and surface-water outflow from a basin in Herkimer County, N.Y. were analyzed to determine the effects of acid precipitation (average pH 4.3) on weathering rates of metasedimentary rocks underlying the basin. About 45 percent of the net cation outflow from the basin is due to weathering by acid precipitation. The remainder of the cation load in the outflow is associated with interactions between atmosphere, rock, and soil water in the unsaturated zone. Weathering rates for this basin may have increased by 75 percent as a result of acid precipitation.

1506
TURK, J. T., and PETERS, N. E., 1979, Acid-rain weathering of a metasedimentary rock basin, Herkimer County, New York, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 136-145.

1507
TURK, R., and WIRTH, V., 1975, The pH dependence of SO_2 damage to lichens: Oecologia, v. 19, p. 285-291.

Thalli of lichens (*Hypogymnia physodes*) were exposed to buffer solutions ranging in pH from 2-8 and subsequently exposed to sulfur dioxide to determine the influence of hydrogen ion concentration on plant injury. Net photosynthesis was used as a criterion of vitality. The degree of damage to lichens exposed to 4 mg of SO_2/m^3 air for 14 hours was dependent on the pH of the buffer solutions. The least amount of damage to *Hypogymnia physodes* was observed at pH 7. The degree of damage increased with increasing acidity. No apparent photosynthesis occurred after lichens were exposed to SO_2 gas at pH 3.

1508
TURNER, John, JOHNSON, D. W., and LAMBERT, M. J., 1980, Sulphur cycling in a Douglas-fir forest and its modification by nitrogen applications: Acta Oecologica-Oecologia Plantarum, v. 1, no. 1, p. 27-35.

This article describes the relationship of sulfur and nitrogen in a nitrogen-deficient Douglas-fir stand at the University of Washington, Seattle. Of the total sulfur in the above-ground components, 14 percent was sulfate-sulfur, and 81 percent of the sulfur transferred to the floor was also in this form. It is suggested that the biochemical relationship between nitrogen and sulfur in plant proteins is directly related to the cycling of organic nitrogen and sulfur in forest ecosystems. Excess sulfur can cycle as sulfate in forest ecosystems and can operate somewhat independently of nitrogen or carbon cycles. Results of the study show that additions of nitrogen result in the incorporation of sulfate-sulfur into organic forms.

1509
TURNER, John, and LAMBERT, M. J., 1980, Sulfur nutrition of forests, in Shriner, D. S., Richmond, C. R., Lindberg, S. E., eds., 1980, Atmospheric sulfur deposition --Environmental impact and health effects: Ann Arbor, Mich., Ann Arbor Science, p. 321-333.

1509 (continued)
Sulphur is an essential major tree nutrient, and the biochemical relationship between S and N in plant proteins dictates that neither element can be adequately assessed without reference to the other. The sulphate sulphur status of the foliage provides an indicator of the S status of both the tree and the site. Sulphur deficiency is often associated with dieback in *Pinus radiata.* It also leads to the accumulation of particular amino acids, such as arginine, and this is associated with high foliar disease susceptibility. It appears that S toxicity in trees is confined to limited areas where concentrations of sulphur dioxide are high whereas in most situations S inputs are as sulphate, and damage symptoms are not produced. A comparison of various conifer species has indicated that species native to coastal situations, with high maritime S inputs, were more elastic in their utilization of S than species native to inland locations. Additions of N to forest stands result in the incorporation of sulphate sulphur into organic forms and thus the sulphate cycle in forest ecosystems is regulated to a large extent by N status and N cycling. [Abstract reprinted by permission of Ann Arbor Science Publishers.]

1510
TVEITE, Bjorn, 1980, Effects of acid precipitation on soil and forest, 8. Foliar nutrient concentrations in field experiments, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 204-205.

1511
TVEITE, Bjorn, 1980, Effects of acid precipitation on soil and forest, 9. Tree growth in field experiments, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 206-207.

1512
TVEITE, Bjorn, and ABRAHAMSEN, Gunnar, 1980, Effects of artificial acid rain on the growth and nutrient status of trees, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 305-318.

1513
TYLER, Germund, 1972, Heavy metals pollute nature, may reduce productivity: Ambio, v. 1, no. 2, p. 52-59.

1513 (continued)
This article describes the deposition, accumulation, and possible effects of lead, cadmium, copper, zinc, nickel, iron, and manganese on terrestrial sites. A discussion is given on the effects of ions on the accumulation of lead. An increase in hydrogen ion concentration in precipitation may deteriorate the sorption conditions of metal ions. Some conclusions are drawn on the relationship between hydrogen ions in precipitation and lead transport.

1514
TYLER, Germund, 1978, Leaching rates of heavy metal ions in forest soil: Water, Air, and Soil Pollution, v. 9, p. 137-148.

Leaching rates of Mn, Zn, Dc, Ni, V, Cu, Cr, and Pb were investigated in two organic spruce forest soils in southern Sweden--one a control soil and the other a similar soil polluted by Cu and Zn from a brass foundry. Soils were treated with simulated acid rainfall with pH values of 4.2, 3.2, and 2.8. Residence times, estimated from experimental data, varied from 3 yr (Mn) to 70 to 90 yr (Pb) in the control soil and from 2 yr (V) to >200 yr (Pb) in polluted soil with a precipitation water of pH 4.2. Residence times for most elements (except V and Cr) decreased with declining pH of precipitation water.

1515
TYREE, S. Y., Jr., 1981, Rainwater acidity measurement problems: Atmospheric Environment, v. 5, p. 57-60.

Three methods for determining rainwater acidity are (1) pH measurement, (2) titration, and (3) strong acid measurement (solution at or below pH 5.6.) These methods produce inconsistent values. Published results of laboratory studies on determining acidity of simulated acid rainwater show that adequate analytical results are not being attained.

U

1516
ULRICH, Bernard, 1980, Production and consumption of hydrogen ions in the ecosphere, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 255-282.

1517
ULRICH, Bernard, MAYER, Robert, and KHANNA, P. K., 1980, Chemical changes due to acid precipitation in a loess-derived soil in central Europe: Soil Science, v. 130, no. 4, p. 193-199.

1517 (continued)
The effect of acid precipitation on soil states and ion fluxes in a forest ecosystem was studied in a stand of European beech (*Fagus silvatica*) at the Solling highland, West Germany during 1966-79. A transition in soil state was observed that was characterized by increases in aluminum concentration in the soil solution and organic storage in the forest floor. During the transition, acid precipitation induced the production of H^+ in the soil, partly by a probable change in the type of nitrogen nutrition and partly by accumulation of organic matter poor in nitrogen. Aluminum concentration in soil solutions reached toxic levels in the stand.

1518
ULTSCH, G. R., 1978, Oxygen consumption as a function of pH in three species of freshwater fishes: Copeia, v. 2, p. 272-279.

The rate of oxygen consumption in three species of freshwater fishes previously exposed to water of pH 7.5 to 5.0 was measured while the fish were exposed to water ranging from pH 3.5 to 7.0. Acute exposure to pH 3.5 (H_2SO_4) was lethal to all species. This suggests that the importance of anoxia as a factor contributing to the death of fish at low pH varies among species.

1519
UNDERWOOD, J. K., 1980, pH of precipitation and annual deposition of excess sulfate, acidity, and nitrate on Nova Scotia, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 25-34.

1520
UNDERWOOD, J. K., 1981, Acidic precipitation in Nova Scotia: Halifax, Nova Scotia Department of the Environment, 24 p.

Acid precipitation is common and widespread in Nova Scotia, according to analyses of precipitation chemistry data collected from 1977-80. More than 85 percent of all rain and snow samples collected during the study period had pH values less than 5.6. Sulfuric acid and nitric acid in a ratio of 2 to 1 are the major contributors to the acid precipitation in Nova Scotia. The majority of these acids appears to originate from sources outside Nova Scotia. Salmon are no longer populating a significant number of rivers in Nova Scotia. Lakes in Nova Scotia do not appear to be as severely affected as the rivers, but those near the Halifax-Dartmouth area show chemical and biological changes attributable to acid deposition.

1521
UNITED STATES-CANADA TRANSBOUNDARY AIR POLLUTION WORKING GROUP 1, 1981, United States-Canada memorandum of intent on transboundary air pollution: Washington, D.C., United States/Canada Impact Assessment Working Group on Transboundary Air Pollution, 14 p.

The Impact Assessment Work Group is charged with identifying and assessing the physical and biological effects of transboundary air pollutants. This report summarizes the impacts of acidic atmospheric deposition on aquatic and terrestrial ecosystems, human health, and buildings and structures. A discussion is given on estimating the economic benefits of controlling long-range transport of air pollution.

1522
U.S. CONGRESS. HOUSE OF REPRESENTATIVES. COMMITTEE ON FOREIGN AFFAIRS, 97TH CONGRESS, 1ST SESSION, 1981, United States--Canadian relations and acid rain: Washington, D.C., U.S. House of Representatives, 121 p.

This report consists of statements by scientists and government officials on transboundary air pollution. In the eastern United States, about 90 percent of the emissions of sulfur oxides result from the combustion of fossil fuels and smelting activities; the remainder can be attributed to natural sources and transboundary flow from Canada. The major U.S. sources of sulfur oxides are in the industrailized regions of the midwestern and mid-Atlantic States; however, prevailing winds carry these emissions into the entire northeastern United States and into eastern Canada. About 45 percent of the atmospheric deposition of sulfur oxides in eastern Canada are attributed to man-made emission sources, and another 45 percent are attributed to long-distance transport of man-made sulfur emissions from the United States.

1523
U.S. CONGRESS. SENATE. COMMITTEE ON ENERGY AND NATURAL RESOURCES, 96TH CONGRESS, 2D SESSION, 1980, Effects of acid rain--phenomenon of acid rain and its implications for a National energy policy: Washington, D.C., U.S. Senate Publication no. 96-126, part 1, 752 p.

Legislation on the conservation of powerplant fuels prompted the Committee on Energy and Natural Resources to conduct hearings on the nature, sources, and effects of acid precipitation. This report presents statements by researchers on the following issues by 1) the effect of additional emissions from fossil-fuel powerplants on the acid precipitation problem; 2) the integration of knowledge of acid precipitation into national energy policies; and 3) the international scope of the

1523 (continued)
acid precipitation problem and implications for United States-Canada relations. Appendix 1 contains a reprint of a report titled "National Program for Assessing the Problem of Atmospheric Deposition (Acid Rain)."

1524
U.S. CONGRESS. SENATE. COMMITTEE ON ENERGY AND NATURAL RESOURCES, 96TH SESSION, 1980, Effects of acid rain--the nature, source and effects of acid rain and how the potential growth in emissions from coal burning powerplants will affect acid rain problems: Washington, D.C., U.S. Senate, Publication no. 96-126, part 2, 121 p.

This report describes the environmental effects of acid precipitation in New Hampshire and includes testimonies by scientists, legislators, and representatives of citizen's groups. Acid precipitation is a threat to fish and marine life in New Hampshire's lakes and streams; it may also impair the growth of forests and crops.

1525
U.S. CONGRESS. SENATE. SELECT COMMITTEE ON SMALL BUSINESS AND COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS, 96TH CONGRESS, 2D SESSION, 1980, Economic impact of acid rain: Washington, D.C., U.S. Senate, 224 p.

This report presents reviews of the environmental effects and subsequent economic impacts of acidic atmospheric deposition, given by scientists who are specialists in acid precipitation research, at a 1980 congressional hearing. Statements by four U.S. Senators and 12 scientists are given.

1526
U.S. ENVIRONMENTAL PROTECTION AGENCY, 1977, Acid rain: An environmental threat: EPA Journal, v. 3, no. 6, p. 14-16.

An overview is given on the acidity of rainfall and its effect on the natural environment. Rainwater in the northeastern United States has an average pH of 4.0. Acid precipitation may cause sharp declines in fish population of lakes in high-elevation watersheds and may possibly decrease forest productivity. An EPA investigation is being conducted at the Corvallis Environmental Research Laboratory to determine the effects of acid precipitationon the complex ecosystem of a hardwood forest.

1527
U.S. FISH AND WILDLIFE SERVICE, BIOLOGICAL SERVICES PROGRAM, 1978, Impacts of coal-fired power plants on fish, wildlife, and their habitats: Ann Arbor, Michigan, U.S. Fish and Wildlife Service, FWS/OBS-78/29, 260 p.

1527 (continued)
This report presents an assessment of coal-fired powerplant emissions on terrestrial and aquatic biota and their habitats. Acute, chronic, or long-term effects on plants and animals can be caused by air pollutants such as sulfur dioxide, nitrogen oxides, and particulates. Acid precipitation, a pollutant associated with emissions from coal-fired powerplants, is deleterious to terrestrial and aquatic ecosystems; some of the effects are injury to foliage, leaching of nutrients from plants and soils, and elimination of certain fish species from streams and lakes.

1528
U.S. GENERAL ACCOUNTING OFFICE, 1981, The debate over acid precipitation--opposing views--Status of research: Gaithersburg, Maryland, General Accounting Office, EMD-81-131, 44 p.

Results of a study conducted by the General Accounting Office (GAO) suggest that much of the acid precipitation debate is confused by innaccurate and misleading statements. However, most scientists agree on the issue of damage to aquatic ecosystems. This report summarizes issues being researched by scientists in the United States. Low alkalinity or buffering capacity of terrain underlying lakes in certain areas, especially in the northeastern United States and southeastern Canada, makes the lakes susceptible to acidification. Lakes in these areas are becoming increasingly acidic. Damage to terrestrial ecosystems has been less documented than damage to aquatic ecosystems. Some views on proposed strategies to abate acid precipitation are given.

1529
URONE, Paul, and SCHROEDER, W. H., 1978, Atmospheric chemistry of sulfur-containing pollutants, _in_ Nriagu, J. O., ed., Sulfur in the environment, part 1--the atmospheric cycle: New York, John Wiley, p. 297-324.

1530
USHIJIMA, T., and TAZAKI, T., 1977, The influence of sulfur dioxide on the photosynthetic and transpiration rate in several higher plants: International Clean Air Conference, 4th, Tokyo, 1977, Proceedings: Tokyo, Japanese Union of Air Pollution Prevention Associations, Proceedings, v. 4, p. 84-87.

This article desdribes the effect of short-term exposure of higher plant species to low concentrations of sulfur dioxide (SO_2) on photosynthetic and transpiration rates. Photosynthetic and transpiration rates were measured simultaneously in sunflowers; results indicated that the inhibition rate was highest in leaves with high photosynthetic activity. The inhibition photosynthetic

1530 (continued)
rate began earlier than inhibition in transpiration rate. These observations is suggest that two components of SO_2 influence photosynthetic rate through carbon dioxide fixation reaction and through the closure of stomata.

1531
UTHE, J. F., and FREEMAN, H. C., 1980, Polychlorinated biphenyl, levels and biological effects in cod (*Gadus morhua*), in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 62-63.

V

1532
VAALA, S. S., MITCHELL, R. B., and ANTHONY, Adam, 1969, Cytophotometric studies of DNA in circulating erythrocytes of brook trout exposed to acid pH: Proceedings of the Pennyslvania Academy of Science, v. 43, p. 191-194.

This article describes the effect of acid waters on hemopoiesis in brook trout. Trout exposed to water with pH 3.5 for 4 days accumulated excessive PAS-positive mucin, especially in the gill region. No evidence of enhanced hemopoiesis or increased red cell destruction was observed in fish exposed to acidic water. It is suggested that trout die in acidic water because compensatory erythropoiesis does not occur or is not as rapidly initiated as in homeotherms in response to a lack of oxygen.

1533
VAALA, S. S., MITCHELL, R. B., and ANTHONY, Adam, 1971, Erythrocytic changes associated with subacute acid exposure of brook trout (*Salvelinus fontinalis*): Pennyslvania Academy of Science, v. 45, p. 82-87.

Brook trout (*Salvelinus fontinalis*) were exposed to subacute acidic water (pH 4.9) for 28 days in a gravity-flow proportional diluter system. Hematocrit and hemoglobin measurements showed a compensatory erythrocytic response to the acid exposure. Oxygen tension levels from subacute acid exposed trout were normal. Analyses of data show that trout acclimate to prolonged exposure to acidic water and reach a new level of homeostasis.

1534
VAN DEN HEUVEL, A. P., and MASON, B. J., 1963, The formation of ammonium sulphate in water droplets exposed to gaseous sulphur dioxide and ammonia: Quarterly Journal of the Royal Meteorological Society, v. 89, p. 271-275.

This article describes one experiment to evaluate the formation rate of ammonium sulfate in water droplets exposed to air containing known concentrations of gaseous sulfur dioxide. Results show that the mass of sulfate formed is proportional to the product of the surface area of the drops and the exposure time. The authors suggest that the ammonium sulfate particles, which are an important constituent of the large nuclei in polluted air, are formed through the absorption of sulfur dioxide and ammonia by cloud and fog droplets.

1535
VAN EVERDINGEN, R. O., and BANNER, J. A., 1971, Precipitation of heavy metals from natural and synthetic acidic aqueous solutions during neutralization with limestone: Ottawa, Canada, Inland Waters Branch, Technical Bulletin no. 35, 24 p.

A test of neutralization with limestone was conducted to determine precipitation of iron (Fe), manganese (Mn), aluminum (Al), copper (Cu), lead (Pb), and zinc (Zn) from natural and synthetic acidic water with hydrogen ion concentrations ranging from 4.0×10^{-3} to 6.3×10^{-4}. Results of the test showed a neutralization of acidity and removal of as much as 99.9 percent of dissolved Fe, 96.6 percent of Al, 35 to 52 percent of Mn, 99.8 percent of Cu, 99.9 percent of Pb, and 97.1 percent of Zn. Intensive aeration accelerated the neutralization process by increasing the rate of oxidation from Fe^{++} to Fe^{+++}, and by removing dissolved carbon dioxide generated by solution of the limestone.

1536
VANGENECHTEN, J. H. D., 1980, Interrelations between pH and other physicochemical factors in surface waters of the Campine of Antwerp (Belgium)--with special reference to acid moorland pools: Archiv für Hydrobiologie, v. 90, no. 3, p. 265-283.

Water samples were collected from 53 pools in bogs at Campine of Antwerp, North of Belgium, and analyzed for pH, Na, K, Ca, Mg, SO_4, Cl, HCO_3, CO_3. Some of the relations between ionic components are dependent on the pH-class of the water body, which indicates different relationships between ions according to the pH of the water. Analyses show that acidification of the pools is caused by sulfur-rich rainwater. The acidification of the Belgian pools appears to be similar to acidification of lakes in Scandinavia and North America.

1537
VANGENECHTEN, J. H. D., BOSMANS, F., and DECKERS, H., 1981, Effects of short-term changes in rain water supply on the ionic composition of acid moorland pools in the Campine of Antwerp (Belgium): Hydrobiologia, v. 76, p. 149-159.

Changes in pH, corrected conductivity, Na, K, Ca, Mg, Cl and SO_4 in 21 shallow acid bogs in the Campine of Antwerp, Belgium were monitored from autumn 1975 through spring 1979. High peak concentrations were observed among some ions during 1976, possibly because the hot, dry summer that year caused extreme evaporation in the pools. In pools that dried out completely, strong increases of calcium, magnesium, and sulfate concentrations were found during the first months of refilling in autumn. The pH, potassium, and chloride remained unchanged. The significant changes in ionic concentrations and composition that may occur during periods of evaporation and subsequent refilling can induce severe stress on aquatic organisms.

1538
VANGENECHTEN, J. H. D., VAN PUYMBROECK, S., and VANDERBORGHT, O. L. J., 1980, Effect of pH on the chloride uptake and influx in two waterbugs (insecta, hemiptera) from acid freshwaters: Comparative Biochemistry and Physiology, v. 67A, p. 85-90.

This article describes the effect of pH on the exchange and uptake of chloride and on chloride influx in *Corixa dentipes* and *Corixa punctata*. The highest uptake rate occurred at pH 4 and 3. Chloride uptake as a function of external chloride concentation can be described by enzyme saturation kinetics (Michaelis-Menton equation). The K_m and the maximum uptake value (V_{max}) of the Michaelis relation increased significantly at acid pH levels. Chloride influx was also affected by pH.

1539
VANGENECHTEN, J. H. D., VAN PUYMBROECK, S., VANDERBORGHT, O. L. J., BOSMANS, F., and DECKERS, H., 1981, Physico-chemistry of surface waters in the Campine region of Belgium, with special reference to acid moorland pools: Archiv für Hydrobiologie, v. 90, no. 4, p. 369-396.

Data on pH, conductivity, and nine constituents were collected from 53 water bodies in northern Belgium from 1975-78. The pH of these waters ranged from below 4.5 to above 7.0. Total ionic composition in pools with pH at or below 4.5 (4 meq/L) and ionic composition in pools with moderate pH levels were comparable to that of extremely acidic waters. Sulfate was the dominate anion in all sampled pools.

1540
VANGENECHTEN, J. H. D., and VANDERBORGHT, O. L. J., 1980, Effect of acid pH on sodium and chloride balance in an inhabitat of acid freshwaters--the waterbug *Corixa punctata* (Illig.) (Insecta, Hemiptera), <u>in</u> Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 342-343.

1541
VARSHNEY, C. K., DOCHINGER, L. S., 1979, Acid rain--emerging environmental problems: Current Science [Bangladore, India], v. 48, no. 8, p. 337-340.

The acidity of rainwater has increased considerably in recent years in many developed countries as a result of industrial activities. The effect of acid precipitation or terrestrial ecosystems is complex and long term. Loss of fertility of terrestrial ecosystems and ecological disturbances in the species composition of terrestrial and aquatic communities result in an overall decrease in biological productivity.

1542
VARSHNEY, C. K., and GARG, J. K., 1979, Plant responses to sulfur dioxide pollution: CRC Critical Reviews in Environmental Control, v. 9. no. 1, p. 27-49.

This article describes a review of plant responses to sulfur dioxide pollution. Different phases of plant life react differently to the same levels of sulfur dioxide. Investigations of stomatal response to different levels of sulfur dioxide are needed. Some physiological processes are extremely sensitive to air pollution; the inhibition of photosynthetic rate is directly related to increasing levels of sulfur dioxide in the atmosphere.

1543
VARSHNEY, C. K., and GARG, K. K., 1980, Significance of leaf surface characteristics in plant responses to air pollution: Water, Air, and Soil Pollution, v. 14, p. 429-433.

This article examines the relationship between leaf-surface characteristics and susceptiblity of plants to air pollution. Plant responses to air pollution vary with type of leaf vesture. Significant reduction in leaf area, leaf biomass, total plant biomass, and chlorophyll content is observed in plants with pilose or pubescent leaf surface.

1544
VASUDEVAN, C., CLESCERI, N. L., 1981, Effect of a forested watershed on acidic precipitation, in American Chemical Society, Division of Environmental Chemistry, 182nd National Meeting, New York, N.Y., Preprints, v. 21, no. 2: Washington, D.C., American Chemical Society, p. 76-78.

1545
VELTISHCHEVA, N. S., 1979, A model for evaluation of transboundary sulphur dioxide flux with the inclusion of vertical motions, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 289-296.

1546
VERMEULEN, A. J., 1978, Acid precipitation in The Netherlands: Environmental Science and Technology, v. 12, no. 9, p. 1017-1021.

A definite relationship between sulfur dioxide emissions (SO_2) and the acidification of precipitation has been observed in the Netherlands. A similar relationship cannot be demonstrated for NO_x emissions and acidification, probably because of the altitude of NO_x emissions. Because 40 percent of NO_x emissions are 30 cm above road surface, most of the emissions are absorbed by the direct surroundings. The remaining 60 percent of NO_x (170,000 tons) is not considered to play a significant role in the acidification process.

1547
VERMEULEN, A. J., 1980, The acidic precipitation phenomenon--a study of this phenomenon and of a relationship between the acid content of precipitation and the emission of sulfur dioxide and nitrogen oxides in The Netherlands, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 7-60.

The Netherlands is a nation which is highly industrialized and densely populated. Along with other European countries noting the increase in acidity of the precipitation, The Netherlands became part of the extensive European network of atmospheric measuring stations which are coordinated by the International Meteorological Institute (IMI) in Stockholm. Three stations are part of this network, and in addition the province of North Holland has installed 22 sampling stations. The extensive information available over a period of years has made possible the correlation between the acidification of precipitation and the acidic gas content of the atmosphere. A pronounced relationship between the total interior emission of SO_2 and

1547 (continued)

the acidification was found, but no such relationship could be shown for the nitrogen oxides. Factors which have an influence such as the wind direction and the dust content have been investigated.

The total acidity in the years around 1966 was the highest in the world for this country. Increased energy requirements combined with a change from pit coal to oil resulted in the increased sulfur dioxide emissions. The reduction after 1967 was then credited to a large conversion to gas when the largest coherent natural gas field in the world was found in the province of Groningen. Because of a prior commitment for the exportation of much of this gas, the domestic use will be reduced until the year 2000. In the meantime a reconversion to oil and coal will be necessary to satisfy the energy requirements, and the SO_2 emissions accompanied by increased acid deposition are expected to rise. [Abstract reprinted by permission of Plenum Press.]

1548
VERRY, E. S., 1981, Acidity of lakes and impoundments in north-central Minnesota: U.S. Forest Service, North Central Forest Experiment Station, Research Note NC-273, 4 p.

Water samples were collected from 21 lakes and seven shallow waterfowl impoundments near the Marcell Experiment Forest in north-central Minnesota and analyzed for pH and specific conductance from 1974 to the spring of 1980. pH and calcium data from some of the lakes were plotted and compared with curves from another lake acidification study; the plots indicate normal pH levels in the sampled lakes.

1549
VIEMEISTER, P. E., 1960, Lightning and the origin of nitrates found in precipitation: Journal of Meteorology, v. 17, p. 681-683.

This article examines the origin of nitrates in precipitation. Lightning is one of many sources, but its contribution may be overestimated. It is possible that nitrates in precipitation may result from nitrogen oxides produced in regions far from the area of observation.

1550
VOGLER, D. R., and PRONOS, John, 1980, Ozone injury to pines in the southern Sierra Nevada of California, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43. p. 253.

1551
VOIGT, G. K., 1980, Acid precipitation and soil buffering capacity, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 53-57.

1552
VOLCHOK, H. L., 1980, Atmospheric deposition of man-made radioactivity, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 435-448.

For the past two decades, the major radioactive component in rain has been the debris resulting from nuclear tests in the atmosphere. In studying fallout from these test, rather extensive networks of precipitation collections were developed which have proven to be extremely useful in maintaining an inventory of the fallout radionuclides on the earth's surface. Additionally, the models used for estimating current and future human exposure to these substances are in large part based upon the rainfall data. A study of total, wet and dry deposition is described, concluding that dry fallout should not be neglected and that it can successfully be collected on artificial surfaces. [Abstract reprinted by permission of Plenum Press.]

1553
VOLKOVA, V. P., 1972, Khimicheskiy sostav atmosfernykh osadkov, vypadayushchikh na territorit Deputatskogo rayona: Moskovskii Universitet Vestnik, Seriya 4: Geologiya, no. 4, p. 97-100. [In Russian.]

Rainwater and snow samples were collected and analyzed as part of a hydrogeological survey conducted by the Yukutsk expedition of Moscow State University near the Deputatskiy settlement in northeast Yakutsk, USSR from 1967-70. Annual precipitation in the area ranged between 230 and 480 mm. The pH of meteoric waters ranged from 5.0-6.5. Meteoric waters containing bicarbonate and chloride made up 34 percent of all the samples. Trace constituents were determined through spectral analysis of dry residues.

W

1554
WAGMAN, J., LEE, R. E., Jr., and AXT, C. J., 1967, Influence of some atmospheric variables on the concentration and particle size distribution of sulfate in urban air: Atmospheric Environment, v. 1, p. 479-489.

1554 (continued)

The effect of location, humidity, sulfur dioxide level, and time of day on variations in distribution and concentration of atmospheric sulfate was investigated. Samples were collected for a week in four cities--Cincinnati and Fairfax, Ohio, Chicago, Ill., and Philadelphia, Penn. Average sulfate mass median equivalent diameters (MMD) in the first three cities were about 0.42 μ; that in Philadelphia was 0.66 μ and was attributed in part to dust produced by roadside construction near the sampling site. Sulfate MMD increased with increasing relative humidity; sulfate concentration correlated more closely with absolute humidity except when sulfur dioxide levels exceeded 3 parts per hundred million.

1555
WAINWRIGHT, M., 1978, Distribution of sulphur oxidation products in soils and on *Acer pseudoplatanus* L. growing close to sources of atmospheric pollution: Environmental Pollution, v. 17, p. 153-160.

This article describes the distribution of elemental sulfur, tetrathionate, and sulfate on leaf surfaces of sycamore litter (*Acer pseudoplatanus* L.). The sampling sites were close to sources of atmospheric pollution. Leaf and litter contained the three oxidation products, and the highest concentrations of these constituents occurred in the litter. The surfaces of polluted leaves and litter had higher concentrations of sulfur(S) ions than unpolluted substrates; the most abundant ion was sulfate. Analysis of the distribution of sulfur oxidation products in soils beneath the canopy show that the canopy had a concentrating effect. Concentrations of S-ions were higher and pH lower in soils below the canopy than in soils sampled at a distance from the canopy.

1556
WAINWRIGHT, M., 1978, Sulphur-oxidizing micro-organisms on vegetation and in soils exposed to atmospheric pollution: Environmental Pollution, v. 17, p. 167-174.

Sulfur-oxidizing micro-organisms were isolated from leaves, litter, and soils polluted with high levels of sulfur dioxide (SO_2) to determine their distribution. *Thiobacillus thioparus* was the predominant autotrophic species of leaf surfaces, and *Thiobacillus novellus* was the predominant species isolated from leaf litter and soils.

1557
WAINWRIGHT, M., 1980, Man-made emissions of sulphur and the soil: International Journal of Environmental Studies: v. 14, p. 279-288.

A discussion is given on the sulfur cycle and how sulfur influences soil processes and

1557 (continued)
microbial acitivity. Most of the effects have a direct influence on soil fertility. Acid precipitation affects soil processes by altering base status and increasing ion leaching rates. An increase in sulfur ion concentration and a decrease in pH is likely to affect microbial colonization and activity in polluted soils.

1558
WALKER, D. R., 1969, Sulfur in precipitation in central Alberta: Canadian Journal of Soil Science, v. 49, p. 409-410.

Precipitation samples were collected during 1966-69 at sites in central Alberta and analyzed for sulfate. Sulfate sulfur concentration of individual samples ranged from 0.16 to 3.65 ppm; the majority ranged from 0.4 to 1.5 ppm. Samples collected within a radius of 10 to 24 km from a sulfur extraction plant did not contain more sulfate sulfur than samples collected further away.

1559
WALKER, D. R., DICK, A. C., and NYBORG, Marvin, 1981, Deposition of sulphur gases from multiple scattered sources in Alberta: Water, Air, and Soil Pollution, v. 16, no. 2, p. 223-231.

This article describes measurements of the amount of sulfur (S) deposited in rainfall and absorbed by soils, plants, and free water surfaces in Alberta, Canada in 1973 and 1975. About 7 to 9 kg/ha of sulfate S was deposited annually in 4,600 km^2 area. Ten S emission sources with emissions of approximately 330 tonne S per year are within or adjacent to the boundaries of the sampling area. The annual deposition rate decreased to 4 to 6 kg/ha at distances of 40 or more km from the emission sources.

1560
WALTON, Susan, 1980, Coal conversion will increase acid rain damage: BioScience, v. 30, no. 5, p. 293-295.

This article discusses the effect of increased use of coal-buring powerplants on precipitation. Many scientists believe that stricter emission controls are needed. The effects of acid precipitation are severe and widespread. Studies show that acid precipitation may affect the recycling of nutrients in the soil. The number and variety of algae species and also the proportions of species are affected by acid precipitation. Fish have varying sensitivity to increased acidity; fish populations in Scandinavian lakes have decreased radically, particularly salmon and trout.

1561
WANG, J. C., and HIMMELBLAU, D. M., 1964, A kinetic study of sulfur dioxide in aqueous solution with radioactive tracers: American Institute of Chemical Engineers Journal, v. 10, no. 4, p. 574-580.

A kinetic study of homogeneous reactions in the sulfur dioxide-sodium bisulfate water system was conducted by a radioactive tracer technique. The influence of the diffusion of sulfur dioxide into and out of the aqueous solution can be divorced from the kinetic effects of the chemical reaction by operating the system at chemical equilibrium and at isotopic disequilibrium. The rate of reaction of this system was then studied by analyzing radioactive sulfur-35 in the form of gaseous sulfur dioxide using the Bernstein-Ballentine technique.

1562
WATERS, T. F., 1956, The effects of lime application to acid bog lakes in northern Michigan: American Fisheries Society Transactions, v. 86, p. 329-344.

Two acidic, soft-water, colored bog lakes in the upper peninsula of Michigan were treated with lime to investigate the correlation between alkalinity and productivity of lake waters. Lime applications in the summer raised the pH and increased alkalinity, total hardness, and conductivity in the epilimnion only. Applications of lime in autumn produced similar effects in the lower hypolimnion. A bloom of nannoplankton was observed in one lake after the release of epilimnial phosphorus. Chemical data show that the higher bicarbonate concentrations cause nannoplankton to use carbon dioxide at a higher rate than would be possible without lime application.

1563
WATT, W. D., 1980, The impact of local industrial emissions on the acidity of lakes in the Halifax area, _in_ Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 86-90.

1564
WATT, W. D., 1981, Present and potential effects of acid precipitation on the Atlantic salmon in eastern Canada, _in_ Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 39-45.

1565
WATT, W. D., SCOTT, D., and RAY, S., 1979, Acidification and other chemical changes in Halifax County lakes after 21 years: Limnology and Oceanography, v. 24, no. 6, p. 1154-1161.

This article discusses acidification trends in lakes in Halifax County, Nova Scotia. Results of one study indicate that 16 of 23 lakes sampled in 1955 show no significant physical alterations within their drainage basin during 21 years, which suggests that chemical changes in the water quality of the lakes may be caused by changes in atmospheric deposition. The pH of all 16 lakes has declined, and the lakes having higher pH values show the greatest decrease in pH. Concentrations of sodium, magnesium, calcium, potassium, and sulfate have not significantly changed. Sulfate and hydrogen ions are correlated and both show significant regressions on distance from major industrial sources in the Halifax area.

1566
WEAVER, G. T., and JONES, J. D., 1980, Modification of chemical contents of precipitation by passage through oak forests, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 254.

1567
WEBB, A. H., 1980, The effect of chemical weathering on surface waters, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 278-279.

1568
WEBER, T. W., II, 1981, Response of phytoplankton to acidification in experimental streams: Washington, D.C., U.S. Environmental Protection Agency, EPA-600/S3-81-042, 2 p.

The effect of acidification on stream phytoplankton communities was investigated at three streams in Minnesota. For 2-week intervals from May 30 to July 11, 1979, water from the Mississippi River was pumped into three streams having pH levels of 8.1, 6.3, and 5.3 (controlled by the addition of sulfuric acid). The density of phytoplankton in the streams with pH 8.1 and 6.3 was highest during the first month of sampling; but in the stream with pH 5.3, it was highest in the second month. At the end of the sampling period, phytoplankton density was low. Diversity of phytoplankton was similar in all three streams. Species composition was dominated by diatoms and was almost identical in all streams. The sublethal value for diatoms was pH 5.3.

1569
WEBSTER, D. A., and FLICK, W. A., 1979, Fish management options in Adirondack lakes impacted by acid precipitation, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 121-125.

1570
WEDDING, J. B., CARLSON, R. W., STUKEL, J. J., and BAZZAS, F. A., 1977, Aerosol deposition on plant leaves: Water, Air, and Soil Pollution, v. 7, no. 4, p. 545-550.

An aerosol generator and wind tunnel system designed for use in aerosol deposition are described. Gross deposition on rough pubescent leaves was nearly seven times greater than on smooth, waxy leaves. Results suggest that aerosol deposition, on a per unit area basis, for single horizontal streamlining leaves is similar to that for arrays of leaves under similar flow conditions. Wind re-entrainment of $PbCl_2$ particles was negligible, while 2.54 cm of simulated rainfall was sufficient to remove 85% of recently applied aerosol. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1571
WEDDING, J. B., LIGOTKE, Michael, and HESS, F. D., 1979, Effects of sulfuric acid mist on plant canopies: Environmental Science and Technology, v. 13, no. 7, p. 875-878.

Four- to six-week old soybean plants were treated with sulfuric acid mist droplets in a study to assess qualitative and quantitative effects. A 10-percent solution produced severe necrotic lesions and large chlorotic regions on the acropetal leaves. Heavy application of a 1-percent solution produced similar effects, but with fewer necrotic lesions. No visible effects were observed after 24 hours of a light application of the 1-percent solution.

1572
WELLBURN, A. R., MAJERNIK, O., and WELLBURN, F. A. M., 1972, Effects of SO_2 and NO_2 polluted air upon the ultrastructure of chloroplasts: Environmental Pollution, v. 3, p. 37-49.

An electron microscope was used to examine the ultrastructure of mature bean tissue exposed to air containing sulfur dioxide (SO_2) or nitrogen dioxide (NO_2) at maximum

1572 (continued)
stomatal aperture for short periods of time. Swelling of the thylakoids within the chloroplasts was caused by both pollutants, but extra-chloroplastidic damage was not detected. The thylakoid swelling was reversed by removing the pollutants from the air flow or changing the rate of gas flow within the tissue.

1573
WENTZEL, K. F., and GASCH, Gunther, 1980, Seasonal variation of inorganic and organic sulfur in coniferous needles intensified by SO_2 pollution, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 255.

1574
WEST, Susan, 1980, Acid from Heaven: Science News, v. 117, p. 76-78.

This article discusses the causes of acid rain and its effects on aquatic and terrestrial ecosystems. Acidic atmospheric deposition is causing the pH of lakes to decline, which is having dramatic effects on lake ecosystems. The diversity and number of fish species decrease rapidly when pH decreases from 6 to about 5.5. All fish, most of the frogs, and many insects die when pH decreases to 4.5. Forest species such as white pine, jack pine, trembling aspen, and white birch seem to be the most susceptible to acid precipitation. Acid precipitation may cause damage to the protective waxy surface of leaves, interfere with transpiration and gas exchange; poison plants by letting acidic substances diffuse into the leaves and branches; and decrease photosynthesis and seed germination.

1575
WEST, Susan, 1980, Acid solutions: Science News, v. 117, p. 106-108.

Acid rain research has increased significantly since the mid-1950's, when Eville Gorham began to identify some of the problems associated with the phenomenon. Recent research reflects the multidisciplinary aspects that are necessary in studying causes and effects on terrestrial and aquatic ecosystems. A long-term ecosystem study has been conducted at the Hubbard Brook Experimental Forest in the White Mountains of New Hampshire since 1963. Another whole-ecosystem study was begun in the Adirondack Mountains of New York in 1977 by the Electric Power Research Institute (EPRI). Previously titled the Adirondack Lake Project, the investigation is now titled the Integrated Lake Watershed Acidification Study. Three Adirondack lakes with neutral, intermediate, and low pH are compared to quantify the effects of acid precipitation on a lake system; the goal is to develop a model to predict the effects of air quality on the system.

Several other research projects are summarized, including the study of the Boundary Waters Canoe Area in Minnesota.

1576
WESTCOTT, C. C., 1978, pH measurements: New York, Academic Press, 172 p.

This book presents techniques for obtaining accurate pH measurements. Chapters address the following topics: (1) basic theory of pH, (2) characteristics, care, and performance of pH equipment, and (3) techniques for difficult applications. A glossary of terms and a subject index are included.

1577
WESTMAN, W. E., and PRESTON, K. P., 1980, Sulfur dioxide and oxidant effects on Californian coastal sage scrub, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 256.

1578
WETSTONE, G. S., 1979, Development of an international legal remedy to the problem of acid rain and snow in North America, in, Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 222-227.

1579
WETSTONE, G. S., 1980, The need for a new regulatory approach: Environment, v. 22, no. 5, p. 9-43.

This article discusses air quality and emission standards, the Clean Air Act, and State implementation plans. Several industries in the United States attempted to undermine many Clean Air Act programs. Political and economic considerations must be assessed to avoid inflationary and unnecessarily restrictive measures that may severly limit industrial growth. However, documentation of the effects of acidic atmospheric deposition on crops, forests, soils, materials, and aquatic ecosystems justifies regulatory action.

1580
WETSTONE, G. S., 1981, Legal and social options, in Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, 1980, Proceedings: New York, International Atlantic Salmon Foundation Special Publication Series no. 10, p. 149-154.

1581
WHELPDALE, D. M., 1976, Particulate concentration and dry deposition measurements: Journal of Great Lakes Research, v. 2, supplement no. 1, p. 82-87.

This article describes techniques of measuring atmospheric particulate concentrations and methods for determining dry deposition loading to lakes, with emphasis on techniques to determine dry deposition to the Great Lakes. In measurement of particulate matter, simultaneous measurements of several aerosol constituents are recommended to characterize the aerosol and to define that portion of the aerosol spectrum being sampled in a particular measurement. Knowledge of chemical composition as a function of particulate size is essential. Concurrent gas-phase sampling is also recommended. Sample degradation on collecting surfaces should be considered.

1582
WHELPDALE, D. M., 1976, Dry deposition over the Great Lakes, in Atmosphere-Surface Exchange of Particulate and Gaseous Pollutants, Richland, Wash., 1974, Proceedings: [Oak Ridge, Tenn.], U.S. Energy Research and Development Administration, ERDA Symposium Series 38, p. 382-390.

This article examines the importance of dry deposition by direct gas-phase exchange and particulate fallout in relation to wet deposition by precipitation in the Great Lakes basin. Studies of SO_2 flux measurements over Lake Ontario and particulate loading determinations in the same region are reviewed. Estimates of lake loading rates for S, inorganic N, Fe and Pb are given. Direct gas-phase deposition of SO_2 can contribute nearly as much S to the lakes as the precipitation of SO_4, and particulate fallout of Fe and Pb can account for a signficant fraction of the total atmospheric input of these elements. It is concluded that dry deposition processes are important contributors to the total atmospheric loading of the lakes.

1583
WHELPDALE, D. M., 1978, Large-scale atmospheric sulfur studies in Canada, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 661-670.

1583 (continued)
This review describes efforts underway in Canada to investigate large-scale atmospheric sulfur pollution. An assessment of the susceptibility of various parts of the country, in terms of receptor sensitivity, meteorological regime, and source-receptor configuration, as well as evidence of ecosystem damage in North America and Europe, has led the federal Department of Fisheries and Environment to undertake a comprehensive program to investigate the long-range transport of air pollutants in eastern Canada. The program includes studies of emissions, atmospheric phenomena, and aquatic and terrestrial ecosystem effects. Atmospheric aspects of particular interest include long-range transport, regional particulate-sulfate levels, and the acidity and sulfate content of precipitation.

Results from an intensive, month-long study of particulate and precipitation sulfate in eastern Canada indicate that episodes of elevated particulate sulfate concentration occur over a large part of the region, usually in association both the southerly flows behind large areas of high pressure situated over the eastern portion of the continent. Most severely affected is the lower Great Lakes region, with 24 h average sulfate concentrations in the 40-50 $\mu g\ m^{-3}$ range and averages for the period near $10 \mu g\ m^{-3}$. Precipitation chemistry measurements from this study and other ongoing monitoring programs indicate that the southeastern portion of the country is also affected by high precipitation-sulfate concentrations and low pH values, typically 5 mgl^{-1} and 4.3 respectively.

The geographical distributions of both particulate-sulfate and precipitation acidity are consistent with those found in the eastern United States. Air pollution problems associated with sulfur compounds are of a large-regional nature in eastern North America, affecting both Canada and the United States. International approaches to their further study and eventual solution are a necessity. [Abstract reprinted by permission of Pergamon Press.]

1584
WHELPDALE, D. M., 1980, An overview of LRTAP--Emissions, transport, transformation and deposition, in Workshop on Long Range Transport of Air Pollution and its Impact on the Atlantic Provinces, Dartmouth, Nova Scotia, 1979, Proceedings: Bedford, Nova Scotia, Canada, Department of the Environment, Atmospheric Environment Service, p. 3-4.

1585

WHELPDALE, D. M., and GALLOWAY, J. N., 1979, An atmospheric budget for eastern North America, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 213-222.

1586

WHITBY, K. T., 1978, The physical characteristics of sulfur aerosols, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 135-159.

A review of the physical characteristics of sulfur-containing aerosols, with respect to size distribution of the physical distributions, sulfur distributions, distribution modal characteristics, nuclei formation rates, aerosol growth characteristics, and *in situ* measurement, has been made.

Physical size distributions can be characterized well by a trimodal model consisting of three additive log-normal distributions.

When atmospheric physical aerosol size distributions are characterized by the trimodal model, the following typical modal parameters are observed.

1. Nuclei mode-geometric mean size by volume, DGV_n, from 0.015 to 0.04 μm, s_{gn} = 1.6, nuclei mode volumes from 0.005 over the remote oceans to 9 μm^3 cm^{-3} on an urban freeway.

2. Accumulation mode-geometric mean size by volume DGV_a, from 0.15 to 0.5 μm, s_{ga} = 1.6-2.2 and mode volume concentrations from 1 for very clean marine or continental backgrounds to as high as 300 μm^3 cm^{-3} under very polluted conditions in urban areas.

3. Coarse particle mode-geometric mean size by volume, DGV_c, from 5 to 30 μm, s_{gn} =2-3, and mode volume concentrations from 2 to 1000 μm^3 cm^{-3}.

It has also been concluded that the fine particles (D_p<2 μm) are essentially independent in formation, transformation and removal from the coarse particles (D_p>2 μm).

Modal characterization of impactor-measured sulfate size distributions from the literature shows that the sulfate is nearly all in the accumulation mode and has the same size distribution as the physical accumulation mode distribution.

Average sulfate aerodynamic geometric mean dia. was found to be 0.48 ± 0.1 μm (0.37 ± 0.1 μm vol. dia.) and s_g = 2.00± 0.29.

1586 (continued)

Concentrations range from a low of about 0.05 μg m^{-3} over the remote oceans to over 80 μg m^{-3} under polluted conditions over the continents.

Review of the data on nucleation in smog chambers and in the atmosphere suggests that when SO_2 is present, SO_2-to-aerosol conversion dominates the Aitken nuclei count and, indirectly, through coagulation and condensation, the accumulation mode size and concentration. There are indications that nucleation is ubiquitous in the atmosphere, ranging from values as low as 2 cm^{-3} h^{-1} over the clean remote oceans to a high of 6 x 10^6 cm^{-3} h^{-1} in a power plant plume under sunny conditions.

There is considerable theoretical and experimental evidence that even if most of the mass for the condensational growth of the accumulation mode comes from hydrocarbon conversion, sulfur conversion provides most of the nuclei. [Abstract reprinted by permission of Pergamon Press.]

1587

WHITBY, K. T., CANTRELL, B. K., and KITTELSON, D. B., 1978, Nuclei formation rates in a coal-fired power plant plume, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 313-321.

From total aerosol concentration data obtained with a condensation nuclei counter (CNC) and size distribution information obtained with an electrical aerosol analyzer (EAA), in and adjacent to the Labadie power plant plume near St. Louis, Missouri, nucleation rates, QN, and the fraction of aerosol mass from gas-to-particle conversion going into the nuclei mode and accumulation mode have been calculated. Nucleation rates in the plume ranged from 1700 cm^{-3} s^{-1} at 0630 in the morning close to the stack to 1 at night and long distances. Background rates ranged from 2 to 4 in the middle of the day to essentially zero at night. Approximately 5% of the new mass from gas-to-particle conversion in the plume formed new nuclei while the remainder condensed directly on accumulation mode particles. Nucleation rates calculated from the photooxidation of SO_2 in smog chamber experiments were found to compare favorably with those in the plume. Futhermore, the number of new nuclei formed per unit volume of aerosol formed by the gas-to-particle conversion were found to be comparable in the plume and in the smog chamber experiments, being about 5 x 10^6 μm^{-3} in the smog chamber and 0.6 to 2.6 x 10^6 μm^{-3} in the plume. The ratio of the volume formation rate of aerosol to SO_2 concentration in the plume and in the smog chamber were found to be comparable, 38 μm^3 cm^{-3} h^{-1} ppm^{-1} in the smog chamber compared to 57 in the plume.

1587 (continued)
These ratios were somewhat smaller than those calculated for aerosol formed in a sulfur-containing propane flame by Barsic (1977) and alongside of a Los Angeles freeway by Clark et al. (1976). A simple correlation between the total number concentration of the aerosol and the number of particles in the accumulation mode (Na) has been found to be NT = 10 (Na) 0.904 (NT, Na cm^{-3}). Using the lumped mode model, a further simple relationship between NT and the nucleation rate, QN_n, has ben found to be NT = $1.725 \times 10^4 (QN_n)^{1/2}$. These later correlations would only apply to well-aged aerosol several hours away from fresh injections of combustion nuclei (QN_n no. cm^{-3} s^{-1}). [Abstract reprinted by permission of Pergamon Press.]

1588
WHITBY, L. M., STOKES, P. M., HUTCHINSON, T. D., and MYSLIK, G., 1976, Ecological consequence of acidic and heavy-metal discharges from the Sudbury smelters: Canadian Mineralogist, v. 14, p. 47-57.

The effects of heavy-metal emissions and acidic deposition on lakes in the Sudbury region are severe. Phytoplankton populations have been significantly reduced in many lakes close to the Coniston smelter, Falconridge, and Copper Cliff. The levels of nickel (up to 6.5 ppm) and copper (up to 0.2 ppm) in these lakes, combined with acidity, are causing major problems to the survival of primary producers. The food chain has become extinct in some of the lakes, especially those in the northwest region of Sudbury. Sulfur dioxide emissions damage extensive areas of the forest, and soil acidification and erosion are common results. High concentrations of heavy metals accumulate in surface soils of a wide area, and the levels may be toxic to many species even in the absence of sulfur dioxide.

1589
WHITE, E. J., and TURNER, F., 1970, A method of estimating income of nutrients in a catch of airborne particles by a woodland canopy: Journal of Applied Ecology, v. 7, p. 441-461.

Presented is a method of estimating inputs of macronutrients (Potassium, magnesium, calcium, phosphorus, and sodium) to a woodland ecosystem in catch of airborne particles by the tree canopy. Catch at mean canopy height was continuously sampled in natural air-flow impactors, which were replaced monthly. Income of nurients per hectare per month is estimated. The method is based on some assumptions, such as turbulence, efficiency of catch, and characteristics of leaf surfaces. Some overestimation is detected, especially during windy months. Estimated mean velocity of deposition for elements studied varied from 3.0 to 7.1 cm/s.

1590
WHITE, W. H., HEISLER, S. L., HENRY, R. C., HIDY, G. M., and STRAUGHAN, I. R., 1978, The same-day impact of power plant emissions on sulfate levels in the Los Angeles air basin, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 779-784.

On the basis of emissions inventories, power plants are estimated to contribute about 45% of the SO_2 released annually in the Los Angeles Basin. The day-to-day variability of SO_2 emissions from power plants is comparable to the day-to-day variability of the basin's ambient sulfate concentrations. This paper examines the statistical relationship between the daily SO_2 emmissions of Los Angeles power plants and the 24-h average sulfate concentration monitored at West Covina, a "receptor" site characterized by high sulfate levels. Little correlation between emissions and ambient levels is found, even after much of the influence of meteorology has been factored out. The lack of correlation is consistent with the hypothesis that sulfate production in the Los Angeles Basin is limited by factors other than sulfur emissions. It is also consistent with the hypothesis that sulfate production is a linear function of sulfur emissions, if only a small fraction of the average sulfate concentration at West Covina is contributed by the same-day emissions of Los Angeles power plants. [Abstract reprinted by permission of Pergamon Press.]

1591
WHITEHEAD, H. C., and FETH, J. H., 1964, Chemical composition of rain, dry fallout, and bulk precipitation at Menlo Park, California, 1957-1959: Journal of Geophysical Research, v. 69, no. 16, p. 3319-3333.

Winter precipitation at Menlo Park, Calif. was studied in two phases--rain and bulk precipitation--and each phase has its own distinct chemical characteristics. Rain is strongly influenced by the Pacific Ocean and San Francisco Bay. Dry fallout is strongly effected by locally derived materials in the atmosphere. Bulk precipitation is affected by both influences and has 4 to 10 times greater mineral concentration than rainwater. Bulk precipitation is considered the geochemically significant phase that should be used in studies of the contribution of atmospheric salts to surface-water and ground-water supplies, weathering, and plant growth. Bulk precipitation contains more dissolved minerals than rainwater.

1592
WHITTAKER, R. H., BORMANN, F. H., LIKENS, G. E., and SICCAMA, T. G., 1974, The Hubbard Brook ecosystem study--forest biomass and production: Ecological Monographs, v. 44, p. 233-252.

The Brookhaven system of forest dimension analysis is used to study ecosystems of watersheds at Hubbard Brook in New Hampshire. The study investigates (1) dimensional relations of deciduous forest trees, (2) forest productivity and biomass, and volume and surface dimensions of the watershed, (3) characterization of forest dynamics, and (4) nurient circulation in the forest community. The productivity and net ecosystem production of the Hubbard Brook forest is lower than other young temperate deciduous forests that have been studied. Analysis of stem wood volume increments shows an abrupt and significant decrease of 18 percent in volume growth and productivity from 1956-60 to 1961-65. Drought and increased acidity of rainfall may be responsible for the decrease in productivity.

1593
WIEDERHOLM, T., and ERIKSSON, L., 1977, Benthos of an acid lake: Oikos, v. 29, p. 261-267.

Presented are data on composition and distribution of benthic fauna in Lake Tresticke1n, an acid lake (pH 3.9 to 4.6) in western Sweden. Compared to fauna of three other lakes with higherr pH, the fauna of this lake is low in abundance, and few taxa are represented. The benthos of Lake Trestickeln is similar to that of a typically polyhumic reference lake. Mollusks and large crustaceans are absent, but chironomid species are numerous, and little or no reduction in their distribution is observed.

1594
WIERSMA, G. B., and BROWN, K. W., 1980, Background levels of trace elements in forest ecosystems, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-43, p. 31-37.

This study was conducted as part of a project to develop a pollutant monitoring system for biosphere reserves. Sampling was carried out in the Great Smoky Mountains National Park and Olympic National Park. Results are reported for copper, lead, manganese, aluminum, calcium, and phosphorus. Olympic National Park has much lower levels of lead and copper than Great Smoky Mountains National Park. Moss appeared to be a good collector for lead and copper. Results indicate that reference levels for trace elements can be established for remote areas, although they cannot be considered true background levels. [Abstract reprinted by permission of U.S. Forest Service.]

1595
WIKLANDER, Lambert, 1974, The acidification of soil by acid precipitation: Grundforbattring, v. 26, no. 4, p. 155-164.

This article describes the effect of acid precipitation on soil cation exchange. Acidification of soils results in a decrease of pH and base saturation. This reaction is caused by the replacement of exchangeable base cations such as Ca^{2+}, Mg^{2+}, K^+, and Na^+ by H_3O^+ from precipitation. The ability of H_3O^+ to replace base cations is determined by (1) soil pH, (2) degree of base saturation, (3) cation exchange capacity, and (4) acidic strength of the cation exchanging groups. The concentration of H_3O^+, NH_4^+, and Ca^{2+}, Mg^{2+}, Na^+, and K^+ in precipitation also affects cation exchange. Acid precipitation and nitrified NH_4^+ have significant cation replacing and dissolving effects in neutral and slightly acid soils, but in highly acidic soils the effect is weaker. The adverse effects of acidic atmospheric deposition on soils are related to buffering capacity of the soil and the amount of neutral salts deposited on the ground. Calcareous soils and cultivated soils have high buffering capacity and low sensitivity.

Slightly acidic, sandy soils and loams are more sensitive to acidification.

1596
WIKLANDER, Lambert, 1975, The role of neutral salts in the ion exchange between acid precipitation and soil: Geoderma, v. 14, p. 93-105.

The deposition of neutral salts by precipitation or other mechanisms to the ground reduces the acidification of soils by acid precipitation. The effect of neutral salts on soil acidification is caused by cation exchange occurring after the rainwater contacts the soils. Acid components of precipitation are H_2SO_4, HNO_3, HCl, and HN_4^+ after nitrification in the soil. The significance of the salt effect depends on the bonding energy of H_3O^+, and the cations Ca^{2+}, Mg^{2+}, Na^+, K^+, NH_4^+ in the soil. The concentrations of H_3O^+ and the cations listed above in precipitation also affect the role of neutral salts. The salt effect may be significant in very acidic soils; however, it decreases with rising pH to become very small or negligible in neutral soils, mostly because of the increasing bonding energy of H_3O^+. Slightly acidic and neutral soils with low buffering capacity against changes in pH are more likely to be adversely affected by acid precipitation than very acidic soils.

1597
WIKLANDER, Lambert, 1980, Interaction between cations and anions influencing absorption and leaching, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 239-254.

1598
WIKLANDER, Lambert, 1980, The sensitivity of soils to acid precipitation, in Hutchinson, T. C., and Havas, M., eds., Effects of acid precipitation on terrestrial ecosystems: NATO Conference on Effects on Acid Precipitation on Vegetation and Soils, Toronto, Canada, 1978: New York, Plenum Press, p. 553-567.

1599
WILLEN, Torbjorn, 1972, The gradual destruction of Sweden's lakes: Ambio, v. 1, no. 1, p. 6-14.

The deterioration and eutrophication of fresh and coastal waters in Sweden have been steadily increasing. Reported here are results of a study titled "The Lake Malaren Research Project," which began in 1964. An increase in population in the drainage basin of Lake Malaren and industrial wastes draining into the lake have caused increased water pollution. This article discusses the effects of pH changes on flora and fauna and includes information on the acidification of other lakes in Sweden.

1600
WILLIAMS, R. M., 1981, Exchange of particles and gases across water surfaces, in Eisenreich, S. J., ed., Atmospheric pollutants in natural waters: Ann Arbor, Mich., Ann Arbor Science, p. 67-78.

1601
WILSON, B. D., 1923, The quantity of sulfur in rain water: Journal of the American Society of Agronomy, v. 15, p. 453-456.

This article discusses results of investigations on sulfur in rainwater at Ithaca, New York. Data presented indicate a wide range in sulfur content of rainwater from year to year; distance from cites and industries seems to be the most significant factor. The amount of sulfur added to the soil by precipitation in a given year is dependent on the amount of annual rainfall.

1602
WILSON, B. D., 1926, Nitrogen and sulfur in rainwater in New York: Journal of the American Society of Agronomy, v. 18, p. 1108-1112.

Rainwater samples were collected at sites at Ithaca, Brockport, and Alfred, N.Y., and analyzed for sulfur and nitrogen. Nitrogen of rainwater was mostly in the form of ammonia. The concentrations differed among sites and varied from year to year at the same site. The quantity of sulfur deposited by rain is largely dependent on annual preciptation quantity. The data indicate that rainfall during winter months contained a greater amount of sulfur than in summer.

1603
WILSON, Jerre, MOHNEN, V. A., and KADLECEK, J. S., 1980, Wet deposition in the northeastern United States: Albany, State University of New York, Atmospheric Sciences Research Center, 139 p.

Wet deposition and concentration of pollutants at selected stations in the northeastern United States are being studied to determine the origin of air masses. This report describes a regional deposition pattern of dominant ion species. The data suggest that acidic atmospheric deposition occurs over the entire northeastern United States.

1604
WILSON, W. E., 1978, Sulfates in the atmosphere--a progress report on project MISTT, in Sulfur in the atmosphere, Proceedings of the International Symposium, Dubrovnik, Yugoslavia, 1977: New York, Pergamon Press, p. 537-547.

The size and sulfate content of atmospheric aerosols and the rate and mechanisms for sulfate formation from sulfur dioxide in power plant plumes are reviewed. Emphasis is given to results from the recent USEPA study, Project MISTT (Midwest Interstate Sulfur Transformation and Transport). The rate of conversion of sulfur dioxide to sulfate aerosol in power plant plumes is low near the point of emission, but increases to several percent h^{-1} as ambient air mixes with the plume. Tall stacks reduce ground level concentrations of sulfur dioxide, resulting in a reduction of the amount removed by dry deposition. In urban plumes, which are well-mixed to the ground near the source, sulfur dioxide is removed more rapidly by dry deposition. Thus, tall stacks increase the atmospheric residence time of sulfur dioxide, which leads to an increase in atmospheric sulfate formation. These sulfate aerosols may be transported over distances of several hundred kilometers and produce air pollution episodes far from the pollution source. [Abstract reprinted by permission of Pergamon Press.]

1605
WILSON, W. E., and GILLANI, N. V., 1979, Transformation during transport--a state of the art survey of the conversion from SO_2 to sulphate, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 157-164.

1606
WILT, R. W., 1979, Acid rain--a lawmaker's response, in Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 298-301.

1607
WINCHESTER, J. W., 1976, Approaches to evaluating dry deposition of atmospheric aerosol pollutants onto lake surfaces: Journal of Great Lakes Research, v. 2, Supplement no. 1, p. 33-41.

Atmospheric transport as a pathway of pollutants to lake water is difficult to assess quantitatively. Dry deposition of particulate matter on the lake surfaces is especially difficult to quantify. This article discusses some approaches to laboratory and field investigations.

1608
WINCHESTER, J. W., FEREK, R. J., LAWSON, D. R., PILOTTE, J. O., THIEMENS, M. H., and WANGEN, L. E., 1979, Comparison of aerosol sulfur and crustal element concentrations in particle size fractions from continental U.S. locations: Water, Air, and Soil Pollution, v. 12, p. 431-440.

This article compares concentrations of sulfur (S), silicone (Si), potassium (K), calcium (Ca), titanium (Ti), iron (Fe), and zinc (Zn) in aerosol samples as a function of particle size during April 1976 at nonurban sites in New Mexico, Colorado, and New Hampshire, and at urban and nearby rural sites at St. Louis. S occurred predominately in the coarse particle (>1 µm) fraction and exceeded Si, K, Ca, Ti, and Fe in the submicrometer diameter range at all sites. Particle-size distributions for each element were similar among the five sites; however, prominent concentration anomalies and secondary size distribution differences were noted. This suggests differences in aerosol production processes and in strengths of relative pollution sources.

1609
WINCHESTER, J. W., and NIFONG, G. D., 1971, Water pollution in Lake Michigan by trace elements from pollution aerosol fallout: Water, Air, and Soil Pollution, v. 1, no. 1 p. 56-64.

1609 (continued)
Air pollution along the southwest shores of Lake Michigan may be a significant source of trace elements contributed to the lake. This article presents an inventory of 30 trace elements derived from stack emissions in Chicago, Milwaukee, and metropolitan areas of northwest Indiana. The inventory is compared with contributions of zinc (Zn), copper (Cu), and nickel (Ni) to streams and estimates of preindustrial unpolluted contributions of 28 elements to streams. Results indicate that the atmosphere may be a major source of Zn to Lake Michigan, and atmospheric contributions of Cu and Ni to Lake Michigan are considerable. Data also show that atmospheric deposition of additional elements to Lake Michigan may result in additional water pollution problems.

1610
WINKLER, E. M., 1976, Natural dust and acid rain: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 295-302.

Atmospheric dust originates from three sources: terrestrial airborne matter, volcanic, and cosmic. Terrestrial natural dust makes up the main bulk reflecting the soil composition to 150 mi away. Soil erosion from flood plains, plowed fields and construction sites is the main source. Quartz, feldspar, the carbonates calcite and dolomite, and clay minerals are the components in decreasing order of frequency. Natural dust in the atmosphere interacts with rainwater converting the carbonates to benign gypsum ($CaSO_4$, $2H_2O$). Naturally leached soils produce less calcite than unweathered sediments on flood plains and construction sites, and in granitic and crystalline rocks less than in limestone areas.

Heavy industrialization associated with high emission of CO_2 and SO_2 on the one hand, and excess production of dust on the other, appears to counteract man's interference with natural ecosystems in the opposite direction. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1611
WISNIEWSKI, Joe, and COTTON, W. R., 1977, Chemical analysis of south Florida's environment, in Precipitation scavenging, Champaign, Ill., 1974, Proceedings: [Oak Ridge, Tenn.], U.S. Energy Research and Development Administration, ERDA Symposium Series 4, p. 611-624.

A total of 280 rainwater samples were collected over South Florida during the 1973 Florida Area Cumulus Experiment (FACE). These samples were collected both on the surface and at the cloud-base level (600 m) aboard the NOAA-DC6 (39C) aircraft. All 280 samples were analyzed for silver and lead concentrations. Twenty-four were analyzed

1611 (continued)
for five inorganic nonmetallic pollutants (SO_3, SO_4, NO_2, NO_3, and NH_4) and pH. Approximately 100 were analyzed for pH and four of the species mentioned above, five common ions (sodium, potassium, magnesium, calcium, and chlorine), ortho-PO_4, and total dissolved iron. These analyses are discussed with regard to variations between cloud-base peninsula samples, cloud-base marine samples, surface rural samples, and surface urban (Miami) samples. Comparisons of results with other sampling networks are discussed.

A more extensive and continuous 2-year surface rainwater collection network began operations during mid-July 1974 in South Florida. Rainwater is being collected by several groups; the National Oceanic and Atmospheric Administration (NOAA) Laboratories, the Central and South Florida Flood Control District, the U.S. Army Corps of Engineers, and the Everglades National Park Service. Samples are being analyzed at the Central and South Florida Flood Control Laboratories. Analyses for SiO_2, total PO_4, and alkalinity have been added to the 1973 list of chemical constituents. The network and preliminary results are discussed. Some general problems to be aware of when designing and operating a rainwater collection network are discussed. Specific examples from the South Florida studies are given.

1612
WISNIEWSKI, Joe, and MILLER, J. M., 1977, A critical review of precipitation chemistry studies--North America and adjacent areas, in World Meteorological Organization, Air pollution measurement techniques: Geneva, Switzerland, World Meteorological Organization, Special Environmental Report no. 10, WMO-no. 460, p. 63-69.

1613
WODZNISKI, R. S., and ALEXANDER, Martin, 1978, Effect of sulfur dioxide on algae: Journal of Environmental Quality, v. 7, no. 3, p. 358-360.

Soil with a pH of 7.1 was exposed to 0.5 ppm of sulfur dioxide (SO_2) in air for 10 days. During that time, photosynthetic activity was unaffected. The photosynthetic activity of *Anabeana flosaquae* and *Chlamydomonas reinhardtii* suspended in a thin layer of medium at pH 6.0 was almost totally inhibited within 24 hours by treatment with 1.0 ppm of SO_2 in air. The pH of the medium decreased to 5.2 or below at this time. When a phosphate buffer was added to the soil, no inhibition of photosynthesis was observed. However, the addition of an acidic soil to a medium of pH 4.9 gave no protection from the adverse effects of SO_2. The data suggest that the decrease in pH of samples exposed to SO_2 was not the only cause of inhibition of photosynthetic activity.

1614
WODZINSKI, R. S., LABEDA, D. P., and ALEXANDER, Martin, 1977, Toxicity of SO_2 and NO_x--selective inhibition of blue-green algae by bisulfite and nitrite: Journal of the Air Pollution Control Association, v. 27, no. 9, p. 891-893.

This article investigates the sensitivity of blue-green algae to bisulfate and nitrate, which are readily produced in water from sulfur dioxide (SO_2) and nitrogen oxides (NO_x), respectively. Microorganisms were exposed to bisulfate at concentrations of 0.1 and 1.0 mM and nitrite at a concentration of 1.0 mM. The results of the investigation demonstrate that blue-green algae are perhaps one of the microbial groups most sensitive to adverse affects of sulfur dioxide and nitrogen oxide pollution. Because blue-green algae are the dominant N_2-fixing organisms in some ecosystems, the sensitivity of blue-green algae to atmospheric SO_2 is a critical factor.

1615
WOLFF, G. T., LIOY, P. J., GOLUB, Howard, and HAWKINS, J. S., 1979, Acid precipitation in the New York metropolitan area--its relationship to meteorological factors: Environmental Science and Technology, v. 13, no. 2, p. 209-212.

This article summarizes the spatial meteorological, and seasonal factors associated with pH of precipitation of eight sites in the New York metropolitan area during 1975-77. pH varied among the eight sites; the mean pH was 4.28, and the lowest seasonal values occurred during summer. Showers and thunderstorms associated with cold fronts and air masses yielded the lowest pH values--4.17 and 3.91, respectively. Somewhat higher values were produced by closed low-pressure systems. Air mass and frontal storms were generally associated with winds from the west and southwest according to air-parcel trajectory analyses.

1616
WOOD, J. M., 1980, The role of pH and oxidation-reduction potentials in the mobilization of heavy metals, in Toribara, T. Y., Miller, M. W., and Morrow, P. E., eds., 1980, Polluted rain: New York, Plenum Press, p. 223-236.

The effect of pH and standard reduction potential (E°) is discussed in terms of the kinetics and mechanisms for the biomethylation of a number of toxic metals. In the aerobic environment, conditions have been delineated to explain the methylation of Hg^{II}, Pb^{IV}, and Se^{VI} compounds.

The methylation and mobilization of mercury is especially important in lakes which are susceptible to acid precipitation. The accumulation of methylmercury in fish taken from

1616 (continued)
acid-sensitive oligotrophic lakes is rationalized in terms of the chemistry and biochemistry of mercury compounds. [Abstract reprinted by permission of Plenum Press.]

1617
WOOD, L. W., 1978, Limnology of remote lakes in the Adirondack region of New York State with emphasis on acidification problems: Albany, New York State Department of Health, Environmental Health Report no. 4, 65 p.

Fifty-seven lakes in the Adirondack Mountains of New York were surveyed in August 1975 to study limnlogical features and trophic characteristics and to determine effects caused by acid precipitation. The pH of lakes ranged from 3.95 to 6.47, and the most acidic lakes were those in the western part of the region, except for two lakes at higher elevations in the central region. High acidity was significantly correlated with the absence of fish and with concentration of lead in the water column. Relatively high concentrations of lead were observed in the lake water (mean 2 µg/L). The source of acidity was probably atmospheric sulfate originating in Cleveland, Ohio; Erie, Penn., and Buffalo, N.Y.

1618
WOOD, L. W., 1979, Limnology of remote lakes in the Adirondack region of New York State with emphasis on acidification problems, in Tzard, H. H., and Jacobson, J. S., 1978, Public Meeting on Acid Precipitation, Lake Placid, N.Y., Scientific papers: Albany, N.Y., New York State Assembly, Science and Technology Staff, p. 119-120.

1619
WOOD, M. J., ed., 1979, Ecological effects of acid precipitation--report of a workshop, Galloway, Scotland, 1978, Proceedings: Palo Alto, Calif., Electric Power Research Institute, EPRI EA-79-6-LD, 1 v.

This volume presents 6 papers on chemistry and deposition of precipitation, vegetation interactions and effects, soil interactions and effects, surface waters aquatic ecology, fish and fisheries, and mathematical modeling of the lake-acidification process that were given at a 1978 workshop sponsored by the Electric Power Research Institute. Some of the conclusions indicate the need for additional research on the interactions between acidic atmospheric deposition and vegetation and soils. Acidic surface waters can be characterized by the relationship between pH and Ca++, which is an indicator of abnormal progressive acidification of surface waters. It is suggested that bicarbonate is lost in acid lakes and is replaced by an equivalent amount of sulfate; therefore, excess sulfate concentration may also be used as an indicator of acidification.

1620
WOOD, M. J., 1979, International inventory of current and planned research projects on acid precipitation: Palo Alto, Calif., Electric Power Research Institute, EPRI SOA77-403, 1 v.

This report gives a summary of current and planned research projects on the ecological effects of acidic deposition. The following information on each project is given: (1) sponsoring agency, (2) performing agency, (3) project leader, (4) number of staff, and (4) project description.

1621
WOOD, Tim, and BORMANN, F. H., 1974, The effects of an artificial acid mist on the growth of *Betula alleghaniensis* Britt.: Environmental Pollution, v. 7, p. 259-269.

This article describes the effects of acidity on the growth and development of plants. Yellow birch (*Betula alleghaniensis* Bri H.) seedlings were exposed to simulated acid rain with pH ranging from 4.7 to 2.3 for intervals up to 15 weeks. Foliar tissue damage occurred at pH 3.0 and below, and significant growth decreases were observed at pH 2.3.

1622
WOOD, Tim, and BORMANN, F. H., 1975, Increases in foliar leaching caused by acidification of an artificial mist: Ambio, v. 4, no. 4, p. 169-171.

The rate of nutrient cation leaching from leaves of plants may be significantly affected by precipitation acidity. Foliar leaching may involve cation exchange processes in which hydrogen ions in rain replace nutrient cations held on binding sites in the leaf cuticle. The effects of acid mist on leaching from pinto bean and sugar maple leaves are examined. Foliar leachate was collected and analyzed for sodium, potassium, magnesium, and calcium cation concentrations. Foliar losses of potassium, magnesium, and calcium from the bean and maple seedlings increased as the acidity of the artificial mist increased. Tissue damage caused by high H+ concentrations occurred at pH 3.0 and below and may have contributed to the increased cation losses found at these levels. Significant increases in leaching were observed at pH 3.3 and 4.0 when no tissue injury was observed.

1623
WOOD, Tim, and BORMANN, F. H., 1977, Short-term effects of a simulated acid rain upon the growth and nutrient relations of *Pinus strobus*, L.: Water, Air, and Soil Pollution, v. 7, no. 4, p. 479-488.

Acidified precipitation may affect the productivity of forests by altering the availability of plant nutrients or by affecting the

1623 (continued)
ability of trees to absorb and assimilate those nutrients. In this study, the short-term effects of simulated acid rain (pH range 5.6 to 2.3) upon the growth and nutrient relations of Eastern White Pine seedlings (*Pinus strobus*, L.) grown in a sandy loam soil were examined. Soil chemistry, soil leachate chemistry, seedling tissue chemistry, and seedling productivity were monitored.

Despite increased leaching of cations from the soil, resulting in near depletion of available K^{+1}, Mg^{+2}, and Ca^{+2} at pH 2.3, seedling productivity increased with acidity through the 20-week experimental period. Foliar nitrogen concentrations indicate that fertilization with NO_3^{-1}, added to the rain as HNO_3, may have caused the growth increase. Implications of cation losses and NO_3^{-1} fertilization are discussed. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1624
WRIGHT, R. F. CONROY, N. I., DICKSON, W. T., HARRIMAN, R., HENRIKSEN, Arne, and SCHOFIELD, C. L., 1980, Acidified lake districts of the world--a comparison of water chemisty of lakes in southern Norway, southern Sweden, southwestern Scotland, the Adirondack Mountains of New York, and southeastern Ontario, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 377-379.

1625
WRIGHT, R. F., DALE, Torsetin, GJESSING, E. T., HENDREY, G. R., HENRIKSEN, Arne, JOHANNESSEN, Merete, and MUNIZ, I. P., 1976, Impact of acid precipitation on freshwater ecosystems in Norway: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 483-499.

Extensive studies of precipitation chemistry during the last 20 yr have clearly shown that highly polluted precipitation over large areas of Scandinavia, and that this pollution is increasing in severity and geographical extent. Precipitation in southern Norway, Sweden, and Finland contains large amounts of H^+, $SO_4^{=}$, and NO_3^- ions, along with heavy metals such as Cu, Zn, Cd, and Pb, that originate as air pollutants in the highly industrialized areas of Great Britain and central Europe and are transported over long distances to Scandinavia, where they are deposited in precipitation and dry-fallout.

In Norway the acidification of fresh waters and accompanying decline and disappearance of fish populations were first reported in the 1920s, and since then in Sorlandet (southernmost Norway) the salmon have been eliminated from several rivers, and hundreds of lakes have lost their fisheries.

Justifiably, acid precipitation has become Norway's number-one environmental problem, and in 1972 the government launched a major research project entitled "Acid precipitation--effects on forest and fish" (the SNSF-project). Studies of freshwater ecosystems conducted by the SNSF-project include intensive research at 10 gauged watersheds and lake basins in critical acid-areas of southern Norway, extensive surveys of the geographical extent and severity of the problem over all of Norway, and field and laboratory experiments on the effect of acid waters on the growth and physiology of a variety of organisms.

Large areas of western, southern, and eastern Norway have been adversely affected by acid precipitation. The pH of many lakes is below 5.0, and sulfate, rather than bicarbonate, is the major anion. Lakes in these areas are particularly vulnerable to acid precipitation because their watersheds are underlain by highly resistant bedrock with low Ca and Mg contents.

Apart from the well-documented decline of fish populations, relatively little is known about the effects of acid precipitation on the biology of these aquatic ecosystems. Biological surveys indicate that low pH-values inhibit the decomposition of allochthonous organic matter, decrease the species number of phyto- and zooplankton and benthic invertebrates, and promote the growth of benthic mosses.

Acid precipitation is affecting larger and larger areas of Norway. The source of the pollutants is industrial Europe, and the prognosis is a continued increase in fossil-fuel consumption. The short-term effects of the increasing acidity of freshwater ecosystems involve interference at every trophic level. The long-term impact may be quite drastic indeed. [Abstract reprinted by permission of D. Riedel Publishing Company.]

1626
WRIGHT, R. F., and DOVLAND, Harald, 1978, Regional surveys of the chemistry of the snowpack in Norway, late winter 1973, 1974, 1975, and 1976: Atmospheric Environment, v. 12, p. 1755-1768.

Snowpack samples were collected from sites in Norway in late winters of 1973-76 and adjacent areas of Sweden and Finland in 1976. Samples were analyzed for major ions and several trace metals. Results show that the snowpack in southeastern and northernmost Norway is characterized by high concentrations of hydrogen ion (H^+), sulfate

1626 (continued)
(SO_4^{--}), nitrate (NO_3^-), and ammonium ion (NH_4^+) components that principally come from the long-range transport of air pollutants. Snowpack along the west and northwest coast is characterized by seawater salts, chlorine (Cl), sodium (Na), and magnesium. The two patterns of concentrations of components in the snowpack are similar to those in fresh precipitation collected at 16 sites in Norway. Component concentrations in snowpack are less than those measured in winter precipitation probably as a result of mid-winter melting that preferentially depletes the chemical impurities in the snowpack.

1627
WRIGHT, R. F., and GJESSING, E. T., 1976, Acid precipitation: Changes in the chemical composition of lakes: Ambio, v. 5, no. 6, p. 219-223.

Freshwaters in large areas of northern Europe and eastern North America are being acidified by atmospheric pollutants. Many of the lakes in these regions have low buffering capacities and are thus vulnerable to inputs of acidity. Some of the affects of acidic atmospheric deposition on lakes are loss of fish populations and the disturbance of vital ecosystem components and processes.

1628
WRIGHT, R. F., HARRIMAN, R., HENRIKSEN, Arne, MORRISON, B., and CAINES, L. A., 1980, Acid lakes and streams in the Galloway area, southwestern Scotland, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 248-249.

1629
WRIGHT, R. F., and HENRIKSON, Arne, 1978, Chemistry of small Norwegian lakes, with special reference to acid precipitation: Limnology and Oceanography, v. 23, no. 3, p. 487-498.

Major ion concentrations of 155 small, pristine lakes in southern Norway were determined. Results indicate that (1) atmospheric inputs of seawater salts supply most of the Cl and Na, (2) acid precipitation supplies most of the SO_4 and H^+, and (3) terrestrial inputs of chemical weathering products account for most of the Ca, Mg, and HCO_3. The interaction between the geologic environment and acid precipitation affects the pH of the lakes. Lakes underlain by granitic terrains have low concentrations of major ions, low buffering capacities, and are commonly acidic (pH <5) in areas subject to acid precipitation, and sulfate is the major ion. Lakes underlain by granitic terrains that are not subject to highly acidic precipitation have pH levels >5.5, and bicarbonate is the major anion.

1630
WRIGHT, R. F., and JOHANNESSEN, Merete, 1980, Input-output budgets of major ions at gauged catchments in Norway, in Drablos, D., and Tollan, Arne, eds., 1980, Ecological impact of acid precipitation: International Conference, Sandefjord, Norway, 1980, Proceedings: Oslo, Norway, SNSF Project, p. 250-251.

1631
WRIGHT, R. F., and SNEKVIK, Einar, 1978, Acid precipitation—chemistry and fish populations in 700 lakes in southernmost Norway: International Association of Theoretical and Applied Limnology, Proceedings, v. 20, p. 765-775.

A survey of 700 small lakes (0.1-1.0 km^2) in Sorlandet (southernmost Norway) was conducted in 1974-75 to determine concentrations of major chemical components. The pH and conductivity of the lakes were determined, and qualitative information on fish populations was investigated. The chemical composition of lakes in Sorlandet shows distinct and regular geographic patterns, and adjacent lakes are similar. The pH levels range from 4.4 to 4.6 in lakes near the coast to 5.0 to 5.2 in lakes 100 km inland. It is suggested that precipitation chemistry is the dominating influence on lake water chemistry in this region. Fish populations, particularly brown trout (*Salmo trutto* L.), have been eliminated from 40 percent of the lakes; an additional 40 percent have sparse populations. The reproductive process in fish is the most sensitive to acid stress; hence recruitment has completely or partially failed in 80 percent of the lakes. Multiple linear regression analyses of fish and chemical data indicate that pH and Ca are the two most important factors relating to fish status in acid lakes.

1632
WRIGLEY, J., APSIMON, H. M., and GODDARD, A. J. H., 1979, Meteorological data and the MESOS model for long-range transport of atmospheric pollutants, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 281-288.

Y

1633
YAALON, D. H., 1964, The concentration of ammonia and nitrate in rain water over Israel in relation to environmental factors: Tellus, v. 16, no. 2, p. 200-204.

1633 (continued)
Composite rainwater samples were collected monthly at seven sites in Israel and analyzed for ammonia and nitrate. Ammonia concentration showed a significant dependence on soil temperature. The mean concentration of ammonium ion during the winter was 0.17 equivalents per million (epm), and the concentration increased fourfold during spring. The release of pedogenic ammonia from calcareous soils, which is accelerated at the beginning of spring, is considered the major source of the ammonia. Nitrate concentration was less variable and averaged 0.04 epm during the winter.

1634
YAMAZOE, F., and MAYUMI, H., 1977, Vegetation injury from interaction of mixed air pollutants, in International Clean Air Congress, 4th, Tokyo, 1977, Proceedings: Tokyo, Japanese Union of Air Pollution Association, p. 106-109.

The effect of mixed air pollutants on vegetation is synergistic and occasionally antagonistic. This article investigates changes of plant ingredients after fumigation with mixed air pollutants and the relationship between susceptibility of plant species to mixed gases and climatic or cultural conditions. A typical symptom of plant injury by air pollution is discoloration of leaves. Light seems to be the major factor affecting plant sensitivity to pollutants. Nitrogen oxides are probably less poisonous to vegetation than sulfur oxides or the oxidants.

1635
YAN, N. D., 1978, Acid precipitation--a review: Toronto, Canada, University of Toronto, Pub. No. EE-9, 35 p.

This report discusses worldwide literature on acid precipitation. Major topics include precipitation processes, composition, chemical contribution to watersheds, and sources of strong acids. References to research on atmospheric transformations of sulfur dioxide and deposition and long-range transport of sulfur compounds are included. Research on the impacts on acid preciptation on aquatic and terrestrial ecosystems is also documented.

1636
YAN, N. D., 1979, Phytoplankton community of an acidified, heavy metal--contaminated lake near Sudbury, Ontario--1973-1977: Water, Air, and Soil Pollution, v. 11, p. 43-55.

Presented are data on phytoplankton collected from Clearwater Lake near Sudbury, Ontario. The lake is acidic and contaminated by heavy metals. *Peridinium inconspicuum* comprises 30 to 55 percent of the average biomass of 0.33 to 0.73 mg/L during ice-free periods. Data are compared with those from three other contaminated lakes and 10 uncontaminated lakes in Ontario. Phytoplankton communitites of all contaminated lakes were dominated by *P. inconspicuum*, and chrysophytes dominated the uncontaminated lakes.

1637
YAN, N. D., GIRARD, R. E., and LAFRANCE, C. J., 1979, Survival of rainbow trout, *Salmo gairdneri*, in submerged enclosures in lakes treated with neutralizing agents near Sudbury, Ontario: Rexdale, Ontario, Limnology and Toxicity Sections, Ontario Ministry of the Environment, 26 p.

A submersible enclosure was designed for short-term experiments to measure the survival of rainbow trout in three lime-treated lakes near Sudbury, Ontario. Rates of trout mortality were rapid in two lakes (Middle and Lohi) from which fish populations has been previously eliminated, possibly because of copper toxicity and acidification. Fish survived much longer in Lake Panache, the third lake, which supports a good fishery. Despite reductions in heavy-metal concentrations through experimental neutralization of the lakes, levels of copper and possibly zinc and nickel acting in conjunction with copper remained high enough to cause the observed fish mortalities.

1638
YAN, N. D., JONES, J. D., CAVE, B., SCOTT, L., and POWELL, M., 1977, The effects of experimental elevation of lake pH on the chemistry and biology of Nelson Lake near Sudbury, Ontario: Rexdale, Ontario, Limnology and Toxicity Section, Ontario Ministry of the Environment, 27 p.

Changes in the chemistry and biology of acidic Nelson Lake near Sudbury, Ontario, following a two-stage addition of base and carbonate were studied. The addition of calcium hydroxide and calcium carbonate raised the pH of the lake from 5.7 to 6.5. The base treatment did not affect lake temperature, oxygen structure, or nutrient content. Decreases in concentrations of iron, manganese, aluminum, and copper in the water column were observed. Phytoplankton and zooplankton communities of Lake Nelson were similar to those found in nonacidic shield lakes. Benthic and fish communities, however, were affected by acidification.

1639
YAN, N. D., SCHEIDER, W. A., and DILLON, P. J., 1977, Chemical and biological changes in Nelson Lake, Ontario, following experimental elevation of lake pH, in Canadian Symposium on Water Pollution Research, 12th, Toronto, 1977, Proceedings: Toronto, Institute for Environmental Studies, University of Toronto, Water Pollution Research in Canada, no. 12, p. 213-231.

1639 (continued)
The pH of Nelson Lake, near Sudbury, Ontario, was 5.7 in 1975. The chemistry of the lake was characteristic of most Precambrian Shield Lakes; however, low alkalinity, high sulfate concentrations, and elevated levels of heavy metals were observed. When the lake was treated with calcium hydroxide and calcium carbonate, the pH rose to 6.4, and concentrations of heavy metal returned to background level. Phytoplankton and zooplankton communities were not affected by the pH elevation.

1640
YAN, N. D., and STOKES, P. M., 1976, The effects of pH on lake water chemistry and phytoplankton in a LaCloche mountain lake, in Canadian Symposium on Water Pollution Research, 11th, Canadian Center for Inland Waters, 1976, Proceedings: Toronto, Institute for Environmental Studies, University of Toronto, Water Pollution Research in Canada, no. 11, p. 127-137.

A study was conducted on the effects of pH on water chemistry and phytoplankton in Carlyle Lake in the La Cloche Mountain region of Ontario. The pH of water in cylinders floating in the lake was maintained at 4.0, 5.0, and 6.5 for 6-week periods by the addition of sulfuric acid or sodium hydroxide. Phytoplankton biomass was estimated, and species were identified and quantified regularly during the experiment. Maximum algal biomass in the cylinders occurred at pH 5.0, which was close to the pH of the lake. Major taxa had a maximum biomass near pH 5.0 except *Cryptomonas ovata* E., *Chroomonas candata* G., and *Peridinium limbatum* (Stokes) L., which had biomass maxima at pH 4.0.

1641
YAN, N. D., and STOKES, P. M., 1978, Phytoplankton of an acidic lake, and its responses to experimental alternations of pH: Environmental Conservation, v. 5, no. 2, p. 93-100.

Carlyle Lake in the La Cloche Mountains of Ontario is morphometrically typical of Precambrian Shield lakes. The pH of the lake was reduced to 4.5 by acidic snowmelt in spring 1974. The pH is about 5.0 in summer, which suggests a low buffering capacity. Biomass of the phytoplankton community is not typical of oligotrophic circumneutral lake. No reduction of phytoplankton community biomass was observed during the study. When pH falls below 5.6 and the number of phytoplankton species is reduced, community diversity seems to be a more sensitive indicator of lake acidification than community biomass.

1642
YAN, N. D., and STRUS, R., 1980, Crustacean zooplankton communities of acidic, metal-contaminated lakes near Sudbury, Ontario: Canadian Journal of the Fisheries and Aquatic Sciences, v. 37, no. 12, p. 2282-2293.

Data on zooplankton in Clearwater Lake, which is acidic and contaminated by heavy metals, are compared with data from four other contaminated lakes near Sudbury and six uncontaminated lakes in the Muskoka-Haliburton region of Ontario. Community biomass and species richness are reduced in the contaminated lakes. The greatest reductions is in Hannah Lake, which also has the highest levels of metals. Cladocera form 80-96 percent of the average biomass in the ice-free period in Clearwater Lake, one of the contaminated lakes. Zooplankton biomass in the contaminated lakes, excluding Hannah Lake, was not significantly correlated with pH, copper, nickel, total phosphorus, or total phytoplankton biomass.

1643
YEAGER, K. E., 1971, Air pollution control for coal-fired power plants, in, Action Seminar on Acid Precipitation, Toronto, Canada, 1979, Proceedings: Toronto, Canada, ASAP Coordinating Committee, p. 191-196.

1644
YEE, M. S., BOHN, H. L., and MIYAMOTO, Seiichi, 1975, Sorption of sulfur dioxide by calcareous soils: Soil Science Society of America, Proceedings, v. 39, p. 268-270.

Sulfur dioxide sorption rates and sorption capacities of calcareous soils were measured by a steady-state method in which a stream of air and sulfur dioxide (SO_2) passes rapidly through soil. Air-dry calcareous soils were saturated with SO_2 from a gas stream within 15 minutes; this process was done at room temperature. Sorption capacities of 0.4 to 1.6 g of S per 100 g of soil at 0.34 percent SO_2 in air increased with SO_2 concentration and greater surface area of the soils. Moisture in the air and (or) soils increased the SO_2 sorption capacities.

1645
YOCOM, J. E., 1979, Air pollution damage to buildings on the Acropolis [Athens, Greece]: Journal of the Air Pollution Control Association, v. 29, no. 4, p. 333-338.

This article discusses the deterioration of principal buildings of the Acropolis in Greece and methods to prevent or ameliorate materials damage. The disfigurement and decay of these buildings is caused by air pollution, specifically from sulfur-

1645 (continued)
containing fuels used in the Athens area. Damage to the calcium carbonate and iron results primarily from chemical reactions between sulfur dioxide in the atmosphere and moisture. Several mechanisms by which air pollutants damage building materials are discussed.

1646
YOKOBORI, Makoto, 1978, Measuring of phytotoxic air pollution based upon response of bryophytes using a filtered-air growth chamber: Japanese Journal of Ecology, v. 28, p. 17-23. [In Japanese.]

The degree of phototoxicity of air was measured at nine sites near the Kashima industrial district by a small, filtered-air growth chamber in which gemmae of *Marchantia polymorpha* were cultivated. Rainwater samples were collected at the same sites and analyzed for sulfur dioxide, nitrogen oxide, nitrogen dioxide, pH, and electrical conductivity. The degree of phototoxicity of air was severe downwind from the pollution sources.

1647
YORDANOV, D., DJOLOV, G. D., and SYRAKOV, D., 1979, Influence of vertical motions induced by the frictional convergence in planetary boundary layer on long-range pollution, in WMO Symposium on the Long-Range Transport of Pollutants and its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria, 1979, Papers: Geneva, Switzerland, World Meteorological Organization, WMO-no. 538, p. 367-370.

1648
YOUNG, R. T., 1938, The effect of balanced versus unbalanced solutions of pH and distilled water on fish: Ecology, v. 19, no. 1, p. 126-140.

This article investigates the effects of varying salt concentrations, distilled water, and pH on surf perches, killifish (marine fish), and freshwater sunfish. The fish survive better in solutions of Na, K, Ca, and Mg than in solutions of one element alone; however, the exact proportion of these elements is considered less important. Sunfish can withstand a wide range in pH levels. Distilled water is fatal to the marine fish and sunfish, more by its lack of essential salts rather than low pH or toxicity.

1649
YOUNG, J. A., WOGMAN, N. A., TANNER, T. M., and THOMAS, C. W., 1976, Transport and deposition of pollutants downwind of St. Louis, in Atmosphere-Surface Exchange of Particulate and Gaseous Pollutants, Richland, Wash., 1974, Proceedings: [Oak Ridge, Tenn.], U.S. Energy Research and Development Administration, ERDA Symposium Series 38, p. 96-103.

1649 (continued)
The St. Louis Metropolitan area introduces large quantities of pollutant materials into the atmosphere. These contaminants are carried large distances by prevailing winds and may affect regions considerably downwind of St. Louis. The concentrations of trace elements, sulfates, SO_2, and Freon-11 have been measured in air samples collected upwind, in, and downwind of St. Louis during July of 1973 to determine the atmospheric concentrations of these contaminants producd by St. Louis and to determine the rates at which the concentrations are decreased downwind by atmospheric mixing processes, dry deposition on the earth's surface, and, in the case of SO_2, chemical reactions. The rate of decrease in concentration due to mixing processes was determined from the rate of decrease in concentration of the essentially conservative gas Freon-11, which is released in large quantities by aerosol spray cans.

The concentrations of lead, bromine, and SO_2 averaged 20 times higher at the Federal Building in downtown St. Louis than upwind of St. Louis.

The lead, bromine, and Freon-11 concentrations 20 miles downwind of the St. Louis arch averaged only 20%, 13%, and 60% respectively, of their downtown concentrations. On days with westerly winds the SO_2 concentrations 20 miles east of the arch averages 2.5 times higher than at the Federal Building, due to the large SO_2 sources along the Mississippi east of St. Louis. However, on days with easterly winds the SO_2 concentrations 20 miles west of the arch averaged only 65% of those at the Federal Building.

The lead, bromine, and Freon-11 concentrations 60 miles downwind of the arch averaged 68%, 74%, and 90%, respectively, of those at 20 miles. These numbers suggest that atmospheric mixing processes decreased the contaminant concentrations 10%, and dry deposition removed 20% between 20 miles and 60 miles downwind of St. Louis.

The SO_2 concentration decreased much more rapidly with distance, and the concentrations 60 miles downwind averaged only 27% of the concentrations 20 miles downwind, giving a calculated atmospheric half-residence time of 3.5 hr. The surface concentrations increased somewhat with distance downwind of St. Louis due to the conversion of SO_2 to sulfate. [Abstract reprinted by permission of U.S. Department of Energy.]

1650
YUE, G. K., MOHNEN, V. A., and KIANG, C. S., 1976, A mechanism for hydrochloric acid production in cloud: Water, Air, and Soil Pollution, v. 6, nos. 2,3,4, p. 277-294.

A theoretical model describing the general interaction between atmospheric trace gases,

1650 (continued)
such as SO_2, NH_3, CO_2, and O_2, chemical reactant gaseous product H_2SO_4 and hydrometeors containing NaCl is proposed to study a possible mechanism for HCl production in nonprecipitating cloud and the determination of the pH value of cloud droplets.

Four different cloud droplet distributions have been used to estimate the upper limit of the amount of gaseous HCl released into the atmosphere resulting from the evaporation of cloud droplets. It is shown that the acid production and the amount of HCl released depend on the following factors: (1) the temperature of the cloud; (b) the oxidation rates; (c) the ambient concentration of SO_2, NH_3, and H_2SO_4; (d) the life cycle of the cloud; and (e) the liquid content of the cloud.

This proposed chemical model also predicts a pH value spectrum depending on the cloud droplet distribution. Field measurements for the dependence of pH value on particle size and spatial distribution of gaseous HCl are recommended. [Abstract reprinted by permission of D. Riedel Publishing Company.]

Z

1651
ZASOSKI, R., DAWSON, H., and LESTELLE, L., 1977, Impacts of forest management practices on the aquatic environment--phase III: Seattle, Washington University, College of Forestry, 105 p.

Streams on the Quinault Reservation in Washington that have low pH and reduced salmonid production were studied to evaluate the impact of forest management practices on the aquatic environment. Streams in the Camp Creek watershed were studied through undisturbed soil columns and field lysimeters to monitor oxidation-reduction conditions, dissolved iron, organic matter, and solution pH. Stream waters in upper Camp Creek appear to be equilibrated with the acid soils. The low pH may originate from the oxidation of ferrous iron to ferric iron. Aeration of column effluents causes decreases in pH of up to 0.5 units; however, dissolved organics seem to stabilize ferrous ion in solution.

1652
ZEEDIJK, H., and VELDS, C. A., 1973, The transport of sulphur dioxide over a long distance: Atmospheric Environment, v. 7, p. 849-862.

An air-pollution monitor was tested by continuous measurement of sulfur dioxide concentration in the atmosphere at Eindhoven, The Netherlands. Air pollution was expected to be low because of the large-scale conversion of coal and oil to natural gas for industrial and domestic heating about a year before the investigation. The predictions generally were verified by the data, with the exception of high sulfur dioxide concentrations that occasionally occurred in easterly winds. These concentations were inconsistent with the relatively slight urbanization east of the measuring station. It is suggested that high sulfur dioxide concentrations at Eindhoven may be caused by long-range transport of pollutants from the German Ruhr area, located 100 km away, and from Antwerp.

1653
ZEMAN, L. J., 1975, Hydrochemical balance of a British Columbia mountainous watershed: Catena, v. 2, p. 81-94.

Precipitation and stream-water samples were collected weekly at 12 sites at the Jamieson Creek experimental watershed in Vancouver, from November 1970 to October 1971 and analyzed for 11 major constituents. There were net losses of sodium, potassium, calcium, magnesium, bicarbonate, sulfate, chloride, silica, and phosphate from the watershed in streamflow. Atmospheric fallout supplied most of the nitate, ammonium, sulfate, and chloride.

1654
ZEMAN, L. J., and NYBORG, E. O., 1974, Collection of chemical fallout from the atmosphere: Canadian Agricultural Engineering, v. 16, no. 2, p. 69-72.

Analytical data on wet and bulk precipitation at Point Grey, Vancouver, British Columbia are compared statistically, and the differences between these two types of fallout are calculated as percentage of bulk fallout. Samples were analyzed for sodium, potassium, magnesium, bicarbonate, sulfate, chloride, nitrate, silica, ammonium, and phosphate. Higher concentrations of silica, calcium, magnesium, potassium, and bicarbonate in bulk precipitation most likely result from local sources of mineral soil dust. Anthropogenic sources are influencial in producing the higher concentations of sulfate and nitate in bulk fallout.

1655
ZEMAN, L. J., and SLAYMAKER, Olav, 1978, Mass balance model for calculation of ionic input loads in atmospheric fallout and discharge from a mountainous basin: Hydrological Sciences Bulletin, v. 23, no. 1, p. 103-117.

This article describes a mass balance that determines the contribution of ionic loads in atmospheric fallout to stream discharge from a pristine forested mountain basin in British Columbia. The hydrochemical balance for precipitation and stream chemistry variations, weathering, erosion and denudation rates are discussed.

1656
ZIEGLER, E. N., 1979, Precipitation composition--northeastern United States, in Advances in Environmental Science and Engineering: New York, Gordon and Breach Science Publishers, v. 1, p. 160-183.

No trend in annual pH levels in precipitation in the northeastern United States was observed during 1970-77, mean annual pH of precipitation ranged from 3.9 to 5.3 at all sampling stations. The three precipitation sampling networks used in this study produced sufficient data to monitor annual and monthly changes in pH. No correlation between seasons and pH was indicated. The pH of rain increases with the amount and duration of rainfall and generally decreases with increasing aqueous nitrate level. The decrease in pH with increase in sulfate is not as conclusive as the correlation between pH and nitate and is possibly affected more by local sources.

1657
ZINDER, S. H., and BROCK, T. D., 1978, Microbial transformations of sulfur in the environment, in Nriagu, J. O., ed., Sulfur in the environment, part II--ecological impacts: New York, John Wiley, p. 445-466.

1658
ZINKE, P. J., 1980, Influence of chronic air pollution on mineral cycling in forests, in Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, Calif., 1980, Proceedings: Berkeley, Calif., U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PWS-43, p. 88-99.

This paper reviews the literature concerning the impact of chronic air pollution on mineral element cycling in forests. The concept involves the forest trees taking up essential and other elements from the soil and surrounding environment eventually to return them to the soil upon mortality and decay. Chronic pollutants are considered in the context of this cycling as another form of elemental addition to the site subject of the major elements, carbon, nitrogen, and sulfur, and the trace metallic elements. In addition, pollutant effects upon the ecosystem living components in terms of producers and decomposers are considered along with potential changes in the redox and pH state of the different portions of the forest. Some original data on foliar composition of Big Cone Spruce (*Pseudotsuga macrocarpa* (Vasey) Mayr) in relation to pollution exposure, and the evaluation of a soil subject to increments of hydrogen in simulated acid rain leaching are presented. [Abstract reprinted by permission of U.S. Forest Service.]

1658 (continued)

1659
ZOLLER, W. H., GLADNEY, E. S., and DUCE, R. A., 1974, Atmospheric concentrations and sources of trace metals at the South Pole: Science, v. 183, p. 198-200.

Atmospheric particulate matter collected at the South Pole was collected; analysis indicate that Al, Sc, Sm, Th, V, Mn, Eu, Fe, La, Ce, Co, Cr, Na, Mg, and Ca are derived from the oceans or crustal weathering. Some volatile elements are probably derived from other sources, such as vapor-phase condensation or a high-temperature dispersion source.

1660
ZUKOWSKA-WEISZCZEK, Danuta, and ZIMNY, Henryk, 1980, Plant biotests in the bioindication of the rainfall pollution in an oil refinery region: Plant and Soil, v. 55, p. 321-325.

Rainwater samples were collected from March through August 1975 at four sites near an oil refinery in Poland and analyzed for pH and major constituents. Pollution by heavy metals and acidity is noted. The study shows beetroot, beans, and cucumbers to be suitable test plants for bioindicators of atmospheric pollution.

COAUTHOR INDEX

Names are followed by reference numbers
assigned to each item in the bibliography.

SUBJECT INDEX

Index terms are followed by reference numbers
assigned to each item in the bibliography.