## What is the Role of NADP in Understanding the Effects of Airborne Pollutants on Ecosystems?

The purpose of NADP is to collect and analyze precipitation samples for acids, nutrients, base cations, and mercury to assess long-term spatial and temporal trends in wet deposition. The NADP has a longstanding interest in the effects of deposition on ecosystems, sponsoring many sessions on assessing ecosystem responses to airborne pollutants at its annual Scientific Symposium. In 2006, the NADP Executive Committee formed the Critical Loads Ad-Hoc Sub-committee (CLAD) specifically to facilitate coordination of the efforts of multiple federal and state agencies, scientists, and other partners related to the science of critical loads (http://nadp.isws.illinois.edu/clad). CLAD provides a venue for discussion of current and emerging issues regarding the science and application of critical loads for atmospheric deposition in the United States. CLAD meets twice yearly at the spring and fall NADP meetings, and welcomes all NADP participants and interested parties. The goals of CLAD are to:

- Facilitate sharing of technical information on critical loads topics;
- Identify gaps in critical loads development in the U.S., and develop strategies to fill them;
- Provide consistency in development and use of critical loads in the U.S.;
- Promote understanding of the critical loads approach through development of outreach and communications materials.

The long-term, spatially extensive wet deposition data provided by NADP are instrumental in developing critical loads in the U.S., thereby helping to quantify the impacts of air pollution on ecosystems.

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National Atmospheric Deposition Program

# Critical Loads

## Evaluating the Effects of Airborne Pollutants on Terrestrial and Aquatic Ecosystems

**Critical loads describe the point at which a natural system is impacted by air pollution. They can be used to assess ecosystem health, guide resource management decisions, and evaluate the effectiveness of emissions reduction strategies.**

## What is a Critical Load?

Air pollution emitted from a variety of sources is deposited from the air into ecosystems. These pollutants may cause ecological changes, such as long-term acidification of soils or surface waters, soil nutrient imbalances affecting plant growth, and loss of biodiversity. The term critical load is used to describe the threshold of air pollution deposition that causes harm to sensitive resources in an ecosystem. A critical load is technically defined as "the quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment are not expected to occur according to present knowledge." Critical loads are typically expressed in terms of kilograms per hectare per year (kg/ha/yr) of wet or total (wet + dry) deposition. Critical loads can be developed for a variety of ecosystem responses, including shifts in microscopic aquatic species, increases in invasive grass species, changes in soil chemistry affecting tree growth, and lake and stream acidification to levels that can no longer support fish. When critical loads are exceeded, the environmental effects can extend over great distances. For example, excess nitrogen can change soil and surface water chemistry, which in turn can cause eutrophication of downstream estuaries. Target loads are based on critical loads, but can include consideration of the timeframe needed to achieve a desired ecosystem condition as well as incorporating policy or management goals.

## What is the Critical Load Approach?

Critical loads describe the point at which a natural system is impacted by air pollution. For ecosystems that have already been damaged by air pollution, critical loads help determine how much improvement in air quality would be needed for ecosystem recovery to occur. In areas where critical loads have not been exceeded, critical loads can identify levels of air quality needed to protect ecosystems in the future. U.S. scientists, air regulators, and natural resource managers are currently developing critical loads for areas across the United States and collaborating with scientists developing critical loads in Europe and Canada. Once critical loads are established, they can then be used to assess ecosystem health, inform the public about natural resources at risk, evaluate the effectiveness of emission reduction strategies, and guide a wide range of management decisions.

## How Are Critical Loads Developed?

**Empirical approaches** are based on observation of ecosystem responses (such as changes in plant diversity, soil nutrient levels, or fish health) to specific deposition levels. These relationships are developed using dose-response studies or by measuring ecosystem responses to increasing gradients of deposition over space or time. Empirical information can be used to develop site-specific critical loads or generalized to estimate critical loads over a broader area.

**Mass balance approaches** consider the net loss or accumulation of acids, nutrients, and base cations in soils and surface waters. This approach relies on current science to determine the thresholds at which depletion of essential nutrients or accumulation of toxic elements are likely to change or damage ecosystems. For example, excess sulfur and nitrogen can strip beneficial nutrients (calcium and magnesium) from soils and release aluminum at levels toxic to plants and fish into soils and surface waters. **Steady state models** are used to estimate the deposition level (critical load) that will allow ecosystem sustainability over the long term. Water and soil chemistry, mineral soil weathering rates, deposition data, and an understanding of ecosystem responses to chemical changes are all used in these models. The steady state approach does not estimate how long it will take for ecosystem response (improvement or decline) to occur, rather it estimates the critical load of deposition that will allow ecosystem sustainability over the long term.

**Dynamic models** also use a mass balance approach but give a more realistic representation of how ecosystems actually function by modeling ecosystem responses to deposition changes over time. Dynamic models often require more detailed input data on ecosystem processes, such as accumulation of nitrogen in soils and plants, or exchange of base cations between soil and soil solution. The benefit is that they can predict the effects of deposition reductions or increases on ecosystems, and the time until either ecosystem damage or recovery occurs in response to changed deposition levels.

## How Are Critical Loads Used in Environmental Assessments?

The use of critical loads for ecosystem protection requires interaction among many groups, including natural resource managers, scientists, and regulatory agencies. Resource managers and policymakers create the context for ecosystem protection by setting goals that will allow ecosystem protection or recovery to a specific baseline. One example might be the recovery of a fixed percentage of the lakes in the designated area to a pH or acid neutralizing capacity (ANC) that will support sensitive fish species and healthy aquatic ecosystems. Scientists provide ecosystem response information establishing the threshold deposition levels, or critical loads, below which natural resources will be protected from damage. Federal and state regulatory agencies can then use the scientifically derived critical loads to develop emissions reduction goals and assess the effectiveness of current and proposed emissions reductions. Processes establishing target loads may incorporate agency or stakeholder input, and usually consider the degree of ecosystem protection desired and the time needed to achieve this protection.