ACID DEPOSITION and the ENVIRONMENT

The Annual 'Grey Literature' Environmental Reference Collection

1989 Update

A Listing and Guide to Part Two of the Research Publications Collection

Edited by Dr. James W. S. Longhurst

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ACID DEPOSITION AND THE ENVIRONMENT
The Annual 'Grey Literature'
Environmental Reference Collection

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PUBLISHER'S NOTE

This Second Part of the series Acid Deposition and the Environment makes available a wealth of documentation relating to the environmental, economic, political and social aspects of Acid Deposition and the attempts to control or mitigate its effects. This material is predominantly in the form of "grey literature". That is, pamphlets, reports, teaching packs, bulletins and similar materials, most of which would not normally find their way into libraries. Nevertheless they present an informed, detailed picture of the current debate and it is hope that they will be of great benefit to teachers and researchers alike.

The majority of the publications included in this Second Part were originally issued in 1989. Eighteen groups/organisations are covered, including five appearing for the first time. These represent viewpoints from Britain, Denmark, France, Sweden, Switzerland and The United States of America.

For the convenience of the user, a bibliographical guide to Acid Deposition and the Environment accompanies the collection. The documents have been arranged, listed and filmed in a way which enables the user to locate any item very easily and quickly. The filming sequence is alphabetical by group name with corresponding publications arranged chronologically. Every item is numbered clearly in the top right hand corner of the cover. Each organisation begins a fresh numerical sequence. The Guide incorporates a series of helpful indexes and listings. A thematic index subdivides the groups into pertinent categories; and an author index provides a further mode of identification. The detailed listing of all material issued by each group identifies a particular item, the publication title, the date of issue and the number of the fiche on which the publications may be located. An alphabetical list of groups with brief biographical details is also included as a source of reference.

This collection seeks to close a major gap in the coverage of acid deposition documentation. It is the first reference scheme to make available on microfiche a body of information designed solely to illuminate this important environmental issue. It will be of interest to researchers and the general public alike.

Acknowledgement

Research Publications are grateful for the support of all groups, organisations and departments featured in the collection. A sincere and special thank you must go to the consultant editor, Dr. James Longhurst, Director of the Acid Rain Information Centre at Manchester Polytechnic. His expertise, unstinting assistance and unbounded enthusiasm have proved invaluable during the lengthy process of obtaining and assembling material into a comprehensive and informative package. Research Publications are also grateful to Jo Mullins for her earlier work on this project and to Tanya Black and Sue Yan for their help in putting this guide together.

HOW TO USE THE INDEX

The Guide to Acid Deposition and the Environment is arranged with a detailed index system, such that any item can be found quickly and easily.

The three main indexes are divided into an Agencies and Authors index, an Author index and a detailed Thematic index. This enables the reader to locate any author, the organisation for whom he or she has written and the topic under discussion.

The Agencies and Authors index is an alphabetical listing of each organisation participating in the collection, and all ascribing authors. The publications are arranged chronologically, and feature material up to and including June 1988.

The Author index lists alphabetically every author contributing to the collection. In many cases several authors contribute to a single item or article. When this occurs, items are listed under the first author in their entirety, but also under the secondary authors in abbreviated form. Thus, each author is listed both in his or her own right, and the items can easily be located by cross-reference, as shown below.

Hare, SE, Longhurst, JWS and Lee, DS. A Comparison of Rainwater Acidity between Greater Manchester and Greater Lisbon during October, November and December 1988. July 1989, 37pp. (Cards 351 - 352)

Lee, DS. A Comparison of Rainwater Acidity between Greater Manchester and Greater Lisbon during October, November and December 1988. See Hare, SE.

Longhurst, JWS. A Comparison of Rainwater Acidity between Greater Manchester and Greater Lisbon during October, November and December 1988. See Hare, SE.

The Thematic index aims to give a detailed breakdown of the most important themes in Acid Deposition and the Environment.

The index is divided into five main areas:
General Works; Emission, Transport and Deposition Processes; Environmental Effects; Social, Economic and Political Aspects and Control and Mitigation Measures. The latter two categories contain much material and are therefore further divided into sub-sections.

In many instances, a degree of overlap occurs, whereby items cover more than one thematic area. The items are then included in all relevant sections. For instance, the Report by the Panel on Acidic Deposition in New Jersey appears in four of the five main thematic areas.

In each index, a card number appears against the entries. This indicates the microfiche on which the item can be found.

ACID DEPOSITION AND THE ENVIRONMENT

The Annual Grey Literature
Environmental Reference Collection

Edited by Dr James W. S. Longhurst

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ACID DEPOSITION AND THE ENVIRONMENT

An Introduction to the Collection and Guide

The material presented in this collection is intended to meet the needs of students, researchers and others studying the complex subject of acid deposition and the environment.

It is first and foremost an introduction to the `grey literature' on acid deposition, that large body of information which lies, for whatever reason, outside of the domain of the scientific journals and mainstream book publishers. This literature covers a wide range of providers, local, national (eg Ministere d l'Environnement, France) and international (eg World Health Organisation), encompassing publications of government agencies (eg National Swedish Environmental Protection Board, U.S Fish and Wildlife Service and the Forestry Commission, GB), commercial company publications (eg Davy McKee Ltd), and environmental pressure groups (eg World Wide Fund for Nature).

The collection is also a primer for researchers, students and teachers wishing to obtain a grounding in the subject or seeking to improve their understanding of the causes, processes and implications of environmental acidification. Individual workers will also find the collection useful in establishing first contact, or to the expand their range of contacts, with practitioners in this multidisciplinary area.

Acid deposition knows no boundaries and likewise this collection is deliberately international in perspective. Materials from 18 organisations, including 6 international bodies, from 5 countries are represented and reflecting this international perspective the collection is multilingual with publications in French, Swedish, Danish and English although the latter is the dominant language.

The guide is arranged in five parts:

1 Introduction to Acid Deposition and the Environment.

2 Alphabetical listing of participating agencies including short biographical description.

3 Alphabetical list of agencies with all authors ascribed to their agency.

4 Alphabetical listing by author.

5 Thematic listing in five subject areas.

Thematic listing

Five subject areas comprise the thematic listing as follows:

i General Works,

ii Emission, Transport and Deposition Processes.

iii Environmental Effects:
- aquatic
- terrestrial
- human health
- materials and cultural artefacts
- effects monitoring.

iv Economic, Political and Social Aspects:
- policy and regulation
- education
- pressure groups.

v Control and Mitigation Measures.

Whilst a degree of overlap between categories exists those materials categorised as General works will includes overview publications addressing more than one thematic area and material of a non-specific nature.

Emissions, Transport and Deposition materials include emission data, meteorology, atmospheric chemistry, physics and transport, deposition processes, deposition monitoring, chemical analysis of deposition and modelling.

Environmental Effects - aquatic deals with materials on freshwater chemistry, biogeochemistry, aquatic flora and fauna; that headed terrestrial is concerned with soils, forests, crops, animals and acidified ecosystems; effects monitoring is concerned with surveys and inventories of damage.

Economic, Political and Social Aspects holds materials classified as laws and regulation, government policies and initiatives, educational initiatives and relating to the activities and publications of pressure groups.

Control Mitigation and Correction section holds materials on emission reduction technologies, demand side management initiatives and chemical amelioration techniques such as liming.

Acid Deposition and the Environment

Introduction

The purpose of this paper is to provide an overview of the causes, effects and controls on acid deposition so that the scale and importance of the phenomena can be understood and appreciated. It will provide the national and international context of the problem within the materials presented in the second edition of `Acid Deposition and the Environment: the annual grey literature environmental reference collection' may be more fully understood.

The environmental implications of acid deposition and acidification are the subject of extensive international and national research programmes addressed at the local, regional and global sources and effects of sulphur dioxide, nitrogen oxides and hydrocarbons. The complete relationship between cause and effect is not yet fully understood as there are complicated interactions between pollutions, within soils and water leading to direct and indirect effects. However, the relationship between sulphur and nitrogen emissions and environmental change is understood well enough to enable local, national and supra-national control policies to be formulated. For example in the U.K., the Government has authorised the Central Electricity Generating Board to retrofit flue gas desulphurisation equipment to 3 large power stations (DOE 1986), to modify the boilers of the 12 largest power stations, to reduce nitrogen oxide production (CEGB 1987) and to require such control technology to be installed on all new coal fired power stations, 2 of which have been announced, and a further 2 are expected for completion by the turn of the century (CEGB 1986). The situation in the UK and the relationship between the U.K. and its' European neighbours with regard to acid deposition exemplifies many of the important issues in an understanding of the cause effect and control of acidifying air pollutants and this paper will use this relationship as a perspective.

Acid deposition is not a new environmental problem. It was first described and named in 1852 by R.A. Smith working in the city of Manchester (Smith 1852). At the time, sulphur was clearly the main pollutant and the effects of acid deposition were clearly an urban and near-urban phenomenon. Environmental effects described and quantified by Smith included damage to building materials, metalwork and textiles. Vegetation effects were also described (Smith 1872). The southern Pennines of England received acid precipitation as a direct consequence of acid emissions in Manchester and other cities (Press et al 1983). The combination of dry and wet deposition of sulphur compounds profoundly affected the sphagnum moss communities, leading to species reduction, habitat change, moorland drying and subsequent erosion (Woodin et al 1987).

The distribution of pollutants from industrial and urban areas was generally no more than regional in scale although longer range transport of pollutants to Norway from the U.K. is considered to have occurred as early as 1881 (Brogger 1881). Regional acidification of south west Scotland, the English Lake District and the southern Pennines is considered to have begun at the onset of the industrial revolution.

In the U.K. the Clean Air Act of 1956 significantly reduced urban sulphur pollution. The combination of the closure of small urban power stations, the improvement in combustion technology, changing energy use, industrial restructuring and the building of power stations remote from urban areas in the U.K., all contributed to an improved urban pollution situation.

The consequence, however, has been a spreading of acid emissions further afield by the U.K. through the use of tall chimney stacks at power stations, at a time when European sulphur and nitrogen emissions were starting to rise steeply. This is a pattern replicated in other industrial nations.

Sources of emission and pollutant distribution. The latest available European figures are for 1983. The U.K. emitted 3,690,000 tonnes of sulphur dioxide out of a total 44,889,000 tonnes (DOE 1987). Some 44% of this sulphur is deposited in the U.K., 34% at sea and 22% abroad. By 1987 the U.K. SO_2 emission had risen to 3,867,000 tonnes, of which 73% is estimated to arise from power stations, 14% from industrial sources, 4% from the domestic sector, 4% from refineries, 3% from the commercial sector and 1% from road transport (DOE 1988).

Nitrogen oxide emissions are more difficult to estimate; the U.K. is estimated to have emitted 2,303,000 tonnes in 1987, 45% from road transport, 35% from power stations, 10% from other industrial sources and the remainder from a variety of sources (DOE 1988), the estimated European NO_x emissions is 17,977,000 tonnes. U.K. emissions of hydrocarbons are estimated at 2,355,000 tonnes, 46% from industrial processes, 28% from road transport and 17% from gas leakage (DOE 1988).

Sulphur and nitrogen have clearly defined natural cycles but in the industrialised northern hemisphere, covering less than 10% of the earth's surface, more than 90% of sulphur in the atmosphere is of anthropogenic origin. Thus on the regional scale, man-made emissions dominate (Beilke 1982).

After emission the sulphur and nitrogen gases undergo chemical and physical processes of transport and conversion within the atmosphere, until they or their reaction products are removed. Removal is by two main routes, wet and dry deposition with occult deposition a third removal mechanism which is particularly important in uplands areas for the transfer of cloud/mist/fog water to vegetation and ground surfaces. Photochemically stimulated atmospheric reactions of nitrogen oxides and hydrocarbons are important for the production of ozone, itself important both in the reaction chemistry of sulphur dioxide and as a potentially phytotoxic pollutant.

Dry deposition predominates as a removal mechanism for gases closer to emission sources (<300km of emission) (Beilke, 1982). Wet deposition occurs after chemical transformation, dependent upon the presence and concentrate of ozone, hydroxyl radicals and sunlight. The resulting acid products, sulphate, nitrate and hydrogen ions may reach the earth's surface via wet deposition or dry deposition. The surfaces upon which wet and dry depositions fall are subject to chemical change as a consequence.

In 1984, the U.K. is estimated by the European Monitoring and Evaluation Programme (E.M.E.P.) to have deposited 644,000 tonnes of sulphur to other countries by these processes (Eliassen 1987). Approximately 10% of the sulphur deposited in southern Sweden has its' origin in the U.K. (Eliassen 1987). A further 28% of such deposition cannot be attributed to any one nation, but it can be assumed that a percentage of this originates in U.K., as well as from natural sources, other European nations and North America. In Norway and Sweden, 92% and 82% of sulphur deposition respectively is considered to be received from other countries (Eliassen 1987).

E.M.E.P. has calculated the distribution of pH (a logarithmic expression of acidity) across Europe based upon data supplied by participating nations for the period 1978-1982 (NILU 1984). This indicates that the majority of the U.K. (excluding Northern Ireland, north west Scotland and south west Cornwall), southern Scandinavia, northern France, northern Austria, Switzerland and north eastern Europe is bound by the pH 4.5 isoline and the most acidic precipitation occurs in central Europe bound by the pH 4.1 isoline, encompassing northern Belgium, the Federal Republic of Germany, the D.D.R., eastern Czechoslovakia and Poland.

Natural unpolluted rainfall is considered to have a pH of 5.6, the pH of carbon dioxide dissolved in rainwater (RGAR 1983). Some workers consider that natural fluctuations in the sulphur cycle can depress the pH of rain to 5.0 (Charlson et al 1982).

Monitoring of acid deposition on a systematic regular basis only began in the U.K. at the beginning of 1986 (RGAR 1986). Data from the first years operating of the monitoring networks, established by Warren Spring Laboratory on behalf of the DOE, has recently been published (Campbell et al, 1989) and this broadly confirms previous observations at a smaller number of monitoring stations (RGAR 1983, 1987). Namely that:-

i) the concentration of H+ ion increases from west to east with a maximum between the Humber and the Wash

ii) maximum concentrations of non marine sulphate, nitrate and ammonium occurred in the east, particularly south of the Wash

iii) greatest deposition occurred in areas of highest rainfall, particularly parts of Highland Scotland, north Wales, Cumbria and the Pennines, where acid deposition is comparable to areas of southern Scandinavia

iv) largest concentrations of non marine sulphate occur in low rainfall easterly air flows

v) highest deposition occurs in high rainfall westerly air flow.

The importance of reliable, quality assured monitoring data such as provided by the U.K. acid precipitation monitoring networks cannot be over emphasised. It is vital in defining patterns and trends, in providing data for model validation and of course in providing data from which potential and actual environmental effects can be assessed. A great wealth of such data now exists and the Research Publications collection contains materials from the National Atmospheric Deposition Programme in the USA and urban data from Greater Manchester, UK.

Environmental Effects

Air pollution, acid rain and acidification have been implicated in a wide range of environmental effects, particularly damage to forest systems and freshwaters. Some of these are direct effects others indirect, occurring at the end of a complicated chain of cause and effect. The following section seeks to summarise these effects.

Forest systems Forest systems have always been subjected to environmental stress; harsh climate, poor nutrition and pathogens have all taken their toll of forestry resources. However, since the 1970's an unprecedented decline of forest ecosystems has occurred in Central Europe. Species affected include silver fir, Norway spruce, beech, Scot's pine, larch and oak (Innes, 1989). Symptoms of decline include growth reduction and growth alteration. Forest decline is particularly severe in coniferous trees in Switzerland, the Netherlands, Czechoslovakia and the Federal Republic of Germany. In the latter, more than 50% of the forest area is affected by the decline. Numerous hypotheses have been proposed to account for the decline. Most include air pollution as a predisposing and/or inciting factor for decline. These include:

i) damage by atmospheric SO_2 concentrations (eg Innes, 1989)
ii) ozone/acid mists (eg Krause et al 1986, Sandermann et al 1989)
iii) soil acidification (eg Ulrich 1983)
iv) excess nitrogen (eg Nihlgard 1985)
v) epidemics of pathogens (eg Krause et al 1986)
vi) multiple stress (eg Schutt and Cowling, 1985).

As the decline has occurred over a wide area in many species at approximately the same time, it suggests a common link; air pollution, with a triggering factor of perhaps climate, e.g. drought, a sudden temperature decline. Debate continues as to whether the decline is `top down' or `bottom up', i.e. direct effects of acid air pollutants and ozone on trees or indirect effects through soil acidification.

Surveys of forest health conducted in the U.K. by the Forestry Commission do not reveal identical symptoms of damage to those seen in Central Europe (Binns et al 1985a, b, Innes 1989) although air pollution is now recognised by the Forestry Commission as being a contributory factor in the explanation of U.K. forest health (GEMS, 1988). Data compiled as part of the Forest Damage Survey in Europe, 1987, (GEMS, 1988) clearly indicates that the scale of the problem is European. Comparison of the 1986 (UNECE, 1987) with the 1987 data shows that there has been a slight decrease in the extent of defoliation of conifer forests but an increase in defoliation of broadleaved forests. In most countries air pollution is considered to be the major destabilising factor affecting forest health. In, for example, Austria, F.R. Germany, the DDR, Czechoslovakia, the Netherlands, Yugoslavia and Switzerland such pollution is considered the determining factor and forest management decisions are strongly influenced by air pollution risks (GEMS, 1988). In Bulgaria, Denmark, Hungary, Italy, Sweden and the U.K. air pollution is regarded as one of the contributing factors for forest damage.

The overall situation in European forests clearly indicates that further measures to abate air pollution are required (GEMS, 1988). The effects of acid deposition on U.K. forest resources are reviewed in the First Report of the Terrestrial Effects Review Group (TERG, 1988). They conclude that there is, as yet, no direct proof of pollution related forest decline in the U.K., but note that some forests are subjected to pollution climates that may be expected to cause stress. They also conclude that isolated trees in hedgerows or urban areas may be at risk. The Group concludes that surveys of forest damage be continued and that more specific diagnostic tests for pollution damage be developed.

<u>Surface and groundwater acidification</u> Only in certain areas are surface and ground waters acidified or sensitive to acidification. These are areas where geological weathering rates are slow and where soils are already naturally acid, and have little ability to neutralise any further increase in acidity (Hammerton, 1988).

Water acidification arises from natural processes in soils, atmospheric deposition and land use practices, interacting in complex ways.

Factors influencing the chemical change to rainfall in a catchment include soil buffering capacity, alkalinity production, volume of run off, size of catchment and water transfer time (AWRG 1986). Storage of pollutants in snow packs also has a profound influence on water quality (Haines, 1981). The physical and chemical consequences of water acidification include decreased calcium availability and loss of base cations from the soil; mobilisation of aluminium and heavy metals; low phosphate and selenium availability.

The relationship between acid deposition water acidification is thus complicated by the interaction of soils, geology, vegetation and land use. For example, reservoirs receiving drainage from Pennine peat moorlands, have elevated levels of acidity due to organic acids produced in the past (Diamond et al 1987). In the U.K. uplands elevated levels of acidity are also thought to have arisen as a result of the cessation of the farming subsidy for lime, thus reducing the amount applied and consequently, calcium levels in watercourses (Crawshaw 1986).

Acid lakes and streams are usually found in catchments with poor thin soils and naturally acid bedrock, dominated by moorland or coniferous vegetation with variable hydrological characteristics (AWRG 1986). Ecological effects are documented for many water courses where damage arises from a changing acidity - alkalinity balance and speciation of toxic metals. In such areas, effects on plankton, invertebrates, benthic fauna, fish and aquatic plants have all been described and, where possible, quantified. (Rosseland et al 1986, Hestagen et al 1989, Appleberg et al 1989).

In areas of high sulphate deposition and low calcium content, surface waters are likely to be acid with high aluminium levels. Sulphate ions soil into watercourses. Acidity is fatal at different levels to different fish; at pH 4 no fish will be found. If aluminium concentrations are >100 ug l^{-1} and calcium levels >300 ug l^{-1} then pH 5 can be fatal to fish (AWRG 1986). Acid pulses following snow melt and associated with elevated aluminium levels are particularly hazardous to fish (Haines, 1981).

Freshwater acidification has been documented in many countries including Norway, Sweden, Canada, the USA and the U.K. In a review of Acid Waters in the U.K., Tickle (1988) concludes that acidification of surface waters has been demonstrated unequivocally in Britain over a far wider area of the country than hitherto thought and that incontrovertible palaeoecological evidence from upland Britain (Batterbeen et al 1988) has defined the extent and the timescale of acidification.

The Research Publications collection contains further information on this topic drawn from the Forth River Purification Board, the World Health Organisation and the World Meteorological Organisation.

<u>Agricultural crops</u> Sulphur dioxide in laboratory experiments is toxic to crops at levels >100 ug m^{-3} and in mixtures of pollutions at 50 ug m^{-3} levels of this nature can be found in eastern Europe and in the south east of the Federal Republic of Germany (Shell 1986). There is no evidence of direct effects of acid deposition on crops but indirect effects through soil acidification represents a potential risk. Whole plant harvesting reduces the input of nutrients and acid neutralising substance to the soil, with no countermeasures, such as liming and the application of fertilisers such as ammonium sulphate, soil acidification results.

Some experimental work indicates that agricultural crops are affected by ozone concentrations of 100 ug m^{-3} causing growth reductions and yield losses. A combination of SO_2 NO_x and ozone may affect enzyme activity and net photosynthesis of crops hence depressing crop yields. The U.K. Terrestrial Effects Review Group (1988) concluded that there is unlikely to be damage to major agricultural crops in the U.K. at current rural concentrations of sulphur dioxide and nitrogen oxides. However, in most summers concentrations of ozone occur in wide areas of southern Britain that are likely to reduce sensitive crop yields. They note that the interaction between pollutant stresses and others such as pests can have extremely important influences upon crop yields. The Group were not able to make precise assessments of the effects of air pollutant upon national crop yields (TERG, 1988).

Soil acidification

An understanding of the effects of acid deposition upon soils is a prerequisite to our understanding of effects upon freshwaters as many recently acidified lakes receive most of their water from drainage through, or over, soils (Cresser et al, 1989).

Soil susceptibility to acidification is related to natural acidity, soil particle size, soil depth, soil moisture, alkalinity production, bedrock geology and local terrain (Cresser and Edwards 1987). Soil acidification can arise from either natural or anthropogenic activities either singularly or in combination. These include: land uses such as agriculture and forestry, natural processes such as microbial respiration, nitrification and decomposition processes and atmospheric deposition of acidifying materials.

Soil acidification decreases the reserves of exchangeable cations, liberates aluminium and heavy metals, disrupts soil decomposition processes, binds phosphate reducing its availability to plants and reduces the diversity of soil microorganisms. Atmospheric deposition also enriches the nitrogen store in soils leading to saturation. Some plants with low nitrogen requirements may be eliminated and for surviving plants other nutrients may become limiting factors in plant growth (Nihlgard 1985). The U.K. Terrestrial Effects Review Group concluded that it has become increasingly evident that acid deposition is accelerating soil acidification and that soil biology changes will result. Such changes will alter plant nutrition and give rise to a changed chemistry in surface and ground waters which in turns may affect the biology of surface waters (TERG, 1988).

Materials and cultural property B uildings, materials and cultural property are subject to slow decay under the action of climatic factors. This is a natural process which acts even in the absence of human involvement. Building materials degrade but most will not be seriously affected within their expected lifetime. However air pollution, including acid deposition attack can accelerate the rate of degradation of building materials such that increased maintenance in the form of cleaning, conservation or restoration becomes necessary (Coote et al, 1989). In recent decades there has been a dramatic reduction in the level of atmospheric pollutants traditionally associated with the degradation of building materials in the urban environment but Coote et al (1989) argue that despite improved urban air quality there is no evidence of a reduction in the rate of building material degradation.

Atmospheric pollutants and their transformation products affects materials in two ways (Kucera 1987):

i) atmospheric corrosion, a direct effect mainly at the local level
ii) corrosion in water/soil systems, an indirect effect experienced at the regional level

Atmospheric corrosion is mainly due to dry deposition of pollutants, particularly SO_2, but also in combination with No_x. A range of important technical materials and cultural and historical monuments are at risk such as sandstone, limestones, marble, metals such as zinc and steel, and painted surfaces (Kucera 1987).

Corrosion resulting from soil and water acidification is a threat to technical and economically valuable materials on a regional scale. Structures such as water pipes, cables and culverts are at risk from water and soil acidification. Water acidification represents a health risk due to increased corrosivity of water.

The Research Publications collection presents data from the Acid Rain Information Centre on the spatial variation of corrosion in an environment subjected to high levels of acidic gases and acid deposition.

Potential health effects Any assessment of the risks posed to human health by acid deposition are best considered within the framework suggested by Goyer (1985), namely that acid deposition is an environmental phenomena not a toxic substance per se but that it can be the rainson detra for increased human exposure to air pollutants and toxic metals. Thus health effects arising from acid deposition can be divided into direct effects of precursors (air pollutants) and indirect effects of precursors (air pollutants) and indirect effects such as mobilisation of and increased risk of exposure to heavy metals in drinking water.

Direct effects have been extensively studied and reviewed by international and national organisations. Concentrations at which SO_2 and NO_x affect human health have been established and guidelines produced to ensure that such concentrations are not exceeded (WHO 1977, 1979). Direct effects occur through inhalation of acid gases and particles, individually or in combination. NO_2 and SO_2 are irritant, acidic, gases potentially damaging to the respiratory tract (Waller, 1988). NO_2 can enter the lungs as a gas where it will form an acid, whereas SO_2 may be an aerosol, attached to particulate matter or a gas. Acidic gases can induce airway resistance and render individuals more susceptible to bronchitis and pneumonia. They may also affect the ability of the lungs to extract oxygen from the air and this effect may be enhanced at times of maximum ventilation such as during exercise. Acute exposure to high NO_2 concentrations can be fatal and long term exposure can cause lung disease such as emphysema (WHO, 1987). Effects appear particularly related to sharp peaks in concentration rather than to average concentrations. Lung function changes in the most sensitive subjects (asthmatics) occur at concentrations of 500 ug m^{-3} NO_2 (WHO, 1987).

The U.K. does not set statutory limits upon ambient air pollutant concentrations. However the European Community has issued Directives on guide and limit values. A Limit Value is set to protect human health and a Guide Value to improve the protection of human health and to contribute to the long term protection of the environment from both peak and long term concentrations of SO_2, particulate smoke, and NO_2. Limit Values must not be exceeded by 98% of the daily mean values and guide values must not be exceeded by either 50% or 98% of the daily mean values.

The WHO recommends a 1 hour exposure guideline of 400 ug m^{-3} for NO_2 and a 24 hour exposure value of 150 ug m^{-3} and SO_2 a 10 minute guideline of 500 ug m^{-3} and a 1 hour guideline of 350 ug m^{-3}. The World Health Organisation recommends a long term annual daily average for SO_2 of 50 ug m^{-3}, (WHO, 1987).

These guidelines are set to ensure human health in extreme circumstances (WHO, 1987) and thus contain a significant protective margin over concentrations known to be deleterious to health.

Indirect effects of acid deposition occur as a result of ingestion of contaminated foodstuffs or drinking water (WHO 1986). Mobilisation of heavy metals by acidified water increases the risk of exposure to contaminated food stuffs such as freshwater fish (WHO 1986). Acidified waters that are untreated and used as a drinking water supply, eg a groundwater well, may corrode copper, lead and cadmium from plumbing systems. In parts of southern Sweden more than 50% of the drinking water supply comes from wells where 400,000 people and 650,000 recreation houses are dependent upon such sources of supply.

The Research Publications collection presents materials on this topic from the California Air Resources Board and the World Health Organisation.

Ecological Effects in the UK and Scandinavia Selected examples drawn from the UK and Scandinavia are used to exemplify the ecological impacts associated with acid deposition and air pollution. Both have a historical dimension and effects can be ascribed to both nationally derived acidifying pollutants and to long range transport of pollutants.

Ecological effects of acidification in the U.K. Extensive research and field monitoring programmes provide unequivocal evidence for the ecological effects of acid deposition upon both terrestrial and freshwater ecosystems in the U.K.. Such effects may be considered as historical where the cause has been past exposure to high concentrations of gaseous pollutants and recent where new effects are being recorded.

Historical damage by SO_2 has included a failure of tree plantings in the southern Pennines (Lines 1984), decline of lichen species in polluted urban areas (Hawksworth and Rose 1976) and the extinction of sphagnum moss species in moorlands of the southern Pennines (Woodin et al 1987). Such damage may be described as historical, although sphagnum community decline continues today upon the Pennine moorlands.

Woodin et al (1987) have suggested that the increasing deposition of nitrogen compounds onto the English southern Pennines has been responsible for the inability of transplanted sphagnum species to recolonise the moorlands where the moorlands have historically been exposed to both gaseous sulphur dioxide and rainwater solutions of sulphur oxidation products since the onset of the industrial revolution.

The impact and importance of acid deposition and precursor gases on the health of U.K. forest resources is an area of dispute between the Forestry Commission and environmental groups. The latter argue that the relatively large percentage of U.K. trees assessed as being damaged to one degree or another has parallels in the development of the forest decline syndrome in Central Europe.

Within geologically sensitive areas of the U.K. such as parts of upland Scotland and Wales, the English Lake District and the Pennines, freshwater acidification has been recorded. The North West Water Authority (NWWA has reported freshwater acidification in streams in the Lake District draining the rivers Duddon and Esk where fish deaths following `acid surges' have been experienced (Diamond et al 1987, Crawshaw 1986). Impoverished fauna communities are present which have also been observed by the Freshwater Biological Association in tarns and other water courses (Sutcliffe 1983). The Welsh Water Authority has identified reductions in plant and animal species diversity in acid waters in Wales (Stoner et al 1984), and changes in the ecology of streams subjected to acidification in Scotland have been observed by Harriman and Morrison (1982). Recently a national network of 20 surface water monitoring sites has been established by the Department of the Environment (Watson, 1989) in response to a recommendation by the Acid Waters Review Group (AWRG, 1986).

A significant decline in fish stocks has been observed in geological sensitive areas of the U.K., such as Galloway in Scotland, where as many as 40 lochs may now be acidified and in danger of loosing their fish stocks. The onset of acidification has been determined by sediment analysis to be the later part of the 19th century, with the rate accelerating this century (Batterbee and Flower 1985). More recent palaeoecological investigations provides evidence of a much more widespread acidification of freshwater lochs and lakes (Batterbee et al, 1988). Salmon and trout stocks are also thought to have undergone a significant reduction in certain Welsh rivers as a result of freshwater acidity, elevated aluminium levels and depressed calcium levels (Gee and Stoner 1984).

Changes to fish populations and to general freshwater chemistry affects other parts of the aquatic food chains including amphibians, birds and plants, directly by changing habitat and indirectly by reductions in food stuff availability. It has been suggested that dipper populations in Wales have declined due to the reduction in food stuff availability (Ormerod et al 1985). An investigation into the effects of afforestation and land management on stream acidity is being undertaken by the Welsh Water Authority and others, in the Llyn Brianne area of mid Wales where streams had become acidified to the extent that they, in some cases, could no longer support fish (Welsh Water Authority, 1988). Gee & Stoner (1989) have reviewed the causes of surface water acidification in Wales and conclude that there is clear ecological damage as a consequence of acid deposition. This damage has been exacerbated by land use changes, such as afforestation, and reduction in the rate of moorland liming. Predictive models developed by the Welsh Water Authority (Gee & Stoner, 1989) indicate that a combination of emission reductions and land use changes will be required to protect acid sensitive areas in Wales.

Land use management investigations are also being undertaken by the Central Electricity Generating Board, and others, at Loch Fleet in SW Scotland. The objectives, as with the Llyn Brianne investigations, are to identify the processes which have led to the decline and elimination of fish species, large scale manipulations of the catchment so as to reduce the impact upon water quality and maintenance of water quality conditions suitable for fish survival.

Catchment management solutions clearly have a role to play in ameliorating the effects of acidification, however, as the management team of the joint U.K. - Scandinavian `Surface Water

Acidification Project' concluded in 1987 "the relationship between deposition of sulphur compounds and water acidification is now established, though other factors may play a role. Reduced deposition is necessary if water quality is to be improved for fish" (Muniz et al, 1989). The UK Acid Waters Review Group (AWRG, 1989) concluded that a reduction of 90% in 1985 emission levels would be required to return most surface waters to near pristine conditions. To maintain water quality at current levels a deposition reduction of 30% will be required. They also note that the response of surface waters to acid deposition reductions will lag behind emission reductions by up to several decades and that some waters will never recover. The AWRG conclusion of a 90% reduction mirrors the emerging understanding of critical loads and levels of air pollutants for ecosystems. The United Nations Economic Commission for Europe (UNECE, 1988a, b) has promulgated the concepts of critical load and critical level as a means to safeguard ecological resources.

A critical load is defined as "a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge" (UNECE, 1988a).

A critical level is defined as "the concentration(s) of pollutant(s) in the atmosphere above which direct adverse effects on receptors such as plants, ecosystems or materials, may occur according to present knowledge" (UNECE, 1988b).

The concept of a critical load is a new and relatively inexact in its formulation but its application does give some guidance as to the importance of current levels of deposition and the scale of reduction necessary to bring current rates of deposition into line with theoretical critical loads.

Within the Research Publications collection information on the ecological effects of acid deposition in the U.K. are provided by the Forestry Commission.

Ecological effects Scandinavia

Aquatic effects The decline of Norwegian fish populations due to acidic water started as early as the 1920's but the most rapid losses occurred during the decade 1960-1970 (Rosseland et al 1986). By 1978 the population of Atlantic salmon had disappeared from southern Norway (Rosseland et al 1986). In the same area more than half of the brown trout populations had disappeared by 1985. Fishery inventories conducted by local fish authorities show that lakes known to have fish populations in the late 1970's had experienced a 30% loss of brown trout and a 12% loss of perch between 1978 and 1983. Although initially based on interview survey data, this trend was subsequently confirmed by test fishing in lakes where there were good time series data on fish catches (Sevaldrud et al 1986) and this is despite a reduction in acid deposition falling in southern Norway. Hesthagen et al (1989) report data from a survey of 8040 fish stocks in 6033 lakes where brown trout is clearly the main fish species affected by acid deposition. Some 3149 stocks of brown trout are known to be affected with 58% virtually eliminated.

Episodic fish kills due to rapid changes in water quality as a result of `acid surges' have severely affected salmon rivers on the west coast of Norway. Most severely affected have been smolts of Atlantic salmon and spawning migrating salmon on returning to acidified home waters (Rosseland et al 1986). Mortality has been extremely episodic and occurs most frequently after pH depression (Hesthagen et al 1989).

A continuing and increasing acidification of lake waters is being experienced in both central Sweden and in high mountainous areas with fish and invertebrate populations affected. An increase in acidic deposition during the last decades has been experienced in Finland which has led to acidification in the most sensitive freshwater systems.

Aquatic status Southern Norway contains 33 000 km^2 of acidified freshwater systems which are unable to support a normal ecological community. It is estimated by the Norwegian Government that to restore water quality to lakes and rivers in this area, to that in which fish could survive, would cost 250,000,000 N.K. per annum (Delegation of Norway 1986). In Sweden, the National Environment Protection Board estimates that 18,000 lakes and 100,000 km of running water have pH values where damage to freshwater organisms can be expected.

Terrestrial effects No effects of forest decline were reported until 1980. Inventories of forest health have been conducted in all of Sweden and parts of Norway, assessing needle loss, crown density and tree growth rates (Andersson 1985). Norway spruce is particularly affected, with needle loss increasing with tree age. In southern Sweden a decrease in crown density and tree growth has also been recorded. Needle loss does not only occur as a result of air pollution, it is a non specific signal of stress. It is unlikely that direct effects of sulphur dioxide could cause such needle loss but high episodic levels of ozone have been measured at a level that may lead to chronic injury (Andersson 1985). Increased soil acidity is reported from forests in southern Scandinavia with a possible cause being a combination of natural biogeochemical processes and acidic deposition. Mobilisation of aluminium and heavy metals from the soil, loss of base cations and reduced availability of phosphorus are all consequences of soil acidification. Reduced phosphorus availability may become a limiting factor on forest growth (Andersson 1985). In southern Scandinavia air pollution stress and soil acidification stress are superimposed upon climatic and meteorological stress (Andersson 1985) thus providing both predisposing and inciting factors in forest decline.

Terrestrial status In the 1987 Forest Damage Survey of Europe, conducted on behalf of the United Nations Economic Commission for Europe, 31.7% of the Swedish and 35.9% of the Norwegian coniferous trees are exhibiting signs of defoliation, on a scale graded from slight defoliation to severe and dead (GEMS, 1988).

Within the Research Publications collection further information on the status of acidification in Scandinavia is provided by the National Swedish Environmental Protection Board, the Swedish NGO Secretariat on Acid Rain, NOAH's Forlag and Boksgogen och Miljoforbundet.

Acidificatio n control programmes in Scandinavia By 1994 the Norwegian Government aims to have reduced national sulphur emissions by 50% based on 1980 levels, and the Swedish government intends to have a 65% reduction by 1995 and an 80% reduction by 2000. However acid deposition in Scandinavia occurs primarily as a result of long range transport from Europe. Consequently, the action of national governments is severely constrained if operating alone. International agreement on emission reductions is recognised in Scandinavia as the only route by which acidification can be halted and then reversed. In particular, action can be progressed through such bodies as the Nordic Council and the United Nations Economic Commission for Europe (UNECE), the latter being a particularly important forum offering the opportunity for significant international agreement on emission reductions. The UNECE Convention on Long Range Transboundary Air Pollution was adopted in 1979 and entered into force in 1983 as the first multilateral treaty to protect the atmospheric environment (UNECE 1987). Thirty two parties have ratified this convention which lays down principles and provides a framework for co-operation. Two protocols to the convention provide the instruments by which emission reductions can be achieved and base line monitoring carried out. These are:

a) The protocol on the reduction of sulphur emissions or their transboundary fluxes by at least 30% adopted in Helsinki, July 1985

b) The protocol on the long term financing of the co-operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe.

The 30% protocol has been ratified by 16 nations and entered into force in September 1987. This protocol, the so called `30% club', aims for a 30% reduction in 1980 sulphur emissions by 1993 (UNECE 1987). By 1988 10 parties to the protocol have reduced emissions by 30%, 11 parties have announced a reduction of 50% and 4 parties have announced reductions of 65% or more. A protocol to control NO_x is under discussion and may enter in to force by the early 1990's.

Such emission reductions are essentially political agreements relying upon social and economic acceptance of the reduction rather than the capacity of environmental systems to receive deposition. However this latter approach has recently been adopted by Scandinavian scientists working on behalf of the Nordic Council who have defined critical loads for deposition to sensitive ecosystems, such that deposition loads will not cause chemical change and long term effects to sensitive systems (Nilsson 1986). This concept has been translated into ecologically derived emission reduction equal to 90% of European sulphur emissions and 75% of nitrogen emissions (Elsworth and Agren 1987). There is pressure from Scandinavia for these ecological target reductions to supplant the politically derived figures of the 30% protocol. This pressure will intensify as European environmental groups at a meeting at Lida, Stockholm in 1986, set a timescale of 1993 for the S and 1995 for N emissions reduction, based upon 1983 emissions (Elsworth and Agren 1987). In 1989 European environmental groups met at Ede, the Netherlands to review progress with the scale and timing of emission reductions (Acid News, 1989). The resolution from this meeting reaffirmed their commitment to large scale reductions in calling for a 90% cut in sulphur dioxide and nitrogen oxide emissions, a 75% cut in ozone levels and a 90% cut in ammonia emissions. The meeting based their reductions upon a 1980 base line and wished to see at least a 75% cut in sulphur dioxide and nitrogen oxides by 1995 with the rest of the cut to follow as soon as possible thereafter (Acid News, 1989).

Sweden has taken independent action to ensure her own emission reductions are, as far as is possible, consistent with the best scientific evidence. Consequently, Sweden has developed an impressive range of counter measures to combat both the emission and effect of acid deposition (Statens Naturvardsverket, 1987). Central to the 1987 action plan is the concept of critical load. These actions include:

i) reduction in sulphur emissions by 65% between 1980 and 1995

ii) nitrogen dioxide emission reduction of 30% by 1995, including adoption of U.S. `83 standard for emissions from petrol engined vehicles

iii) countermeasures against forest soil acidification

iv) improved agricultural practices to reduce use of acidifying fertilisers and limit ammonia emissions

v) improved research and monitoring programmes

vi) reductions in hydrocarbon emissions

vii) measures to reduce traffic growth

viii) more liming of forests, soils, watercourses and groundwater supplies

ix) measures to protect the cultural heritage

These actions will significantly reduce Swedens' own contributions to acidification but will not achieve the target set by the critical load calculations. This will require concerted international action.

Within the Research Publications collection further information on the status of Swedish control measures is provided by the National Swedish Environmental Protection Board.

Action in the U.K. to reduce acid precursor emissions The U.K. has not signed the protocol to the U.N.E.C.E. convention calling for a 30% reduction in SO_2 emissions between 1980 and 1993, but acknowledges that acid deposition is an area of major international concern (DOE 1987), U.K. SO_2 emissions have been reduced by 40% from their peak emission of 1970 and the government aim to ensure a reduction of 30% of the 1980 figure by the end of the century. However the most recent emissions figures for the U.K. (1987) indicate that thanks to a reviving economy and a strong and growing demand for electricity, the national sulphur dioxide emission has risen by 200,000 tonnes on 1986 levels (DOE, 1988).

To achieve the governments stated intention of a 30% reduction by 1999 two measures were announced in September 1986:

i) the retrofitting of three 2000MW coal fired power stations with flue gas desulphurisation (FGD) equipment over the next ten years

ii) a policy of equipping new coal fired power stations with F.G.D.

In May 1987, the government authorised the Central Electricity Generating Board to begin a 10 year programme to reduce NO_x emissions at the 12 largest power stations through the use of low NO_x burners.

Together these measures will significantly reduce sulphur and nitrogen emissions from coal fired stations, and should achieve the governments aim of a 30% reduction by 1999, based on 1980 figures.

The European Community has been instrumental in creating the conditions in which emission reductions within Western Europe may be achieved. E.C. Directives principally affect motor vehicle exhausts and large combustion plant. Broad agreement on a framework for new vehicle emission standards for the European Community as a whole has been reached (Longhurst, 1989). This will involve the use of catalysts to reduce emissions from vehicles and may also encourage, in tandem, the development of fuel efficient lean burn engines. However, pressure from certain E.C. members for still tougher standards will be maintained (Longhurst, 1989; Harrison et al, 1989).

An E.C. proposal for a Council Directive on the limitations of emissions of pollutants into the air from large combustion plant (COM [83] 704 Final) called for a reduction of 60% in SO_2

emissions from large plant (i.e. greater than 50 MW) and a 40% reduction in NO_x emission (CEC, 1984). The base year again being 1980 with the reduction to be achieved by 1995. After much dispute agreement has finally been reached on this draft directive which sets a longer time scale for implementation that first suggested and introduces phased reduction levels. It is now government policy to require FGD at both new power stations rated over 100 MWth and to retrofit FGD to such power stations as are necessary to meet the emission reductions required by the European Community Large Combustion Plant Directive. The agreed Directive requires phased reductions of sulphur dioxide emissions such that the 1980 emission is reduced by 20%, 40% and 60% by the years 1993, 1998 and 2003. Neither the exact details of the retrofit programme nor the identity of the stations have been finalised but at least 12000 MW of capacity will be needed. This is 8000MW of capacity over and above the Drax retrofit announced in 1986 as part of the CEGB's voluntary FGD programme.

Within the Research Publications collection materials on abatement technology are presented by Davy McKee Ltd and the OECD.

Conclusions

Despite the length of study devoted to acid deposition and its environmental effects much still remains to be properly understood, although this should not be used as an excuse to delay the implementation of countermeasures.

Throughout the last decade of research new problems have emerged particularly the importance of nitrogen compounds, the role and importance of hydrocarbons and photochemical pollutants such as ozone. Work has clarified the timescales of acidification and the importance of land use factors in explaining the occurrence of observed effects. Timescales are now clearly dated to the onset of industrialisation although rates of acidification are obviously related to periods of intense air pollution emission. Soil mediation in explaining environmental effects is now more fully understood and pathways through soil recognised as important in explaining the chemical status of freshwater bodies, particularly with regard to mobilisation of aluminium and depression of calcium levels. Replacement of base cations to both soils and watercourses is recognised as a requirement if effects are to be ameliorated. Reversibility of acidification has become an important issue with original time estimates of decades now looking untenable as new evidence points towards much faster rates of recovery, to a point where normal freshwater life may become tenable, once deposition loadings are reduced.

Even though the role of acidifying air pollutants in forest decline is far from clear, with numerous hypotheses to explain the occurrence of forest decline, few now dispute the requirement to reduce emissions of acidifying air pollutants. The debate now is concerned with the rate at which emission reductions will take place and, importantly, when politically acceptable emission reduction targets are to be superseded by ecologically derived targets. Adoption of ecological reduction targets will require much more significant reductions in sulphur dioxide and nitrogen oxide emissions.

REFERENCES FOR THE INTRODUCTION OF ACID DEPOSITION AND THE ENVIRONMENT.

Acid News (1989) More than we thought. No. 3, July, Goteborg.

AWRG (1986) Acidity in U.K. Freshwaters. Interim Report, U.K. Acid Waters Review Group, Department of the Environment Publication Sales Unit, South Ruislip.

AWRG (1988) Acidity in U.K. Freshwaters. U.K. Acid Waters Review Group. H.M.S.O., London.

Andersson, F. (1986) Acidic deposition and its effects upon the forests of Nordic Europe. Water Air & Soil Pollution 30, 17-29.

Appleberg, M., Degerman, E, and Nyberg, P. (1989) Species composition and relative abundance of the fish fauna in acidified and limed lakes in Sweden. In Longhurst, J.W.S. (Ed) Acid deposition : sources, effects and controls British Library Science Reference and Information Service and Technical Communications Ltd, London and Letchworth.

Batterbee, R.W. & Flower, R.J. (1985) Palaeoecological evidence for the timing and causes of lake acidification in Galloway. southwest Scotland. Working paper 8, Palaeoecological Research Unit, University College, London.

Batterbee, R.W., Anderson, N.J., Appleby, P.G., Flowers, R.J. Fritz, S.C., Haworth, E,Y., Higgitt, S., Jones, V.J., Kreiser, A., Munro, M.A.R., Natkanski, J., Oldfield, F., Patrick, S.T., Richardson, N.G., Rippey, B. & Stevenson A.C. (1988) Lake acidification in the United Kingdom 1800 - 1986. Evidence from analysis of lake sediments. Prepared for the Department of the Environment by Palaeoecological Research Unit, University College, London, ENSIS, London.

Beilke, S. (1982) Acid deposition: the present situation in Europe. In Beilke, S. & Elshout, A.J. (Ed) Acid deposition Proceedings of the CEC workshop physico - chemical behaviour of atmospheric pollutants. Berlin. 1982 D. Reidel, Dordrecht.

Binns, W.O., Redfern, D.B., Rennolls, K. & Betts, A.J.A. (1985a), Forest health and air pollution: 1984 survey. Forestry Commission Research and Development Paper 142, Edinburgh.

Binns, W.O., Redfern, D.B., Boswell, R. & Betts, A.J.A. (1985b), Forest health and air pollution: 1985 survey. Forestry Commission Research and Development Paper 147, Edinburgh.

Brogger, W.C. (1881) Naturen 5, 47

Campbell, G.W., Cocksedge, J.L., Coster S.M., Dennis, A.L., Devenish, M., Heyes, C.J., Perrin, D.A., Stone, B.H., and Irwin, J.G. (1988) Acid rain in the United Kingdom: spatial distributions and seasonal variations in 1986. Warren Spring Laboratory, Stevenage.

Central Electricity Generating Board (1986) New coal stations. Statement from the CEGB. CEGB Press Information, London.

Central Electricity Generating Board (1987) £170 million emission control programme. CEGB Press Information, London.

Commission of the European Community (1984) Official Journal of the European Community 49, 1-7.

Charlson, R.J. & Rodhe, H. (1982) Factors controlling the acidity of natural rainwater, Nature 295, 683-685.

Coote, A.T., Lewry, A.J., Yates, T.J.S. & Butler, R.N. (1989) Acid deposition and building material. In Longhurst, J.W.S. (Ed) Acid deposition: sources, effects and controls British Library Science Reference and Information Service and Technical Communications Ltd, London and Letchworth.

Crawshaw, D.H. (1986) The effects of acidic run off on streams in Cumbria. In Ineson, P. (Ed) Pollution in Cumbria Institute of Terrestrial Ecology Symposium 16, I.T.E., Grange over Sands.

Cresser, M. & Edwards, A. (1987) Acidification of freshwaters. Cambridge Environmental Chemistry Series, C.U.P., Cambridge.

Cresser, M., Billet, M. & Skiba, U. (1989) The effects of acid deposition on soils. In Longhurst, J.W.S. (Ed) Acid Deposition: sources, effects and controls British Library Science Reference and Information Service and Technical Communications Ltd, London and Letchworth.

Delegation of Norway (1986) Presentation of the delegation of Norway. In Schneider, T. (Ed) Acidification and its policy implications Studies in Environmental Science 30, Elsevier, Amsterdam.

Department of the Environment (1986) Government proposes new action to tackle the problem of acid rain. DOE News Release, London.

Department of the Environment (1987) Acid deposition and its effects, DOE, London.

Department of the Environment (1988) Digest of Environmental Protection and Water Statistics No. 11, H.M.S.O., London.

Diamond, M., Crawshaw, D., Prigg, R.F., & Cragg - Hine, D. (1987) Stream water chemistry and its influence on the distribution and abundance of aquatic invertebrates and fish in uplandstreams in north west England. In Perry, R., Harrison, R.M, Bell, J.N.B. & Lester, J.N. (Editors) Acid rain: scientific and technical advances Selper, London.

Eliassen, A. (1987) Air pollution, dispersion, conversion measurement programme. In Proceedings Nordic Council's International Conference on Air Pollution. Stockholm, September 1986. Nordic Council, Stockholm.

Elsworth, S. & Agren, C. (1987) The limits to nature's tolerance. Report from the N.G.O. Conference on Acid Rain, Lida, Stockholm, September 1986. Swedish N.G.O. Secretariat on Acid Rain, Goteborg.

Farrar, J.F., Relton, J. & Rutter, A.J. (1977) Sulphur dioxide and the scarcity of Pinus sylvestris in the industrial Pennines. Environmental Pollution 14 63-68.

Gee, A.S. & Stoner, J.H. (1984) The effects of seasonal and episodic variation in water quality on the ecology of upland waters in Wales. Paper presented to the Acid Rain Symposium, Birmingham, March 23rd. Institute Water Pollution Control.

Gee, A.S. & Stoner, J.H. (1989) A review of the causes and effects of acidification on surface water in Wales and potential mitigation techniques. Archives of Environmental Contamination and Toxicology. 18 (1-2) 121-130.

Global Environmental Monitoring System (1988) Forest damage and air pollution. Report of the 1987 forest damage survey in Europe UNECE, Geneva.

Goyer, R.A. (Ed) (1985) Potential human health effects of acid rain. Report of a workshop. Environmental Health Perspectives 10 355-368.

Haines, T.A. (1981) Acid precipitation and its consequences for aquatic ecosystems: a review. Transactions of the American Fisheries Society 110 (6) 669-701.

Hammerton, D, (1988) Freshwater. In Mellanby, K. (Ed) Air pollution. Acid rain and the environment Watt Commitee on Energy Report 18. Elsevier, Barking.

Harriman, R. & Morrison, B.R.S. (1982) Ecology of streams draining forested and non-forested catchments in an area of central Scotland subject to acid precipitation. Hydrobiologia 88, 251-263.

Harrison, B., Searles, R.A., & Wilkins A.J.J. (1989) Car exhaust pollution control: lean burn engines and the continuing requirement for platinum - containing autocatalysts. In Longhurst, J.W.S. (Ed) Acid deposition: sources, effects and controls British Library Science Reference and Information Service and Technical Communications Ltd. London and Letchworth.

Hawksworth D.L. & Rose, F. (1986) Lichens as pollution monitors. Studies in Biology 6., Edward Arnold, London.

Hestahagen, T., Berger, H.M., Larsen, B.M. Hansen, L.P., Blaker, I., Sevaldrud, I.H., Enge, E., Field, E., Hegge, O., Strand, R. & Tysse, O. (1989) The effects of acid precipitation on freshwater fish in Norway. In Longhurst, J.W.S. (Ed) Acid deposition: sources, effects and controls British Library Science Reference and Information Service and Technical Communications Ltd, London and Letchworth.

Innes, J.L. (1987) Air pollution and forestry. Forestry Commission Bulletin 70. HMSO, London.

Innes, J.L. (1989) Acid rain and trees. In Longhurst, J.W.S. (Ed) Acid deposition: sources, effects and controls British Library Science Reference and Information Service and Technical Communications Ltd, London and Letchworth.

Krause, G.H.M., Arndt, U. Brandt, C.J., Bucher, J., Kenk, G. & Matzner, E. (1986) Forest decline in Europe: development and possible causes, Water Air & Soil Pollution 31 (3-4) 647-668.

Kucera, V. (1987) Effects of corrosion on buildings and materials: need for protective measures. In Proceedings Nordic Council's International Conference on Air Pollution. Stockholm, September 1986, Nordic Council, Stockholm.

Lines, R. (1984) Species and seed origin trials in the industrial Pennines. Journal of Forestry 78 (1) 9-23.

Longhurst, J.W.S. (Ed) (1989) Acid deposition: sources, effects and controls British Library Science Reference and Information Service and Technical Communications Ltd, London and Letchworth.

Longhurst, J.W.S. (1989) Autocatalysts and motor vehicle emission contro., Clean Air 19 (1) 14-21.

Muniz, I., Seip, I.M. & Samstag, T. (1989) Acid rain: time for action Ministry of Environment, Oslo, Norway.

Nihlgard, B. (1985) The ammonium hypothesis - an additional explanation to the forest decline in Europe. Ambio 14, 2-8.

Nilsson, J. (Ed) (1986) Critical loads for nitrogen and sulphur Nordic Council Report 1986: 11, Stockholm.

Norwegian Institute for Air Research (1984) Summary report from the chemical co-ordinating centre for the second phase of EMEP. EMEP/CCC Report 2/84, NILU, Lillestrom.

Ormerod, S.J., Tyler, S.J. & Lewis, J.M.S. (1895) Is the breeding distribution of Dippers influenced by stream acidity? Bird Study 23, 32-39.

Press, M.C., Ferguson, P. & Lee, J.A. (1983) Two hundred years of acid rain. Naturalist 108, 125-129.

RGAR (1986) Acid deposition in the United Kingdom. United Kingdom Review Group on Acid Rain. Warren Spring Laboratory., Stevenage.

RGAR (1986) Future acid deposition monitoring in the United Kingdom. United Kingdom Review Group on Acid Rain. Warren Spring Laboratory, Stevenage.

RGAR (1987) Acid deposition in the United Kingdom 1981 - 1985. United Kingdom Review Group on Acid Rain. Warren Spring Laboratory, Stevenage.

Rosseland, B.O, Skogheim, O.K. & Sevaldrud I.H. (1986) Acid deposition and effects in Nordic Europe. Damage to fish populations in Scandinavia continues apace. Water Air & Soil Pollution 30, (1-2) 65-74.

Sandermann, Jr., Schmitt, R., Heller, W., Rosemann, D. & Langebartels, D. (1989) Ozone induced early biochemical reaction in conifers. In Longhurst, J.W.S. (Ed) Acid deposition: sources, effects and controls British Library Science Reference and Information Service and Technical Communications Ltd, London and Letchworth.

Schutt, P. & Cowling, E. (1985) Waldsterben - a general decline of forests in central Europe: symptoms, development and possible causes. Plant Diseases 69 (7) 448-458.

Sevaldrud, I.H. & Skogheim, O.K. (1986) Changes in the fish population in southernmost Norway during the last decade. Water Air & Soil Pollution 30 (1-2) 381-386.

Shell International Petroleum (1985) Long range air pollutio study exercise Report HSE 002, Shell International Petroleum, the Netherlands.

Smith, R.A. (1852) On the air and rain of Manchester. *Memoirs and Proceedings of the Manchester Literary and Philosophical Society* 10 (2) 207-217.

Smith, R.A. (1872) *Air and rain. The beginning of a chemical climatology.* Longmans Green & Co., London.

Statens Naturvardsverket (1987) *Aktionsplan '87 mot luftfororeningar och forsurning.* SNV Rapport 3379. Solna, Sweden.

Stoner, J.H., Gee, A.S. & Wade, K, R. (1984). The effects of acid precipitation and land use on water quality in the upper Tywi catchment in West Wales. *Environmental Pollution.* (A) 35, 125-157.

Sutcliffe, D.W., (1983) Acid precipitation and its effects on aquatic systems in the English Lake District. *Report of the Freshwater Biological Association.* 51st, 30-62. Ambleside.

TERG (1988) *The effects of acid deposition on the terrestrial environment in the U.K.* First Report, U.K. Terrestrial Effects Review Group. HMSO, London.

Tickle, A. (1988) *Acid waters in the U.K.: evidence, effects and trends.* Air Pollution Report 3, Greenpeace Environment Trust, London.

Ulrich, B. (1983) *Soil acidity and its relation to acid deposition* In Elrich, B & Pankrath, J. (Eds) *Effects of accumulation of air pollutants in forest ecosystems* Reidal, Dordrecht.

United Nations Economic Commission for Europe (1987) Air pollution. Status of the Convention on Long-range transboundary air pollution and its related protocols (as of 1st July 1987) UNECE, Geneva.

United Nations Economic Commission for Europe (1988a) Conclusions and draft recommendations on the workshops on critical levels for forests, crops, and materials and on critical loads for sulphur and nitrogen, UNECE Report EB.AIR/R.30, Geneva.

United Nations Economic Commission for Europe (1988b) EC critical levels workshop, Bad Harzburg, FRG, 14-18 March 1988, UNECE, Geneva.

Waller, R.E. (1988) Effects on health of ozone, oxides of nitrogen and some other pollutants considered in the WHO Air Quality Guidelines Project 1984-87. IAPSC 4/3, Summer 1988, Birmingham.

Watson, D.C. (1989) Acid waters monitoring in the U.K.: moving towards a ntional perspective. In Longhurst, J.W.S. (Ed) Acid deposition: sources, effects and controls British Library Science Reference and Information Service and Technical Communications Ltd, London and Letchworth.

Welsh Water Authority (1988) Llyn Brianne Acid Waters Project. Second Technical Summary Report, W.W.A., Llanelli.

Woodin, S.J., Studholme, C.U., & Lee, J.A. (1987) Effects of acid deposition on peatlands. In Perry, R., Harrison, R.M., Bell, J.N.B. & Lester, J.N. (Editors) Acid rain: scientific and technical advances Selper, London.

World Health Organisation (1977) Oxides of nitrogen Environmental Health Criteria 4, W.H.O., Geneva.

World Health Organisation Working Group (1986) Health impacts of acid deposition. Science of the Total Environment 52, 157-158.

World Health Organisation (1987) Air quality guidelines for Europe European Series No. 23, WHO, Copenhagen.

PARTICIPATING AGENCIES

The Groups participating in the 1989 update of Acid Deposition and the Environment are listed below. Those groups participating for the first time have brief bibliographical details and a contact address. Descriptions of the established groups can be found in the guide and bibliographical fiche to the Basic Set - 1988.

Acid Rain Information Centre
Bokskogen Och Miljöförbundet
California Air Resources Board
Davy McKee (London) Ltd
Department of Geography, Lampeter University
Fish and Wildlife Service
Forestry Commission
Forth River Purification Board
Ministère De L'Environment, France
National Atmospheric Deposition Program
National Swedish Environmental Protection Board
Noah's Forlag
Nordic Council
Organisation for Economic Co-Operation And Development
Swedish N.G.O. Secretariat on Acid Rain
World Health Organisation
World Meteorological Organisation
World Wide Fund for Nature

DESCRIPTION OF GROUPS PARTICIPATING FOR THE FIRST TIME

DEPARTMENT OF GEOGRAPHY, LAMPETER UNIVERSITY

Lampeter,
Dyfed,
West Wales.

The Department is concerned with the effects of environmental changes on local geography. Thus David Kay, of the geography department, and John Stoner of Welsh Water have collaborated to produce a report discussing acid rain and its effects on stream water in catchments, Welsh.

FORTH RIVER PURIFICATION BOARD

Colinton Dell House
West Mill Road
Colinton
Edingburgh EH13 0PH

The Board deals with all aspects of water purification and pollution. It aims to control acidic and sensitive surface waters, and to improve detection of water impurities. The Balquidder Report, begun in 1981, was the first of its kind to be undertaken in the UK.

NATIONAL SWEDISH ENVIRONMENT PROTECTION BOARD

Information Section
Box 1302
S-171 25 Solna
Sweden

The Protection Board produces a wide range of reports on the effects of air pollution and acidification. Its aim is to inform, and increase public awareness in , of the increasing problems of acid rain, in Sweden, and Scandinavia as a whole. Through a variety of action programmes, it hopes to influence governments on future environmental policy measures.

WORLD METEOROLOGICAL ORGANISATION

The Secretariat
41 Avenue Giuseppi Motta
Geneva
Switzerland

The agency of the U.N. aims to encourage World Wide Co-operation in the establishment of national networks to collect meteorological works of statistics, and to improve meteorological observation. It also promotes the setting up and maintenance of centres providing meteorological and related services, and hopes to encourage the application of meteorology to water problems, agriculture and other human activities. The report analyses atmospheric pollution and its effects on inland waters.

WORLD WIDE FUND FOR NATURE

WWF International
CH - 1196 Gland
Switerland

Formerly known as the World Wildlife Fund, this is a conservation organisation which promotes the protection of all forms of wildlife. The fund is concerned with the problem of acid rain and its effects an forests, lakes and natural habitats, and particularly the resulting implications for the species who live within them.

ACID DEPOSITION AND THE ENVIRONMENT

The Annual `Grey Literature'
Environmental Reference Collection

1989 Update

An Agency, Author and Thematic Index

AGENCIES AND AUTHORS

ACID RAIN INFORMATION CENTRE

1. Longhurst, JWS. Motor vehicle emission control by catalyst. Report for the Manchester Area Pollution Advisory Council Meeting. January 17th 1989, 8pp. (Card 349).

2. Longhurst, JWS. Privatisation of the Electricity Supply Industry. Report for the Association of Greater Manchester Authorities. January 1989, 6pp. (Card 349).

3. Green, SE; Longhurst, JWS and Lee, DS. Acid Rain. Secondary Teaching Pack. April 1989, 83pp. (Cards 349-350).

4. Green, SE; Longhurst, JWS; Myszor, AM and Lee, DS. Spatial Variation in Environmental Corrosion. An educational case study of environmental corrosion in the conurbation of Greater Manchester. May 1989, 79pp. (Cards 350-351).

5. Hare, SE; Longhurst, JWS and Lee, DS. A Comparison of Rainwater Acidity between Greater Manchester and Greater Lisbon during October, November and December 1988. July 1989, 37pp. (Cards 351-352).

6. Hare, SE; Longhurst, JWS and Lee, DS. A Comparison of Rainwater Acidity between United Kingdom, Portugal and Sweden during October, November and December 1988. August 1989, 18pp. (Card 352).

7. Hare, SE and Myszor, AM. Greater Manchester Schools Environmental Corrosion Monitoring Survey. Part 2 March-July 1989 August 1989, 68pp. (Cards 352-353).

8. Lee, DS; Longhurst, JWS; Gee, DR and Hare, SE. Urban Acid Deposition. Results from the GMADS Network, 1988. August 1989, 19pp. (Cards 353-357).

BOKSKOGEN OCH MILJÖFÖRBUNDET

1. Nielsen, K; Nielsen, B and Igeland, L. Halften Bort! 1989, 43pp. (Cards 358-360)

2. Grennfelt, P; Holmer, B; Leksell, I; Lindahl, B; Lindskog, A; Persson, B; Steen, B; Wallin, G; Värmby, G and Agren, C. Luftvård. 1989, 214pp. (Card 360).

CALIFORNIA AIR RESOURCES BOARD

1. Atmospheric Acidity Protection Program. Five - Year Research Plan. June 1989, 29pp. (Card 361)

2. The Health and Welfare Effects of Acid Deposition in California: Technical Assessment. June 1989, 166pp. (Cards 361-363).

DAVY McKEE LTD

1. Ford, PG. Wellman Lord takes the S out of SO_2. June 1987 4pp. (Card 364).

2. Hallsworth, JA. Improving the Environment with the Wellman - Lord Process. June 1988, 20pp. (Card 364).

3. Ford, PG. Flue Gas Desulphurisation and the Wellman Lord Process. October 20th 1988, 14pp. (Card 364).

4. Akroyd, RC. From Flue Gas Sulphur Emissions to Fertiliser. May 1989, 17pp. (Card 364).

5. Worldwide Listing of Wellman Lord SO_2 Recovery Facilities. 1989, 3pp. (Card 364).

6. Flue Gas Desulphurisation. (undated) 2pp. (Card 364).

7. The Wellman Lord Process. (undated) 2pp. (Card 364).

8. The Wellman Lord Process. (undated) 2pp. (Card 364).

DEPARTMENT OF GEOGRAPHY, LAMPETER UNIVERSITY

1. Kay, D and Stoner, J. The effects of catchment land use on stream water quality in an acid-susceptible region of West Wales: the implications for compliance with EC drinking water and fishery directives. Applied Geography (1988), 8, 191-205. 15pp. (Card 365).

FISH AND WILDLIFE SERVICE, U.S. Dept. of the Interior

1. Schreiber, RK and Britt, DL. Acid Precipitation Mitigation: Implementation of the US Fish and Wildlife Service Research Program. Fisheries, Vol. 12. No. 3. May-June 1987, 5pp. (Card 366).

2. Brown, JM and Goodyear, CD. Acid Precipitation Mitigation Program - Research Methods and Protocol. September 1987, 126pp. (Cards 366-367).

3. Newman, JR and Schreiber, RK. Air Pollution and Wildlife Toxicology: An Overlooked Problem. October 16th 1987, 10pp. (Card 369).

4. Schreiber, RK; Goodyear, CD and Hartman, WA. Challenges and progress in the federal state. May 1988, 5pp. (Card 369).

5. Schreiber, RK and Newman, JR. Acid Precipitation Effects on Forest Habitats: The Implications for Wildlife. From Conservation Biology Vol. 2. No. 3, September 1988, 11pp. (Card 369).

6. Schreiber, RK and Newman, JR. The Nature and Effects of Atmospheric Deposition on Wilderness: Monitoring and Researc Needs. October 16th 1988, 6pp. (Card 369).

FORESTRY COMMISSION RESEARCH DIVISION

1. Innes, JL and Boswell, RC. Forest Health Surveys 1987. Part 1: Results. Bulletin 74. 1987, 24pp. (Card 370).

2. Innes, JL and Boswell, RC. Forest Health Surveys 1987. Part 2: Analysis and Interpretation. Bulletin 79. 1987, 52pp. (Card 370).

3. Innes, JL and Boswell, RC. Forest Health Surveys 1988 - Preliminary Results. Research Information Note 139. Novembe 1988, 6pp. (Card 370).

4. Taylor, G; Dobson, MC; Freer - Smith, PH and Davies, WJ. Tree Physiology and Air Pollution in Southern Britain. Research Information Note 145. February 1989, 3pp. (Card 371).

5. Nisbet, TR. Liming to alleviate surface water acidity. Research Information Note 148. February 1989, 3pp. (Card 371).

FORTH RIVER PURIFICATION BOARD

1. Balquidder Water Quality Studies - Analytical Quality Control Programme. FRPB Report No6, FC 9/87. March 1988, 64pp. (Card 372).

MINISTÉRE DE L'ENVIRONNEMENT, FRANCE

1. Deforpa. Dèpèrissement des Forêts et Pollution Atmospherique. Volume 1. Mars 23 1989, 162pp. (Cards 374-376).

2. Deforpa. Dépérissement des Forêts et Pollution Atmospherique. Volume 2. Mars 23 1989, 162pp. (Cards 376-378).

3. Deforpa. Dépérissement des Forêts et Pollution Atmospherique. Volume 3. Mars 23 1989, 280pp. (Cards 378-382).

4. Deforpa. Dépérissement des Forêts et Pollution Atmospherique. Volume 4. Mars 23 1989, 186pp. (Cards 382-384).

NATIONAL ATMOSPHERIC DEPOSITION PROGRAM

1 NADP/NTN Data Report: Precipitation Chemistry; July - 31 December 1988. Volume X1 Number 2. July 1989, 220pp. (Cards 385-391).

2. NADP/NTN:Monitoring Network. Locations of Active sites in the NADP/NTN network. Volume X1, No. 2. August 15th, 1989, 7pp. (Cards 392-394).

3. NADP Report: Monitoring Network. August 1989, 5pp. (Card 394).

NATIONAL SWEDISH ENVIRONMENTAL PROTECTION BOARD

1. Acid Magazine. No. 7, December 1988, 24pp. (Card 395).

2. Acidification Research in Sweden. December 7th 1988, 12pp. (Card 395).

3. Effects of Air Pollutants and Acidification. Research Programme for the period 1988-89 to 1992-93. June 1988, 27pp. (Card 395).

4. *Acidification and Air Pollution.* (undated), 94pp. (Cards 395-396).

5. *Action Program - Against Air Pollution and Acidification.* (undated), 77pp. (Cards 396-397).

6. *Air Pollution and Acidification.* (undated), 11pp. (Card 397).

NOAH'S FORLAG

1 *Som Vinden Blaeser Miljoproblemer i Polen, DDR og Tjekkoslovakiet.* Chapter 3, Luftforurening, pages 46-62. (Card 398).

NORDIC COUNCIL

1. Seip, HM; Andersen, B; Andersson, G; Gahnström, G; Hov, O; Kucera, V and Mosenholm, L. *Acid Precipitation - Literature Review for 1987.Miljorapport 1989:4.* 1989, 209pp. (Cards 399-401).

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

1. *Clean Coal Technology. Programmes and Issues.* 1987, 175pp. (Cards 402-404).

2. *Transport and the Environment.* Selected Chapters. 1988, 58pp. (Card 404).

SWEDISH NGO SECRETARIAT ON ACID RAIN

1. *Acid News.* No 3, October 1988, 23pp. (Card 405).

2. *Acid News.* No 1, February 1989, 23pp. (Card 405).

3. *Acid News.* No 3, July 1989, 15pp. (Card 405).

WORLD HEALTH ORGANISATION

1. Acid Precipitation Part 1. Water Quality Bulletin. Volume 8, No, 2. April 1983, 55pp. (Card 406).

2. Acid Precipitation Part 2. Water Quality Bulletin. Volume 8, No. 3. July 1983, 59pp. (Cards 406-407).

3. Acid Precipitation and Human Health - Part 1. Water Quality Bulletin Volume 11. No. 1. January 1986, 64pp. (Card 407).

4. Acid Precipitation and Human Health - Part 2. Water Quality Bulletin. July 1986, 55pp. (Cards 407-408).

WORLD METEOROLOGICAL ORGANISATION

1. Impact of Atmospheric Pollution on Inland Waters. UNEP/WHO/UNESCO/WMO project on Global Water Monitoring (Gems/Water). February 1986, 51pp. (Card 409).

WORLD WIDE FUND FOR NATURE

1. Acid Rain and Air Pollution. 1989, 44pp. (Card 410).

AUTHOR INDEX

Ågren, C. Luftvård. Bokskogen och Miljöförbundet. See Grennfelt, P.

Andersen, B. Acid Precipitation - Literature Review, 1987. Miljorapport 1989:4. See Seip, HM.

Andersson, G. Acid Precipitation. See Andersen, B.

Boswell, RC. Forest Health Surveys 1987. Part 1: Results. See Innes, JL.

Boswell, RC. Forest Health Surveys 1987. Part 2: Analysis and Interpretation. See Innes, JL.

Boswell, RC.Forest Health Surveys 1988 - Preliminary Results. See Innes, JL.

Britt, DL. Acid Precipitation Mitigation: Implementation of the US Fish and Wildlife Service Research Program. See Schreiber, RK.

Brown, JM. Acid Precipitation Mitigation Program - Research Methods and Protocol. Fish and Wildlife Service. September 1987, 126pp. Item 2. (Cards 366-368).

Davies, WJ. Tree Physiology and Air Pollution in Southern Britain. See Taylor, G.

Dobson, MC. Tree Physiology and Air Pollution in Southern Britain. See Taylor, G.

Ford, PG. Wellman Lord takes the S out of SO . Davy McKee Ltd. (undated), 4pp. Item 1. (Card 364).

Ford, PG. Flue Gas Desulphurisation and the Wellman - Lord Process. Davy McKee Ltd. 20th October 1988, 14pp. Item 3. (Card 364).

Freer-Smith, PH. Tree Physiology and Air Pollution in Southern Britain. See Taylor, G.

Gahnström, G. Acid Precipitation - Literature Review 1987. Miljorapport 1989:4. See Seip, HM.

Gee, DR. Urban Acid Deposition. Results from the GMADS Network. 1988. See Lee, DS.

Goodyear, CD. Acid Precipitation Mitigation Program-Research Methods and Protocol. See Brown, JM.

Goodyear, CD. Challenges and Progress in the Federal/State. See Schreiber, RK.

Grayson, AJ. Carbon Dioxide, Global Warming and Forestry. Research Information Note 146. Forestry Commission. February 1989, 3pp. Item 5. (Card 371).

Green, SE; Longhurst, JWS and Lee, DS. Acid Rain. Secondary Teaching Pack. Acid Rain Information Centre. April 1989, 83pp. Item 3. (Cards 348-349).

Green, SE; Longhurst, JWS; Myszor, AM and Lee, DS. Spatial Variation in Environmental Corrosion. An educational case study of environmental corrosion in the conurbation of Greater Manchester. Acid Rain Information Centre. May 1989, 79pp. Item 4. (Cards 350-351).

Grennfelt, P; Holmer, B; Leksell, I; Lindahl, B; Lindskog, A; Persson, B; Steen, B; Wallin, G; Värmby, G and Ågren, C. Luftvård. Bokskogen Och Miljöförbundet. 1989, 214pp. Item 2. (Cards 358-360).

Hallsworth, JA. Improving the Environment with the Wellman-Lord Process. Davy Mckee Ltd. June 1988, 20pp. Item 2. (Card 364).

Hare, SE; Longhurst, JWS and Lee, DS. A Comparison of Rain-water Acidity between Greater Manchester and Greater Lisbon during October, November and December 1988. Acid Rain Information Centre. July 1989, 37pp. Item 5. (Cards 350-351).

Hare, SE; Longhurst, JWS and Lee, DS. A Comparison of Rain-water Acidity between United Kingdom, Portugal and Sweden during October, November and December 1988. Acid Rain Information Centre . August 1989, 18pp. Item 6. (Card 351).

Hare, SE and Myszor, AM. Greater Manchester Schools Environmental Corrosion Monitoring Survey. Part 2: March - July 1989. Acid Rain Information Centre. August 1989, 68pp. Item 7. (Cards 352-353).

Hare, SE. Urban Acid Deposition. Results from the GMADS Network, 1988. See Lee, DS.

Hartman, WA. Challenges and Progress in the federal\state. See Schreiber, RK.

Holmer, B. Luftvård. See Grennfelt, P.

Hov, O. Acid Precipitation - Literature Review, 1987. See, Seip, HM.

Igeland, L. Hålften Bort! See Nielsen, K.

Innes, JL and Boswell, RC. Forest Health Surveys 1987. Part 1: Results. Bulletin 74. Forestry Commission. 1987, 24pp. Item 1. (Card 370).

Innes, JL and Boswell, RC. Forest Health Surveys 1987. Part 2. An Analysis and Interpretation. Forestry Commission. 1988, 52pp. Item 2. (Card 370).

Innes, JL and Boswell, RC. Forest Health Surveys 1988 - Preliminary Results. Research Information Note 139. Forestry Commission. November 1988, 6pp. Item 3. (Card 370).

Kay, D and Stoner, J. The effects of catchment land use on stream water quality in an acid - susceptible region of West Wales: the Implications for compliance with EC drinking water and fishery directives. Applied Geography (1988),8,191-205. Department of Geography, Lampeter University. 1988, 15pp. Item 1. (Card 365).

Kucera, V. Acid Precipitation - Literature Review, 1987. Miljorapport 1989:4. See Seip, HM.

Lee, DS. Acid Rain. Secondary Teaching Pack. See Green, SE.

Lee, DS. Spatial Variation in Environmental Corrosion. See Green, SE.

Lee,DS. A Comparison of Rainwater Acidity between Greater Manchester and Greater Lisbon during October, November and December 1988. See Hare, SE.

Lee,DS. A Comparison of Rainwater Acidity between United Kingdom, Portugal and Sweden during October , November and December, 1988 . See Hare, SE.

Lee,DS. Acid Rain. Secondary Teaching Pack. See Green, SE.

Leksell, I. Luftvård. See Grennfelt, P.

Lindahl, B. Luftvård. See Grennfelt, P.

Lindskog, A. Luftvård. See Grennfelt, P.

Longhurst, JWS. Motor Vehicle Emission Control By Catalyst. A Report for the Manchester Area Pollution Council Meeting. Acid Rain Information Centre. January 17th, 1989., 2pp. Item 1. (Card 349).

Longhurst, JWS. Privatisation of the Electricity Supply Industry. Report for the Greater Manchester Authorities. Acid Rain Information Centre. January 1989, 6pp. Item 2. (Card 349).

Longhurst, JWS. Acid Rain. Secondary Teaching Pack. See, Green, SE.

Longhurst, JWS. Spatial Variation of Environmental Corrosion in the Conurbation of Greater Manchester. See Green, SE.

Longhurst, JWS. A Comparison of Rainwater Acidity between Greater Manchester and Greater Lisbon during October, November and December 1988. See Hare, SE.

Longhurst, JWS. A Comparison of Rainwater Acidity between United Kingdom, Portugal and Sweden during October, November and December. See Hare, SE.

Longhurst, JWS. Urban Acid Deposition. Results from the GMADS Network, 1988. See Lee, DS.

Mosenholm, L. Acid Precipitation - Literature Review, 1987. Miljorapport 1989:4. See Seip, HM.

Myszor, AM. Spatial Variation in Environmental Corrosion. An educational case study of environmental corrosion in the conurbation of Greater Manchester. See Green, SE.

Myszor, AM. Greater Manchester Schools Environmental Corrosion Monitoring Survey. Part 2: March - July 1989. See Hare, SE.

Newman, JR. Air Pollution and Wildlife Toxicology: An Overlooked Problem. Fish and Wildlife Service. October 16th, 1989, 10pp. Item 3. (Card 369).

Newman, JR. Acid Precipitation Effects on Forest Habitats: Implications for Wildlife. See Schreiber, RK.

Newman, RK. The Nature and Effects of Atmospheric Deposition on Wilderness: Monitoring and Research Needs. See Schreiber, RK.

Nielsen, B. Hålften Bort! See Nielsen, K.

Nielsen, K; Nielsen, B and Igeland, L. Hålften Bort! Bokskoge och Miljöförbundet. 1989, 43pp. Item 2. (Card 360).

Persson, B. Luftvård. See Grennfelt, P.

Schreiber, RK and Britt, DL. Acid Pecipitation Mitigation: Implementation of the US Fish and Wildlife Service Research Program. Fisheries Volume 12. No. 3. Fish and Wildlife Service. May - June 1987, 5pp. Item 1. (Card 366).

Schreiber, RK. Air Pollution and Wildlife Toxicology: Ann Overlooked Problem. See Newman, JR.

Schreiber, RK and Newman, JR. Acid Precipitation Effects on Forest Habitats: Implications for Wildlife. Conservation Biology, Volume 2. No. 3. September 1988, 11pp. Item 5. (Card 369).

Schreiber, RK and Newman, JR. The Nature and Effects of Atmospheric Deposition on Wilderness: Monitoring and Network Needs. Fish and Wildlife Service. October 16th, 6pp. Item 6. (Card 369).

Schreiber, RK; Goodyear, CD and Hartman, WA. Challenges and progress in the federal/state. May 1988, 5pp. (Cards 369).

Seip, HM; Andersen, B; Andersson, Gahnström, G; Hov, O; Kucera, V and Mosenholm, L. Acid Precipitation - Literature Review, 1987. Miljorapport 1989:4. Nordic Council. 1989, 209pp. Item 1 (Cards 399-401).

Steen, B. Luftvård. See Grennfelt, P.

Stoner, J. The effects of catchment land use on stream wate quality in an acid - susceptible region of West Wales: The Implications for compliance with EC drinking water and fishery directives. See Kay,D.

Taylor, G; Dobson, MC, Freer-Smith, PH and Davies, WJ. Tree Physiology and Air Pollution in Southern Britain, Research Information Note 145. Forestry Commission. February 1989, 3pp. Item 4. (Card 371).

Vårmby, G. Luftvård. See Grennfelt, P.

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THEMATIC INDEX

GENERAL WORKS

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Hare, SE and Myszor, AM. Greater Manchester Schools Environmental Corrosion Monitoring Survey. Part 2 March - July 1989. August 1989, 68pp. Item 7. (Card 352)

Lee, DS. Longhurst, JWS, Gee, DR and Hare, SE Urban Acid Deposition. Results from the GMADS Network, 1988. August 1989, 190pp. Item 8. (Card 364)

Grennfelt P, Holmer B; Leksell, I; Lindahl, B; Lindskog A; Persson, B; Steen, B; Wallin, G; Värmby, G and Agren, C. Luftvaid. 1989, 214pp. Item 1 (Card 358)

Nielsen B; Nielsen K and Igeland L. Halften Bort! 1989, 43pp. Item 2. (Card 360)

National Swedish Environmental Protection Board. Acid Magazine Number 7. December 1988, 24pp. Item 1. (Card 395)

National Swedish Environment Protection Board. Acidification Research in Sweden. December 7th 1988, 12pp. Item 2. (Card 395)

National Swedish Environment Protection Board. Effects of Air Pollutants and Acidification. Report 3516. Research programme for the period 1988-89 to 1992-93. June 1988, 27pp. Item 3. (Card 395)

National Swedish Environment Protection Board. Acidification and Air Pollution. (Undated), 94pp. Item 4. (Cards 395 - 396)

National Swedish Environment Protection Board. Action Program - Against Air Pollution and Acidification. (Undated), 77pp. Item 5. (Cards 396 - 397)

National Swedish Environment Protection Board. Air Pollution and Acidification (Undated), 11pp. Item 6. (Card 397)

Noah's Forlag. Som Vinden Blaeser. Miljoproblemer i Polen, DDR og Tjekkoslovakiet. Chapter 3, Luft forurening, p46-62. November 1986, 22pp. Item 1. (Card 398)

Seip, HM; Andersen, B; Anderson, G; Gahnström, G; Hov O; Kucera, V and Mosenholm, L. Acid Precipitation - Literature Review. Miljorapport 1989: 4. 1989, 209pp. Item 1. (Cards 399 - 401)

World Health Organisation. Water Quality Bulletin. Volume 8, No.2. April 1983, 55pp. Item 1. (Card 406)

World Health Organisation. Acid Precipitation - Part 2. Water Quality Bulletin. Volume 8, No.3. July 1983, 59pp. Item 2. (Cards 406 - 407)

World Health Organisation. Acid Precipitation and Human Health - Part 1. Water Quality Bulletin. Volume 11, No. 1. January 1986, 64pp. Item 3. (Card 407)

World Health Organisation. Acid Precipitation and Human Health - Part 2. Water Quality Bulletin. Volume 11, No. 3. July 1986, 55pp. Item 4. (Cards 407 - 408)

World Wide Fund For Nature. Acid Rain and Air Pollution. 1989, 44pp. Item 1. (Card 410)

EMISSION, TRANSPORT AND DEPOSITION PROCESSES

Hare, SE; Longhurst, JWS and Lee, DS. A Comparison of Rainwater Acidity between United Kingdom, Portugal and Sweden during October, November and December 1988. Acid Rain Information Centre. August 1989, 18pp. Item 6. (Card 352)

Lee, DS; Longhurst, JWS; Gee, DR and Hare, SE Urban Acid Deposition. Results from the GMADS Network, 1988. August 1989, 19pp. (Cards 353 - 357)

Nielsen, B; Nielsen, K and Igeland, L. Halften Bort! Bokskogen och Miljöförbundet. 1989, 214pp. Item 2. (Cards 358 - 360)

National Atmospheric Deposition Program. NADP/NTN Data Report: Precipitation Chemistry, July - 31 December 1988. Volume XI No.2. July 1989, 220pp. Item 1. (Cards 385 - 391)

National Atmospheric Deposition Program. NADP/NTN: Monitoring Network. Locations of Active Sites in the WADP/NTN network. Volume X, No.2. August 15th 1989, 7pp. Item 2. (Cards 392 - 394)

National Atmospheric Deposition Program. NADP Report: Monitoring Network. August 1989, 5pp. Item 3. (Card 394)

National Swedish Environmental Protection Board. Action Program - Against Air Pollution and Acidification. (Undated), 77pp. Item 5. (Cards 396 - 397)

ENVIRONMENTAL EFFECTS: AQUATIC

Kay, D and Stoner, J. The effects of catchment land use on stream water quality in an acid-susceptible region of West Wales: the implications for compliance with EC drinking water and fishery directiver. Dept. of Geography, Lampeter University. 1988, 15pp. (Card 365)

Innes, JL and Boswell, RC. Forest Health Surveys. 1987 - Part 1: Results. Bulletin 74. Forestry Commission Research Division. 1987, 24pp. Item 1 (Card 370)

Balquidder Water Quality Studies - Analytical Quality Control Programme. FRPB Report No. FC 9/87. Forth River Purification Board. March 1988. 64pp. (Card 372)

World Health Organisation. Water Quality Bulletin. Volume 8, No.2. April 1983, 55pp. (Card 406)

World Health Organisation. Acid Precipitation Part 2. Water Quality Bulletin. Volume 8, No.3. July 1983, 59pp. (Cards 406 - 407)

World Health Organisation. Acid Precipitation and Human Health - Part 1. Water Quality Bulletin. Volume 11. No.1. January 1986, 64pp. (Card 407)

World Health Organisation. Acid Precipitation and Human Health - Part 2. Water Quality Bulletin. July 1986, 55pp. (Cards 407 - 408)

World Meteorological Organisation. Impact of Atmospheric Pollution on Inland Waters. UNEP/WHO/UNESCO/WHO project on Global Water Monitoring. (Germs/Water) February 1986, 51pp. (Card 409)

ENVIRONMENTAL EFFECTS: TERRESTRIAL

Newman, JR and Schreiber, RK. Air Pollution and Wildlife Toxicology: An Overlooked Problem. Fish and Wildlife Service. October 16th 1987, 10pp. Item 3. (Card 369)

Schreiber, RK; Goodyear, CD and Hartman, WA. Challenges and progre in the federal/state. Fish and Wildlife Service. May 1988, 5pp. It (Card 369)

Schreiber, RK and Newman, JR. Acid Precipitation Effects on Forest Hebitats: Implications for Wildlife. From Conservation Biology Vol.2. No.3. September 1988, 11pp. Item 5. (Card 369)

Schreiber, RK and Newman JR. The Nature and Effects of Atmospheric Deposition on Wilderness: Monitoring and Research Needs. October 16th 1988, 6pp. Item 6. (Card 369)

Innes, JL and Boswell, RC. Forest Health Surveys 1987 Part 1: Results. Forestry Commission Research Division. Bulletin 74. 1987, 24pp. Item 1. (Card 370)

Innes, JL and Boswell, RC. Forest Health Surveys 1988 - Preliminary Results. Forestry Commission Research Division. Bulletin 79. 1987, 52pp. Item 2. (Card 370)

Innes, JL and Boswell, RC. Forest Health Surveys 1988 - Preliminary Results. Research Information Note 139. Forestry Commission Research Division. November 1988, 6pp. Item 3. (Card 37

Taylor, G; Dobson, MC; Freer-Smith, PH and Davies, WJ. Tree Physology and Air Pollution in Southern Britain. Research Information Note 145. Forestry Commission Research Division. February 1989, 3pp. Item 4. (Card 371)

Nisbet, TR. Liming to alleviate surface water acidity. Research Information Note 148. Forestry Commission Research Division (Card

Deforpa. Dèpèrissement dès Forêts et Pollution Atmospherique. Volume 1. Ministere De L'Environment, France. Mars 23 1989, 162pp. Item 1. (Cards 374-376)

Deforpa. Dèpèrissement des Forêts et Pollution Atmospherique. Volume 2. Ministere De L'Environment, France. Mars 23, 1989. Item 2. 280pp. (Cards 376-378)

Deforpa. Dèpèrissemnet des Forêts et Pollution Atmospherique. Volume 3. Ministere De L'Environment, France. Mars 23, 280pp. Item 3 (Cards 378-382)

Deforpa. Dèpèrissement des Forêts et Pollution Atmospherique. Volume 4. Minitere De L'Environment, France. Mars 23, 1989. 186pp. Item 4. (Cards 382-384)

ENVIRONMENTAL EFFECTS: HUMAN HEALTH

California Air Resources Board: The Health and Welfare Effects of Acid Deposition in California: Technical Assessment, June 1989, 166pp. Item 2. (Card 361)

World Health Organisation. Acid Precipitation and Human Health - Part 1. Water Quality Bulletin, Volume 11, No.1. January 1986, 64pp. Item 3. (Card 361).

World Health Organisation. Acid Precipitation and Human Health - Part 2. Water Quality Bulletin. July 1986, 55pp. Item 4. (Cards 407-408)

ENVIRONMENT EFFECTS: MATERIALS AND CULTURAL ARTEFACTS

Green, SE; Longhurst, JWS; Myszor, AM and Lee, DS. Spatial Variation in Environmental Corrosion. An educational case study of environmental corrosion in the conurbation of Greater Manchester. Acid Rain Information Centre. May 1989, 79pp. Item 4. (Cards 350-351)

Hare, SE and Myszor, AM. Greater Manchester Schools Environmental Corrosion Monitoring Survey. Part 2 March - July 1989. August 1989, 68pp. (Cards 352-353).

ENVIRONMENTAL EFFECTS: MONITORING AND MODELLING

Green SE; Longhurst, JWS; Myszor, AM and Lee, DS. Spatial Variation in Environmental. Corrosion of an educational case study environmental corrosion in the conurbation of Greater Manchester Acid Rain Information Centre. May 1989, 79pp. Item 4. (Cards 350-351)

Lee, DS; Longhurst, JWS; Gee, DR and Hare, SE. Urban Acid Deposition. Results from the GMADS Network, 1988. Acid Rain Information Centre. August 1989, 19pp. (Cards 353-357)

Schreiber, RK and Newman, JR The Nature and Effects of Atmospheric Deposition on Wilderness: Monitoring and Research Needs. Fish and Wildlife Service. October 16th 1988, 6pp. (Card 369)

NADP/NTN: Monitoring Network Locations of Active Sites in the NADP/NTN network. Volume XI, No.2. National Atmospheric Deposition Program. July 1989, 220pp (Cards 385-391)

NADP Report: Monitoring Network. National Atmospheric Deposition Program. August 1989, 5pp. Item 3. (Card 394).

SOCIAL, ECONOMIC AND POLITICAL ASPECTS: POLICY AND REGULATION

Longhurst, JWS. Privatisation of the Electricity Supply Industry. Report for the Association of Greater Manchester Authorities. Acid Rain Information Centre. January 1989, 6pp. Item 2. (Card 349)

California Air Resources Board. Atmospheric Acidity Protection Program. Five-Year-Research Plan. June 1989, 29pp. Item 1. (Cards 361)

Brown, JM and Goodyear, CD. Acid Precipitation Mitigation Program - Research Methods and Protocol. Fish and Wildlife Service. September 1987, 126pp. Item 2. (Cards 366-368)

Schreiber, RK; Goodyear, CD and Haitman, WA. Challenges and progress in the Federal State. Fish and Wildlife Service. May 1988, 5pp. Item 4. (Card 369)

Brown, JM and Goodyear, CD. Acid Precipitation Mitigation Program - Research Methods and Protocol. Fish and Wildlife Service. September 1987, 126pp. Item 2. (Cards 366-367)

Organisation for Economic Co-Operation and Development. Clean Coal Technology. Programmes and Issues. 1987, 175pp. Item 1. (Cards 402-404)

Organisation for Economic Co-Operation and Development. Transport and the Environment. Selected Chapters. 1988, 58pp. Item 2. (Cards 404)

SOCIAL, ECONOMIC AND POLITICAL ASPECTS: EDUCATION

Green, SE; Longhurst, JWS and Lee, DS. Acid Rain. Secondary Teaching Pack. Acid Rain Information Centre. April 1989, 83pp. Item 3. (Cards 349-350)

Green, SE; Longhurst, JWS; Myszor, AM and Lee, AM. Spatial Variation in Environmental Corrosionn. An educational case study of environmental corrosion in the conurbation of Greater Manchester. Acid Rain Information Centre. May 1989, 79pp. Item 4. (Cards 350-351).

Hare, SE; Longhurst, JWS and Lee, DS. A Comparison of Rainwater Acidity between Greater Manchester and Greater Lisbon during October, November and December 1988. Acid Rain Information Centre. July 1989, 37pp. Item 5. (Cards 351-352)

Hare, SE; Longhurst, JWS and Lee, DS. A Comparison of Rainwater Acidity between United Kingdom, Portugal and Sweden during October, November and December 1988. Acid Rain Information Centre. August 1989, 18pp. Item 6. (Card 352)

Hare, SE and Myszor, AM. Greater Manchester Schools Environmental Corrosion Monitoring Survey. Part 2 March - July 1989. August 1989, 68pp. (Cards 352-353)

SOCIAL, ECONOMIC AND POLITICAL ASPECTS: PRESSURE GROUPS

Swedish NGO Secretarial on Acid Rain. Acid News. No.3., October 1988, 23pp. Item 1. (Card 405)

Swedish NGO Secretarial on Acid Rain. Acid News. No.1, February 1989, 23pp. Item 2. (Card 405)

Swedish NGO Secretarial on Acod Rain. Acid News. No.3, July 1989, 15pp. Item 3. (Card 405)

CONTROL AND MITIGATION MEASURES

Longhurst, JWS. Motor vehicle emission control by catalyst. Report for the Manchester Area Pollution Advisory Council Meeting. Acid Rain Information Centre. January 17th 1989, 8pp. Item 1. (Card 349)

Ford, PG. Wellman Lord takes the S out of SO_2. Davy McKee Ltd. June 1987, 4pp. Item 1. (Card 364)

Hallsworth, JA. Improving the Environment with the Wellman Lord Process. Davy McKee Ltd. June 1988, 20pp. Item 2. (Card 364)

Ford, PG. Flue Gas Desulphurisation and the Wellman Lord Process. Davy McKee Ltd. October 20th 1988, 14pp. Item 3. (Card 364)

Akroyd, RC. From Flue Gas Sulphur Emissions to Fertiliser. Davy McKee Ltd. May 1989, 17pp. Item 4. (Card 364)

Davy McKee Ltd. Worldwide Listing of Wellman Lord SO_2 Recovery Facilities. 1989, 3pp. Item 5. (Card 364)

Davy McKee Ltd. Flue Gas Desulphurisation. (undated), 2pp. Item 6. (Card 364)

Davy McKee Ltd. The Wellman Lord Process. (undated), 2pp. Item 7. (Card 364)

Davy McKee Ltd. The Wellman Lord Process. (undated), 2pp. Item 8. (Card 364)

Schreiber, RK and Britt, DL. Acid Precipitation Mitigation: Implementation of the US Fish and Wildlife Service Research Program. Fisheries, Bol.12. No.3. Fish and Wildlife Service. May - June 1987, 5pp. Item 1. (Card 366)

Brown, JM and Goodyear, CD. Acid Precipitation Mitigation Program - Research Methods and Protocol. Fish and Wildlife Service. September 1987, 126pp. Item 2. (Cards 366-367)

Nisbet, TR. Liming to alleviate surface water acidity. Research Information Note 148. Forestry Commission. February 1989, 3pp. Item 5. (Card 371)

National Swedish Environmental Protection Board. Action Program - Against Air Pollution and Acidification. (undated), Item 5. (Cards 396-397)

Organisation for Economic Co-Operation and Development. Clean Coal Technology Programmes and Issues. 1987, 175pp. Item 1. (Cards 399-401)

Organisation for Economic Co-Operation and Development. Transport And the Environment. Selected Chapters. 1988, 58pp. Item 2. (Card 404)