ACID PRECIPITATION AND ITS EFFECTS ON FRESHWATER ECOSYSTEMS: AN ANNOTATED BIBLIOGRAPHY[1,2]

RICHARD F. WRIGHT,[3] The SNSF-project (Acid Precipitation - Effects on Forest and Fish), 1432 Aas-NLH, Norway.

INTRODUCTION

It is especially difficult to obtain an overview of the literature on acid precipitation and its effects on freshwater ecosystems because this research covers disciplines in meteorology, chemistry, biology, geology, and hydrology. In addition, much of the work done in Scandinavia is not published in international journals and thus not included by major abstract services. Furthermore, many of these reports are written in Swedish and Norwegian and are, therefore, of little use to non-Scandinavian scientists.

The aim of this annotated bibliography is to provide a ready access to the literature by gathering together pertinent articles from the diverse sources and by supplying a brief description in English of the contents of each article.

DESCRIPTION OF LITERATURE COVERAGE

This bibliography contains literature on two topics:

1) Atmospheric and precipitation chemistry, and
2) The chemical and biological effects on aquatic ecosystems.

Included in this bibliography is literature available prior to the First International Symposium on Acid Precipitation and the Forest Ecosystem, held 12-15 May 1975 at The Ohio State University, Columbus, Ohio, USA.

The early literature on atmospheric and precipitation chemistry was thoroughly reviewed by Eriksson (1952a, 1952b) and more recently by

---

[1] Published as a supplement to the Symposium Proceedings for the purpose of enhancing their usefulness as a reference source on acid precipitation research. The editors are indebted to Dr. Wright for this contribution.

[2] SNSF-contribution FA 3/75.

[3] Norwegian Institute for Water Research, P. O. Box 333, Oslo 3, Norway.

Gorham (1961). Since then research has been more or less confined to one of the several areas where the phenomenon of acid precipitation has been recognized. Recent overviews of precipitation chemistry for these areas are given by Summers and Whelpdale (1975, Proc. 1st Intl. Symp. Acid Precipitation and the Forest Ecosystem, Ohio State University) for Canada, Cogbill and Likens (1975) for the northeastern U.S., Oden (1972) for Scandinavia, and Bolin et al. (1971) for Sweden.

Adverse effects of acid precipitation on aquatic ecosystems in these areas have been investigated. Recent overviews published in English in international journals include Canada (Stokes et al. 1973, Jeffries et al. 1974, Beamish et al. 1975), northeastern U.S. (Schofield 1975, Proc. 1st Intl. Symp. Acid Precipitation and the Forest Ecosystem, Ohio State University), Sweden (Almer et al. 1974, Grahn et al. 1974), Norway (Jensen and Snekvik 1972, Wright et al. 1975, Proc. 1st Intl. Symp. Acid Precipitation and the Forest Ecosystem, Ohio State University), and Great Britain (Sutcliffe and Carrick 1973a, 1973b, 1973c). This bibliography probably includes nearly all articles that specifically deal with the effects of acid precipitation on aquatic ecosystems.

Another part of the literature that is pertinent to studies on aquatic ecosystems deals with physiological responses of aquatic organisms to acidity, sulfate, heavy metals, and other chemicals associated with acid precipitation. Here, although a number of relevant articles have been included, an exhaustive literature search was not attempted.

Finally a few references on the effects of acid mine drainage have been included, merely as an introduction to the extensive literature on this related subject (cf. Katz 1968, Packer and Dunson 1972).

CLASSIFICATION BY GEOGRAPHIC AREA

Following the bibliography is a list of articles grouped by geographic area. The areas are: world, Europe, Scandinavia, Norway, Sweden, Finland, British Isles, North America, Canada, United States, Antarctic/Arctic, and miscellaneous (theoretical articles etc.).

ABBREVIATIONS AND SOURCE NOTES

Following the short description of each article is a capital letter denoting the language in which the article is written. These letters stand for English (E), French (F), Finnish (Fi), German (G), Japanese (J), Norwegian (N), and Swedish (S).

Some of the Scandinavian articles are available from the institutes listed below:

NORWAY:

Direktoratet for vilt og ferskvannsfisk, Freshwater Fisheries Research Institute, Directorate of Fish and Wildlife, 1432 Ås.

IHD-Norden, International Hydrological Decade, P.O. Box 5091, Oslo 3.

Landbrukshøgskole, Norwegian Agricultural College, 1432 Ås.

Miljøverndepartementet, The Ministry of Environment, Oslo 1.

NILU, Norwegian Institute for Air Research, P.O. Box 15, N-2007 Kjeller.

NIVA, Norwegian Institute for Water Research, P.O. Box 333, Oslo 3.

Norges Vassdrags- og Elektrisitetsvesen, Norwegian Water and Electricity Board, Middelthunsgate 29, Oslo 3.

SNSF, The SNSF-project, NISK, 1432 Ås-NLH.

SWEDEN:

Agricultural College, 75007 Uppsala.

Institute of Meteorology and International Meteorological Institute, University of Stockholm, P.O. Box 19111, 10432 Stockholm 19.

Royal College of Forestry, 10405 Stockholm 20.

Statens Naturvårdsverk, National Swedish Environment Protection Board, Fack, 17102 Solna 1.

Swedish Water and Air Pollution Research Laboratory, Box 5207, 40224 Gothenburg.

Sötvattenslaboratoriet, Drottningholm, Institute of Freshwater Research, Drottningholm, Fack, 17011 Drottningholm.

EUROPE:

EIFAC, European Inland Fisheries Advisory Committee, Dept. of Fisheries, FAO, Via delle Terme di Caracella, 00100 Rome, Italy.

ACKNOWLEDGEMENTS

This bibliography would not have been possible without the cooperation of many individuals who kindly supplied copies of their published and unpublished reports. B. Bøhmer took much of the responsibility for procuring, cataloging, and classifying the articles.

Financial support came in part from the Royal Norwegian Council for Scientific and Industrial Research.

Ahl, T., and S. Oden. 1972. Nya undersökningar ger besked Åkrarnas Kväve gödslar vattnet. Forskning og Framsteg 7: 23-26.

Data from the synoptic study of Scandinavian rivers (1965 and 1970) and from monthly samples from several Swedish rivers (1965-1972) indicate that the NO_3-N content of these waters is strongly affected by variations in weather. About 70% of NO_3-N comes from precipitation and 30% from agricultural fertilizers. S.

Allen, S. E., A. Carlisle, E. T. White, and C. C. Evans. 1968. Plant nutrient content of rainwater. J. Ecology 56: 497-504.

The deposition of Na, K, Ca, Mg, P, and N was measured at 5 sites for 3 years. The amounts of these elements contained in precipitation are related to rainfall volume and to agricultural and marine influences. E.

Almer, B. 1972a. Ragnarök och fiskdöd. Svenskt Fiske. No. 12: 40-44.

This is a general discussion of the increasing acidification of Swedish lakes and rivers and the effects on fish, especially the phenomenon of large, old fish that survive in acid lakes. S.

Almer, B. 1972b. Försurningens inverkan på fiskbestånd i västkustsjöar. Information från Sötvattens-Laboraotiret, Drottningholm, No. 12. 47 p.

Test fishing and other investigations in 50 lakes in western Sweden showed that the increasing acidification of lakes causes a discoloration of water, decrease in plankton abundance and drastic alterations in fish fauna. The roach is affected at pH less than

5.5. Many acid lakes contain only old and large fish due to the inhibition of reproduction. Perch is similarily affected. S(E summary).

Almer, B., W. Dickson, C. Ekström, E. Hörnström, and U. Miller. 1974. Effects of acidification on Swedish lakes. Ambio 3: 330-336.

An investigation of 400 lakes on the Swedish west coast during 1970-72 revealed that about 25% of the lakes in the area are adversely affected by acid precipitation (pH less than 5.0), and that the pH in some lakes has declined 1.8 units over the last 20-30 years. Sulfate increased also. Biologic effects such as changes in phytoplankton species composition, zooplankton and fish populations are reported. E.

Andersen, C. 1966. Vannets kjemiske forhold. Norg. Jeg. og Fiskeforb. Tidsskr.: 174-175.

This is a general discussion of pH and hardness in natural waters. N.

Andersson, Gun, and P. Grennfelt. 1974. The concentration of some trace elements in fuel oils and an estimation of the atmospheric emission of these elements from oil combustion in Sweden. Swedish Water and Air Pollution Research Laboratory, Gothenburg, Publ. B204. 6 p.

Emissions of 13 trace elements from fuel combustion in Sweden were estimated from the analysis of commercial fuel oils. E.

Andersson, Gunnar. 1971. Vattenkemi och långtidsmässiga förändringar i Anebodaområdets sjöar. Limnol. Inst. Lund, Sweden. Unpubl. report. 37 p.

The chemistry of 30 small lakes in the south Swedish highlands was studied during 1967-69, and the results were compared with data from the 1930's. In 6 forest lakes the pH has declined, while in lakes influenced by cultural activities the pH has risen. Specific conductance has risen by 10-30 micromhos/cm in 28 of the lakes to about 50 micromhos/cm. Sulfate concentrations have also increased. The chemistry of these lakes is strongly influenced by inputs from the atmosphere. S.

Andersson, G., K. J. Gustafson, and T. Lindström. 1971. Rödingen i Rösjöarna på Fulufjäll. Information från Sötvattenslaboratoriet, Drottningholm No. 8. 9 p.

Fish surveys and test fishing in several small acid lakes in Sweden show that acidification has altered the fish populations during the past 50 years. S.

Ångström, A., and L. Högberg. 1952a. On the content of nitrogen (NH_4-N and NO_3-N) in atmospheric precipitation. Tellus 4: 31-42.

NH_4-N and NO_3-N concentrations in precipitation depend on the amount of precipitation previously fallen and the type of air mass (tropical versus polar). The constant ratio of 2:1 (NH_4-N/NO_3-N) suggests a common origin. E.

Ångström, A., and L. Högberg. 1952b. On the content of nitrogen in atmospheric precipitation in Sweden II. Tellus 4: 271-279.

Deposition maps of NH_4-N for Sweden show lower amounts at higher latitudes, probably due to lower contents of NH_4-N in the atmosphere at these latitudes. The constant ratio of NH_4-N to NO_3-N in precipitation may be due to a common photochemical reaction. E.

Anon. 1972. Sulphur pollution across national boundaries. Ambio 1: 15-20.

This article briefly summarizes the results from "Sweden's case study" (Bolin et al. 1971). E.

Anon. 1974a. Sur nedbør-problemet, status idag. Miljøverndepartementet, Oslo, Informasjon, Nr. 12: 2-4.

This is a brief report of the December 1974 meeting in Oslo on the European monitoring of air pollutants. N.

Anon. 1974b. Miljövårds forskning 1972-75. Swedish National Nature Conservancy Office.

This document is a description of all Swedish research projects that have been funded by the Nature Conservancy Office for 1972-75. S.

Askne, C. 1973. Method of determining strong acid in precipitation based on coulometric titration with application of Gran's plot. Swedish Water and Air Pollution Research Laboratory, Gothenburg, Publ. B152. 41 p.

The construction and design of a function generator is described. It is used for electronic evaluation of Gran's plot titrations. E.

Askne, C., and C. Brosset. 1972. Determination of strong acid in precipitation, lake-water and air-borne matter. Atmospheric Environ. 6: 695-696.

Titration of CO_2-free samples with NaOH allows calculation of the strong acid content. E.

Aston, S. R., D. Bruty, R. Chester, and R. C. Padgham. 1973. Mercury in lake sediments: a possible indicator of technical growth. Nature 241: 450-451.

The Hg concentrations in the sediments of Lake Windermere, England, increased about 10-fold from 1400 AD to the present, due to both anthropogenic Hg that is initially released into the atmosphere and to local pollution sources. E.

Barrett, E., and G. Brodin. 1955. The acidity of Scandinavian precipitation. Tellus 7: 251-257.

Beamish, R. J. 1972. Lethal pH for the white sucker *Catostomus commersoni (Lacepede)* T. Am. Fish. S. 101: 355-358.

Experiments with white sucker show that feeding stops below pH 4.5. Weight-loss, activity patterns and other physiological effects were observed at low and lethal pH levels (3.0-3.8), perhaps due to loss of calcium. E.

Beamish, R. J. 1974. Loss of fish populations from unexploited remote lakes in Ontario, Canada, as a consequence of atmospheric fallout of acid. Wat. Res. 8: 85-95.

Beamish, R. J., and H. H. Harvey. 1972. Acidification of the La Cloche Mountain Lakes, Ontario, and resulting fish mortalities. J. Fish. Res. Bd. Canada 29: 1131-1143.

Loss of fish populations from lakes SW of the Sudbury, Ontario, smelter is attributed to increasing acidification of the lakes due to large loadings of sulfuric acid from the atmosphere. E.

Beamish, R. J., W. L. Lockhart, J. C. Van Loon and H. H. Harvey. 1975.

Longterm acidification of a lake and resulting effects on fishes. Ambio 4: 98-102.

Acidification of a lake in Ontario (pH decreased 0.13 units/yr) resulted in various physiological responses by fish, including failure to spawn, low serum calcium in adult females, appearance of spinal deformities, changes in the average size of age classes, reduction in the population sizes, and disappearance of species. The results suggest that increased acidity interferes with Ca metabolism. E.

Bell, H. L. 1971. Effect of low pH on the survival and emergence of aquatic insects. Water Res. 5: 313-319.

Experiments with mature larvae and nymphs of 9 species at pH 1.0 to 7.0 showed that the pH at which 50% of the individuals died after 30 days of exposure ranges from 2.45 to 5.38 depending on the species, and that all species are more acid-sensitive during the period of emergence. E.

Bell, H. L., and A. V. Nebeker. 1969. Preliminary studies on the tolerance of aquatic insects to low pH. J. of Kansas Entomol. Soc. 42: 230-237.

Laboratory tests on mature larvae of 10 species of aquatic insects showed that the acid-tolerance is species dependent. The lethal pH (50% of individuals die after 96 hours) varied from 4.65 to 1.5. E.

Bertine, K. K., and E. D. Goldberg. 1971. Fossil fuel combustion and the major sedimentary cycle. Science 173: 233-235.

The combustion of fossil-fuel injects many elements into the atmosphere at rates comparable to the rate of weathering. Since most fossil-fuel consumption is in the Northern Hemisphere, the changes in atmospheric- and water-chemistry will be most evident there. E.

Berzins, B. 1966. Kalkning av sjöar. Södra Sveriges Fiskeriförening 1959-1966: 28-35.

Addition of chalk to several acid lakes in southern Sweden resulted in increased pH-levels, increased growth of phytoplankton and survival of salmonoid fishes. S.

Biesinger, K. E., and G. M. Christensen. 1972. Effects of various metals in survival, growth, reproduction, and metabolism of

Daphnia magna. J. Fish. Res. Bd. Canada 29: 1691-1700.

The toxicity of 21 major and trace metals was measured and correlated with the solubility product constant of the metal sulfide, electronegativity, and equilibrium constant of the metal-ATP complex. E.

Bischof, W. 1973. Carbon dioxide concentration in the upper troposphere and lower stratosphere III. Report Al-24, Institute of Meteorology, University of Stockholm, 11 p.

Air samples collected by airplane during 1962-71 show that the CO_2 content of the atmosphere (N Hemisphere) is increasing by 0.09 ppm^2/yr. E.

Bjor, K., R. Horntvedt, and E. Joranger. 1974. Nedbørens fordeling og kjemiske innhold i en skogbestand på Sørlandet (Juli-Desember 1972). SNSF FR 1/74. 28 p.

The chemistry of rainfall, throughfall, and stemflow at Birkenes, Norway, is discussed. N.

Block, C., and R. Dams. 1975. Inorganic composition of Belgian coals and coal ashes. Environ. Sci. & Technol. 9: 146-150.

The concentrations of 44 elements in coals were measured by neutron activation analysis. During combustion of coal the halogens, Hg, As, Se, and Sb are emitted preferentially while the other elements are present in fly-ash in the same concentrations as in bulk coal. E.

Bolin, B., and L. Granat. 1973. Local Fallout and long-distance transport of sulfur. Ambio 2: 87-91.

This article compares Högström's (1973) findings with other studies of the long-distance transport of sulfur, including a discussion of dry-fallout versus washout in precipitation. E.

Bolin, B., L. Granat, L. Ingelstam, M. Johannesson, E. Mattson, S. Odén, S. Rohde, and C. O. Tamm. 1971. Air pollution across national boundaries.

The impact on the environment of sulfur in air and precipitation. Sweden's case study for the United Nations conference on the human environment. 96 p.

More than 75% of the atmospheric sulfur in NW Europe is of anthropogenic origin, and following conversion to sulfate, long-distance transport deposits large amounts of sulfuric acid in Sweden. This "excess" acid causes damage to arable land, forests and lakes and rivers. An economic analysis of the costs of this pollution and of possible remedies is presented. E.

Bolin, B., C. Persson. 1974. Regional dispersion and deposition of atmospheric pollutants with particular application to sulfur pollution over Western Europe. Inst. of Meteorology, Univ. Stockholm, Report AC-28. 60 p.

Assuming a statistical independence of some physical and chemical processes in the atmosphere, a model of sources, sinks and transformations of atmospheric pollutants is constructed. As an example the model is used to describe the sulfur emission, transport and deposition in NW Europe. E.

Börjeson, H., and A. Aldberg. 1974. Buffertkapacitet och pH i mjölke från två övingsstammar. Information från Sötvattenslaboratoriet, Drottningholm No. 3. 6 p.

Trout from lakes in the Kloten area, Sweden, live near the lower pH-tolerance limit. No chemical difference in the milk from this stock and a reference stock could be found. S (E summary).

Borman, F. H. 1974. Acid rain and the environmental future. Environmental conservation 1: 270.

The realization that acid precipitation falls over large areas of the northeastern US raises the concern that serious changes in terrestrial ecosystems might result. E.

Bornefeld, T., and W. Simonis. 1974. Effects of light, temperature, pH, and inhibitors on the ATP level of the blue-green alga *Anacystis nidulans*. Planta 115: 309-318.

Various experiments conducted at pH 6.5-9.0 are described. E.

Borneff, J. 1974. Die Verunreinigung von Grund-und Oberflächenwasser durch organische Substanzen des Luftaerosols, p. 33-45. In H. E. Vogel (ed.) European Fed. Protection Waters, Zürich, Info. Bull. 21.

The concentrations of polycyclic aromatics, pesticides, and polychloric biphenyls may reach harmful levels in surface and ground waters in central Germany. Many of these compounds are introduced into the atmosphere by man and subsequently find their way into freshwaters. G (E, F summary).

Braarud, T., and O. J. Aalen. 1939. Undersøkelser over makrovegetasjonen i en del Aust-Agder-vatn. Nytt Mag. f. Naturv. B. 79: 1-48.

The macrophytes of 40 lakes were studied and the distribution and abundance of individual species were related to geological and geomorphological chemical, climatic, and cultural factors. N (G summary).

Braekke, F. (ed.). 1974a. Hydrokjemiske og hydrobiologiske rapporter fra NIVA. SNSF-project. IR 3/74. 39 p.

This is a collection of interim reports on 1) hydrochemical results from several gauged watersheds in southern Norway, 2) the effect of pH on microbiological decomposition of organic matter, 3) development of a method for measuring primary productivity and results from acidification experiments, and 4) survival of several species of salmonoid fish in water from an acid watercourse. N.

Braekke, F. (ed.). 1974b. Faginnlegg på Kontaktmøte i SNSF-prosjektet 8. Februar 1974. SNSF-project. IR 2/74. 90 p.

This is a collection of reports on the early research conducted by the SNSF-project.

Braekke, F. 1975. Hydrokjemiske myrundersøkelser. SNSF-project. TN 5/75. 28 p.

Studies on the effect of acid precipitation on bog ecosystems include field experiments on bog water-chemistry and laboratory experiments using peat sections and lysimeters. N.

Brandt, N. 1971. Sur Nedbør - Redusert tilvekst i våre skoger? NILU OR 28/71. 16 p.

Based on a limited amount of tree-ring data from pine and spruce forests in eastern Norway, it is concluded that there has apparently been no significant reduction in growth due to acid precipitation. N.

Brosset, C. 1973a. Air-borne acid. Ambio 2: 2-9.

During the combustion of fossil-fuel the sulfur is converted to SO_2 which is oxidized to H_2SO_4 either in the stack or in the atmosphere. This H_2SO_4 is washed out of the atmosphere both in the vicinity of the stack and at long-distances from the stack. Some of the sulfuric acid is deposited as particles, which may present a serious human health-hazard. E.

Brosset, C. 1973b. Danger of water pollution through air. In Proc. Symp. Eur. Fed. Protection Wat., Finland. 11 p.

This general discussion of atmospheric chemistry and long-distance transport of pollutants in Europe focuses on the uncertainties concerning the impact of particulate deposition on aquatic ecosystems. E.

Brosset, C. 1973c. Problems involved in choosing a suitable method of determining hazardous acidity on particles. Swedish Water and Air Pollution Research Laboratory, Gothenburg, Publ. B148. 9 p.

Because there are several types of acid particles, the choice of a suitable measuring technique for particles cannot be made until the hazards to human health presented by each of these particles types are known. E.

Brosset, C. 1974. Introductory comments on sulphur dioxide and acidification made at the IVL-Conf. Stockholm on 11th December, 1973. Swedish Water and Air Pollution Research Laboratory, Gothenburg, Publ. B186. 3 p.

There are 4 processes by which acidification of water by sulfur dioxide is possible, 1) dry deposition of gaseous SO_2, 2) dry deposition of acidic particles, 3) washout of SO_2 gas, and 4) washout of H_2SO_4. E.

Brosset, C. 1975. Acid particulate pollutants in Sweden. Swedish Water and Air Pollution Research Laboratory, Gothenburg, Publ. B222. 20 p.

Under certain weather conditions aerosols of acid ammonium sulfate are transported from distant sources to Sweden, where the deposition of such particles in human respiratory tracts represents a possible health hazard. E.

Brosset, C. and Å. Åkerström. 1972. Long distance transport of air pollutants - measurements of black air-borne particulate matter (soot) and particle-borne sulphur in Sweden during the period of Sept.-Dec. 1969. Atmos. Environm. 6: 661-673.

An extensive description of the sampling and analytical procedures involved in collecting particulate matter from air is accompanied by data for southern Sweden that point to regional rather than local sources for particulates in the air. E.

Brosset, C., K. Andreasson, and M. Ferm. 1974. The nature and possible origin of acid particles observed at the Swedish west coast. Swedish Water and Air Pollution Research Laboratory, Gothenburg. Report B 189. 19 p.

Two types of acid particles exist in air collected from a rural area on the Swedish west coast. The first type is perhaps $(NH_4)_3H(SO_4)_2$, generated by catalytical oxidation of SO_2 absorbed in the water droplets round the particles. The second type is perhaps NH_4HSO_4 (i.e. more acid) and the particles may have been formed by photochemical oxidation of SO_2 in the presence of NO_2. E.

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

Monthly measurements of sulfate in air and precipitation at 3 sites in England conducted as part of the European precipitation network give sulfur deposition rates of 1-3 kg/ha/month. These rates have not significantly increased during the measuring period. E.

Bua, B., and E. Snekvik. 1972. Klekkeforsøk med rogn av laksefisk 1966-1971. Virkning av surhet og saltinnhold i klekkevannet. Direktoratet for vilt og ferskvannsfisk, Norway. Vann 7: 86-93.

Hatching experiments show that the critical pH-limit for salmon is 5.0-5.5, for sea trout 4.5-5.0 and for lake trout 4.5. The hatching success at a given pH is increased by adding neutral salts to the water. N.

Cambray, R. S., D. F. Jefferies, and G. Topping. 1975. An estimate of the input of atmospheric trace elements into the North Sea and the Clyde Sea (1972-3). Environmental and Medical Sciences Division, AERE Harwell, UK, Report R7733. 25 p.

Samples of airborne dust, rainwater and dry deposit were collected at 7 stations in and adjacent to the UK and analyzed for 23 trace elements. The results show that the atmosphere is an important source of heavy metals for the Clyde Sea. An enhancement of trace elements in the surface microlayer of the sea is responsible for high concentrations in rainwater collected in the presence of sea-spray. E.

Carter, L. 1964. Effects of acidic and alkaline effluents on fish in seawater. Effl. & Wat. T. Journ. 484-486.

Experiments with various marine fish indicate that at pH 5.5-9.0 fish mortalities in seawater are unlikely. E.

Cawse, P. A. 1974. A survey of atmospheric trace elements in the UK. Environmental and Medical Sciences Division, AERE Harwell, UK, Report R7669. 84 p.

Samples of airborne dust, rainwater and dry deposition collected at 7 rural sites in the UK were analyzed for 30 trace elements. The results allow a grouping of the elements according to their principal source - soil, industrial emissions, or sea spray. The raw data and details for Peirson et al. (1974) are given. E.

Cawse, P. A., and D. H. Peirson. 1972. An analytical study of trace elements in the atmospheric environment. Atomic Energy Research Establishment, Harwell, England, Report R7134. 25 p.

The levels of 30 trace elements were measured in airborne dust, rainwater and dry deposition at a rural site in NW England using neutron activation analysis. Various experimental difficulties are discussed. The results indicate that the elements can be assigned to either maritime, soil-derived or anthropogenic sources. E.

Chapin, J., and P. D. Uttormark. 1973. Atmospheric contributions of nitrogen and phosphorus. Tech. Rept. 2. Univ. Wisconsin, Water Resources Center. 35 p.

This is a compilation of published data on the amounts of N and P in precipitation and a discussion of the sources, seasonal variations, and regional patterns of these elements in atmospheric precipitation. E.

Chester, R., and J. H. Stoner. 1973a. Pb in particulates from the lower atmosphere of the eastern Atlantic. Nature 245: 27-28.

The Pb concentrations in atmospheric particulate matter show enrichment factors of 10-113 relative to crustal composition with greater enrichment in air streams associated with industrial Europe. E.

Chester, R., and T. H. Stoner. 1973b. Average trace element composition of low level marine atmospheric particulates. Nature 246: 138-139.

The concentrations of other trace elements are also enriched but not as much as for Pb. (See Chester and Stoner 1973a). E.

Cogbill, C. V., and G. E. Likens. 1975. Acid precipitation in the northeastern United States. Wat. Res. Res. (In press).

Precipitation in the northeastern US has a pH less than 4.4, with 65% of the acidity due to H_2SO_4, 30% to HNO_3, and less than 5% to HCl. The acidity has increased since about 1950-55, especially that due to HNO_3. The source region is the industrial Midwest. E.

Conroy, N., D. S. Jeffries, and J. R. Kramer. 1974. Acid shield lakes in the Sudbury Ontario Region. Proc. 9th Canadian Symp. Water Poll. Res. (in press).

A survey of water chemistry of 50 lakes near the Sudbury smelter showed that lakes vary in their susceptibility to inputs of sulfuric acid depending on the geology of the watershed and proximity to the stack. E.

Conroy, N., and L. Maki. 1974. Extensive and intensive lake studies in the Sudbury area, p. 138-143. In Ontario Industrial Wastes Conferences 1974.

The principal factors affecting the pH and heavy-metal concentrations in lakes of the Sudbury, Ontario, region are 1) distance and direction from the smelter stack and 2) geology of the watershed. As the pH declines the biological activity is reduced and heavy metals become more abundant until the fisheries are eliminated. E.

Cook, J. R. 1971. Influence of culture pH and phosphate on synchrony of *Euglerea gracilis*. Experimental Cell Research 69: 207-211.

This alga divides synchronously when exposed to a repetitive light-dark cycle and high phosphate levels in the medium. The pH-dependence of synchronous cell-division may be related to changes in cell transport mechanisms. E.

Costa, H. H. 1966. Responses of *Gammarus Pulex* (L) to modified environment. 1. Reactions to toxic solutions. Crustaceana 11: 245-256.

Experiments on the toxicity of several heavy-metals are described. E.

Costa, H. H. 1967. Responses of *Gammarus pulex* (L) to modified environment. II. Reactions to abnormal hydrogen ion concentrations. Crustaceana 13: 1-10.

Experiments on the effects of various acid and alkaline solutions are described. E.

Dahl, E. 1972. Kostnader ved utslipp av svoveloksyder i atmosfæren. Tekn. Ukeblad 119 (22): 3-5.

This article continues a debate between Dahl, Aksel Lydersen and N. A. Sørensen about the cost to society of SO_2 emissions into the atmosphere, both from local and distant sources. N.

Dahl, E., O. Gjems, and J. Kielland-Lund Jr. 1967. On the vegetation types of Norwegian conifer forests in relation to the chemical properties of the humus layer. Meddr. Norske Skogfors. Ves. 24: 503-531.

The cation supply to forests depends on primary factors (weathering and leaching) and external factors (precipitation inputs). The supply of organic matter and also N depends largely on processes within the forest ecosystem. The types of forest in Norway depend on these various processes. E (N summary).

Dahl, E., and O. Skre. 1971. En undersøkelse av virkningen av sur nedbør på produktiviteten i landbruket. Nordforsk, Miljøvårdssekretariatet No. 1: 27-40.

The acidity of precipitation in southern Scandinavia can potentially affect forest growth by causing decreases in the availability of plant nutrients (especially cations) in the soil. Data from Finland show that the availability of these cations is positively correlated to forest growth. N.

Dahl, K. 1920. Undersøkelser over ørretens utdøen i det sydvestlige Norges fjeldvand. Norsk Jæger- & Fisk. For. Tidsskr. 49: 249-267.

The extensive fish-kills reported in 1916 in southernmost Norway are apparently due to disease. Dahl also remarks on the decrease (14-68%) in salmon-catches from 8 rivers during the period 1903-1919. N.

Dahl, K. 1922. Supplerende bemerkninger til undersøkelser over ørretens utdøen i sydvestlige Norges fjeldvand. Norges Jæger- & Fisk. For. Tidsskr. 51: 64-66.

Additional comments on the fish-kills of 1916 (see Dahl 1920). N.

Dahl, K. 1923. Massedød blant ørret ved forgiftning med avløpsvand fra myrer. Norges Jæger- & Fisk. for. Tidsskr. 52: 1-5.

Chemical analyses show that at the time of the 1920 fish-kills in southern Norway the concentration of sulfuric and nitric acids in the streams was unusually high. The kills are ascribed to accumulation of these acids in bogs during the dry summer followed by flushing during subsequent heavy rains. N.

Dahl, K. 1926. Vandets surhetsgrad og deres virkninger på ørretyngel. Tidsskr. norske Landbr.: 232-242.

The effect of acidity on trout-spawning success is discussed, and a series of pH measurements from lakes and streams in southern Norway is reported. N.

Dale, T., A. Henriksen, E. Joranger, and S. Krog. 1974. Vann- og nedbörkjemiske studier i Birkenesfeltet for perioden 20. juli 1972 til 30. april 1973. SNSF-project TN 1/74. 44 p. + appendix.

The small, forested, gauged watershed at Birkenes, southern Norway is described, and some preliminary precipitation- and streamwater chemistry data reported. N.

Dannevig, A. 1959. Nedbørens innflytelse på vassdragenes surhet og på fiskebestanden. Jeger og Fisker No. 3: 116-118.

This is perhaps the first report linking acid rain to acidity of fresh-waters and thence to fish kills. N.

Dannevig, G. 1966. Auren og det sure vannet på Sørlandet. Norg. Jeg. og Fiskerforb. Tidsskr.: 388-393.

Dannevig reports that some strains of trout are apparently more resistant to acid-stress than others, and these resistant strains can perhaps be used for stocking low-pH lakes in southern Norway. The seasonal and downstream changes in pH for several rivers are discussed. N.

Dannevig, G. 1968. Surt vann og dødelighet på ørret. Zoologisk Revy (Sverige) 30: 53-60.

The disappearance of trout from many lakes and rivers in southernmost Norway is due to increasing acidity of the waters. At low pH breeding, hatching of eggs, and survival of fry are inhibited. Some local stocks are more acid resistant, however. N (E summary).

Dannevig, G. 1970. Auren på Sørlandet dør ut på grunn av forurenset og sterkt sur nedbør. Unpubl. report. 8 p.

Although some fish kills are due to local pollution, the widespread disappearance of fish from lakes and rivers in Sørlandet is due to increasing acidity, as, for example, is the case in Tovdalselva. N.

Dannevig, G., B. Kjos-Hansen, K. W. Jensen, and E. Snekvik. 1971. Fiskebestand og forsurning av vassdrag. Jakt, fiske, friluftsliv 100: 149-151, 198-201.

The increase in acidity of precipitation in southernmost Norway during the last 20 years has caused drastic increases in the acidity of thousands of lakes and rivers and the consequent loss of fisheries. N.

Davis, P., and G. W. Ozburn. 1969. The pH tolerance of *Daphnia pulex* (Leydig, emend., Richard) Can. J. Zool. 47: 1173-1175.

D. pulex is able to survive for 32 hours at pH 4.3 to 10.4, but reproduction was observed only at pH 7.0 to 8.7. E.

DeBary, E., and C. Junge. 1963. Distribution of sulfur and chlorine over Europe. Tellus 15: 370-381.

Using European precipitation-chemistry data for 1954-59, maps of SO_4, Cl, and excess-SO_4 (corrected for sea-water sulfate using Cl) are constructed. Seasonal and geographic patterns are discussed. E.

Delany, A. C., W. H. Pollock, and J. P. Shedlovsky. 1973. Tropospheric aerosol: The relative contribution of marine and continental components. J. Geophys. Res. 78: 6249-6265.

Vertical profiles of the Na, Cl, K, Mn, Br, and Si concentrations in the lower 9 km of the atmosphere (western Pacific, southern California, Nebraska) showed that the middle and upper troposphere has a uniform aerosol composed of 90-95% continental material and 5-10% marine materials. The marine salt, being hydrophilic, is apparently preferentially washed out of the lower layers. E.

Descroix, P. 1974. L'influence de la pollution atmosphérique sur la pollution des eaux en France, p. 93-96. In H. E. Vogel (ed.), European Fed. Protection Waters, Zürich, Info. Bull. 21.

Precipitation falling in the Paris basin has become more acidic during the period 1956-1968. Since the soils and waters of the area are highly buffered, however, this acid precipitation is readily neutralized. Other atmospheric pollutants such as fluorine present greater potential threat to water bodies. F (E, G summary).

Dickson, W. 1971. pH-situationen i Västkustsjöar november-desember 1970. Drottningholm Freshwater Research Laboratory. Unpubl. report. 56 p.

This is a preliminary report on the water chemistry of 314 lakes on the Swedish west coast. Most of these lakes have low buffer capacities and have been greatly affected by atmospheric precipitation. Over 60 of the lakes have pH less than 5, and the pH in some has declined 2 units since the 1930's. S.

Dondoroff, P., and M. Katz. 1950. Critical review of literature on the toxicity of industrial wastes and their compounds to fish. I. Alkalics, acids and inorganic gases. Sewage Ind. Wastes 22: 1432-1458.

This review discusses literature on pH and fish up to about 1950. E.

Dovland, H. 1975. Tidsvariasjonen for noen kjemiske komponenter i elvevann under snøsmeltingen våren 1974. SNSF-project, TN 9/75. 34 p.

The chemistry of several lakes and streams in southwestern and southeastern Norway changed during snowmelt in 1974. These changes are related to the pollutant load in the snowpack and to the buffer capacity of the surface waters, which in turn is related to watershed geology and soils. N.

Dovland, H., T. Dale, and E. Joranger. 1974. Undersøkelse av elvevannets kjemiske sammensetning under snøsmelting. SNSF-project TN 2/74. 61 p.

The chemistry of three rivers was measured during snowmelt in 1973. Although there were indications of a pulse of pollutants during the first phases of snowmelt, major changes in the rivers were not recorded because 1) the pollutant load in the snowpack of 1973 was unusually low, and 2) the chemistry of these rivers is influenced by base flow from the soils. N.

Dovland, H., and A. Semb. 1975. Tilførsel og avrenning av sure komponenter i Tovdalsvassdraget. SNSF-project. TN 6/75. 22 p.

Using the available data from several precipitation chemistry stations and river chemistry data the H^+ balance for a river in southern Norway was computed for 1973. N.

Dugstad, I. 1972. Målinger av luftforurensninger i Bergen 1969-1972. Foreløpige resultater. Geofysisk institutt, Universitetet i Bergen avd. B. Meteorologi Rapport nr. 2. 26 p.

SO_2 and particulate-matter concentrations in air are reported and related to several meteorological parameters. N.

Dunson, W. A., and R. R. Martin. 1973. Survival of brook trout in a bog-derived acidity gradient. Ecology 54: 1370-1376.

The occurrence of fish in a Pennsylvania stream with low pH due to humic acids is related to pH. Only brook trout survive at low pH (4.7), although some insects tolerate lower levels. E.

Dybdahl, K. 1973. Skadevirkningene av sur nedbør dokumenteres. Tekn. Ukeblad 120 (20): 42, 48.

In this interview with parliament member Per Hysing-Dahl the setting-up of the SNSF-project is explained. N.

Eaton, J. S., G. E. Likens, and F. H. Bormann. 1973. Throughfall and stemflow in a northern hardwood forest. J. Ecol. 61: 495-508.

At Hubbard Brook, New Hampshire, the input of hydrogen ions by acid precipitation probably accelerates the removal of cations from the forest canopy, thus facilitating nutrient cycling. E.

Egnér, H. 1955-1960. Current data on the chemical composition of air and precipitation. Tellus 7: 134-139, 266-271, 395-400, 522-527; 8: 112-113, 283-285, 411-412, 513-517; 9: 140-143, 250-253, 423-426, 464-468; 10: 170-175, 281-286, 401-406, 500-505, 508; 11: 139-144, 259-264, 366-372; 12: 112-118.

These are the raw data from the European precipitation network 1954-1960. E.

EIFAC. 1969. Kriterium på vattenkvalitet för europeiske insjöfisker. Om extreme pH-värden och sötvattensfisket. T. B. Hasselrot, Trans. Information från sötvattenslaboratoriet Drottningholm nr. 2.

This is a Swedish translation of the original English review of the literature on pH and fish. S.

Elgmork, K., A. Hagen, and A. Langeland. 1973. Polluted snow in southern Norway during the winters 1968-71. Environ. Pollut. 4: 41-52.

Chemical analysis of snow samples (pH, conductivity, hardness, SO_4, Na, K, Cl, total N, Fe, Mn, Pb, Zn, and total C) document the widespread distribution of airborne pollution. E.

Emanuelsson, A., E. Eriksson, and H. Egner. 1954. Composition of atmospheric precipitation in Sweden. Tellus 6: 261-267.

Isopleth maps for the deposition of Na, Cl, K, Ca, NH_3-N and NO_3-N based on Swedish precipitation data for 1948-50 show that seawater is the major source for Na and Cl (although the Cl/Na ratio varies in an unexplained manner), the soil is the major source for Ca, and agricultural activities are the major source for NH_3-N. E.

Eriksson, E. 1952a. Composition of atmospheric precipitation. 1. Nitrogen compounds. Tellus 4: 215-232.

This paper discusses all measurements of nitrogen compounds in atmospheric precipitation from the 1750's to 1950. The sources for N-compounds are seawater, biologic activity, cyclic dust, anthropogenic sources, and lightning fixation. E.

Eriksson, E. 1952b. Composition of atmospheric precipitation. II. Sulfur, chloride, iodine compounds. Bibliography. Tellus 4: 280-303.

This paper continues from (19) and discusses the literature on S, Sl, and I compounds. The importance of fossil-fuel combustion for the release of S to the atmosphere is stressed, using Cl to estimate "excess sulfur". Some data for Ca and Mg are also presented. E.

Eriksson, E. 1954. Report on an informal conference in atmospheric chemistry held at the Meteorological Institute, University of Stockholm, May 24-26, 1954. Tellus 6: 302-307.

At this meeting of scientists interested in air and precipitation chemistry and geochemical cycling, current research was reported. In addition plans were laid for the establishment of a European precipitation network. E.

Eriksson, E. 1955. Air borne salts and the chemical composition of river waters. Tellus 7: 243-250.

The Cl content of rivers in Scandinavia and in the eastern US points to a marine origin and atmospheric cycling of Cl. The chemical composition of rivers indicates that the atmosphere is a major source for other elements as well, and that chemical denudation rates cannot be inferred directly from the chemistry of groundwater. E.

Eriksson, E. 1959. The yearly circulation of chloride and sulfur in nature; Meteorological, geochemical and pedological implications. Part 1. Tellus 11: 375-403.

The circulation of sea salt via the atmosphere is characterized by fractionation of elements or groups of elements relative to Cl due to differential rates of incorporation from sea spray, reactions in the atmosphere, formation of gaseous and particulate phases, and differential deposition rates in rain and dry-fallout. All of these processes, and the importance of other sources for many elements, result in complicated relationships between various elements. These relationships, however, can be used to follow various meteorological, geological, and pedological processes. E.

Eriksson, E. 1960. The yearly circulation of chloride and sulfur in nature; Meteorological, geochemical and pedological implications. Part II. Tellus 12: 63-109.

See Eriksson (1959). E.

Eriksson, E. 1969. Svoveldioxiden och nederbördens försurning - fakta och spekulationer. Swedish Water and Air Pollution Research Laboratory. Publ. A 28: 86-96.

It is the net acidity (acidic minus basic components) of precipitation that causes damage to forests and freshwater. Isopleth maps of the deposition of net acid from Scandinavian precipitation show changing patterns over the period 1955-66. S.

Fleetwood, Å. 1969. The chemical composition of the precipitation and surface water and its relation to evaporation on Bjørnøya island, Norway. Tellus 21: 113-126.

Precipitation chemistry (for 1965) and water chemistry for 45 lakes on an arctic island north of Norway are interpreted with respect to geology, vegetation, and meteorology (esp. evaporation). E.

Førland, E. J. 1973. A study of the acidity in the precipitation in Southwestern Norway. Tellus 25: 291-299.

Precipitation samples collected every 6 hours during 1970 were analyzed for acidity, and these data were correlated with various meteorological parameters. Analysis of the data shows that precipitation from air masses that have passed over central Europe or Great Britain have pH values of 4.0-5.0, while unpolluted air masses from the Norwegian Sea have pH values of 5.1-6.6. E.

Førland, E. J., and Y. T. Gjessing. 1975. Snow contamination from washout/rainout and dry deposition. Atmospheric Environm. 9: 339-352. By comparison, the chemistry of snow sampled just after snowfall and 3-4 days later, the relative contributions of washout/rainout, dry-deposition and filtering were estimated. E.

Førland, E. J., E. Meisingseth, A. Skartveit, and I. Wefring. 1975. Hydrokjemiske data fra Nordhordland/Ytre Sogn. SNSF TN 8/75.

The frequency distribution of storms, their directions, and assooiated precipitation chemistry is reported from western Norway for the period 1/1 1973 to 30/6 1974. These observations are used to interpret chemical data from several streams. The raw data are included. N.

Fredriksen, H. 1973. Utslipp av svoveldioksyd fra norsk industri. Norges Industri nr. 20: 22-25.

Norway's SO_2 emissions are only 46 kg/person versus 360 kg/person for East Germany. A listing of SO_2 emission by the industrial and private sectors is presented. N.

Furmyr, S. (ed.). 1973a. Hydrological data - Norden. Representative basins Romerike Norway. Data 1965-1971. Norweg. Nat. Commit. for the Internat. Hydrol. Decade, Oslo. 77 p.

This report describes the Romerike site (southeastern region), gives the sampling and analytical procedures for hydrologic and meteorologic parameters, and lists the raw data for 1968-71. E.

Furmyr, S. (ed.). 1973b. Hydrological data - Norden. Filefjell, Norway. Data 1966-1971. Norwegian Nat. Commit. for the Internat. Hydrological Decade, Oslo. 69 p.

This report describes the Filefjell site (central mountain region) and gives the precipitation, surface-water and meteorological data for 1966-71. E.

Gambell, A. W. 1962. Indirect evidence of the importance of water-soluble continentally derived aerosols. Tellus 14: 91-95.

Based on Junge and Werby's (1958) precipitation chemistry data for the US, the Ca/Cl ratio is proposed as a logical index of the predominence of continental or marine water-soluble aerosols. Except in near-coastal areas, the continental sources dominate the composition of precipitation. E.

Gambell, A. W., and D. W. Fisher. 1964. Occurrence of sulfate and nitrate in rainfall. J. Geophys. Res. 69: 4203-4211.

Data from 6 individual storms in Virginia show that much of sulfate in rainfall is formed from the oxidation of SO_2 in cloud droplets, perhaps with NO_2 as a catalyst. Sulfate, nitrate, and ammonia in rainfall are primarily derived from gaseous components. E.

Gilbert, O. L. 1970. Further studies on the effect of sulphur dioxide on lichens and bryophytes. New Phytol. 69: 605-627.

Six years of data on lichens and bryophytes around Newcastle upon Tyne, England, are reported. Survival depends on shelter, pH and buffer capacity of the substratum, and nutrient flushing. E.

Gjems, O. 1970. Jordbunnen og forurensningsproblemer. Tidsskr. Skogbr. No. 2: 272-277.

The nutrient status, weathering processes, and atmospheric deposition influences on various Norwegian soil-types are discussed with particular reference to acid precipitation. N (E summary).

Gjessing, E. T. 1974. Effects of polluted precipitation on water quality In Proc. 7th Int. Conf. Water Poll. Research, Paris. 5 p.

Preliminary precipitation- and runoff-chemistry results from Birkenes, Norway, are discussed. E.

Gjessing, Y. T., and E. Gjessing. 1973. Chemical composition of an antarctic snow profile. Vatten 6: 233-237.

The concentration increase with depth in a 10 m snow profile is probably the result of filtering of aerosols. The decrease in sulfate, however, is related to a general increase in atmospheric sulfur. E.

Gjessing, Y., and E. Gjessing. 1975. Sneenskjemiske sammensetning som indikator på luftforurensninger. SNSF-project. TN 7/75. 18 p.

The pumping of air through snow colomns showed that snow is an effective filter of atmospheric contaminants. The chemistry of a 10-m snow/ice core from the Hardanger glacier, southern Norway, indicates that contaminants are lost preferentially during melting and may be found in high concentrations in ice layers. N.

Goffeng, G. (ed.). 1973. Hydrological Data - Norden. IHD stations Basic Data 1970-71. Nat. Commit. for the Internat. Hydrolog. Decade in Denmark, Finland, Iceland, Norway and Sweden. 110 p.

This report presents basic physiological, meteorological and geological data for the IHD stations in Scandinavia and also gives hydrologic and chemical data for 1970-71. E.

Gore, A. J. P. 1968. The supply of six elements by rain to an upland peat area. J. Ecology 56: 483-495.

The annual deposition of Na, K, Ca, Mg, N and P was measured over a 6-year period. Various experimental difficulties are discussed. E.

Gorham, E. 1955. On the acidity and salinity of rain. Geochim. et Cosmochim. Acta 7: 231-239.

The chemical composition of 42 rainwater samples collected in 1954 at the English Lake District results from seawater inputs of Na and Cl, and inputs SO_4 and H^+ from industrial sources (soot). E.

Gorham, E. 1958. The influence and importance of daily weather conditions in the supply of chloride, sulphate and other ions to fresh waters from atmospheric precipitation. Phil. Trans. Roy. Soc. B. 241: 147-178.

Chemical analyses of daily precipitation samples collected in the English Lake District during 1955 and data on amount of precipitation, wind direction, wind velocity and temperature showed that sulfate is supplied principally from atmospheric pollution, that Na and Cl are of marine origin, and that atmospheric precipitation is a major source of major ions to fresh waters. E.

Gorham, E. 1961. Factors influencing supply of major ions to inland waters, with special reference to the atmosphere. Geol. Soc. Amer. Bull. 72: 795-840.

The chemistry of inland waters is determined by chemical inputs from the atmosphere (rain, dry fallout, snow, gases) and from soil and rock weathering. The atmosphere, in turn, receives its chemicals from the sea, soil, air pollution, volcanoes and organic matter. This paper includes an extensive literature review. E.

Grahn, O., and H. Hultberg. 1974. Försurningens effekter på oligotrofa sjöars ekosystem - integrerade förandringar i artssammensätning och dynamik. Meddelanden nr. 2. Swedish Water and Air Pollution Research Laboratory, Gothenburg. Report, 17 p.

Grahn, O., H. Hultberg, and L. Landner. 1974. Oligotrophication - a self-accelerating process in lakes subjected to excessive supply of acid substances. Ambio 3: 93-94.

Intensive studies, including whole-lake manipulations are described for 6 lakes in a very acid region of western Sweden. The long-term effects of acidification cause lakes to decrease in productivity and thereby move towards a more oligotrophic state. Alterations in macrophytes, invertebrates and fish populations are discussed. E.

Granat, L. 1972. On the relation between pH and the chemical composition in atmospheric precipitation. Tellus 24: 550-560.

Using chemistry data from 2000 precipitation samples collected on the European Atmospheric Chemistry Network, the relationship between pH and acidity was explored. Since pH is the net result of several acid and basic compounds of different origins, pH and sulfate are not highly correlated. E.

Granat, L. 1974. On the deposition of chemical substances by precipitation (as observed with the aid of the atmospheric chemistry network in Scandinavia). WMO Special Environm. Report No. 3: 71-78.

The problems in the calculation of areal deposition rates from precipitation chemistry data are discussed, and the 20-year record from the European Atmospheric Precipitation Network is used as an illustration. E.

Grande, M. 1966. Vannets pH og dens betydning for ferskvannsfiske. En orientering om norske undersøkelser og erfaringer. NIVA O-139/64. 13 p.

This is a summary of Norwegian information on the effect of acid-waters on fish. N.

Griffiths, D. 1973a. The structure of an acid moorland pond community. J. Animal Ecol. 42: 263-284.

The spatial relations of plants and animals in a small acid (pH 4.4) pond in S.W. England are described, and species abundances and distributions are discussed. E.

Griffiths, D. 1973b. The food of animals in an acid moorland pond community. J. Animal Ecol. 42: 285-294.

By examining the gut contents of animals, the factors affecting food sources were evaluated. E.

Grøterud, O. 1972a. Zooplankton and fish in relation to acid melt water and anaerobic deep water in a lake. Vatten 28: 329-332.

The distribution of a copepod and the fish in an acid lake near Oslo appears to be controlled by the pH in the surface waters and H_2S content of the hypolimnetic waters. E.

Grøterud, O. 1972b. Ice-analyses. Data from three Norwegian lakes. Hydrobiologia 40: 371-391.

Ice analyses indicate that freeze-out concentrates nutrients (N, P) in ice layers. These nutrients are then released during spring-melt. E.

Grøterud, O. 1972c. Hydrographical data from two soft water lakes with special reference to precipitation (melt water). Arch. Hydrobiol. 70: 277-324.

Two acid lakes just west of Oslo were studied in detail, and the chemistry of these lakes explained in terms of precipitation chemistry, melt-water chemistry, and biological activity in the lakes themselves. E (G summary).

Grøterud, O. 1973. Noen sure innsjøer i Norge. Vatten 2: 153-158.

Chemistry of 8 small lakes just west of Oslo is discussed. These lakes are characterized by low pH, low-conductivity and declining fish-populations. N.

Gunnerød, T. B. 1973. Forsøk med utsetting av lakseunger i Siravassdraget med Moisåna i 1972 og 1973. Direktoratet for jakt, viltstell og ferskvannsfiske, Norway. Unpubl. report. 10 p.

Attempts to stock salmon fry in several rivers of southern Norway were unsuccessful, probably because the water was too acid. N.

Haapala, K. 1972. The quality of rainwater in Finland according to observations made during 1971. National Board of Waters, Helsinki Finland.

Precipitation chemistry data from the 42-station network in Finland for 1971 show that northern Finland receives less dissolved solids than southern Finland due to the greater distance from the sea, the greater distance from industrial pollution sources, and the lesser amount of precipitation. Fi (E summary).

Haapala, K. 1974. Undersökningar av nedfallets sammansättning i Finland 1971-73, p. 344-358. In Nordisk Hydrologisk Konference, Copenhagen.

Precipitation chemistry data from the 42-station network in Finland show that precipitation in southernmost Finland has high concentrations of sulfate, nitrate and hydrogen-ion. S.

Hagen, A., and A. Langeland. 1973. Polluted snow in southern Norway and the effect of the meltwater on freshwater and aquatic organisms. Environ. Poll.: 5: 45-57.

Polluted snow and surface ice considerably alter the lake-water chemistry during spring-melt with possible adverse affects on fish and invertebrates due to low pH and high Zn concentrations. E.

Hagen, O., G. Norby. 1967. Noen undersøkelser i forbindelse med problemet surt vann og dets betydning for lakse- og ørretbestanden på Sørlandet. Norg. Jeg. og Fiskeforb. Tidsskr.: 250-255.

The relationship between acid precipitation and acid lakes and rivers is discussed, and the salmon-catch data from 1951-1964 from several rivers in Southern Norway are presented and explained on the basis of pH. N.

Hales, J. M., and S. L. Sutter. 1973. Solubility of sulfur dioxide in water at low concentrations. Atmos. Environm. 7: 997-1001.

Experiments were conducted using SO_2-concentrations at levels commonly found in nature, and the results agree well with theoretical values. E.

Hallsworth, E. G., and W. A. Adams. 1973. The heavy metal content of rainfall in the East Midlands. Environ. Poll. 4: 231-236.

The concentrations of 16 trace elements in rainfall and fly-ash collected during 1963-64 were measured. Particulate emissions from nearby power plants account for only part of the deposition. E.

Hanson, M. 1974. Zooplankton i Fulufjällsjöar med lågt pH. Information från Sötvattenslaboratoriet, Drottningholm No. 5. 17 p.

The zooplankton in 2 alpine lakes with low pH (less than 5) has been affected by the acid conditions with several species (*Daphnia*) absent. S (E summary).

Harrison, A. D. 1958. The effects of sulphuric acid pollution on the biology of streams in the Transvaal, South Africa. Verh. internat. Ver. Limnol. 13: 603-610.

Several streams polluted by acid mine drainage have low pH (as low as 2.9). At pH less than 5 specialized flora and fauna develop, and only these species survive at pH less than 4. E.

Haugbotn, O. 1973. Nedbørundersøkelser i Sarpsborgdistriktet, og undersøkelser over virkninger av forsurende egensskaper. Unpubl. report. Norges Landbrukshøgskole. 151 p.

The local deposition of S in the vicinity of the Norwegian industrial center of Sarpsborg is measured, and the effects on soil chemistry investigated. N (E summary).

Henriksen, A. 1972a. Regresjonsanalyse av pH- og hårdhetsobservasjoner i Sørlandselver. Vann 1: 1-9.

Snekvik's pH and hardness data from 19 rivers in southernwest Norway during the period 1965-70 are treated with various statistical techniques. A decline in pH, increase in hardness, and cyclic periodicity of the data are demonstrated. N.

Henriksen, A. 1972b. Quantitative chemical analysis of snow. Vatten 5: 409-412.

Complete analysis of 1 snow profile from Norway. N.

Henriksen, A., T. Dale, and S. Haugen. 1974. Smelting av forurenset snø i termostatert lysimeter. SNSF IR 1/74. 18 p.

The fractionation and concentration processes during snow-melt were investigated in the laboratory. Eleven chemical components were measured. N.

Henriksen, A., and M. Johannessen. 1975. Avsyring av sure vann. En litteraturoversikt og generell vurdering. SNSF-project. IR 5/75. 44 p.

Based on published and unpublished reports the use of limestone, calcium hydroxide and other alkaline compounds to counteract the acidification of lakes and rivers is evaluated. Experience in Norway indicates that such practice is reasonable only for small streams and ponds. N.

Herman, F. A., and E. Gorham. 1957. Total mineral material, acidity, sulphur and nitrogen in rain and snow at Kentville, Nova Scotia. Tellus 9: 180-183.

Monthly samples of precipitation collected 1952-54 in rural eastern Canada had on average pH of 5.7, and acidic samples also had higher concentrations of nitrate and sulfate. Snow samples had much lower concentrations than rain, suggesting a difference in washout efficiency. E.

Högström, N. 1973. Residence time of sulfurous air pollutants from a local source during precipitation. Ambio 2: 37-41.

Sulfur emitted from local sources in Uppsala is washed out as sulfate within 1-2 hours or 50-100 km from the sources. These results indicate that local sulfate sources are important (25-50%), rather than negligible as previously asserted (see Bolin and Grannat 1973). E.

Holtan, H. 1972. Kjemisk-fysiske undersøkelser i IHD's representative område på Filefjell. Unpubl. manuskript. NIVA. 9 p.

The IHD watershed at Filefjell, Norway, is described, and some data for precipitation - and runoff-chemistry are discussed. N.

Holt-Jensen, A. 1973. Acid rains in Scandinavia. Ecologist 3: 378-382.

This is an overview of acid-rain and its impact on soils, forests and fisheries in Scandinavia. E.

Horntvedt, R., and E. Joranger. 1974. Nedbørens fordeling og kjemiske innhold under traer: Juli-november 1973. SNSF-project TN 3/74. 29 p.

The chemistry of precipitation and throughfall was measured at two forested sites, one in an area of southern Norway that receives acid precipitation and one in a relatively unaffected area of northern Norway. N.

Huge, D., and Å. Killingtveit (eds.) 1973. Hydrological data - Norden. Sagelva, Norway. Data 1968-1971. Norweg. Nat. Comm. for the Internat. Hydrol. Decade, Oslo. 67 p.

This report describes the Sagelva site (north coastal region), gives the sampling procedures for precipitation, surface waters and meteorologic data, and lists the raw data for 1968-71. E.

Hultberg, H., and J. Stenson. 1970. Försurningens effekter på fiskefaunaen i två bohusländska småsjöar. Fauna och Flora. 65: 1-20.

Huitfeldt-Kaas, H. 1922. Om aarsaken til massedød av laks og ørret i Frafjord-elven, Helle-elven og Dirdalselven i Ryfylke høsten 1920. Norges Jæger- & Fiskfor. Tidsskr. 51: 37-44.

The fish-kills (salmon) of autumn 1920 are described, and although the cause was not apparent, the kills were ascribed to the washout of humic substances from the soils following an unusually dry summer. N.

Hutchinson, T. C., and L. M. Whitby. 1974. A study of airborne contamination of vegetation and soils by heavy metals from the Sudbury, Ontario, copper-nickel smelters, p. 175-178. In D. O. Hemphill (ed.) Trace Substances in Environmental Health - VII.

Analysis of Cu and Ni contents of soils and vegetation, and laboratory experiments on toxicity of these metals to plants, indicate that the soils of the Sudbury region contain inhibitory levels of Cu and Ni. E.

Jensen, K. W. 1972. Laks, ørret og pH i Sørlandsvassdrag. Vann 1: 1-6.

Jensen discusses the 100-year record of salmon catches from 79 major rivers in Norway and the documentation of declining salmon catches in rivers of Aust- and Vest-Agder counties. He also presents and discusses fish data from 2083 lakes in Telemark, Aust- and Vest-Agder, and Rogaland. 741 of these are barren, most of them since 1940, and this is highly correlated with pH levels in the lakes. N.

Jensen, K. W., and E. Snekvik. 1972. Low pH levels wipe out salmon and trout populations in southernmost Norway. Ambio 1: 223-225.

The gradual decline in pH of many lakes and rivers in southernmost Norway has resulted in drastic declines of fish populations (salmon in rivers, brown trout in lakes). Documentation comes from salmon-catch records for the last 100 years and extensive reports from fishery authorities in each community. This is essentially an English version of Jensen (1972). E.

Jernelöv, A. B. 1973. Mercury fall-out from the atmosphere. In Proc. Symp. Eur. Fed. Protection Wat., Finland. 8 p.

The geochemical cycle of Hg has been altered by man's activities such that Hg fallout is high and increasing. Most of the Hg from a local source is incorporated into the regional or global atmosphere; only a small fraction is washed out locally. E.

Johnson, N. M., R. C. Reynolds, and G. E. Likens. 1972. Atmospheric sulfur: Its effect on the chemical weathering of New England. Science 177: 514-516.

Data from Hubbard Brook, New Hampshire, indicate that sulfuric acid may control chemical weathering processes in areas that receive large inputs of acidic precipitation. E.

Jonasson, J. R. 1973. Migration of trace metals in snow. Nature 249: 447-448.

Jonsson, B., and R. Sundberg. 1972. Has the acidification by atmospheric pollution caused a growth reduction in Swedish forests? Royal College of Forestry, Dept. of Forest Yield Res., Stockholm. Research Note No. 20. 47 p.

A statistically significant reduction in growth between two groups of forest stands (on soils of lesser and greater buffer capacity) of 3-6 permil was found, but due to the non-experimental nature of the data this growth reduction cannot definitely be ascribed to acid precipitation. E (summary).

Jordan, D. H. M., and R. Lloyd. 1964. The resistance of rainbow trout *(Salmo gairdnerii* Richardson*)* and roach *(Rutilus rutilus* (L.)*)* to alkaline solutions. Int. J. Air Wat. Poll. 8: 405-409.

Experiments on the survival of fish in alkaline solutions (pH above 9.5) show that acclimatization to alkaline waters lengthens survival times. E.

Junge, C. E. 1956. Recent investigations in air chemistry. Tellus 8: 127-139.

Aerosol measurements made on the US east coast showed that there are two particle size-classes (0.08-0.8 micron and 0.8 to 8 micron). Nitrate appears not to be of industrial origin but rather due to mixing of continental and marine air masses. E.

Junge, C. E. 1960. Sulfur in the atmosphere. J. Geophys. Res. 65: 227-237.

Estimates of the sulfur budget of the global atmosphere indicate that 30% is of anthropogenic origin (excluding sulfate in sea salt particles). Since the concentration of sulfate in Greenland ice back to 1915 has not increased as much as the increase in anthropogenic emissions, much of the sulfur is removed before air masses reach polar regions. This agrees with estimates of residence times of 5 days for SO_2 and 40 days for total S. E.

Junge, C. E., and P. E. Gustafson. 1957. On the distribution of sea salt over the United States and its removal by precipitation. Tellus 9: 164-173.

Data for chloride concentrations in rainwater collected during

1955-56 at 62 US stations indicate that the drop in concentration along the coast and the constant inland levels are due to large-scale vertical mixing in the troposphere rather than by washout. E.

Junge, C. E., and R. T. Werby. 1958. The concentration of chloride, sodium, potassium, calcium, and sulfate in rainwater over the United States. J. Meterol. 15: 417-425.

One-year's data (1955-56) from a US precipitation network showed that the ocean is the major source of Cl, that the soil supplies Na and K, that Ca is highest in dust storm areas of the southwest, that sulfate originates from sea spray but 30% is anthropogenic, and that the average global sulfate residence time is 40 days. E.

Kamijo, H., T. Watanabe, and K. Mashiko. 1974. The attached algal flora of the Nagase-Gawa, a strong acid water river and its tributaries, Fukushima prefecture. Japanese Journ. Ecology 24: 147-152.

At sampling points where the river water was very acid the standing crops were poor and the flora contained only diatoms and green algae. At less acid points blue-green algae were abundant. J (E summary).

Karlén, A. 1972. Svoveldioxidens inverkan på mark och skog, sjöar, vattendrag och fisk. Svenska Reproduktions AB, Stockholm. 8-44.

Katz, M. 1968. The biological and ecological effects of acid mine drainage with particular emphasis to the Appalachian region streams. Appalachian Regional Commission, Washington, D.C., unpubl. report.

Katz, M., and R. T. Oglesby. 1967. A review of the literature of 1966 on wastewater and water pollution control. Biology. J. Water Poll. Cont. Fed. 39: 1049-1096.

This annual literature review includes some references on the effects of acidity. E.

Katz, M., D. E. Sjolseth, D. R. Andersson, and L. R. Tyler. 1970. A review of the 1969 literature on wastewater and water pollution control. Effects of pollution on fish life. J. Water Poll. Cont. Fed. 42: 983-1001.

This annual literature review includes some references on the effects of acidity. E.

Kettner, H. 1974. Beeinträchtigung oberirdischen Gewässer durch anorganische Stoffe, p. 18-32. In H. E. Vogel (ed.) European Fed. Protection Waters, Zürich, Info. Bull. 21.

Data from central Germany on dry deposition and washout of major and trace elements indicate that the effects on fresh waters in this area are 1) an increase in concentration of anions such as Cl, F, SO_4 and 2) an increase in heavy metal concentrations, particularly in sediments. G(G summary).

Kjos-Hanssen, B. 1970. Fiske og surt vann. Fiskedødeligheten har virkelig skutt fart i 1950/60-årene. Tekn. Ukebl. 117: 38.

The adverse effects of acid precipitation on fish populations have increased dramatically during the 1950's and 60's. N.

Kohonen, T. 1974. The washing out of alkaline earths in the watersheds, p. 315-326. In Nordisk Hydrologisk Konference, Copenhagen.

The washout of Ca, K, and Na during 1962-68 was measured at 34 small gauged-watersheds over all of Finland. Washout is related to watershed geology and land-use. E.

Koide, M., and E. D. Goldberg. 1971a. Atmospheric sulfur and fossil fuel combustion. J. of Geophys. Res. 76: 6589-6595.

Sulfate-chloride ratios in ice samples from Greenland indicate that fossil-fuel combustion introduces more S into the atmosphere than natural processes such as volcanism and decomposition of organic matter. Since the amount of S covaries with Pb, a similar source and atmospheric path for these two elements is likely. E.

Koide, M., and E. D. Goldberg. 1971b. Mercury in a Greenland ice sheet: Evidence of recent input by man. Science 174: 692-694.

The increased Hg content in ice over the last several decades is probably due to the dissemination of Hg into the atmosphere by man, thus augmenting the natural Hg supply from degassing of the earth's crust. E.

Kramer, J. R. 1973a. Fate of atmospheric sulphur dioxide and related substances as indicated by chemistry of precipitation. Department of Geology, McMaster University, Hamilton, Ont. Unpubl. report. 143 p. + appendix 44 p.

A 3-year study of precipitation chemistry at 35 stations in

Ontario indicates that high concentrations of some components are due to local anomalies and/or regional sources. The fates of various components are discussed with special reference to lake water-chemistry and biology. E.

Kramer, J. R. 1973b. Atmospheric composition and precipitation of the Sudbury region. Alternatives (Trent Univ., Peterborough, Ontario) 2 (No. 3): 19-25.

A comparison of air quality at Sudbury and New York City shows that "unhealthy" levels of SO_2 are often reached at both localities. Precipitation near Sudbury contains large amounts of sulfate, acid, and heavy metals that have serious effects on the plants, soils and lakes of the region. E.

Kramer, J. R., and W. R. Snyder. 1974. Precipitation scavenging of sulfur oxides using stable sulfur isotopes. Proc. 1974 U.S. Atomic Energy Commission Conference (in press).

The mass balance for sulfur emitted from the Sudbury, Ontario, smelter was calculated using stable sulfur isotopes, and while 76% of the omitted H_2SO_4 is deposited within 100 km of the stack, most of the emitted S is exported from the region. E.

Krishna, D. 1953. Effect of changing pH on developing trout eggs and larvae. Nature 171: 434.

Both eggs and larvae die at pH levels below about 5 and above 9. E.

Laamanen, A. 1972. Areal evaluation of sulfates in dustfall, rainfall, acidity and needle injuries. Work-Environm. Health 9: 26-39.

Acidity and sulfate concentrations in dustfall in urban Finland have resulted in damage to coniferous tree needles. This pollution is increasing in severity but is related to local sources.E.

Låg, J. 1963. Tilføring av plantenæringsstoffer med nedbøren i Norge. Forsk. Fors. Landbr. 14: 553-563.

Låg discusses precipitation chemistry from the period 1870-1951 (5 Norwegian articles) and then the Norwegian data from 1954-60 from the IMI network. N (E summary).

Låg, J. 1968. Relationships between the chemical composition of the precipitation and the contents of exchangeable ions in the humus layer of natural soils. Acta Agr. Scand. 18: 148-153.

The main results from an analysis of 981 humus samples collected in central Norway are discussed, and it is concluded that an ion exchange occurs between precipitation (often polluted) and raw humus. E.

Låg, J., and E. Steinnes. 1974. Soil selenium in relation to precipitation. Ambio 3: 237-238.

Data from 3000 soil humus samples indicate that the principal source for selenium is precipitation, probably of marine origin, whereas arsenic originates elsewhere. E.

Laney, R. L. 1965. A comparison of the chemical composition of rainwater and ground water in western North Carolina. U.S. Geol. Surv. Prof. Paper 525-C: 187-189.

Analysis of 33 rainwater samples collected during 1962-63 at 8 sites and 321 groundwater samples showed that there is a rapid change in chemistry as the rainwater infiltrates from a calcium sulfate-bicarbonate rainwater to a mixed-cation bicarbonate groundwater. E.

Larson, T. E., and I. Hettick. 1956. Mineral composition of rainwater. Tellus 8: 191-201.

Analysis of 62 rain samples collected 1953-54 near Chicago showed that the sea salt component is negligible and that both N and S are supplied by combustion of fossil fuels. E.

Larson, T. V., R. J. Charlson, E. J. Knudson, G. D. Christian, and H. Harrison. 1975. The influence of a sulfur dioxide point source on the rain chemistry of a single storm in the Puget Sound Region. Water Air Soil Poll. (in press).

Rainwater samples collected during a single storm indicate that a copper smelter influences rain chemistry out to 40 km by increasing the acidity and sulfur content of rain. E.

Le Barre, N. 1973. Lead contamination of snow. Water Res. 7: 1215-1218.

Ledbetter, J. O. 1972. Variation of pollutant concentration with sampling time. Environmental Letters 3: 159-169.

Temporal fluctuations in air pollutants must be considered when planning sampling schedules, or the resulting errors may be considerably larger than errors in the sampling and analytical methods. E.

Leivestad, H., and I. Pl Muniz. 1974. Fiskedøk ved lav pH. SNSF-project. TN 4/74. 17 p.

Preliminary results using a new technique to measure Na, Cl, pH and HCO_3 in fish blood indicate that the blood of acid-stressed fish has abnormal levels of these components. N.

Likens, G. E. 1972. The chemistry of precipitation in the central Finger Lakes region. Cornell University Water Resources and Marine Science Center, Ithaca, NY, Tech. Rept. 50. 47 p.

Precipitation chemistry data at 5 stations in upstate NY 1970-71 show that the atmosphere is an important source of nutrients for ecosystems and that precipitation is often highly polluted with acid compounds of sulfur and nitrogen that originate from combustion of fossil fuels in the industrial areas of the north-central US.

Likens, G. E., and F. H. Bormann. 1974. Acid rain: A serious regional environmental problem. Science 184: 1176-1179.

Rain with an average annual acidity of pH 4 falls on most of the northeastern US. The acidity has increased during the past 30 years due to different fuel uses and emissions. Little is known about the ecological and economic effects of this acid rain. E.

Likens, G. E., F. H. Bormann, and N. M. Johnson. 1972. Acid rain. Environment 14: 33-40.

This is an introduction to the acid-rain phenomenon in North America, and especially the potential impacts on whole ecosystems, both terrestrial and aquatic. E.

Lillehammer, A. 1974. Norwegian stoneflies. II. Distribution and relationship to the environment. Norsk ent. Tidsskr. 21: 195-250.

This report discusses the stonefly distributions in terms of dispersion and various environmental factors. No chemistry data are included. E.

Little, P., and M. H. Martin. 1974. Biological monitoring of heavy metal pollution, Environ. Pollut. 6: 1-19.

Using *Sphagnum* moss suspended in nylon nets the deposition of heavy metals from the atmosphere can be measured. This technique was used to measure the Zn, Pb and Cd deposition around a smelter in southern England. E.

Lloyd, R., and D. H. M. Jordan. 1964. Some factors affecting the resistance of rainbow trout (*Salmo gairdnerii* Richardson) to acid water. Int. J. Air Wat. Poll. 8: 393-403.

The resistance to short term exposure to acid waters was unaffected by the acclimatization pH but was increased with increased water hardness. The acid appears to affect the maintenance of buffer capacity in blood, and death was apparently due to acidaemia. Extrapolation of the results suggests that exposure to pH 5.0 waters for 3 months is harmful. E.

Lunde, G., and J. Gether. 1974. Analyse av organiske mikroforurensninger i nedbør. SNSF-project. IR 4/74. 86 p.

A gas chromatograph-mass spectrometer technique for the separation and identification of trace amounts of organic pollutants in precipitation is presented. Measurements of 5 samples showed differences in concentrations and composition of organic micropollutants present in polluted and unpolluted precipitation in Norway. N.

Malmer, N. 1974. Förslag till forskningsprogram över "Försurningens effekter" för budgetåren 1974/75 - 1977/78.
Avd. för Ekologisk Botanik, Lunds Universitetet, Sweden. Unpubl. report. 10 p.

This research proposal describes Malmer's plans for acid-precipitation research, 1974-1978. He proposes to undertake broad studies on freshwater, forest and land ecosystems. S.

Matveev, A. A. 1970. Chemical hydrology of regions of East Antarctica. J. Geophys. Res. 75: 3686-3696.

The chemistry of precipitation, snow, and ice is strongly dominated by marine constituents with admixture of some continental material, especially sulfur. E.

McKim, J. M., G. M. Cristens, J. H. Tucker, and M. T. Lewis. 1973. Effects of pollution on freshwater fish. J. Water Poll. Cont. Fed. 45: 1370-1407.

This literature review discusses the effects of all types of pollution on freshwater fish, including heavy metals, pesticides, O_2-depletion, salinity, organic chemicals, radioactive isotopes, and pH. E.

Mellquist, P. 1972. Statistisk analyse av pH-data fra Sira-Kvina-vassdragene. Norges vassdrags - og elektrisitetsvesen VN Rapport 1-72. 10 p.

Extensive statistical treatment of pH, hardness and specific conductance data for 1965-70 from several water sources in southernmost Norway failed to show significant differences between regulated and unregulated water bodies. N.

Michelski, M. F. P., and J. Adamski. 1974. Restoration of acidified lakes Middle and Lohi in the Sudbury area, p. 163-175. In Ontario Industrial Wastes Conferences 1974.

Addition of $CaCO_3$ and $Ca(OH)_2$ to two acid lakes resulted in elevation of pH, decrease in concentration of heavy metals, and a decrease in chlorophyll a concentrations. The latter is probably a short-term effect due to flocculation and precipitation. E.

Miljøverndepartementet. 1974. Internasjonale tiltak for bekjempelse av sur nedbør. Miljøverndepartementet informerer i sept.

This report describes various international efforts to document the SO_2 emissions and transport (OECD project), and to negotiate reductions in SO_2 emissions. N.

Miller, J. M., and R. G. de Pene. 1972. Contribution of scavenged sulfur dioxide to the sulfate content of rain water. J. Geophys. Res. 77: 5905-5915.

Experiments show that SO_4 is readily formed in rain drops in the presence of SO_2 (polluted atmosphere). Furthermore, the sulfate content of rainwater reflects particle washout rather than gaseous washout. In the presence of NH_3 and SO_2 particles of cloud-nucleus size are produced. E.

Mrose, H. 1966. Measurements of pH, and chemical analyses of rain-, snow-, and fog-water, Tellus 18: 266-270.

Analysis of 200 precipitation samples collected 1957-64 at Dresden, East Germany, showed that the acidity (pH 4.5) did not change significantly over this period, while precipitation in West Germany and elsewhere in western Europe is increasing in acidity. This difference is perhaps due to changes in fuel use. Some data on the radioactivity of fog and rain are presented. E.

Muller, E. F., and J. R. Kramer. 1974. Precipitation scavenging in Central and Northern Ontario. Ministry of Environment, Ontario, Canada. Unpubl. report. 11 p.

The deposition of SO_4, Fe, Ni and Cu in Ontario is related to the distance from the Sudbury smelter and was altered after installation of the 381-meter stack. E.

Nordø, J. 1973. Meso-scale and large-scale transport of air pollutants. In Proc. 3rd Int. Clean Air Congress, Düsseldorf. B 105-107.

For several "episodes" the trajectories and concentrations of pollutants in air masses are measured and found to fit a theoretical model of mixing and transport in the atmosphere. E.

Nordö, J. 1974. Quantitive estimates of long range transport of sulphur pollutants in Europe. Annalen der Meteorologie (N.F.), Nr. 9: 71-77.

Using the continuity equation the long-range transport of sulfur can be estimated knowing the emission and wind field. Application of several models shows that calculated deposition rates are within a factor of two of the measured rates. E.

Nordö, J., and K. Hjortnæs. 1967. Statistical studies of precipitation on local, national and continental scales. *Geophysica Norvegica* 26 (12): 1-46.

A statistical analysis of Norwegian precipitation data indicates that orographic release of precipitation is dominent at time scales ranging from 12 hours to 1 month. E.

Novakov, T., S. G. Chang, and A. B. Harker. 1974. Sulfates as pollution particulates: Catalytic formation on carbon (soot) particles. Science 186: 259-261.

Laboratory experiments show that SO_2 is readily oxidized to SO_4 in the presence of soot, and that this mechanism is consistent with field observations. E.

Odén, S. 1968. Nederbördens och luftens försurning - Dess orsaker, förlopp och verkan i olika miljöer. Statens Naturvetenskapliga Forskningsråd, Stockholm, Ekologikommitten, Bull. No. 1. 86 p.

Odéns thorough summary of the acid-rain problem includes a discussion of the European precipitation-chemistry data (1954-1965), the survey of Scandinavian rivers and lakes, and the observed and anticipated effects on aquatic and terrestrial ecosystems. S (E summary).

Odén, S. 1969. Regionale aspekter på miljöstörningar. Vann 3: 93-111.

This is another overview of the increasing acidity, SO_4, and NO_3 contents of precipitation in Scandinavia and the effects on soils, forests, and freshwaters. S.

Odén, S. 1971a. Nederbördens försurning - ett generellt hot mot ekosystemen. In Forurensning og biologisk miljøvern. 63-98.

This overview of acid precipitation and its effects on terrestrial and aquatic ecosystems in Scandinavia is similar to Oden (1968). S.

Odén, S. 1971b. The general eutrophication of the environment. 1. Phosphorous. Dept. of Soil Science, Agricultural College, Uppsala, Sweden. Unpubl. report. 16 p.

Phosphorus concentrations in precipitation and in bog profiles indicate that the atmospheric deposition of P has dramatically increased due to man's activities with the subsequent enrichment of P-poor bog, lake and forest ecosystems. E.

Odén, S. 1972. The extent and effects of atmospheric pollution on soils. FAO Soils Bull. 16: 179-194.

The chemical climate of Europe is changing rapidly (acidity, S, N, chlorinated hydrocarbons), and the effects on soils, forests, and fresh-waters in Scandinavia are large and potentially dramatic. E.

Odén, S. 1973. Markförsurning på grund av kvävelgödsling och atmosfäriskt nedfall av ammonium. Agricultural College, Dept. Soil Science, Uppsala, Sweden. Unpubl. report. 10 p.

The application of N-fertilizers (esp. NH_4) results in soil acidification, especially if nitrification proceeds. In addition the sizeable deposition of atmospheric NH_4^+ further acidifies the soil, and the result is a major CaO-deficit. S.

Odén, S., T. Ahl. 1970. Forsurningen av skandinaviske vatten. Ymer, Årsbok: 103-122.

Over 10 years of chemistry data from lakes and rivers in Scandinavia show a long-term decrease in pH in waters over large areas of southern Norway and Sweden. S (E summary).

Odén, S., and T. Ahl. 1974. The longterm changes in the pH of lakes and rivers in Sweden. Unpubl. report. 13 p.

Monthly data from 15 rivers in Sweden show that the pH is declining by about 0.25 units/year over the period 1965-69. These trends, if they continue, indicate that the pH will reach biologically critical levels in 30-50 years. This paper refers to section 5.2 of Sweden's case study for the UN Conf. on Human Environment (see Bolin et al. 1971). E.

Odén, S., and R. Andersson. 1974. The long-term changes in the chemistry of soils in Scandinavia due to acid precipitation. Unpubl. manuscript.

This paper refers to section 5.6 of Bolin et al. (1971), Sweden's case study. E.

Odén, S. and J. Bergholm. 1971. The chemistry of snow. 1. Ionic separation during melting. Dept. of Soil Science, Agricultural College, Uppsala, Sweden. Unpubl. manuscript.

The first meltwater from snow is considerably enriched in all major ions relative to the bulk snow. E.

OECD Environment Directorate. 1973. Survey on regional sulphur dioxide emission. Air management sector group, Org. for Economic Cooperation and Development, Paris. 79 p.

This restricted document lists SO_2 emissions by country and type of industry. E.

Økland, J. 1969a. Om forsuring av vassdrag og betydningen av surhetsgraden (pH) for fiskens næringsdyr i ferskvann. Fauna 22: 140-147.

Acidification of lake waters in Norway results in adverse affects to fish-food organisms such as *Gammarus lacustris* at pH levels above those found directly harmful to fish. Since lakes in large areas of southern Norway are characterized by very low buffer capacities large areas already may be adversely affected by acid precipitation. N (E summary).

Økland, J. 1969b. Distribution and ecology of the freshwater snails *(Gastropoda)* of Norway. Malacologia 9: 143-151.

This is a preliminary report on the distribution, ecology, and morphology of snails in Norway from 1350 sites. These data are discussed in terms of immigration patterns and modern environmental factors such as pH and total hardness. E.

Økland, K. A. 1969a. On the distribution and ecology of *Gammarus lacustris* G. O. Sars in Norway with notes on its morphology and biology. Norweg. J. Zool. 17. English version of Økland (1970) E.

Økland, K. A. 1969b. List of localities with *Gammarus lacustris* G. O. Sars in Norway with references and notes. Supplement to Contribution No. 89, Zoolog. Mus. Univ. of Oslo. 36 p.

This is the raw data for Økland 1969a and Økland 1970. Only the sites where *Gammarus* was found are listed, and no chemical data are included. E.

Økland, K. A. 1970. Undersøkelser over marfloen *Gammarus lacustris* - ørretens viktigste næringsdyr. Fauna 23: 1-11.

The distribution of *Gammarus lacustris* from 542 localities in Norway is presented. No finds are reported from waters with pH less than 5.9. N (E summary).

Økland, K. A. 1971. On the ecology of *Sphaeriidre* in a high mountain area in south Norway. Norweg. J. Zool. 19.

Overrein, L. N. 1972a. Sulfur pollution patterns observed: leaching of calcium in forest soil determined. Ambio 1: 145-147.

The deposition pattern of pollutants (H^+, Ca, Mg, Fe, Mn, K, Na, SO_4) originating from a major local source in southern Norway is reported, and the effect of H^+ on soil chemistry (esp. washout of Ca) is discussed. E.

Overrein, L. N. 1972b. Forsuring av jordbunnen. Fysiske, kjemiske og biokjemiske forhold. Vann 1: 1-5.

This is a general discussion similar to Overrein (1972a) N.

Overrein, L. N. 1974a. Luftforurensning - Virkning på skog- og fjellnaturen. Proc. Nordisk Hydrologisk Konference, Copenhagen: 479-487.

An overview of the SNSF-project and its goals is presented. N.

Overrein, L. N. 1974b. Årsberetning 1973. SNSF-project. 31 p.

The 1973 annual report of the SNSF-project describes current research on the effects of acid precipitation on forest and aquatic ecosystems. During 1973 over 30 scientists were engaged in the project with a budget of 3.6 million Norwegian kroner. N.

Ottar, B. 1972. Säure Niederschläge in Skandinavien. Umschau 72: 290-291.

The acidity of precipitation in Scandinavia is increasing and causing reduction of fish populations and, possibly, forest growth. The acid rain is due to the transport of industrial pollutants from central Europe and Great Britain. G.

Ottar, B. 1973. The long range transport of air pollutants. In Proc. 3rd Int. Clean Air Congress, Düsseldorf. B 102-104.

The establishment of the OECD project "Longe range transport of air pollutants" is described including some preliminary results from the sulfur-emission survey and deposition measurements. E.

Ottar, B., and A. Semb. 1973. The OECD-Project, Cooperative technical programme to measure the long range transport of air pollutants. Norwegian Inst. for Air Research, Kjeller. 78 p.

This restricted report describes the establishment of the OECD project, some preliminary air-mass trajectory calculations, the application of such calculations to several "episodes" and the compilation of the SO_2-emission grid for Europe. E.

Ottar, B., and A. Semb. 1974. Transport av luftforurensninger over landegrensene. Vann 2: 77-82.

The Organization for Economic Cooperation and Development (OECD) project "LDTAP" (Long Distance Transport of Air Pollutants) was established in 1972 and involves daily measurements of air and precipitation-chemistry at stations throughout NW Europe. This network provides base data for calculating the dispersal and transport of air pollutants. N.

Packer, R. K., and W. A. Dunson. 1970. Effects of low environmental pH on blood pH and sodium balance of brook trout. J. Exp. Zool. 174: 65-72.

Trout from acid streams in Pennsylvania (acid mine drainage) show drop in blood pH and increase in Na efflux at pH 3.5. The former appears to explain the inability of trout to live in waters with pH less than 5. E.

Packer, R. K., and W. A. Dunson. 1972. Anoxia and sodium loss associated with the death of brook trout at low pH. Comp. Biochem. Physio. 41A: 17-26.

The lethal effect of HCl, H_2SO_4, and mine acid (pH 2.0-3.25) appears to be due to inhibition of O_2 uptake and to a large increase in Na loss. The mechanism of the lethal effect may be Na loss, especially at pH 3.25 and above. E.

Peirson, D. H., P. A. Cawse, and R. S. Cambray. 1974. Chemical uniformity of airborne particulate materials, and a maritime effect. Nature 251: 675-679.

The concentrations of 30 elements in airborne dust, rainwater, and dry deposition were measured at 12 stations in or near the British Isles during 1972-73. By comparing the elemental concentrations to Sc, the elements can be grouped according to maritime, soil-derived, or anthropogenic sources. The surface of the North Sea is enriched relative to bulk seawater. E.

Persson, G. 1969. The acidity and the concentration of sulphate in precipitation over Europe. Statens Naturvårdsverk, Stockholm. 4p.

Using data from the European precipitation-chemistry network the long-term trends of acidity and sulfate are calculated. While there have been overall increases in Scandinavia and central Europe, no such trend is seen in the data for the British Isles. E.

Ravera, O. 1973. Lead pollution in air and water. In Proc. Symp. Eur. Fed. Protection Wat., Finland. 13 p.

Man's activities have introduced enormous amounts of Pb into the environment, and Pb enrichment is evident in glaciers, seawater, and terrestrial and aquatic ecosystems. The levels may reach toxicity thresholds and long-term effects may be forthcoming. E.

Rohde, G. 1974. Hazardous heavy metals: Cadmium, mercury, lead and arsenic. WHO Intern. Ref. Cent. for Wastes Disposal, Dübendorf, Switzerland, News No. 6: 1-6.

Toxic heavy-metals present the greatest hazard to man when they are present in the air, for absorbtion is much higher in the respiratory system than in the alimentary tract. The soil-plant system also acts to reduce the danger of heavy-metal pollution through food. E.

Rohde, H. 1970. On the residence time of antropogenic sulfur in atmosphere. Tellus 22: 137-139.

Using data on the S concentration in snow collected near Uppsala, Sweden, the minimum residence time for anthropogenic sulfur is estimated to be 3-5 hours. E.

Rohde, H. 1972. A study of the sulphur budget for the atmosphere over Northern Europe. Tellus 24: 128-138.

Using OECD data for SO_2 emissions in Europe and the precipitation chemistry data from the European network, the sulfur budget is calculated for northern Europe. This calculation shows that sulfur dispersion has a continental character and that the turnover time for anthropogenic sulfur is 2-4 days. E.

Rohde, H., and J. Grandell. 1972. On the removal time of aerosol particles from the atmosphere by precipitation scavenging. Tellus 24: 442-454.

An estimated turnover time for atmospheric aerosols of 35-80 hours in winter and 100-300 hours in summer was calculated using data from a Swedish precipitation station. Only 10% of particles are thus deposited within 100 km of the source, and because precipitation scavenging of SO_2 is even less efficient, the local dqposition of gaseous S would be less. E.

Rossby, C. G., and H. Egnér. 1955. On the chemical climate and its variation with the atmospheric circulation pattern. Tellus 7: 118-133.

Isopleth maps for Na, Cl, S, and pH based on data from the European precipitation chemistry network show that the deposition of these elements depends on the origin and history of air masses over northern Europe. Deposition patterns for S and H^+ are related to combustion of fossil fuels. E.

Rühling, Å., and G. Tyler. 1971. Regional differences in the deposition of heavy metals over Scandinavia. J. Applied Ecology 8: 497-507.

The concentrations of several heavy-metals in mosses are much higher in southern than in northern Scandinavia. The only plausible explanation is that these metals are deposited in greater amounts in southern Scandinavia due to the proximity of large industrial areas. E.

Ruehling, A., and G. Tyler. 1973. Heavy metal deposition in Scandinavia. Water, air, and soil pollution 2: 445-455.

By analyzing the concentration of Pb, Cl, Hg, Cr, Ni, Cu, Zn and Fe in mosses, maps showing the relative deposition rates of these elements in Scandinavia were prepared. Southern Norway and Sweden show the highest concentrations, especially of Pb and Cd. E.

Särkkä, M. 1972. The washing out of nutrients in the watersheds. Aqua Fennica 1972: 88-103.

Data from 34 small gauged-watersheds collected during 1962-68 show that the loss of nutrients from Finland is small relative to other more fertile areas of the world, is dependent on fluctuations in runoff, and is related to land-use (esp. N washout). E.

Schjoldager, J. 1973a. Svovelforurensninger i luft og nedbør ved norske bakgrunnsstasjoner. Døgnmålinger nov. 1971-juni 1972. NILU TN 52/73. 79 p.

As part of the OECD project, daily measurements of air and precipitation were made at 23 stations in Norway. Results from the first half of 1972 show that the greatest deposition of sulfur occurs on the southwestern coast and that most of this sulfur is deposited during a few episodes, which are clearly related to meteorologic parameters. N.

Schjoldager, J. 1973b. Svovelforurensninger i luft og nedbør ved norske bakgrunnsstasjoner. Døgnmålinger 2. halvår 1972. NILU TN 65/73. 60 p.

Same as Schjoldager 1973a but for the first half of 1972.

Schlesinger, W. H., W. A. Reiners, and D. S. Knopman. 1974. Heavy metal concentrations and deposition in bulk precipitation in montane ecosystems of New Hampshire, USA. Environ. Pollut. 6: 39-47.

Measurements of Pb, Hg, and Cd during 4 months of 1971 showed that Pb deposition is high, probably because of major upwind industrial areas. These measurements underestimate the total deposition because cloud water condensation and aerosol impaction are not accounted for. E.

Schroeder, H. A. 1971. Metals in the air. Environment 13: 18-32.

The concentrations of 25 trace metals were measured in the US atmosphere. Eight of these are toxic, and four represent known hazards to man (Ni, Cd, Pb, Hg). High levels of these in the atmosphere can be reduced by readily-available abatement measures. E.

Seleyneva, E. S. 1972. Estimation of the background contamination of the atmosphere from the chemical composition of precipitation. Tellus 24: 122-127.

Precipitation chemistry measured during the 1960's at over 40 stations throughout the USSR show clearly that precipitation is a mixture of marine and terrestrial components. The sulfur content over continental areas is 30-40% natural background and the remaining 60-70% a mixture of local sources, both natural and anthropogenic. In polluted areas there is twice as much excess sulfate as background sulfate. Globally about 10% of the sulfur in precipitation is anthropogenic. E.

Shaw, R. W., and D. M. Whelpdale. 1973. Sulfate deposition by precipitation into Lake Ontario. Water, Air and Soil Pollution 2: 125-128.

Individual snow storms may deposit many times more sulfate than the average daily deposition, and the atmospheric contribution of sulfate to Lake Ontario is as important as industrial effluents. E.

Shukla, S. S., and H. V. Leland. 1973. Heavy metals: A review of lead. J. Water Poll. Cont. Fed. 45: 1319-1331.

This literature review covers all aspects of Pb pollution with references from all continents. E.

Sivertsen, A., and E. Snekvik. 1973. Avsyring av Sandvatn og

Lauvtjønna ved kalking, og ny forsurning med tiden (1967-1973). Direktoratet for jakt, vilt of ferskvannsfisk. Unpubl. report. 61 p.

The pH in 2 small, acid lakes in southern Norway was raised by adding lime, but due to continued inputs of acid from precipitation and runoff, the pH gradually declined once again. N.

Sivertsen, A., and E. Snekvik. 1975. Kjemiske forhold ved vannet i elver i Rogaland, Agderfylkene og Telemark m.m. i 1974. Samlerapport nr. 7 over "Sørlandselver" og referanseelver i andre landsdeler. Direktoratet for vilt og ferskvannsfisk, Norway. Unpubl. report. 54 p.

This is the raw data for pH, hardness and specific conductance in monthly or weekly samples of rivers in southernmost Norway and reference rivers in northern Norway. N.

Skogvold, O. F. 1974. Vi får enorme mengder svovelsyre luftveien fra utlandet. Tekn. Ukebl. 121 (17): 21-24.

The SO_2 emissions in Europe are presented and compared with Norwegian sources. N.

Small, S. H. 1960. Wet and dry deposition of fallout materials at Kjeller. Tellus 12: 308-314.

Measurement of radioactive fallout near Oslo during 1956-59 shows that wet and dry deposition and surface-air activity are all interrelated. E.

Snekvik, E. 1969a. Rapport nr. 2: Forsøk med klekking av yngel ved forskjellig pH og overføringsforsøk av rogn til vann med høyere pH og av yngel til vann med lavere pH. Direktoratet for jakt, vilt og ferskvannsfisk. Unpubl. report. 27 p.

Various fish-hatching experiments showed that the critical pH-level for salmon eggs is about 5.0, but that the success is also dependent on total hardness. N. (See Bua and Shekvik 1972).

Snekvik, E. 1969b. Klekkeforsøk 1968/69. Direktoratet for jakt, vilt og ferskvannsfisk. Unpubl. report. 6 p.

Fish-hatching experiments indicate that success is strongly pH-dependent and that various species exhibit varying tolerance to low-pH water. N.

Snekvik, E. 1969c. Forsurning av elver og vann - Innvirkning på ørret- og laksefisket. Vann No. 3: 113-119.

Snekvik describes the increasing acidity of rivers and lakes in southernmost Norway and traces the history of the effects on fish. N.

Snekvik, E. 1969d. Rapport over fiskedød. Direktoratet for vilt og ferskvannsfisk, Norway. Unpubl. report. 9 p.

The fish kills observed in Rogaland and Sørlandet are probably due to high acidity. N.

Snekvik, E. 1970. Rapport fra Telemark. Direktoratet for vilt og ferskvannsfisk. Unpubl. report. 4 p.

Thirty years of pH and fish data from 12 acid lakes in southern Norway are presented. N.

Snekvik, E. 1972. Forsurning av vassdrag i våre sydligste landsdeler. Vann 1: 1-9.

Snekvik discusses 50 years of records concerning pH from lakes and rivers in southernmost Norway. N.

Snekvik, E. 1974a. Audna som fremtidig lakselv - botemidler mot forsurningen. Direktoratet for vilt og ferskvannsfiske, Norway. Unpubl. report. 7 p.

The acidity in Audna river might be counteracted by the use of limestone or even seawater. N.

Snekvik, E. 1974b. Om surt vann og ferskvannsfisk. Klipp fra fiskeri-inspektørens årsmeldinger i årene 1915-1961. Direktoratet for jakt, vilt og ferskvannsfisk. Unpubl. report. 22 p.

Snekvik, E. 1974c. Sure innsjøer og fiskebestand. Rapport nr. 2. Rogaland-Agder-Telemark. Direktoratet for Vilt og Ferskvannsfisk, Norway. 50 p.

The raw data on the fish status in 2800 lakes in 67 communities of Rogaland-Agder-Telemark are given. Over 1000 now have no fish, and these lakes generally also have pH less than 5. (See Jensen (1972) for N summary and Jensen and Snekvik (1972) for E summary). N.

Snekvik, E. 1975. Generelt om avsyring av sure vassdrag. Direktoratet for jakt, vilt of ferskvannsfisk. Unpubl. report. 7 p.

To neutralize the deposition of acid in southernmost Norway at least 200,000 tons of calcium carbonate per year would be required. N.

Snekvik, E., A. R. Selmer-Olsen, A. Njøs, and R. Bærug. 1973. Undersøkelser av nedbør fra ulike steder i Norge i årene 1965-71. Melding fra Norges Landbrukshøgskole 52 (13): 1-19.

Chemistry of irregularly collected samples of precipitation is reported, and the data subjected to various regression analyses. Conclusions are that pH is decreasing and that Zn, pH and SO_4 are good pollution indicators. E (N summary).

Snekvik, E., and A. Sivertsen. 1975. Diagrammer fra pH og total hårdhet. Elveserie fra det sydligste Norge med referanseelver i andre landsdeler, for perioden 1926 til og med 1974. Direktoratet for vilt og ferskvannsfisk. Unpubl. report. 41 p.

Data for pH and total hardness from monthly samples of 29 rivers in southernmost Norway and 4 reference streams in northern Norway are plotted. Some early data from 1926-45 are also given. N.

Sorokin, C. 1962. Carbon dioxide and bicarbonate in cell division. Archiv für Mikrobiol. 44: 219-227.

Experiments with the green alga, *Chlorella,* show that cell division proceeds best at pH 6.5-7.5, probably because of the inhibitory effect of dissolved, undissociated CO_2. E.

Stokes, P. M., T. C. Hutchinson, and K. Krauter. 1973. Heavy metal tolerance in algae isolated from polluted lakes near the Sudbury, Ontario, smelters. Wat. Poll. Research in Canada 8: 177-202.

The phytoplankton flora is impoverished in species and numbers in acidic lakes that have high concentrations of Cu and Ni. Experiments show that species isolated from these lakes are able to survive and grow at levels of Cu, Ni and Ag above those toxic to laboratory strains. Thus a metal-tolerance mechanism rather than exclusion seems to govern the algal populations in these polluted lakes. E.

Strøm, K. Münster. 1926. The influence of altered H-ion concentrations on *Stentor, Diaptomus* and *Daphnia*. Nyt. Magazin for Naturvidenskapene 64: 109-115.

Experiments conducted over pH 6.6-8.0 showed that *Stentor* was only slightly affected by pH variations while *Diaptomus gracilis* and *Daphnia pulex* preferred slightly acid and slightly alkaline waters, respectively. E.

Strømsøe, S. 1971. Air Pollution from fuel combustion in stationary sources. NILU TN 11/71. 32 p.

This report itemizes the emissions of NO_2, SO_2 and particulates from fossil-fuel consumption in Norway and attempts to estimate future trends. E.

Stumm, W. 1973. Zivilisatorische Aktivität, Luftverunreinigung und Gewässerbelastung. In Proc. Symp. Eur. Fed. Protection Wat., Finland. 7 p.

Due to man's activities a great many elements, in particular heavy metals, are enriched in rain relative to seawater and/or the crust. As a result of man's use of energy and materials, degradation of natural systems is unavoidable. G.

Sunde, S. E. 1926. Surt vand dræper laks- og ørretyngel. Norges Jeger- og Fiskeforb. Tidsskrift No. 2: 1-4.

This early report describes fish kills, apparently due to acid water, at hatcheries in southern Norway and the attempts to raise the pH by adding lime. N.

Sutcliffe, D. W., and T. R. Carrick. 1973a. Studies on mountain streams in the English Lake District. 1. pH, calcium and the distribution of invertebrates in the River Duddon. Freshwat. Biol. 3: 437-462.

There are three types of pH regimes in the River Duddon and its tributaries; pH constant and above 5.7, pH constant and below 5.7, and pH fluctuating seasonally about 5.7. The latter regime is characteristic of tributaries in the headwaters. The benthic fauna is closely related to pH, and pH-bicarbonate limits the distribution of benthic invertebrates, generally herbivores. The limiting effects on insects may operate through the food supply. E.

Sutcliffe, D. W., and T. R. Carrick. 1973b. Studies on mountain streams in the English Lake District. II. Aspects of water chemistry in the River Duddon. Freshwat. Biol. 3: 543-560.

Budgets for Na, K and Ca are calculated for a watershed. Na and K concentrations in stream water are independent of discharge but show a cycle of high concentrations in winter and low concentrations in summer. Some of the tributaries in the watershed are acid (pH 4.5). E.

Sutcliffe, D. W., and T. R. Carrick. 1973c. Studies on mountain streams in the English Lake District. III. Aspects of water chemistry in Brownrigg Well, Whelpside Ghyll. Freshwat. Biol. 3: 561-568.

Although the pH in Brownrigg Well is above 5.7, the concentrations of Na, K, and perhaps Ca are near the lower limit for *Gammarus pulex*. The distribution of most other insect taxa is governed by pH, and these insects probably were more widely distributed prior to the acidification of streams by acid precipitation. E.

Swynnerton, G. H., and E. B. Worthington. 1939. Brown-trout growth in the Lake District. A study of the conditions in "acid" lakes and tarns. Salmon and Trout Mag. 97: 337-354.

The growth rate of trout taken from lakes and ponds of the English Lake District was determined by measuring the annual increments on fish scales. The growth rate is affected by food supply and population pressure, as well as by chemical factors such as pH and alkalinity. E.

Tamm, C. O. 1972. Measuring disturbances of nutrient circulation in ecosystems. IBP i Norden (No. 9): 189-201.

Using tree-ring widths, local and regional changes in growth can be investigated and related to nutritional disturbances such as forest fertilization and soil acidification. E.

Tamm, C. O., and A. Aronsson. 1972. Plant growth as affected by sulphur compounds in polluted atmosphere. A literature survey. Research Note 12. Royal College of Forestry. Dept. Forest Ecology and Forest Soils, Stockholm. 53 p.

This literature review discusses the effects of SO_2 on lichens, forests, and agricultural crops, including the mechanisms of injury, symptoms and physiological pathways. E.

Tamm, C. O., Å. Nilsson, and G. Wiklander. 1974. The optimum nutrition experiment Lisselbo. A brief description of an experiment in a young stand of Scots pine (*Pinus silvestris L*), Royal College of Forestry, Dept. of Forest Ecol. and Soils, Stockholm. Research Note No. 18. 23 p.

Among several forest fertilization experiments several stands were subjected to changes in soil acidity. None of the treatments has produced a significant change in growth rate after 2-3 years. E.

Thornton, K., and J. Wilhelm. 1974. The effects of pH, phenol, and sodium chloride on survival and caloric, lipid and nitrogen content of a laboratory population of *Chironomus attenuatus* (Walk). Hydrobiologia 45: 261-280.

pH had a significant effect on the survival of *C. attenuatus*. E.

Torgersen, H. 1934. Forsøk med opparbeidelse av sure fisketomme vann. Stangfiskeren. Oslo Sportsfiskeres Årbok: 38-46.

This is a description of an early attempt to combat acid-waters by adding lime. N.

Ulbrich-Eberius, C. J. 1973. Die pH-Abhängigkeit der Aufnahme von $H_2PO_4^-$, SO_4^{2-}, Na und K^+ und ihre gegenseitige Beeinflussung bei *Ankistrodesmus braunii*. Planta 109: 161-176.

Phosphate uptake is maximum between pH 5.5-6.5, and is enhanced by Na (in the light) and Ca (in the dark).

Velds, C. A. 1974. Relation between emissions resulting from burning fossil fuels and pollution of surface and groundwater, p. 69-71. In H. E. Vogel (ed.) European Fed. Protection Waters, Zürich, Info. Bull. 21.

Based on the SO_2 emissions in the Netherlands the theoretical pH of precipitation is calculated assuming that all the SO_2 is deposited within the country. This calculated pH of 3.5 is much less than the measured pH values (lowest average for a station 4.7), thus implying that most of the SO_2 is exported. E (F summary).

Ward, R. C. 1971. Small Watershed Experiments. An appraisal of concepts and research developments. University of Hull. Occasional Papers in Geography No. 18. 254 p.

Small watersheds have been used all over the world as research tools for over 100 years. Ward summarizes the goals, techniques and results of such studies in this survey of over 300 articles on this subject. E.

Watanabe, T., H. Kamijo, I. Morishita, T. Shinya, and K. Mashiko. 1973. Studies on the eutrophication of Lake Osoresan-ko, a remarkable inorganic acidotrophic lake in Japan. Ann. Rep. Noto Marine Lab. 13: 35-51.

This lake is acid (pH 3.0-3.2) because of the inflow of sulfuric acid from hot springs. Although the number of species of organisms in the lake is low, biotic productivity is high. The phytoplankton composition has altered since the 1930's, with a bloom of *Aphanotheca* observed in 1972-73. The bottom is covered with an aquatic moss, *Leptodictum* sp. to depths of 9 meters. Large numbers of the fish, *Tribolodon hakonesis* live in the lake, clearly able to tolerate waters as acid as pH 3.0, perhaps because of an unusual type of chloride cell in its gills. J (E summary).

Weiss, H. V., M. Koide, and E. D. Goldberg. 1971. Selenium and sulfur in a Greenland ice sheet: Relation to fossil fuel combustion. Science 172: 261-263.

Comparison of Se and S concentrations in an ice profile from Greenland indicate that while sulfur is translocated great distances after fossil-fuel combustion, selenium is mobilized to a much lesser extent, perhaps due to different chemical and physical properties of the tetravalent oxides. E.

White, E. J., and F. Turner. 1970. A method of estimating income of nutrients in a catch of airborne particles by a woodland canopy. Appl. Ecol. 7: 441-461.

By comparing throughfall water with rainwater, and using air-flow impactors to catch particulate matter, the amounts of plant nutrients (Na, K, Ca, Mg, P and N) that are deposited from the atmosphere by dry-fallout and impaction were estimated. E.

Whitehead, H. C., and J. H. Feth. 1964. Chemical composition of rain, dry fallout and bulk precipitation at Menlo Park, California, 1957-1959. J. Geophys. Res. 69: 3319-3333.

Samples collected during 1962-63 in California showed that dry fallout is mainly derived from local sources, rainwater is mainly of marine origin, and bulk precipitation is a mixture fo these two. E.

Whittaker, R. H., F. H. Bormann, G. E. Likens, and T. G. Siccama. 1974. The Hubbard Brook ecosystem study: Forest biomass and production. Ecol. Monogr. 44: 233-254.

A decrease in forest productivity may be due to increasing air pollution and acidic precipitation. E.

Wright, R. F., and C. Lysholm. 1975. Regional survey of lakes in southern Norway, fall 1974. Preliminary analysis of water-chemistry data. SNSF-project. IR 6/75. 24 p.

A systematic survey of 155 lakes showed that acidic precipitation has affected lakes in large areas of southernmost Norway. Because the bedrock and soils in these areas have very low calcium and magnesium contents, the lakes are poorly buffered and are particularly vulnerable to inputs of acidic precipitation. E (N summary).

CLASSIFICATION BY GEOGRAPHIC AREA

WORLD:

Berntine and Goldberg 1971
Bischof 1973
Chester and Stoner 1973a, 1973b
Eriksson 1952a, 1952b, 1959, 1960
Gorham 1961
Jernelöv 1973
Junge 1960
Ravera 1973
Stumm 1973
Ward 1971

EUROPE:

Ångström and Högberg 1952a
Block and Dams 1975
Bolin and Persson 1974
Borneff 1974
Brosset 1973a, 1973b
DeBary and Junge 1963
Descroix 1974
Egner 1955-60
EIFAC 1969
Eriksson 1954
Granat 1972
Kettner 1974
Mrose 1966
Nordø 1973, 1974
OECD 1973
Ottar 1973
Ottar and Semb 1973, 1974
Persson 1969
Rohde 1972
Rossby and Egner 1955
Seleyneva 1972
Velds 1974

SCANDINAVIA:

Barrett and Brodin 1955
Dahl and Skre 1971
Eriksson 1955, 1969
Goffeng 1973
Granat 1974
Holt-Jensen 1973
Oden 1968, 1969, 1971, 1972
Oden and Ahl 1970
Oden and Andersson 1974
Ottar 1972
Rühling and Tyler 1971, 1973

NORWAY:

Andersen 1966
Anon 1974a
Bjor et al. 1974
Braarud and Aalen 1939
Brække 1974a, 1974b, 1975
Brandt 1971
Bua and Snekvik 1972
Dahl, E. 1972
Dahl, E. et al. 1967
Dahl, K. 1920, 1922, 1923, 1926
Dale et al. 1974
Dannevig, A. 1959
Dannevig, G. 1966, 1968, 1970
Dannevig, G. et al. 1971
Dovland 1975
Dovland et al. 1974
Dovland and Semb 1975
Dugstad 1972
Dybdahl 1973
Elgmork et al. 1973
Fleetwood 1969
Førland 1973
Førland and Gjessing 1975
Førland et al. 1975
Fredriksen 1973
Furmyr 1973a, 1973b
Gjems 1970
Gjessing, E. 1974
Gjessing and Gjessing 1975
Grande 1966
Grøterud 1972a, 1972b, 1972c, 1973
Gunnerød 1973
Hagen and Norby 1967
Hagen and Langeland 1973
Haugboth 1973
Henriksen 1972a, 1972b
Henriksen et al. 1974

NORWAY (cont.)

Henriksen and Johannessen 1975
Holtan 1972
Horntvedt and Joranger 1974
Huge and Killingtveit 1973
Huitfeld-Kaas 1922
Jensen 1972
Jensen and Snekvik 1972
Kjos-Hanssen 1970
Låg 1963, 1968
Låg and Steinnes 1974
Leivestad and Muniz 1974
Lillehammer 1974
Lunde and Gether 1974
Mellquist 1972
Miljøverndepartementet 1974
Nordø and Hjortnaes 1967
Økland, J. 1969a, 1969b
Økland, K. 1969a, 1969b, 1970, 1971
Overrein 1972a, 1972b, 1974a, 1974b
Schjoldager 1973a, 1973b
Sivertsen and Snekvik 1975
Skogvold 1974
Small 1960
Snekvik 1969a, 1969b, 1969c, 1969d, 1970, 1972, 1974a, 1974b, 1974c
Snekvik et al. 1973
Snekvik and Sivertsen 1975
Strømsøe 1971
Sunde 1926
Torgersen 1934
Wright and Lysholm 1975

SWEDEN:

Ahl and Oden 1972
Almer 1972a, 1972b
Almer et al. 1974
Andersson, Gun and Grennfelt 1974
Andersson, Gunnar 1971
Andersson, Gunnar, et al. 1971
Ångström and Högberg 1952b
Anon 1972, 1974b
Berzins 1966
Bolin and Granat 1973
Bolin et al. 1971
Börjeson and Aldberg 1974
Brosset 1975
Brosset and Åkerström 1972
Brosset et al. 1974
Dickson 1971
Emanuelsson et al. 1954
Grahn and Hultberg 1974
Grahn et al. 1974
Hanson 1974
Högström
Hultberg and Stenson 1970
Jonsson and Sundberg 1972
Karlen 1972
Malmer 1974
Oden 1971, 1973
Oden and Ahl 1974
Rohde 1970
Rohde and Grandell 1972
Tamm et al. 1974

FINLAND:

Haapala 1972, 1974
Kohonen 1974
Laamanen 1972
Särkkä 1972

BRITISH ISLES:

Allen et al. 1968
Aston et al. 1973
Brownscombe 1972
Cambray et al. 1975
Cawse 1974
Cawse and Peirson 1972
Gilbert 1970
Gore 1968
Gorham 1955, 1958
Griffiths 1973a, 1973b
Hallsworth and Adams 1973
Little and Martin 1974
Peirson et al. 1974
Sutcliffe and Carrick 1973a, 1973b, 1973c
Swynnerton and Worthington 1973
White and Turner 1970

NORTH AMERICA:

Chapin and Uttormark 1973
Likens et al. 1972

CANADA:

Beamish 1974
Beamish and Harvey 1972
Beamish et al. 1975
Conroy et al. 1974
Conroy and Maki 1974
Herman and Gorham 1957
Hutchinson and Whitby 1974
Kramer 1973a, 1973b
Kramer and Snyder 1974
Michelski and Adamski 1974
Muller and Kramer 1974
Shaw and Whelpdale 1973
Stokes et al. 1973

UNITED STATES:

Bormann 1974
Cogbill and Likens 1975
Delany et al. 1973
Dunson and Martin 1973
Gambell 1962
Gambell and Fisher 1964
Junge 1956
Junge and Gustafson 1957
Junge and Werby 1958
Katz 1968
Laney 1965
Larson, T.E., and Hettick 1956
Larson, T.V. et al. 1975
Likens 1972
Likens and Bormann 1974
Packer and Dunson 1970, 1972
Schlesinger et al. 1974
Schroeder 1971
Whitehead and Feth 1964

ANTARCTIC/ARCTIC:

Gjessing and Gjessing 1973
Jonasson 1973
Koide and Goldberg 1971a, 1971b
LeBarre 1973
Mateev 1970
Weiss et al. 1971

MISCELLANEOUS AND THEORETICAL:

Askne 1973
Askne and Brosset 1972
Beamish 1972
Bell 1971
Bell and Nebeker 1969
Biesinger and Christensen 1972
Bornefeld and Simonis 1974
Brosset 1973c, 1974
Carter 1964
Cook 1971
Costa 1966, 1967
Davis and Ozburn 1969
Dondoroff and Katz 1950
Hales and Sutter 1973
Harrison 1958
Jordan and Lloyd 1964
Kamijo et al. 1974
Katz et al. 1970
Katz and Oglesby 1967
Krishna 1953
Ledbetter 1972
Lloyd and Jordan 1964
McKim et al. 1973
Miller and dePene 1972
Novakov et al. 1974
Oden and Bergholm 1971
Rohde 1974
Shukla and Leland 1973
Sorokin 1962
Strøm 1926
Tamm 1972
Tamm and Aronsson 1972
Thornton and Wilhelm 1974
Ulbrich-Eberius 1973
Watanabe et al. 1973