

The ecological effects of acid deposition

Part I

The editors wish to thank Prof. Oscar Ravera for his invaluable help in planning this multi-author review. This is the second review Prof. Ravera has coordinated for us, the first being 'Cadmium – a complex environmental problem' which appeared in the January and February 1984 issues of EXPERIENTIA.

The ecological effects of acid deposition: An introduction

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The justification for this multi-author review is the growing importance attributed to the effects of acid depositions in terrestrial and aquatic ecosystems. As a consequence, in recent years, knowledge of the nature, distribution and importance of dry and wet acid depositions and their effects in terrestrial and freshwater ecosystems has increased rapidly. In spite of these gains, several important aspects of the problem continue to be subject to discussion and controversy. The research concerning the ecological aspects must be carried out along different approaches: i.e. through laboratory experiments, investigations in the field and experimental acidification. Studies on the ecosystem must be focussed on the interrelations between acid load, biota and environmental characteristics, as well as on the inextricable relationships between atmosphere, soil and water bodies. In addition to the direct effects of acidification, the indirect effects must be studied with particular care, because the latter may often be more important than the former. In an acidified ecosystem the modifications observed may be due not only to the increase of hydrogen ion concentration, but also to the decrease to zero of the alkalinity, the alteration of the nutrient cycles, the sulphate and metal concentration increase and the effects of other pollutants.

Because this review covers most of the aspects of the problem, it may help to identify the areas of greatest concern and the gaps in knowledge. The following is a brief description of the contents of the review which comprises fifteen contributions by specialists representing fields as diverse as chemistry, pedology, plant and animal ecology, zoology and botany.

It seems opportune to begin by describing the characteristics of the acid depositions. As a consequence our review starts with the paper by Valenta et al. which discusses, as an example, the situation in West Germany. This paper concerns the data collected from 1980 to 1984 from 16 automated sampler stations distributed in different areas of West Germany. The analytical problems of the dry and wet depositions and the influence of the meteorological parameters are discussed, as well as the

possibility of estimating the percentage of acid anion in rainwater due to human activity.

The acidification of the soil is the result of the interactions between the acid load from the atmosphere and the soil characteristics. This may explain the difficulty found in correlating the pH values measured in the atmospheric depositions with the soil pH. In addition, the soil is also acidified by agricultural practices and natural processes. These topics are the subject of the paper by Petersen. The acidification mechanisms in the soil are treated clearly and in detail by Ulrich, who also takes into account the influence of the canopy in buffering the acid load and the importance of fog and cloud droplets in soil acidification. An important and neglected problem is the subject of the paper by Schuurkes, which discusses the role of ammonium sulphate deposition in acidifying poorly buffered water bodies. To illustrate his points, the author describes the situation in the Netherlands. In the most industrialized area of this country the acidification is due to sulphur and nitrogen oxides. In the agricultural area, ammonium depositions seem to be the principal causes of water body acidification because ammonium, in contact with the sediment, is transformed into nitrate with consequent production of hydrogen ions. This is a clear example of a base (NH_3), neutralizing acid rains, which causes the acidification of aquatic ecosystems. Rorison in his paper considers the effects of the acid soil on the physiology of the plant as well as the influence of the plant on the pH of the soil. Common crop plants are selected to grow rapidly in optimal conditions: conversely there are some native plants which may grow very slowly in very acid soils. The author suggests the selection of genotypes of crop plants tolerant to low soil pH to obtain a certain agricultural production in acidified areas. In addition, the influence of soil acidification on the microorganisms, nutrient substances and toxic metals is discussed. The influence of ozone on crops and forest is discussed by Bell. This author recommends great caution in drawing conclusions from the results obtained from some experimental practices, for example, short term experiments with artificial rain and fumigation. In addi-

tion, the causes of the decline of forests in central Europe are discussed. The influence of acidification in modifying the terrestrial and aquatic vegetation and in decreasing the number of the species is treated in detail by Roelofs. This author, as does Schuurkes, attaches great importance to the oxidation of ammonium in acidifying the soil and affirms that, at least in the Netherlands, the major damage to the vegetation is due to the ammonium and sulphur compounds and not to ozone. The effects of acidification on soil and water microorganism, macrophytes, aquatic invertebrates, phyto- and zooplankton and amphibians are described in the papers by Francis, Grahn, Økland, Geelen and Leuven. Each of these papers reports fully on the most recent information on the group considered and gives a clever criticism of the results. In addition, up-to-date references, tables and figures enrich these papers; for example, the paper by Økland includes 159 references and 20 illustrations. The biological indicators of acidification are described and discussed by Johnsen. This author reports some examples of the use of mosses and lichens in detecting and mapping the level of air polluted by sulphur oxides. The acidification experiments in natural (lakes and streams) and artificial (outdoor channels and 'enclosures') aquatic eco-

systems is the subject of the paper by Ravera. The author compares the results obtained with these methods with those obtained from investigation using water bodies acidified by atmospheric depositions. The most important advantages of acidification experiments are the following: the early effects (which have never been recorded in natural ecosystems acidified by depositions) may be observed; the pre-acidification is known as well as the intensity, rate and duration of the acidification; the effects due to the hydrogen ion concentration may be isolated from those of other pollutants. The paper by Kramer is the last in the list of the contributions, because, in my opinion, it represents the conclusion of this review. Indeed, it concerns the past, the present and the future trends of ecosystem acidification. The author, after having discussed the present and past knowledge of acid deposition, illustrates some important statements on future emission of sulphur oxides. He underlines the large potential variability in predicting the sulphur emissions for the near future, because several factors interacting with each other may influence the predictions: for example, the rate and quality of industrial development and the changes of the amount and types of fuel used in relation to the different sensitivity of the ecosystems.

The distribution of acid deposition in Germany

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Summary. The distribution of acid deposition by atmospheric precipitation in the Federal Republic of Germany is discussed, based on investigations of the wet H^+ -deposition during the five years 1980–1984, using a network of 16 automated samplers of our own construction located in various categories of ecosystems. Analytical problems of sampling and the electrometric determination of pH in rainwater are briefly discussed. Results for the average amounts of precipitation, the average H^+ -concentrations and average H^+ -depositions in the 16 typical regions of the Federal Republic of Germany are compared and the influences of meteorological parameters are discussed. An increase of the H^+ -concentration and H^+ -deposition values has been observed from 1980 onwards with a maximum in 1981 and a slow decrease in the next two years. The comparison of the values found for rural regions with those for more significantly polluted regions shows that in the latter regions the removal of H^+ -ions by wash-out is more effective. Whereas in the Ruhr region the pH is shifted to more acid values, due to the wash-out of acid particles and aerosols, in regions with metallurgical industry the pH is shifted to more alkaline values due to the wash-out of alkaline particles. In general the free acid in rain and snow is rather uniformly distributed over the whole area as a result of mesoscale transport of the acid precursors SO_2 and NO_x and the concomitant formation of acid in the cloud droplets leading to acid deposition by rain-out. The composition of rainwater and the possibility of determining the proportion of the acid anions in rain which are of anthropogenic origin is briefly discussed.

Key words. Acid rain; rainwater; sampling network; acid distribution; acid deposition; wet deposition; pH; precipitation amount; hydrogen ion concentration.

1. Introduction

Acidification of precipitation due to anthropogenic input has been recognized as one of the most severe environmental problems. The chemical composition of a raindrop is the integral result of the incorporation of aerosol particles as well as the absorption of trace gases. Both processes are effective from the beginning of hetero-

geneous nucleation of water molecules which form a cloud element, and continue until the raindrop reaches the ground.

Absorption of gaseous trace substances takes place both within the clouds as below the clouds. One result of this interaction between trace substances and droplets in the air is acidification of rainwater. If only carbon dioxide (concentration ca. 330 ppmv) were present as a trace