# Inside Rain

## A Look at the National Atmospheric Deposition Program

## How Do I Obtain Data?

Data products are available from the National Atmospheric Deposition Program free of charge. The easiest way to obtain data is by visiting our Internet site at

*http://nadp.sws.uiuc.edu*

Our products include:

- Weekly and daily precipitation chemistry data
- Monthly, seasonal, and annual precipitation-weighted mean concentrations
- Annual and seasonal deposition totals
- Mercury deposition data
- Daily precipitation totals
- Color isopleth maps of precipitation concentrations and wet deposition
- Site photos and information
- Quality assurance data and information

For further information contact:

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# Inside
# Rain

## A Look at the National Atmospheric Deposition Program

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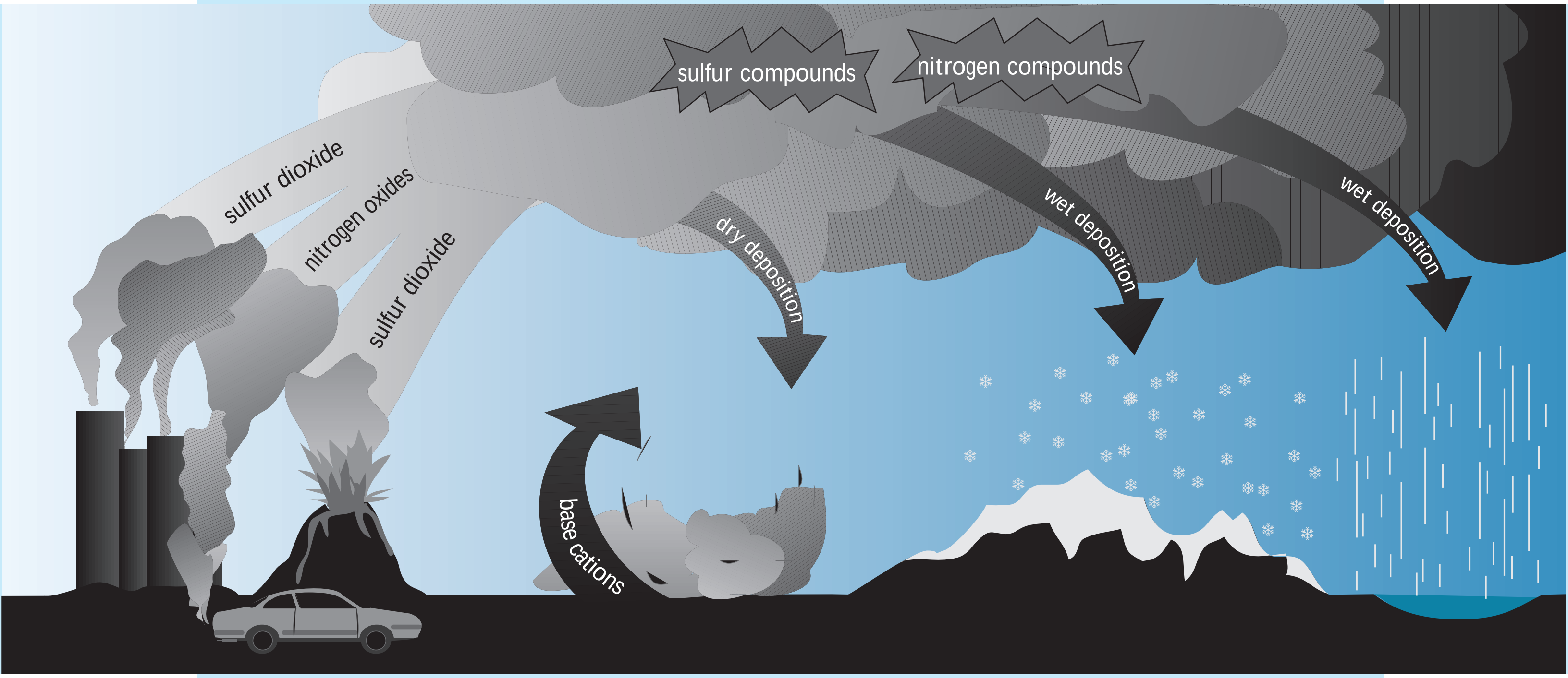
# What Is NADP?

In 1977, the National Atmospheric Deposition Program formed to investigate atmospheric deposition and its effects on the environment. It is a cooperative effort among private, state, and federal organizations. Because of the continued commitment by these organizations we are able to provide the only long-term, nationwide record of the chemistry of U.S. precipitation. We obtain this record through the continuous collection and analysis of precipitation samples from our 220-site network. Our continuing objective is to characterize the chemical climate of the United States and to make information available on spatial and temporal trends in atmospheric deposition—information that is vital for addressing environmental, agricultural, and health issues.

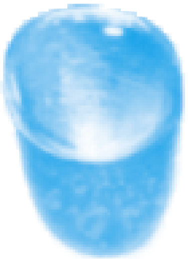
Atmospheric deposition is the process whereby airborne particles and gases are deposited on the earth's surface. These pollutants come either from natural sources, such as forest fires, volcanoes, and oceanic salt, or from power plants, newly plowed fields, motor vehicles, and other human activities. Wet deposition is the fraction of atmospheric deposition contained in precipitation—predominantly rain and snow. Dry deposition (the remainder) is the fraction deposited in dry weather through such processes as settling, impaction, and adsorption.

Atmospheric deposition that is acidic is called acid deposition. Acidic wet deposition is called acid precipitation or, more commonly, acid rain.



"The Congress finds that the presence of acidic compounds and their precursors in the atmosphere and in the deposition from the atmosphere represents a threat to natural resources, ecosystems, materials, visibility, and public health…[and] the problem of acid deposition is of national and international significance… ."

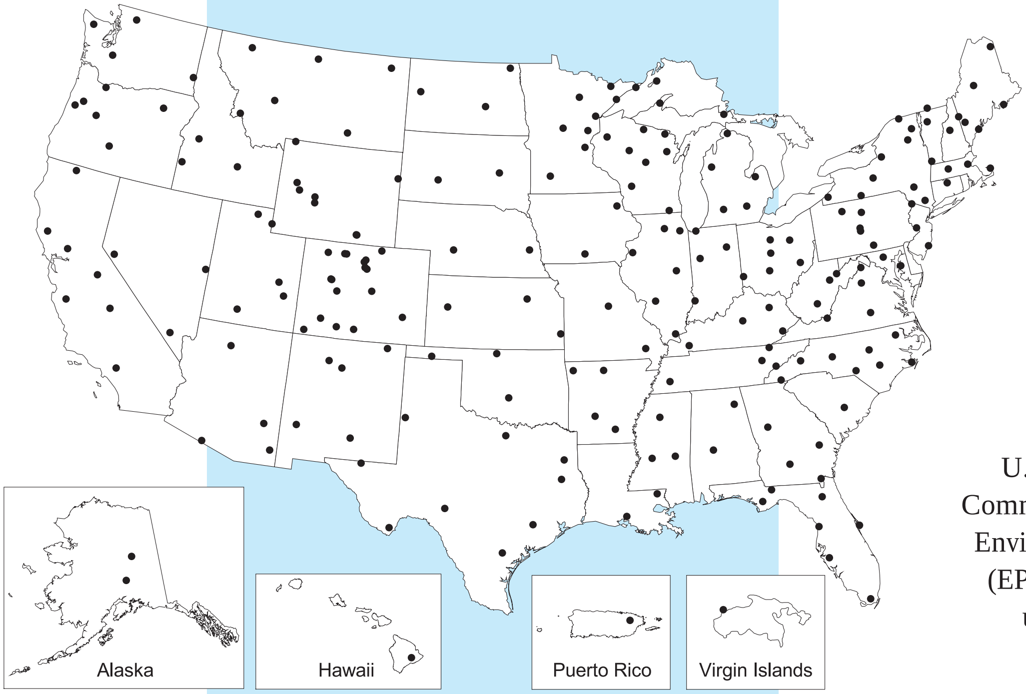
—Clean Air Act (as amended in 1990)

# Wrking Together

The revised Clean Air Act reflects the concern of the U.S. Congress about the threat of environmental damage from acid deposition. In the mid-1970s, scientists began focusing their attention on atmospheric deposition in the United States. European scientists already had been studying the ecological effects of atmospheric deposition in the form of acid rain. European findings suggested that acid rain was causing widespread damage to forests and lakes.

As scientists in North America became aware of the research by their European counterparts, they became concerned that atmospheric deposition might be causing similar effects in this country. But as questions emerged about the effects of atmospheric deposition, scientists and policy makers found that answers to these questions were limited by the lack of historical data for the United States.

This increased awareness of the possible effects from atmospheric deposition resulted in representatives



NTN comprises nearly 220 active sites that provide information on atmospheric deposition to scientists throughout the world.

from environmental groups, research organizations, federal agencies, and industry organizing a meeting to address the issue. This diverse group agreed that there was a compelling need for a nationwide network for monitoring atmospheric deposition, with the ultimate objective of determining geographic patterns and temporal trends in precipitation chemistry in the United States.

As an outcome of this meeting, the National Atmospheric Deposition Program (NADP) was formed. The concept was innovative: NADP would be a cooperative effort among these different groups—all working together toward the common goal of characterizing our chemical climate.

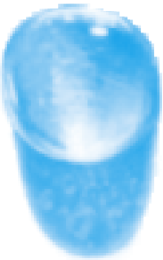
The State Agricultural Experiment Stations and the U.S. Department of Agriculture provided the leadership to get the program up and running. As the program took shape, the U.S. Departments of Interior, Commerce, and Energy; the U.S. Environmental Protection Agency (EPA); utility industries; and universities all provided scientific expertise as well as the financial support for individual monitoring stations.

Organizers designed the network to ensure that monitoring stations would represent the ecological region where they were located while avoiding local influences, such as urbanization, vegetation, and agriculture, that could skew the results. Recognizing the value of cooperative research, participants also encouraged the establishment of monitoring stations near other ongoing ecological research. While some participants had agency-specific or site-specific objectives for joining the network, each agreed to comply with NADP siting criteria, equipment specifications, and sampling protocols, and to use a single analytical laboratory—all to ensure data comparability.

Because of these successful efforts, the network grew rapidly from 22 stations at the end of 1978 to 110 stations by the end of 1982. In 1982, under the leadership of the U.S. Geological Survey (USGS), the National Trends Network (NTN) of the federal National Acid Precipitation Assessment Program (NAPAP) was added, and the NADP network of sites was renamed the NADP/NTN. In 1998, this network designation was shortened to NTN.

The nationwide scope of NTN and its more than 200 sites provides the broad picture of atmospheric deposition needed to track trends and help guide our country’s environmental policy.

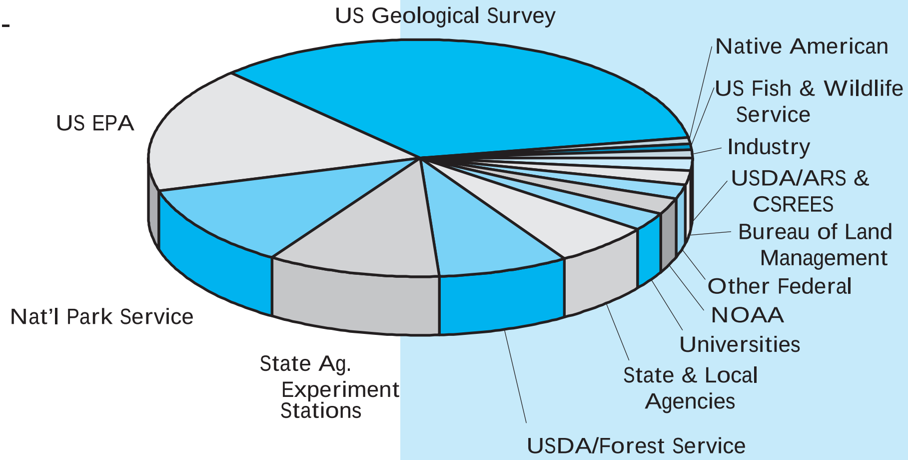
# NTN Today



Today, we know that many regional and global problems—not just acid rain—involve atmospheric transport and deposition of pollutants. The broad suite of chemical measurements from NTN is helping scientists to address many of these issues.

Funding for NTN continues to be provided by a collaboration among federal, state, and private entities. These groups support the program through federal interagency cooperative agreements and through independent agreements with the NADP Program Office at the University of Illinois, Illinois State Water Survey. Approximately one-fourth of the sites are supported directly through individual agreements with universities, state agencies, and private industry. Together, these entities support program management, site operations and maintenance, chemical analysis, data management, and quality assurance.

NTN receives funding from more than100 organizations and government agencies. As the principal coordinator for the federal agencies, the U.S. Geological Survey (USGS) provides a significant portion of the network funding.



NTN is the only nationwide monitoring network that collects precipitation samples for chemical analysis. In addition, NTN has one of the longest multi-site records of precipitation chemistry in the world and has maintained an effective quality assurance program.

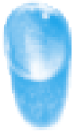
Many of our national parks are experiencing the effects of rapidly growing regional populations and growing numbers of visitors. Scientists are using NTN data to assess the relationship between regional pollution and changes in the ecology of these pristine areas.

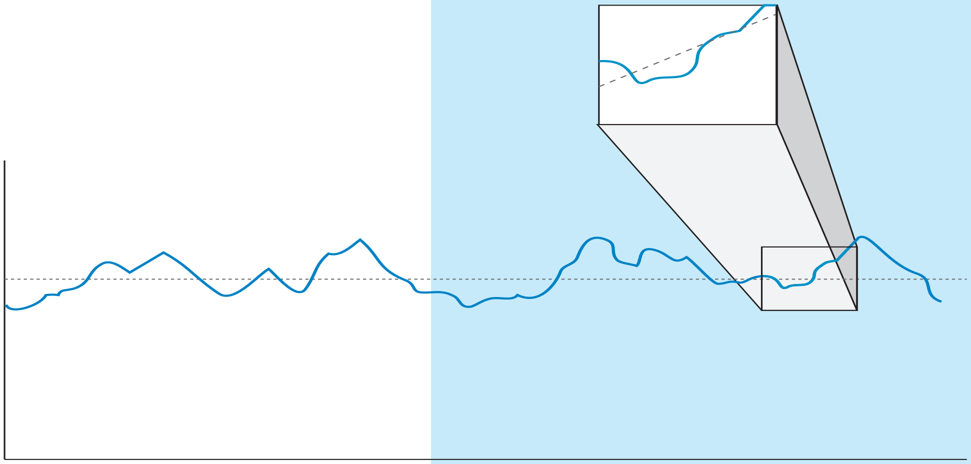
## A Nationwide Network

The broad coverage provided by NTN is crucial for determining how the chemistry of U.S. precipitation varies by region. Although smaller networks are able to determine local conditions, they are unable to provide a complete picture of atmospheric deposition for the country—a necessity if we are to determine the effectiveness of national environmental regulations, differences in regional patterns of deposition, or the international implications of atmospheric deposition.

Environmental regulations often come with substantial costs to the regulated community. For example, the Clean Air Act requires that industry maintain expensive pollution control programs to reduce the sulfur and nitrogen emissions that cause acid rain. It is in all of our interests to ensure that the benefits to society are worth the costs. Data obtained by NTN are the only way that we can verify whether the total deposition across the nation has been reduced as a result of the Clean Air Act—crucial information in determining whether these programs are cost-effective.

Just as it is important to determine who in our communities is bearing the costs of environmental regulations, we must also know who is bearing the environmental burden of our pollution. Different areas of the country have different patterns of, and effects from, atmospheric pollution. Whether these effects take the form of increased crop production, loss of game fish, or extinction of a rare plant, knowing these geographical patterns allows scientists, local officials, and the general public to understand how their communities are affected by regional pollution.





## How long is long enough?

Identifying trends in environmental data is not a simple undertaking because of long-term natural cycles and short-term variability. In the example above, a scientist looking at only a short segment of the data record (exploded view) might easily conclude that the trend was increasing. However, another scientist, taking a longer term view, would conclude that the trend was neither increasing nor decreasing. For this reason, scientists need long-term data that is consistent and comparable from year to year.

International neighbors are also concerned about the migration of atmospheric pollutants across borders. As the only border-to-border U.S. network, NTN is our sole source of information on the movement of pollutants into or out of the country. The critical nature of this information has been recognized by the Canadian government, which is both an active NADP participant and user of NADP data.

## A Long-Term Network

The historical levels of pollutants in the atmosphere provide important clues as to what is happening to the chemistry of our rain today. Scientists and policy makers are being asked to examine the effectiveness of air quality regulations, determine whether changes in land use are affecting atmospheric conditions, and answer other questions regarding atmospheric deposition. However, long-term changes in the atmosphere happen very slowly, obscured by the wide, month-to-month variability in chemistry measurements. In order to see beyond the short-term changes, it is necessary to analyze the chemistry of a single site over many years. With more than 30 stations having at least 20 years of continuous records, and more than 150 having a record length of more than 15 years, NTN provides the data for this type of nationwide long-term analysis.

One goal of NADP is to make our data available and understandable to scientists, policy makers, and the public. In 1994, a consortium of NADP participants sponsored a workshop on trend analysis. This workshop brought together key scientists to compare methods and statistical techniques for identifying long-term trends in atmospheric chemistry. NADP also sponsored a study in 1995 to identify statistically significant trends in concentrations at the longest-running stations in the network. (The report from this study is available from the NADP Program Office.)

## Maintaining High Standards

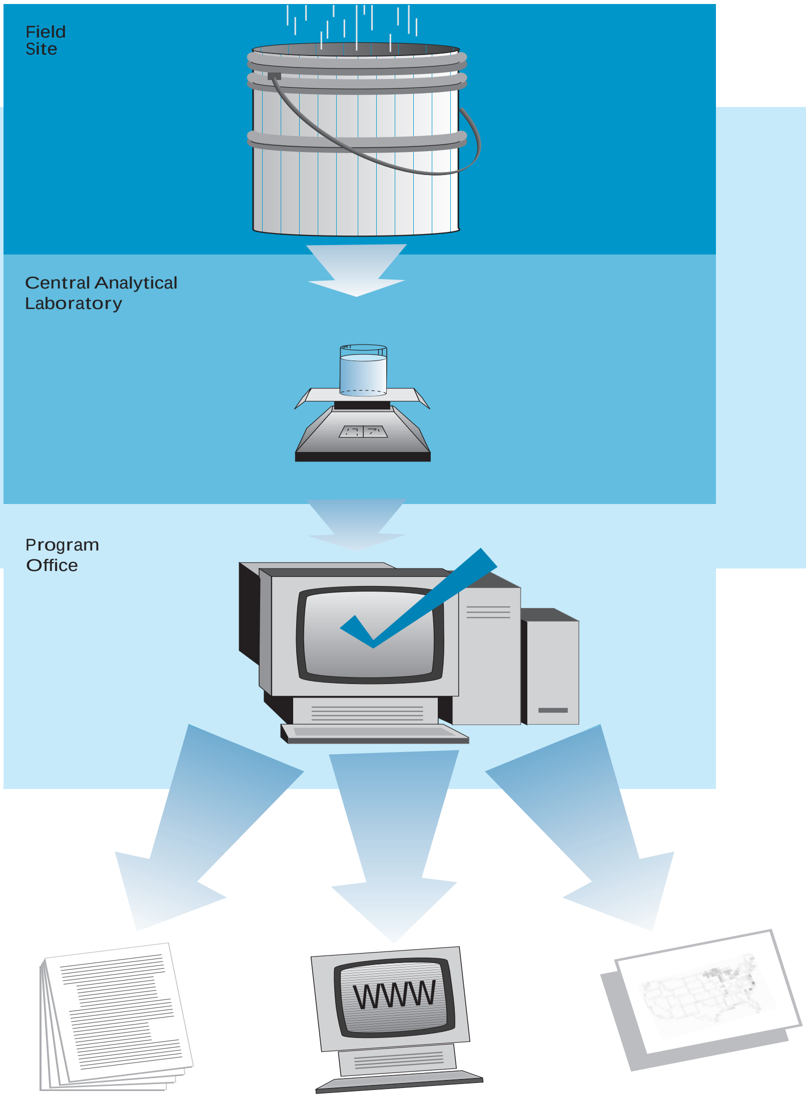
Measurements of any type contain a certain amount of error. This error component may be introduced when samples are collected, transported, stored, and analyzed or when data are stored or transferred electronically. It is the responsibility of quality assurance programs to provide a framework for determining and minimizing these errors through each step of the sample collection, analysis, and data management processes. The quality assurance programs for NTN–among the best in the world for this type of monitoring network–ensure that samples and data are of high quality. As with other aspects of NADP, these programs are cooperative, interagency efforts with expertise and funding provided by the USGS, EPA, NADP Central Analytical Laboratory (CAL), and the Program Office at the Illinois State Water Survey.

Through these efforts, NTN has continually improved the accuracy of its measurements. While desirable, these improvements also represent a change in the long-term data record. This can create special problems as researchers and regulatory agencies use the network's data for long-term analyses. Through the documentation provided by quality assurance programs, investigators are informed of these improvements in data quality and can account for them in their analyses.

## Collecting Samples

Every Tuesday morning at 9:00 a.m., NTN site operators across the country head to their monitoring stations to retrieve their samples of the previous week's precipitation, whether rain, snow, or sleet. Samples are collected continuously in a wet deposition collector. The collector opens automatically

NTN samples are sent to the CAL where they are analyzed for key constituents in precipitation. Analytical results then are sent electronically to the Program Office, which makes data available via the Internet, FTP (file transfer protocol), computer diskettes, paper printouts, or maps.

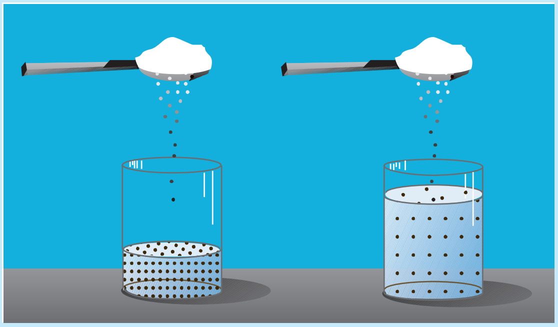


during wet weather, allowing the precipitation to fall into a collection bucket, and then closes as soon as the precipitation stops.

At the site, the operator replaces the collection bucket with one specially cleaned for the next sample. The operator then takes the sample to a field laboratory, where it is weighed and the acidity is measured. Next, the sample is transferred to a shipping bottle and sent to the CAL in Champaign, Illinois.

At the CAL, the concentrations of the important inorganic chemicals in precipitation are analyzed. These chemicals—or analytes—include acidity (measured as pH), sulfate, nitrate, ammonium, chloride, and base cations. The data are checked to ensure their quality, and special codes are applied to help in interpreting the data. These “sample validity” codes indicate the quality of the sample—for instance, whether it was collected according to standard protocols and whether there is any sign of contamination.

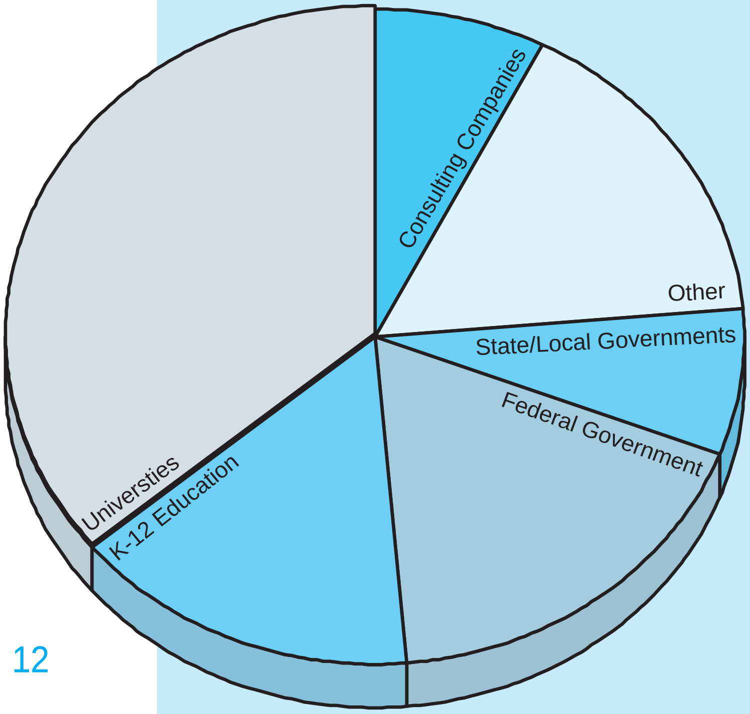
After this initial data processing, the data are sent electronically to the NADP Program Office, which performs further checks of accuracy and completeness. The entire data record is confirmed as being consistent with standard NTN procedures and documentation. Sophisticated data processing programs are run to detect discrepancies in the coding of the sample’s validity and in the completeness of each site’s data records. Any such discrepancies are carefully screened and resolved. Only after data verification is complete is the sample record entered into the NADP database, ready for distribution to the public and inclusion in NADP publications.



## Concentration or deposition: What's the difference?

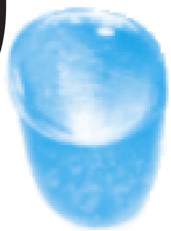
NADP provides all data in terms of deposition and concentration. Deposition is the amount of chemical deposited over an area, whereas concentration is the amount contained in a standard volume. In this illustration, the same amount of salt is deposited in two different glasses. The deposition is the same, but the concentration is greater in the glass having less liquid.

Concentration data are provided in milligrams per liter (mg/L), or microequivalents per liter (μeq/L). Deposition data are provided in kilograms per hectare (kg/ha). Depositions are calculated from the sample concentrations multiplied by the amount of precipitation recorded during the sample period. NTN data are provided in several time periods, ranging in length from the weekly sampling period to annual periods.



Data requests filled by NADP are distributed across many different sectors and parts of the country. Applications range from calculating the atmospheric component of chemicals in groundwater to estimating material corrosion rates and how they vary with location.

NTN analyzes the constituents important in precipitation chemistry, including those affecting rainfall acidity and those that may have ecological effects after deposition.



# What Do We Measure?

## Acidity and Hydrogen

Whether from natural sources or human activities, materials in the atmosphere determine its chemistry. Some emissions, like sulfur and nitrogen oxides, react with compounds in the atmosphere to form acids. Others, like ammonium or certain metals found naturally in the Earth's crust, can make precipitation more alkaline. When acid-forming constituents outnumber neutralizing ones, the acidity of the precipitation increases and acid rain is formed.

The acidity of precipitation is determined by the hydrogen ion concentration, which is usually measured as pH. The pH scale ranges from 0 to 14, with pH 7 being neutral, values less than 7 being acidic, and values greater than 7 being alkaline. Precipitation in an unpolluted atmosphere is slightly acidic

Aquatic ecosystems are particularly susceptible to the effects of acidification. Studies from numerous geographic regions have shown that as a lake or stream becomes more acidic, some of its animal or plant life declines or disappears altogether.

because of chemical reactions with carbon dioxide and other naturally occurring substances in the atmosphere.

Initially dire predictions of extensive environmental damage due to acid rain have not been borne out in the United States. Nevertheless, there is evidence that acid deposition is having environmental effects.

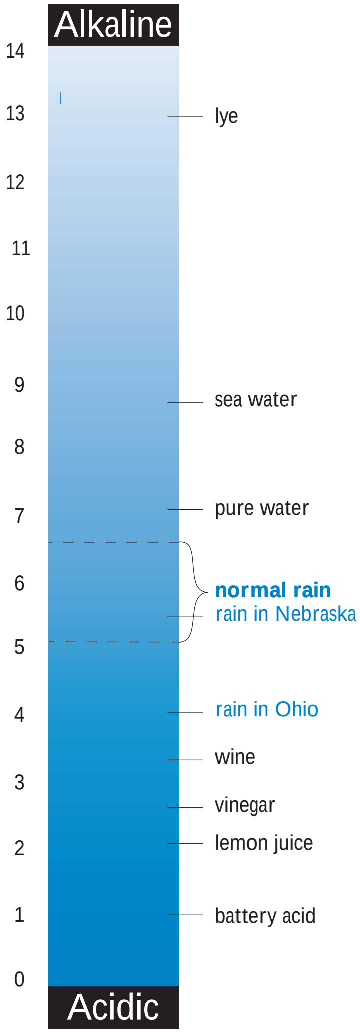
Aquatic ecosystems are particularly susceptible to the effects of acidification. Some species of game fish, native fish, and other aquatic creatures decline as the acidity of streams and lakes increase. Many beneficial aquatic microorganisms also decline as the acidity of their environment increases. Some of these microorganisms are involved in nutrient cycling and play an important role in their ecological community.

Acidic precipitation at current levels has not been shown to cause crop yield reductions or direct, toxic effects in U.S. forests, but it has been linked to the decline of terrestrial ecosystems through indirect effects. These include decreased resistance to pests and drought, increased susceptibility to effects from other pollution, and changes in soil chemistry and ecology.

Many soils, especially those in arid climates and high in calcium carbonate, provide sufficient neutralizing capacity to resist the effects of acidic deposition. Others, such as those found at high elevations or in areas with heavy rainfall, may be susceptible. Acid rain can speed up weathering of these sensitive soils and the underlying bedrock, and can increase the removal of already scarce plant nutrients.

Considered as isolated incidents, none of these effects may seem particularly serious. But considered in an ecological perspective, these changes to the ecosystem may have serious and unanticipated consequences.

Since the mid-19th century, air pollution has been suspected of increasing the natural rate of weathering and decay of many natural and human-made materials. Today, research has shown that acid deposition can damage



metal products, carbonate stone, and painted surfaces. Residents of high-deposition areas have witnessed the degradation of historic stone buildings, monuments, and ironworks.

NTN measures acidity as pH at both the CAL and the field laboratories. The annual averages of acidity in U.S. precipitation range from pH 6.0 in Utah to 4.2 in some areas of the Ohio valley. Because pH is a logarithmic scale, this difference represents about a 60-fold spread in hydrogen ion concentration. The geographic patterns of hydrogen ion concentrations are similar to those of sulfate and reflect the relationship between the two.

## Sulfate

Sulfur emissions are converted to acidic compounds in the atmosphere and are recognized as a principal component of acid rain. Sulfur is also an important plant nutrient and a component of animal and plant proteins. Natural sources of sulfur include the oceans, soil microorganisms, vegetation and crops, volcanic and other geothermal activity, and biomass burning. Today, however, human-made sources of sulfur—especially sulfur dioxide from burning of fossil fuels—have overtaken natural sources as the major contributor to atmospheric sulfur in the Northern Hemisphere.

Sulfate aerosols are considered to be a contributor to health problems associated with airborne particles in the eastern United States. Health-related costs have been estimated to exceed $10 billion. Sulfur  aerosols also are the most important contributors to the loss of visibility associated with smog in many urban areas. As sulfur emissions and sulfate aerosols are added to the atmosphere, the haze and loss of visibility associated with them have become not just an urban problem, but also an issue in many rural and remote natural areas. Visibility is an extremely important part of the experience of visiting spectacular natural areas like the Grand Canyon, Great Smoky Mountains, Yellowstone, and Everglades National Parks. Survey research shows that many people are very aware of poor visual air quality, and their perceptions of visual air quality form an important part of how they perceive beauty and their overall quality of life.

NTN measures sulfur as sulfate ion, with average concentrations ranging from 0.1 mg/L in northern California to over 2.7 mg/L in

This sequence of photos of the Grand Canyon shows the effect aerosols can have on visibility and our perception of a landscape.  The visual air quality of the canyon is as poor or worse as shown in the photos 1 percent (top), 50 percent (center), and 99 percent of the time (bottom).

Bristlecone pines are among the oldest living organisms. Increases in the amount of nitrogen reaching this tree may reduce its chances of survival in this harsh environment.

the Ohio valley. Its patterns of concentration and deposition, similar to that of hydrogen ion, reflect the concentration of sulfur emissions in the Midwest and Ohio valley.

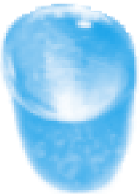
## Nitrate

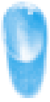
Like sulfur compounds, nitrogen oxides react to form acidic compounds in the atmosphere, which are another principal component of acid rain. Natural sources include lightning, soil microorganisms, biomass burning, and oceans. However, the predominant source of nitrogen oxides in the Northern Hemisphere is human activity. Automobile exhaust and industrial emissions are the largest sources in the United States.

Atmospheric deposition of nitrogen can have a fertilizer effect on natural ecosystems, especially on estuaries such as the Chesapeake Bay. In these ecosystems the added nitrogen stimulates growth of algae that deplete oxygen in the water and can suffocate fish and other aquatic organisms.

Nitrogen deposition on land can result in nitrogen saturation of soils and stream acidification. Stream acidification can be especially pronounced during periods of heavy rainfall or snowmelts as the flushing of nitrogen from soils causes a temporary increase in stream acidity. Although temporary, this “episodic acidification” can cause long-term effects on populations of fish and aquatic insects.

NTN measures nitrate ion, whose annual average concentrations range from less than 0.1 mg/L in the Pacific Northwest to over 2.0 mg/L in New York. Unlike hydrogen and sulfur, for which higher concentrations are centered mainly over industrial areas, high levels of nitrate are apparent in areas like Southern California, the Rocky Mountains, and the Midwest. These concentrations are due to exhaust from cars and other vehicles in urban areas and agricultural activity in the Great Plains states.





## Ammonia

Although the chemistry of ammonia is complex, its main effect on precipitation chemistry is to neutralize acidity. Livestock wastes and fertilizer applications are thought to be the predominant sources of ammonia in the atmosphere, but soils and vegetation also can both emit and absorb ammonia.

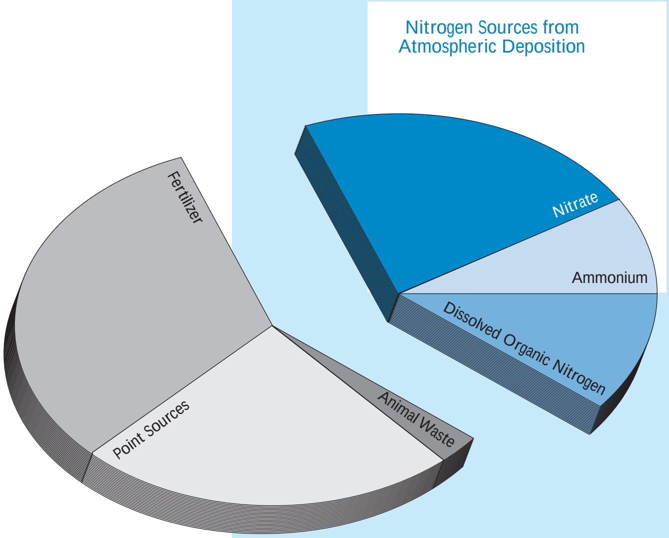
The ammonia molecule contains nitrogen. Ammonium sulfate and ammonium nitrate aerosols are largely responsible for reduced visibility in some parts of the country. Once deposited, ammonia can be converted to nitrate, which contributes to soil and water acidification and nitrogen fertilization.

NTN measures ammonium ion, whose annual average concentrations range from less than 0.02 mg/L in the Pacific Northwest to over 0.6 mg/L in the Central Plains. The highest concentrations of ammonium are found where livestock and fertilizer applications are widespread—generally in the agricultural areas of the Central Plains.

Located far from typical sources of pollution, this NTN collector in Montana provides atmospheric deposition data for the Northern Plains ecosystems. Ammonium and nitrate deposition are generally higher in this part of the country than others, contributing nitrogen to an otherwise nitrogen-poor ecosystem.  While beneficial to many introduced species, nitrogen fertilization may actually put native grasses at a disadvantage.

## Chloride

Chloride may increase the acidity of precipitation, depending on whether its source material is acidic or neutral.  The principal source of chloride in precipitation is salt spray from the oceans, which has no effect on acidity. As expected from its marine origin, the highest concentrations and depositions of chloride are found near coastal areas. The most common acidic source materials for chloride are fossil-fuel combustion products.



Recent research using NTN data shows the importance of atmospheric deposition data in assessing the health of the Chesapeake Bay.  At left is one analysis of nitrogen sources for the bay, with those from atmospheric deposition grouped on the right. Because of the impact of nitrogen on estuaries, water treatment plants and other point sources are now required to reduce nitrogen discharges—often at a huge cost.  With more than 30% of the bay's nitrogen coming from atmospheric sources, additional reductions might be accomplished by reducing atmospheric deposition.

## Base Cations

The base cations are common elements contained in the Earth's crust. They include calcium, magnesium, potassium, and sodium. The sources of base cations include dust from soils, unpaved roads, agricultural tillage, industrial emissions, and salt spray from the oceans. Like chloride, the effect of base cations on precipitation depends on their source material. When base cations (most commonly calcium) are contained in alkaline minerals like limestone they can react to neutralize the acids in precipitation; when contained in neutral minerals or salts they generally have no effect.

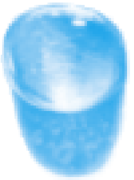
The highest concentrations of base cations are found in the southwest and central regions of the country. This reflects the larger areas of unpaved roads and open fields in these regions, where the potential for wind erosion is greatest.

Levels of base cations in some areas appear to be decreasing, which many researchers attribute to the paving of roads and to improvements in agricultural practices that reduce wind erosion from open fields. Without the neutralizing effect of base cations, the acidity of precipitation in these areas could increase.

Base cations also play an important role in plant nutrition and soil productivity. Increasing evidence indicates that the decreasing levels of cations from atmospheric deposition are leading to substantially reduced productivity of affected soils.

The oceans are a major source of chemicals in precipitation, particularly chloride and sodium. Although they don't contribute to acidification, chloride and sodium do increase the corrosiveness of precipitation and fog.

NADP is pursuing new ways to provide the nation with data on the most pressing issues in atmospheric deposition.

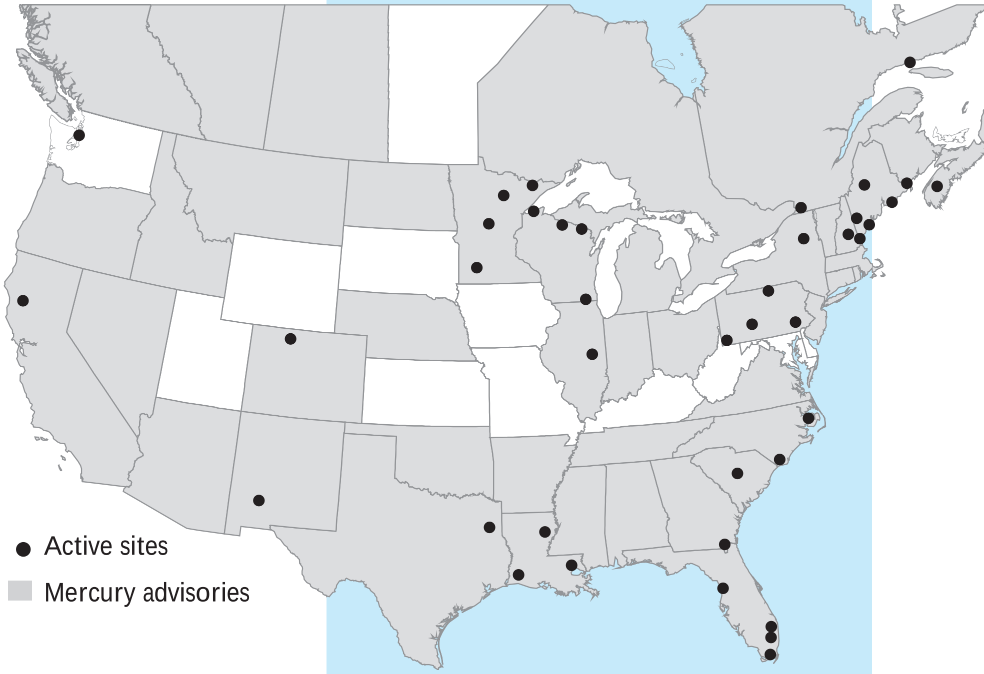
# Respnding to Changing Needs

As research into environmental issues becomes more sophisticated, NADP offers the expertise and the infrastructure to respond to immediate and emerging needs.

Sometimes these needs are unforeseeable. In 1986, NADP was able to respond immediately and supply researchers with precipitation samples from across the United States following the Chernobyl nuclear accident in the Ukraine. Using these samples, scientists were better able to estimate the amount and distribution of small amounts of radioactivity that fell across the country.

NADP also gives researchers an inexpensive way to collect precipitation samples from across the country. From 1990 through 1991, NTN provided samples from 26 states to researchers investigating the concentration and distribution of herbicides in precipitation. This study provided evidence of significant deposition of herbicides and provided justification for the establishment of a separate short-term sampling network.

NADP's Mercury Deposition Network measures mercury in precipitation at 40 stations, with more in the planning stage.



NADP's commitment to emerging needs is reflected in the recent addition of two important networks.

## Mercury Deposition Network

Currently, 44 states and provinces have issued ongoing advisories warning residents about the danger of eating fish contaminated by mercury. In some states, more than 95 percent of all lakes and streams have mercury levels above advisory guidelines. When informed of the advisories, residents may picture hazardous waste sites or industrial discharges and ask, "Where is it coming from?" In most cases there are no factories dumping wastes into these lakes and there are no mercury mines in the area. Instead, recent research shows that the majority of mercury in our lakes and streams is coming from atmospheric deposition.

Atmospheric Deposition is the major source of mercury in wetlands and lakes. Although concentrations in precipitation are extremely small, mercury can become concentrated in fish to levels that exceed public health guidelines.

Many people are familiar with mercury as the common metal that is shiny, bright, and liquid at room temperature. It is an important industrial metal used in fluorescent lamps, thermometers, batteries, and dental fillings. Mercury is also used in fungicides, pharmaceuticals, and in the manufacturing of chlorine and caustic soda. In the form of methyl mercury, it is toxic and volatile.

At low levels of exposure, methyl mercury causes neurological effects including lack of coordination, tremors, and speech and hearing impairments. At higher concentrations it eventually causes paralysis, deformities, and even death. Pregnant women are especially at risk. In addition, methyl mercury tends to bioaccumulate, meaning that the concentration of mercury tends to increase as it moves up the food chain, from microorganisms to fish to humans.

Recognizing the need to know more about the distribution and fate of mercury, NADP responded in 1995 by initiating the NADP Mercury Deposition Network or MDN.

AIRMoN operates nine daily monitoring stations, providing scientists with high-resolution precipitation chemistry data.

Today, nearly 40 monitoring stations exist, and more are proposed. The objective of MDN is to monitor the amount of mercury in precipitation on a regional basis—information crucial for researchers and the public alike to understand what is happening to our lakes and streams.

Samples are collected at all MDN sites using the same standard sampling protocols and sent to the Mercury Analytical Laboratory in Seattle, Washington, for analysis. After being entered into a database at the laboratory, the data are sent electronically to the NADP Program Office for further processing and public release.

## AIRMoN

While NTN provides valuable weekly data on regional trends across the country, researchers and regulators alike  needed a network for shorter term measurements—even daily ones. With funding provided by the National Oceanic and Atmospheric Administration (NOAA), NADP added the Atmospheric Integrated Research Monitoring Network or AIRMoN.

AIRMoN comprises nine monitoring stations where precipitation samples are collected every 24 hours. These daily samples are analyzed at the NADP Central Analytical Laboratory for the same analytes as NTN. This high-resolution sampling provides researchers with the information needed to run models of atmospheric chemical processes and gain a better understanding of the chemistry of atmospheric deposition.

Daily monitoring is also important for regulators and industry groups evaluating the effectiveness of air quality regulations and emission trading practices used by industry. Daily data allow researchers to track individual storm systems and determine the chemical processes occurring in them. These data are then used in models that can accurately predict the effects of reductions in pollutant emissions, which helps policy makers to determine which regulatory mechanisms are most cost-effective in reducing pollution.

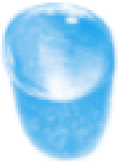
As a small and flexible research network, AIRMoN provides scientists with the tools to refine and improve methods for atmospheric deposition monitoring. The network has provided calibration data for the collection efficiency of ammonium and other forms of nitrogen. Scientists with AIRMoN are also at the forefront of researching new, automated strategies for collecting data and reporting results. In the future, these efforts will enable other monitoring networks to operate with increased efficiency and accuracy.

## Future Directions

Building on the stability of more than 20 years of operation, NADP is looking toward future needs in atmospheric deposition research. Using the long-term NTN database, scientists are now able to analyze trends in precipitation chemistry over time. NADP has sponsored several efforts to analyze trends in atmospheric deposition and plans to continue research on this important topic.

Atmospheric deposition of toxic chemicals—especially heavy metals and pesticides—is receiving intense scrutiny from scientists in a number of disciplines. Along with establishing the Mercury Deposition Network, NADP has participated in other short-term studies on deposition of toxic compounds. Program scientists continue to explore other means for gathering information on long-range transport and deposition of toxics in our rainwater.

Educating the public and future scientists about long-range transport and deposition of pollutants is an important task before us. As a leader and steward of the nation's research on atmospheric deposition, NADP continues to look for new ways to make this research more accessible and understandable to a broad audience, from elementary students to research scientists. Through understanding and appreciation of precipitation chemistry, we can guarantee wise management and protection of this globally shared resource.



Daily samples collected by AIRMoN allow researchers to understand the chemical processes that take place inside storm systems.

# Glossary

**acidic**
Having the properties of an acid, such as a pH less than 7, an excess of hydrogen in solution, and the ability to react with a base to form a salt.

**acid precipitation**
Precipitation (rain or snow) having increased acidity due to atmospheric pollutants.

**adsorption**
The adhesion of an extremely thin layer of gases, solids, or liquids to the surface of another solid or liquid.

**aerosol**
A suspension of very fine solid or liquid particles in the atmosphere. Particle sizes range from approximately $10^{-3}$ to larger than 100 micrometers in radius.

**alkaline** or **basic**
Having the properties of a chemical base, such as a pH greater than 7 and the ability to react with an acid to form a salt.

**analyte**
A chemical or substance that is the subject of a chemical analysis.

**anion**
A negatively charged ion or molecule. The anions measured by NADP are sulfate, nitrate, and chloride.

**atmospheric deposition**
The process whereby airborne particles and gases in the atmosphere are deposited on a surface through precipitation, such as rain or snow, or through settling, impaction, or adsorption.

**base cation**
A positively charged ion that contributes to the alkalinity of a solution or that reduces the acidity of a solution. The base cations monitored by NADP are calcium, magnesium, potassium, and sodium.

**cation**
A positively charged ion or molecule. The cations measured by NADP, other than base cations, are hydrogen and ammonium.

**Clean Air Act**
The legislation passed by the U.S. Congress in 1970 and modified in 1990 that authorizes certain measures to control, reduce, or monitor atmospheric pollution and its effects.

**concentration**
The amount of a substance in a given volume.

**deposition**
The amount of a substance deposited on a given area.

**impaction**
Dry deposition of particles that leave the airflow when they collide with a surface to which they adhere, such as a leaf.

**pH**
A measure of acidity and alkalinity of a solution. A pH value is a number on a scale from 0 to 14 with lower numbers indicating increasing acidity and higher numbers increasing alkalinity. A pH value of 7 represents neutrality. Each unit of change represents a tenfold change in acidity or alkalinity.

**precipitation**
The water deposited on earth as hail, mist, rain, sleet, or snow or through fog.

**settling**
A dry deposition process in which gravity results in particles falling to the surface.

## Acronyms

| | |
|---|---|
| AIRMoN | Atmospheric Integrated Research Monitoring Network |
| CAL | Central Analytical Laboratory |
| EPA | U.S. Environmental Protection Agency |
| MDN | Mercury Deposition Network |
| NADP | National Atmospheric Deposition Program |
| NAPAP | National Acid Precipitation Assessment Program |
| NOAA | National Oceanic and Atmospheric Administration |
| NTN | National Trends Network |
| USGS | United States Geological Survey |

## Conversion Factors

| To Convert From | To | Multiply By |
|---|---|---|
| centimeter (cm) | inch (in) | 0.3937 |
| kilograms per hectare (kg/ha) | grams per square meter ($g/m^2$) | 0.100 |
| kilograms per hectare (kg/ha) | pounds per acre (lb/A) | 0.8922 |
| kilometer (km) | miles (mi) | 0.6214 |
| liter (L) | quart (qt) | 1.057 |
| micrograms per liter (µg/L) | parts per million (ppm) | 0.001 |
| milligrams per liter (mg/L) | grams per square meter ($g/m^2$) | 0.010 x (cm rainfall) |
| milligrams per liter (mg/L) | kilograms per hectare (kg/ha) | 0.100 x (cm rainfall) |
| milligrams per liter (mg/L) | parts per million (ppm) | 1.0 |
| milligrams per liter (mg/L) | pounds per acre (lb/A) | 0.089 x (cm rainfall) |
| milliliter (mL) | fluid ounce (oz) | 0.03381 |
| hectare (ha) | acre (A) | 2.471 |

Conversion from milligrams per liter (mg/L) to microequivalents per liter (µeq/L)

| Constituent (Ion) | Multiply By |
|---|---|
| ammonium ($NH_4^+$) | 55.44 |
| calcium ($Ca^{2+}$) | 49.90 |
| chloride ($Cl^-$) | 28.21 |
| hydrogen ($H^+$) | 1000 |
| magnesium ($Mg^{2+}$) | 82.26 |
| nitrate ($NO_3^-$) | 16.13 |
| potassium ($K^+$) | 25.57 |
| sodium ($Na^+$) | 43.50 |
| sulfate ($SO_4^{2-}$) | 20.83 |

# NADP Cooperators

## State Agricultural Experiment Stations

Auburn Univ.-Black Belt Substa.; Auburn Univ.-Sand Mtn. Substa.; Colorado State Univ.-Central Plains Experimental Range; Cornell Univ.-Aurora Research Farm; Iowa State Univ.-McNay Research & Demonstration Farm; Kansas State Univ.; Louisiana State Univ.-Iberia Research Sta.; Louisiana State Univ.-Southeast Research Sta.; Montana State Univ.-Northern Ag. Research Ctr.; North Carolina State Univ.-Finley Farm; North Carolina State Univ.-Horticultural Crops Research Sta.; North Carolina State Univ.-Peanut Belt Research Sta.; North Carolina State Univ.-Piedmont Research Sta.; Ohio State Univ.-Ohio Ag. Research & Development Ctr.; Oklahoma State Univ.-Panhandle Research Sta.; Oregon State Univ.-Hyslop Farm; Pennsylvania State Univ.; Pennsylvania State Univ.-Fruit Research & Extension Ctr.; Purdue Univ.-Purdue Ag. Research Ctr.; Purdue Univ.-Southwest-Purdue Ag. Ctr.; South Dakota State Univ.-Cottonwood Range & Livestock Research Sta.; Texas A & M Univ.-Texas A&M Ag. Research Sta.-Beeville; Texas A & M Univ.-Texas A&M Ag. Research Sta.-Sonora; Univ. of Arkansas-Ag. Research & Extension Ctr.; Univ. of California-Davis; Univ. of California-Hopland Field Sta.; Univ. of Florida; Univ. of Georgia-Coastal Plain Experiment Sta.; Univ. of Georgia-Georgia Experiment Sta.; Univ. of Illinois-Dixon Springs Ag. Ctr.; Univ. of Illinois-Northern Illinois Agronomy Ctr.; Univ. of Illinois-Northwestern Illinois Ag. Research & Demonstration Ctr.; Univ. of Maine-Greenville Sta.; Univ. of Maryland-Wye Research & Education Ctr.; Univ. of Massachusetts-Suburban Experiment Sta.; Univ. of Michigan-Biological Sta.; Univ. of Michigan-Kellogg Biological Sta.; Univ. of Minnesota-Southwest Experiment Sta.; Univ. of Missouri-Basket Wildlife Area; Univ. of Missouri-Univ. Forest; Univ. of Nebraska-Ag. & Research Development Ctr.; Univ. of Vermont-Proctor Maple Research Ctr.; Univ. of Wisconsin-Spooner Ag. Research Sta.; Utah State Univ.-Utah Ag. Experiment Sta.; Virginia Polytechnic Inst. & State Univ.-Horton Ctr.

## Universities

Alfred Univ.; Cornell Univ.; Eastern Kentucky Univ.; Miami Univ.-Dept. of Geography; Michigan Tech Univ.-Dept. of Biological Sciences; Murray State Univ.; New Mexico State Univ.; North Carolina State Univ.-Southern Oxidant Study; Pennsylvania State Univ.-Meteorology Dept.; State Univ. of New York-Albany; State Univ. of New York-Fredonia; State Univ. of New York-Oswego; State Univ. of New York-Syracuse/Adirondack Ecological Ctr.; Univ. of Alaska,Fairbanks-Water & Environmental Research Ctr.; Univ. of Arkansas-Monticello; Univ. of Colorado-Inst. of Alpine & Arctic Research; Univ. of Delaware-Graduate College of Marine Studies; Univ. of Kentucky-Ctr. for Applied Energy Research; Univ. of Massachusetts-Dept. of Forestry & Wildlife Management; Univ. of Minnesota-Cedar Creek Natural History Area; Univ. of Nebraska-Conservation & Survey Div.; Univ. of New Hampshire; Univ. of Puerto Rico-Ctr. for Energy & Environmental Research; Univ. of Southern Maine; Univ. of Vermont-School of Natural Resources; Univ. of Virginia-Environmental Sciences Dept.;Univ. of Washington-Pack Forest

## United States Government Agencies

National Aeronautics & Space Administration; National Science Foundation-Long Term Ecological Research Network; Tennessee Valley Authority; U.S. Dept. of Agriculture *(Ag. Research Service, Cooperative State Research, Education & Extension Service)*; U.S. Dept. of Agriculture/Forest Service *(Bitterroot Nat'l Forest, Gifford Pinchot Inst. for Conservation Studies, Hiawatha Nat'l Forest, Pacific Northwest, Research Sta.-Forestry & Range Sciences Lab., Pacific Northwest Research Sta..-H.J. Andrews Experimental Forest, North Central Forest Experiment Sta., Northeastern Research Sta.-Forestry Sciences Lab.- Delaware, OH, Northeastern Research Sta.-Hubbard Brook Experimental Forest, Northeastern Research Sta.-Kane Experimental Forest, Northeastern Research Sta.-Timber & Watershed Lab., Pacific Southwest Forest & Range Experiment Sta.-San Dimas Experimental Forest, Rocky Mtn. Forest & Range Experiment Sta., Southern Research Sta.-Coweeta Hydrologic Lab., Superior Nat'l Forest)*; U.S. Dept. of Commerce/National Oceanic & Atmospheric Administration *(Air Resources Lab., Nat'l Severe Storms Lab., Nat'l Weather Service)*; U.S. Dept. of Defense/U.S. Military Academy; U.S. Dept. of Energy *(Argonne Nat'l Lab., Federal Energy Technology Ctr., Los Alamos Nat'l Lab., Oak Ridge Nat'l Lab.)*; U.S. Dept. of Interior/Bureau of Land Management; U.S. Dept. of Interior/Bureau of Reclamation; U.S. Dept. of Interior/National Park Service (*Air Resources Div., Acadia Nat'l Park, Bandelier Nat'l Monument, Big Bend Nat'l Park, Bryce Canyon Nat'l Park, Buffalo Nat'l River,Canyonlands Nat'l Park, Cape Cod Nat'l Seashore, Capulin Volcano Nat'l Monument, North Cascades Nat'l Park, Craters of the Moon Nat'l Monument, Death Valley Nat'l Park, Denali Nat'l Park, Everglades Nat'l Park, Glacier Nat'l Park, Grand Canyon Nat'l Park, Great Basin Nat'l Park, Great Smoky Mountains Nat'l Park, Guadalupe Mountains Nat'l Park, Hawaii Volcanoes Nat'l Park, Indiana Dunes Nat'l Lakeshore, Isle Royale Nat'l Park, Joshua Tree Nat'l Park, Lassen Volcanic Nat'l Park, Little Big Horn Battlefield Nat'l Monument, Mesa Verde Nat'l Park, Mt. Rainier Nat'l Park, Olympic Nat'l Park, Organ Pipe Cactus Nat'l Monument, Pinnacles Nat'l Monument, Rocky Mtn. Nat'l Park, Sequoia Nat'l Park, Shenandoah Nat'l Park, Theodore Roosevelt Nat'l Park, Virgin Islands Nat'l Park, Voyageurs Nat'l Park, Yellowstone Nat'l Park, Yosemite Nat'l Park)*; U.S. Dept. of Interior/U.S. Fish &Wildlife Service (*Attwater Prairie Chicken Nat'l Wildlife Refuge, Chassahowitzka Nat'l Wildlife Refuge, Edwin B. Forsythe Nat'l Wildlife Refuge, Hatchie Nat 'l Wildlife Refuge, Muleshoe Nat'l Wildlife Refuge, Okefenokee Nat'l Wildlife Refuge, Salt Plains Nat'l Wildlife Refuge)*; U.S. Dept. of Interior/U.S. Geological Survey; U.S. Environmental Protection Agency (*Nat'l Health & Environmental Effects Research Lab.-Western Ecology Div., Office of Air & Radiation)*

## State & Local Government Agencies

Casco Bay Estuary Program, ME; City of Bennington, VT; City of Portland, OR; Geneva Lake Environmental Agency, WI; Green River High School, UT; Illinois State Water Survey; Iowa Conservation Commission; Kansas Dept. of Wildlife & Parks; Kentucky-Clark State Fish Hatchery; Louisiana Dept. of Environmental Quality; Maine Dept. of Environmental Protection; Minnesota Pollution Control Agency; New Hampshire Dept. of Environmental Services; New Jersey Dept. of Environmental Protection; New Mexico Environment Dept.; North Carolina Dept. of Environment, Health, & Natural Resources; North Dakota State Parks & Recreation-Icelandic State Park; Northeast States for Coordinated Air Use Management; Pennsylvania Dept. of Conservation & Natural Resources; Pennsylvania Dept. of Environmental Resources; Siskiyou County, CA-Air Pollution Control District; South Carolina Dept. of Health and Environmental Quality; South Florida Water Management District; St. Johns River Water Management District; Tampa Bay Estuary Program, FL; Texas Natural Resource Conservation Commission; West Virginia State Parks & Forests; Wisconsin Dept. of Natural Resources; Wolf Ridge Environmental Learning Ctr., MN

## Industry

BP Amoco; Baltimore Gas & Electric Co.; Boise Cascade Corp.; Consolidated Papers, Inc.; Exxon Co., USA; Frontier Geosciences Environmental Research Corp.; International Paper Co.; Niagara Mohawk Power Corp.; SF Phosphates Limited Co.; Union Camp Corp.

## Native American

Fond du Lac Reservation; Fort Peck Assiniboine & Sioux Tribes; Grand Traverse Band; Penobscot Nation; Round Valley Indian Tribes; St. Regis Mohawk Tribe

## Other Research Organizations

Black Rock Forest Consortium; Electric Power Research Inst.; Environment Canada-Atmospheric Environment Service; Gulf of Maine Council on the Marine Environment; Huntsman Marine Science Centre, Canada; Inst. of Ecosystem Studies; Parks Canada; Quebec Ministry of Environment & Wildlife