SAES-422 Multistate Research Activity Accomplishments Report

Project Number: NRSP-3
Project Title: The National Atmospheric Deposition Program (NADP) – A Long-term Monitoring Program in Support of Research on the Effects of Atmospheric Chemical Deposition
Period Covered: 1-2007 to 12-2007
Date of Report: December 14, 2006
Meeting Dates: September 10 - 13, 2007
Participants & Meeting Minutes: URL: http://nadp.sws.uiuc.edu/meetings/fall2007/minutes/techMtgMinutes2007.pdf

Accomplishments

The NRSP-3 sets a framework for cooperation among State Agricultural Experiment Stations, universities, government agencies, and nongovernmental organizations that participate in and support the National Atmospheric Deposition Program (NADP). The NADP provides quality assured data and information on the exposure of managed and natural ecosystems and cultural resources to acidic compounds, nutrients, base cations, and mercury in precipitation. Researchers use NADP data to investigate the impacts of atmospheric deposition on the productivity of managed and natural ecosystems; on the chemistry of estuarine, surface and ground waters; and on biodiversity in forests, shrubs, grasslands, deserts, and alpine vegetation. These research activities address the "environment, natural resources, and landscape stewardship," one of the Experiment Station Section's top five National Research Priorities. Researchers also use NADP mercury data to examine the role of atmospheric deposition in affecting the mercury in fish tissue, and better understand the link between environmental and dietary mercury and human health, which fits another National Research Priority, "relationship of food to human health."

To provide data for characterizing geographic patterns and temporal trends of atmospheric chemical deposition, the NADP operates three precipitation chemistry networks: (1) The National Trends Network (NTN) is the only network providing a long-term record of the acids, nutrients, and base cations in U.S. precipitation. The NTN began in 1978 at 22 sites and now has more than 250 sites (see http://nadp.sws.uiuc.edu/sites/ntnmap.asp?). (2) The Mercury Deposition Network (MDN) joined the NADP in 1996 and reports the total mercury content of precipitation. Emphasis on increasing the number and geographic coverage of sites has resulted in network growth to more than 100 sites (see http://nadp.sws.uiuc.edu/mdn/sites.asp). (3) The Atmospheric Integrated Research Monitoring Network (AIRMoN) joined the NADP in 1992. Seven sites located in the eastern U.S., provide daily measurements for studying atmospheric processes and developing models (see http://nadp.sws.uiuc.edu/AIRMoN/getamdata.asp).

NADP Web Site. The NADP Web site has registered users from more than 150 countries and from every continent but Antarctica. In 2007, the number of registered users increased by 4,473 (~13.5 percent), bringing the registrant total to 37,148. Atmospheric deposition and watershed studies were the leading topics of researchers using NADP data. A record 24,538 data downloads were recorded in 2007. Over the last decade, this measure of data usage more than doubled, Web page hits increased nearly six-fold to 1.4 million per year, and the number of color concentration and

deposition maps viewed rose five-fold to 126,000 per year. The site lets users selectively retrieve sample and site data, tabular summaries, seasonal and annual averages, trend plots, concentration and deposition maps, reports, manuals, and other data and information about the program.
Emerging Issues. As in 2006, NADP again partnered with the USDA Cereal Disease Laboratory (CDL) to test rain samples for evidence of *Phakopsora pachyrhizi*, commonly known as Asian Soybean Rust (ASR). ASR is an obligate fungal parasite that can inflict significant losses in soybean and other leguminous crops. From infected plants, ASR spreads through aerial release and dispersal of urediniospores, which can remain airborne for hundreds of kilometers before clouds and rain scavenge and deposit them, potentially on a soybean crop. Under the right conditions of temperature, moisture, and crop stage, ASR spores can germinate and spread the infection. ASR now regularly overwinters in kudzu in Gulf Coast states. During the growing season, it spreads northward by deposition of spores in rain and during dry weather.

With partial support from the Agricultural Research Service, weekly samples from 75 eastern-U.S. NTN sites were filtered in entirety. Filters were desiccated, sealed in Petri dishes, and sent to the CDL, where they were assayed for an ASR-specific DNA sequence using nested real-time PCR. Over a 17-week period (29 May-25 September), the CDL reported 89 (or 7 percent of) filters positive for ASR, some from areas where ASR was later reported on soybean or kudzu. For example, late August rain samples from two Iowa NTN sites tested positive; and from 28 September to 23 October, ASR was reported in 13 Iowa counties. Each year since the initial ASR reports in the contiguous U.S. in November 2004, the disease has infected a larger area. Results from this project are being used to study spore deposition, evaluate spore transport and deposition models, and examine how spore deposition and disease outbreak are related.
Educational/Extension Activities. NADP staff members assisted authors and publishers to introduce NADP color isopleth maps into new college textbooks. One example is an introductory chemistry textbook for non-majors entitled *Chemistry in Context, Applying Chemistry to Society*, first introduced as a project of the American Chemical Society in 1994 and now in its fifth printing. The chapter on "Neutralizing the Threat of Acid Rain" uses NADP pH, sulfate and nitrate maps to provide a contextual basis for teaching about acids and bases. Each new addition of this text expands its use of NADP maps and data and plans are to include MDN maps in the next edition. The authors of the new textbook *Fundamentals of General, Organic, and Biological Chemistry* use NTN sulfate maps to illustrate how Clean Air Act rules have affected real-world acid-base chemistry. Similarly, the authors of the recently released *Chemistry the Practical Science* use NTN pH and MDN concentration maps to illustrate acid-base and chemical coordination principles at work in nature; and, an NADP precipitation map is used to illustrate isopleth map-making in the text *Geographic Information Systems Demystified*.

Again in 2007, NADP staff participated in the University of Illinois Agriculture Extension's Stewardship Week, designed to engage elementary school students in hands-on learning activities in the environmental sciences. Eighteen classes of students in grades 2 through 6 participated in a learning activity about water quality by measuring the pH of lake water, drinking water, and rain samples from NADP sites across the country.
Supporting informed decisions on air quality issues. In its most recent progress report, "Acid Rain and Related Programs, 2006 Progress Report," the U.S. Environmental Protection Agency (USEPA) described the NADP networks as a "critical link in the chain of accountability" that

scientists and policymakers use to determine whether emissions decreases required by the 1990 Clean Air Act Amendments have reduced acidic deposition and translated into ecosystem recovery. In its report, the USEPA used NTN data to demonstrate the efficacy of the Act. The report compared average 1989-1991 and 2004-2006 sulfate and dissolved inorganic nitrogen (DIN) deposition in four eastern regions: Mid-Atlantic, Midwest, Northeast, and Southeast. Over this 15-year period, sulfate deposition decreased in all four regions, ranging from an average decrease of 21 percent in the Southeast to35 percent in the Northeast. These decreases were consistent with sulfur dioxide emissions reductions at electric generating units targeted by the Act. Since 1990, these units also trimmed nitrogen oxide emissions by more than 3 million tons. DIN deposition decreased as well, but by only 5 percent on average in the Southeast, 9 percent in the Midwest, 16 percent in the Mid-Atlantic, and 25 percent in the Northeast. In each region, these decreases were only about half of the decreases in precipitation nitrate, owing in part to offsetting increases in ammonium, the other nitrogen compound comprising DIN.

In its 2004 report, *Air Quality Management in the United States*, the National Research Council (NRC) recommended "investigating the use of critical loads as a potential mechanism to address the need for alternative air quality standards to protect ecosystems. A critical load is the quantitative estimate of the exposure to one or more pollutants below which significant harmful effects on sensitive elements of the environment do not occur according to present knowledge." As a follow-up to the NRC report, a multi-agency workshop was held to address critical loads from atmospheric sulfur and nitrogen deposition. A workshop recommendation was to establish an NADP committee that could facilitate communications on the science of critical loads. The NADP Executive Committee acted on this recommendation by forming the NADP Critical Loads AD hoc committee (CLAD). Its purpose is to provide a venue for discussing current and emerging issues regarding the science and application of critical loads for atmospheric deposition in the United States. The CLAD committee meets in conjunction with other spring and fall NADP committee meetings and has a page on the NADP Web site where additional information is accessible (http://nadp.sws.uiuc.edu/clad/).

Publications. There were more than 100 publications, using NADP data or resulting from NRSP-3 activities in 2007. An on-line database that lists citations using NADP data is accessible at http://nadp.sws.uiuc.edu/lib/bibsearch.asp.

Plans for 2007/2008

-Serving science and education. The NADP will continue to support researchers and educators by providing up-to-date quality-assured data and information on acids , nutrients, base cations, and mercury in precipitation. Work is proceeding on an overhaul of the NADP Web site, beginning with a new Home Page and including a new organizational structure. The new site will be less cumbersome to modify and update and will feature more pictures and graphic images, while retaining ready access to maps and tabular and graphical data summaries. A new section on educational resources for K-12 and university students will be added. Plans are to activate the new Web site at the 2008 annual meeting in Madison, Wisconsin, where NADP will celebrate its 30th year of network operations.

- Supporting informed decisions on air quality issues. In 2005, the U.S. EPA promulgated the Clean Air Mercury Rule (CAMR), which requires electric utilities to reduce mercury emissions beginning in 2010. While NADP/MDN data are used to evaluate the relationship between mercury

emissions and wet deposition, there are no comparable measurements of airborne mercury. Airborne mercury is present in three forms: gaseous elemental mercury (GEM), reactive gaseous mercury (RGM), and total particle-bound mercury (TPM). RGM is soluble, reactive, and efficiently removed in wet and dry deposition. Estimates suggest that dry deposition may be three times wet deposition, especially in "hot spots" near atmospheric mercury sources where RGM concentrations are high. This points to the need for airborne mercury measurements, if the emissions reductions under CAMR are to be evaluated accurately. To address this need, the NADP plans to begin retrieving GEM, RGM, and TPM measurements from nine continuous monitors operating under NADP-approved standard operational procedures. Measurements will begin in 2008. Near real-time quality control tests will be applied and valid data will be posted on the NADP Web site. Data will be used for model development, examining the spatial and temporal distributions of airborne mercury concentrations, estimating dry deposition fluxes, and determining the location of mercury deposition hot spots.

- Responding to emerging issues. Recent evidence suggests that gaseous ammonia has an important and increasing role in fine particle formation. NADP/NTN and AIRMoN measure ammonium in precipitation and the Clean Air Status and Trends Network (CASTNet) measures ammonium in aerosols, but gaseous ammonia is not measured routinely. NADP is evaluating the use of passive samplers to measure ammonia in a pilot network of 19 sites, most co-located with NTN and CASTNet sites. Triplicate bi-weekly samples are collected at each site. These data will be used to assess the accuracy of passive ammonia measurements, refine field and laboratory procedures, and evaluate the costs. With a year of data, the NADP Executive Committee will consider the feasibility of adding passive ammonia measurements as a network option.

Impacts:

1. Based on a Seasonal Kendall Trend analysis, ammonium increased at 90% of NADP/NTN sites operating continuously from 1985 to 2004, and nearly 2/3 of the increases were statistically significant, ranging from ~10% to ~90%. Largest increases occurred between the Mississippi River and Pacific Coastal states, an area where average ammonium concentrations in precipitation now exceed sulfate.
2. NTN wet deposition and Clean Air Status and Trends Network dry deposition estimates for 2000-2004 show that wet deposition accounted for 65-80% of the total sulfur and nitrogen deposition during the peak March-August deposition period in Rocky Mountain National Park, where studies show that deposition is affecting surface waters, soils, and vegetation.
3. Nitrogen deposition measurements at two Rocky Mountain National Park NTN sites, plus dry deposition estimates, surface water and diatom measurements, and extensive data on Park biota, have been used to develop a 1.5 kg/ha/yr nitrogen critical load for the Park. These scientific results are being used to shape mitigation strategies for reducing nitrogen emissions and lowering nitrogen deposition below this critical load.
4. In a comprehensive study of atmospheric inputs to the Columbia River Gorge, NTN data were used to quantify chemical deposition to the Gorge from precipitation and, coupled with fog-water and dry deposition measurements, to determine the total atmospheric sulfur and nitrogen entering the sensitive Gorge ecosystem.
5. Results from a unique new study of nitrogen isotopes in precipitation samples from NTN sites in states from Ohio and West Virginia to Maine demonstrated that nitrate is more strongly correlated with nitrogen oxide emissions from stationary sources than from vehicles, thus NTN nitrate trends effectively track power plant nitrogen oxide emissions reductions.

6. In a review of mercury contamination in northeastern U.S. forest and freshwater ecosystems, MDN data were used to quantify mercury deposition and its relationship to mercury emissions and to the mercury content of upland soils, wetlands, streams, reservoirs, ponds, and biota.
7. Using MDN data, researchers reported a link between the amount of ionic mercury deposited by precipitation and the methyl mercury found in mosquitoes and largemouth bass, suggesting a positive relationship between mercury deposition and mercury in biota.
8. Improving atmospheric mercury models was the goal of an effort that first used NTN sulfate data to fine tune meteorological and cloud physics parameterizations in a multi-pollutant model, then used MDN data to evaluate simulations of mercury deposition. Model R-square for sulfate was 91% though for mercury was only 41%, suggesting that important gaps remain in our understanding of mercury emissions, transport, transformation, and removal processes.
9. Although NTN pH data show that over the last 20 years the free acidity of precipitation in the eastern U.S. has decreased by 25-50%, mortality tests show that episodically acidified Adirondack streams continue to fail to support brook trout, because of low stream water pH and high monomeric aluminum concentrations.
10. An assessment of the critical load of acidity at the NTN site in Great Smoky Mountain National Park revealed that base cations from precipitation and weathering are major factors in affecting plant root exposure to toxic aluminum, which has risen in soil solution due to acidic deposition in the Park.
11. Daily measurements from the central Pennsylvania AIRMoN site show that meteorological variables have a significant effect on sulfate concentrations and that weather patterns affect inter-annual variations and should be considered when evaluating the causes of sulfate trends.
12. A methods evaluation conducted at three Indiana MDN sites demonstrated that reactive gaseous mercury could be measured reliably with a potassium-chloride-coated annular denuder, particle-bound mercury with a quartz filter, and gaseous elemental mercury in a trap charged with gold-coated quartz grains. These methods offer a cost-effective approach for adding airborne mercury measurements to the NADP MDN.
13. A study to evaluate total maximum daily loads of mercury has concluded that atmospheric deposition results in 99% of the mercury added to Minnesota lakes and streams and data from the four Minnesota MDN sites are used to assess atmospheric mercury trends and the success of strategies to meet Minnesota's mercury standards.
14. A critical analysis of the effect of missing data on wet deposition estimates demonstrated that NADP criteria requiring 75% or higher data completeness generally limits the uncertainty in computing annual sulfate, nitrate, ammonium, or hydrogen ion deposition fluxes to 20% or less and in computing 5-year deposition fluxes of these ions to 11% or less.

Publications:

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