Effects of Acid Rain on Freshwater Ecosystems

D. W. Schindler, 1988
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REVIEW:
This is an excellent paper for the purpose of our course. It is an interesting and informative article explaining various aspects of the problem of acid rain. The purpose of this paper is to present recent progress made in the understanding of acid rain and its effects on North America n aquatic resources. The author covers several areas, such as the origin and extent of acid rain, rates of increase in acid rain, evidence for biological change, recovery from acidification, and the interaction of acid rain with other pollutants and terre stial ecosystems, giving a wide overview of the problem. The data and examples used by the author are from all over the world, such as eastern North America, Sweden, and other parts of North America and Europe, allowing the reader to get a global view of the problem acid rain poses. The author ends with a clear message: regional air pollution is much more severe than believed in the past, and more comphrehensive measures to control it are necessary to preserve the integrity of the biosphere.
SUMMARY:
The term acid rain, coined by Angus Smith, was first used to describe the effects that industrial emission had on the precipitation of the British Midlands, just over a century ago. The wide spread scale of acid rain effects was not recognized until the mid-20th century, but it wasn't until the late 1970s that governments began sponsoring studies of the problem.
The Origin and Extent of Acid Rain
The pH of natural unpolluted precipitation is close to 5.0. This is due to the saturation of the water with carbon dioxide, as well as the presence of both weak and strong acids of natural origin. Areas within several hundred kilometers of industrial ce nters have precipitation of much lower pH values. Acid rain is widespread in northern Europe and eastern Nor th America. It has also been discovered in western North America, Japan, China, the Soviet Union and South America. Anthropogenic emissions are comparable to natural emissions on the global level, but regionally over 90% of sulfur deposited from the atmo sphere is anthropogenic.
Polluted air masses can be tracked using the trace metal content of polluted air in order to determine the source of the sulfur emission which effects specific areas.
The Extent of Acid-Sensitive Areas
In the United States acid- sensitive areas are found in Minnesota, Wisconsin, upper Michigan, several southeastern states, the mountainous areas of the West, as well as the northeastern states. In Canada, it is estimated that at least half of the 700,000 lakes in the six eastern pr ovinces and south of 52oN have alkalinity values below 50 m eq/liter, indicating they are very acid-sensitive. Other acid-sensitive areas in Canada include parts of all the western provinces, the two territories and Labrador. Other acid-sensitive parts of the world include the Netherlands, Belgium, Denmark, Switzerland, Italy, West Germany, Ireland, the United Kingdom, Scandinavia, and in the Precambrian and Cambrian geology in Asia, Africa, and South America.

Rates of Increase in Acid Rain

Ecological effects of acid precipitation can be determined from the timing of changes in lake chemistry or acid-sensitive micro fossils and metallic pollutants in sediments. Wide spread damage to Scandinavian and North American ecosystems was not noticed until the 1930 s to 1950s. This is thought to be a result of a few factors: 1. increased construction of large power plants and smelters with tall smokestacks coupled with a decrease in use of coal for home heating, converting the local air pollution problem into a lo ng-range, transboundary one; 2. emissions of NO x and other pollutants that aid in the oxidation of sulfur and nitrogen oxide have increased; and 3. it took years for lakes, streams and their catchments to lose their buffering capabilities, so that lower pH levels were not recognized until some time after the precipitation became acidic.

The Extent and Rate of Surface Water Acidification

There are four lines of evidence that indicate widespread acidification of the aquatic ecosystems of many countries is due to acid rain. The first piece of evidence is from geochemical analysis, which has shown that the most sensitive waters in geographi cally sensitive terrain are almost totally devoid of alkalinity, and inputs of strong acid results in large pH decrease s. The second line of evidence is paleoecological pH reconstruction from diatom remains in lake sediment. These results have shown that, in general, more recently acidified lakes and higher rates of acidification have been found in acid-sensitive areas w ith high acid deposition. Chemical comparison from lakes makes up the third line of evidence. These results indicate that there is a correlation between the decline in alkalinity of a lake and an increase in sulfate, and vice versa. The final line of ev idence is from analysis of long-term trends where alkalinity losses grater than 100 meq/L are believed to be caused entirely by acid rain.

EVIDENCE FOR BIOLOGICAL CHANGE

Fish species valued for sport, which are able to tolerate pH values less than 5.5, were the first organisms to be noticeably effected by low pH levels due to acid rain. Juvenile fishes and many organisms lower in the aquatic food chain are intolerant of much higher pH.

Autumn-spawning species of larger game fishes are more sensitive to acidification than spring spawners, since their hatchlings are exposed to acid and aluminum pulse from the early spring snow melt.

The oligotrophication of acidified lakes does not occur in most cases, but there is significant change in the phytoplankton species in these lakes. The formation of large masses of benthic algae or bryophytes in coastal regions of acidified lakes is als o widespread.

THE ROLE OF ALUMINUM IN BIOLOGICAL DAMAGE

Aluminum enters lakes and streams as it is released from acidif ied terrestrial soils and lake sediments. Two form of aluminum, ionic aluminum and aluminum hydroxide, are toxic to fish species, while other aquatic organisms appear to be less susceptible to aluminum toxicity. Aluminum toxicity only occurs at pH values less than 6.0.

RESISTANCE OF LAKES TO ACIDIFICATION

There are thought to be three sources of resistance of lakes to acidification. One form of resistance is by the weathering of geological substrates, another is the result of hydrogen ion exchange for b ase cations in terrestrial soils of watersheds. The third source is due to resistance within the lake itself. This process involves first-order reactions at sediment surfaces.

RECOVERY OF ACIDIFICATION

Lakes and streams whose pH has been reduced due to acid precipitation can recover if sulfate deposition is substantially decreased. Over time, alkalinity and pH values increase, while SO_4^{2-} , aluminum and trace metal concentrations decrease. In some lakes recovery has allowed the lake trout or the brook t rout to be reintroduced, the return of rotifer population, and the reinvasion of the white sucker. Crustacean zooplankton communities are not known to have recovered.

Recovery of these lakes may not be complete due to the extensive depletion of base cation in soils which take many years to be replaced.

LAND USE AND ACIDIFICATION

Acidification of lakes and streams from land use has occurred when large deposits of reduced sulfur are exposed to atmospheric O_2 due to human disturbances, i.e. as in acid mine drainage and exposure of ancient marine and wetland sediment due to drainage and cultivation. The acidification which results from these processes cannot explain the widespread acidification of freshwater lakes seen today.

HOW MUCH MUST WE REDUCE SULFUR DEPOSITIONS?

Currently, 20 to 50 kg ha^{-1} $year^{-1}$ of SO_4^{2-} is deposited into our aquatic ecosystems. It has been suggested to lower this value to somewhere between 9 to 14 kg ha^{-1} $year^{-1}$ in order to protect these ecosystems.

INTERACTION OF ACID RAIN WITH OTHER POLLUTANTS AND TERRESTRIAL ECOSYSTEMS

Nitric acid also plays a role in the acidification process which must be monitored along with SO_2 emissions.

Many toxic trace metals are released from the same sources that release sulfur and nitrogen oxides, which are then widely distributed. As the acidity of a lake increases, the sediment trace metals may be resuspended or remain in solution longer, thereby increasing their exposure to aquatic organisms.

Crop damage, depletion of the ozone layer and climate change are thought to be contributed to by interactions between sulfur and nitrogen oxides, ozone, carbon monoxide, hydrocarbons, and methane.

In forests, agricultural lands, and wetlands acid rain is responsible for mobilization of soil aluminum which causes root damage and in leaching nutrients from plant foliage. Polluted fogs and mists expose terrestrial plants to high acid concentrations, sometimes causing direst foliar damage.

The increase in haze in the Arctic and temperate regions are also believed to be caused by long-range transport of sulfur.

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