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Regional Air Quality Concerns in the West: Acid Deposition and Ozone

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I. Introduction

A. Summary

Most of the Class I wilderness areas located within the National Parks and the National Forests are found in the western United States. Many of the remote regions within the mountainous West are important for timber production and as the source of water supplies for the ever-increasing population. Because these areas are remote from sources of urban and industrial pollution, primary pollutants (sulfur oxides (SOx); nitrogen oxides (NOx); carbon monoxide (CO)) are usually found in low concentrations, except for areas directly downwind of large combustion sources. Rather, it is the transport and transformation of primary gaseous pollutants over relatively long distances that result in the creation of secondary air pollutants. Two of these secondary pollutants that have the greatest potential...
for damaging ecosystems in the western United States are acid deposition and ozone.

The amount of acid deposited annually in rain, snow and cloudwater in the West is in the range of 15-25% of that measured in the northeastern United States. However, much of the precipitation to mountainous areas is in the form of snow that accumulates throughout the winter and then releases acidic pollutants during the short, snowmelt period. Dilute lakes and streams may experience pH depressions during this melt. Deposition of nitrogen compounds (nitrate and ammonium) is more important in both wet and dry forms of deposition in the West than in other parts of the U.S. Nitrogen deposition to forested areas may result in either fertilization or deficiencies in other nutrients (e.g. magnesium) needed for forest growth.

Ozone is transported to mountainous areas in the West, especially downwind of L.A., the Central Valley of CA, Denver, Phoenix and Seattle-Tacoma. In some regions oxidant levels exceed the Federal standard (100 ppb). Damage to pines has been observed in the forests around Los Angeles and on the western slope of the Sierra
Nevada. There is evidence that growth declines have accompanied needle injury in yellow pines.

Federal agency and State agency research and monitoring programs have begun to characterize levels of acid deposition and ozone exposure in remote areas. Research on the effects of these air pollutants on ecosystems has focused on high-elevation lakes and streams and on coniferous forests. Effects research is designed to allow regulators to set ambient air quality standards and deposition standards that will protect western resources and wilderness values.

B. General References


II. Regional Pollutants: Acid Deposition and Ozone

A. Acid Deposition

1. Wet and dry pollutants that are deposited to surfaces are considered to be acidic if their pH (hydrogen ion concentration) is lower than about 5.3-5.6, depending on the location of the monitoring site (Roth et al., 1985).
2. Acid deposition may be in the form of rain, snow, fog, clouds or dry gases and particles. The acids are the result of transformation of gaseous emissions of sulfur oxides (SOx) and nitrogen oxides (NOx) that come from combustion sources, both stationary (power plants, refineries) and mobile (cars, trucks). Acidity (hydrogen ion) is deposited with sulfate, nitrate, or in the buffered form, as ammonium.

3. Early discussion of the "acid rain" problem focused on rainfall acidity in the NE United States and Scandinavia. The West was considered to have "background" pH's in precipitation because of the lack of large combustion sources and the presence of alkaline dust in the atmosphere (Likens, 1976).

4. CARB measured low pH's in rainfall in urban areas of California (CARB, 1981); other western states' concerns involved the transport of acidic pollutants from urban areas, large power plants and smelters (Roth et al., 1985).

5. Ambient acidity is a problem in urban areas where acid droplets, gases or particles can be inhaled or deposited on materials. In remote areas most acidity is deposited in rain and snow.
in alpine regions and as both wet and dry deposition in the mid-elevation, forested regions (Blanchard et al., 1989).

6. Although the total annual deposition of acidity in the West is only about 15-25% of that measured in the northeastern U.S. (NADP, 1988), western ecosystems (dilute lakes, coniferous forests) are extremely vulnerable to changes in deposition chemistry.

7. Snowmelt episodes and low pH rain events have been measured in mountainous areas downwind of Los Angeles, CA's Central Valley, Denver, and large smelters and coal-fired power plants in AZ, WY, and CO.

B. Ozone

1. Ozone is a secondary pollutant formed in the presence of sunlight from nitrogen oxides (NOx) and reactive organic gases (ROG) (also called hydrocarbons (HC)), both gaseous emissions from stationary and mobile sources. This pollutant is a serious problem (smog) in large cities, primarily due to auto exhaust.

2. In some remote areas ozone is measured in excess of the Federal ambient air quality standard (120
ppb). Crop and forest vegetation may be injured at ozone levels considerably below either the Federal or CA standard (100 ppb) (CARB, 1987).

3. Injury to pines in mountains around L.A. and in the southern Sierra Nevada is documented (Miller et al., 1989; Duriscoe and Stolte, 1989).

4. Increased monitoring is showing high ozone in forested areas in the Rockies, Cascades and Arizona (Olson and Lefohn, 1989), with peak concentrations during the growing season in regions where vegetation is susceptible to drought stress.

III. Effects on Resources

Acid deposition and ozone have the potential to cause economic loss (forest products, crops, fisheries) and degradation of wilderness values (Fox et al., 1989).

A. Acid Deposition Effects

1. In mountainous terrain, where soils are thin and vegetation sparse, acid inputs can affect dilute lakes, streams and poorly-buffered watersheds (Melack et al., 1985).
a) Acid deposition may cause loss of watershed buffering.
b) This can result in changes in surface water chemistry, especially during rain and snowmelt episodes (Melack et al., 1989; Blanchard et al., 1987).
c) Chemical changes can then lead to changes in biological populations (fish, insects, amphibians) (Hopkins et al., 1989; Harte and Hoffman, 1989).
d) Acid inputs can lead to acidification of soil water, changes in soil fertility and damage to vegetation (Georgii, 1986).

2. Acidic deposition and inputs of excess nitrogen as nitrate or ammonium can affect the health and productivity of coniferous forests in the West (Olson and Lefohn, 1989).
   a) The deposition of excess nitrogen in forested areas due to wet or dry deposition may result in: (1) fertilization that can alter frost hardness of plants and (2) high concentrations of nitrate in stream water (Riggan et al., 1985).
b) Stress on forests due to acid inputs may be exacerbated by stress due to ozone injury.

c) Forests in mountainous and coastal areas of the West receive wet inputs in the form of cloudwater, which may be acidic (Muir and Bohm, 1989). This input may cause direct damage to needles.

B. Effects of Ozone

1. The resources most likely to be affected by ozone are coniferous trees in the mid-elevation range in the mountainous West, especially in areas downwind of urban areas.

   a) Ozone enters the stomata of pine needles and results in yellowing of the needles (called chlorosis). This leads to premature needle loss and crown injury (Miller et al., 1989).

   b) Ozone injury symptoms have been documented in the San Bernadino Mountains, San Gabriel Mountains (both near L.A.) and in the southern Sierra Nevada (Pronos and Vogler, 1982).
c) There is evidence from tree ring studies that ozone injury causes growth decreases in Jeffrey pine (Peterson et al., 1987).

IV. Monitoring and Research

Federal, State and private research groups (such as utilities and non-profit groups) have sponsored research and monitoring to determine the extent of regional air pollution and the effects (or potential effects) on resources and wilderness values. This list is not exhaustive, but rather representative of the efforts to date.

A. Acid Deposition

1. The Federal government sponsored research and monitoring as part of the 10-year National Acid Precipitation Assessment Program (NAPAP, 1988). Most of these interagency funds went to the eastern U.S. In the West major efforts included the EPA's Western Lake Survey (Landers et al., 1987), the National Park Service watershed studies (NPS, 1988) and the Western Conifers Research Cooperative (Olson and Lefohn, 1989).
a) Under the National Acid Deposition Program/National Trends Network, the U.S. Geological Survey maintained a series of wet and dry deposition stations throughout the country (NADP, 1988).

b) The two EPA projects were the Western Lake Survey (WLS) in regions having low-alkalinity lakes and the Western Conifers Research Cooperative (WCRC) of the Forest Response Program (cosponsored by the Forest Service and NCASI - National Council on Air and Stream Improvement).

c) The National Park Service studied mountain watersheds in Sequoia National Park, Rocky Mountain National Park and Olympic National Park.

d) The U.S. Forest Service pursued a number of programs as part of the WCRC and at Range and Experiment Stations in the West (Fox et al., 1989). National Forests are preparing assessments of Air-Quality Related Values (AQRVs) in wilderness areas which can be used in evaluating new sources under the Prevention of Significant Deterioration permit process (PSD).
2. Western states sponsored research and monitoring programs (NAPAP, 1985).

a) California sponsored two five-year programs, the Kapiloff Acid Deposition Research and Monitoring Program (CARB, 1988) and the Atmospheric Acidity Protection Program (CARB, 1989). These programs include monitoring of wet, dry and fog deposition and research on health, materials and environmental effects, especially in the alpine watersheds of the Sierra Nevada.

b) WESTAR (Western States Acid Rain Program) was set up under an EPA grant to allow state air agencies to coordinate their research and regulatory programs. This group has continued as the WESTAR Council since the conclusion of the EPA program.

c) Other western states, such as Washington and Colorado, have sponsored lake monitoring programs to supplement those of EPA.
3. Private organizations, such as electric utilities, environmental groups and universities, have sponsored acid deposition research in the West.

a) EPRI has funded research on forests (Response of Plants to Integrated Stress (ROPIS) and Integrated Forest Study (IFS)) and on high-elevation watersheds (Regional Integrated Lake Watershed Acidification Study (RILWAS)) at western sites.

b) Private utilities (including Pacific Gas and Electric, Southern California Edison) have performed monitoring and research in remote areas of the West that may be affected by their emissions.

c) Environmental Defense Fund (EDF) (Yunke and Oppenheimer, 1984) and World Resources Institute (Roth et al., 1985) have prepared documents that synthesize information on impacts of acid deposition and recommend control strategies.
B. Ozone

1) The Federal program to monitor air quality and to investigate the impacts of ozone on western forests has been carried out by EPA, WCRC, U.S. Forest Service and National Park Service, Air Quality Office.

   a) Data on ambient ozone concentrations are included in the EPA's Aerometric Information Retrieval System (AIRS).

   b) WCRC focused on ozone effects research in the forests of Washington, Oregon, California, Colorado and Arizona. EPA is now planning to continue forest monitoring with EMAP (Environmental Monitoring and Assessment) program.

   c) USFS monitors ozone in western forest areas and investigates ozone damage to pines in the San Bernadinos and the Sierra Nevada in CA.

   d) NPS Air Quality Office has performed ozone monitoring, modeling and effects research in the National Parks in the western U.S., with emphasis on Sequoia National Park in California (NPS, 1988).
2. Western states have air quality monitoring programs that include ozone, a criteria pollutant.
   a) California Air Resources Board has been active in ozone monitoring and forest effects research through the Extramural Research Program.
   b) Two new ozone-related programs are planned in California: (1) ten-station ozone monitoring and pine injury survey cosponsored by CARB and USFS in the Sierra, and (2) San Joaquin Valley Air Quality Study, a field study during summer 1990 to investigate ozone transport (Blumenthal, 1989).

3. Private groups, such as utilities and oil and gas industries, have participated in monitoring and modeling ozone in the West.
   a) Pacific Gas and Electric, EPRI and the oil producers in California are participating in SJVAQS (San Joaquin Valley Air Quality Study) and AUSPEX (Atmospheric Utility Signatures, Predictions and Experiments) to
determine transport of ozone from urban areas of California to Sierra forests.

b) Utilities often monitor ozone levels downwind of power facilities.

V. Regulation

Air Quality standards are set to protect human health (primary standards) and welfare (e.g. vegetation damage) (secondary standards). Criteria pollutants that are regulated include: (1) ozone, (2) ozone precursors (NOx and ROG), and (3) acid deposition precursors (SOx and NOx). State standards may be more stringent than Federal standards set under the Clean Air Act. Control of precursor gases will limit the amount of acid deposition and ozone that reach remote areas. Federal land managers can protect Class 1 areas by assessing the impact of new sources on wilderness areas under the Prevention of Significant Deterioration (PSD) provisions of the Clean Air Act.

A. Acid Deposition

1. Deposition standards may be devised that limit the amount of acidic substances (or associated
nitrate, sulfate or ammonium) that reaches high-elevation ecosystems. Minnesota is the only state with a deposition standard to protect sensitive lakes.

2. Atmospheric acidity standards would limit the amount of acidic particles and gases in ambient air. The EPA is considering such a standard to protect human health (Lipfert et al., 1989). This type of standard might be used to protect forest resources.

3. To meet these standards States would need to regulate precursor gases: NOx, SOx, ammonia.

B. Ozone

1. The EPA has set a national standard for ozone (120 ppb) (U.S. EPA, 1986); California has a more stringent standard (100 ppb). These are exceeded in remote areas of the West during summer.

2. To protect vegetation a tighter standard, averaged over a more relevant time period, is required (CARB, 1987). Vegetation injury has been observed at levels of between 60-80 ppb of ozone.
3. To prevent ozone levels that cause forest injury, it is necessary to reduce precursor gases.

C. Information Needs

Before the "correct" standards can be set the following information needs to be available.

1. We need better information on how the secondary pollutants are formed and how they are transported to remote areas. This will be achieved by development of atmospheric chemistry models and transport models. Model results need to be verified by remote area monitoring. For this task better remotely-powered monitoring devices are needed.

2. We need better dose-response information to tell us what levels of pollutants will injure sensitive resources.

3. We need to develop watershed and forest models that allow us to predict how changes in pollutant levels will affect ecosystems.
REFERENCES


