The National Atmospheric Deposition Program (NADP)

University of Wisconsin Madison

Approved as of 04/06/2020

Project Director

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Code *Name*

Start Date

02/20/2020

End Date

09/30/2024

Funding Source

Research Capacity Fund (Hatch Multistate)

Primary Critical Issue

Sustainable Use of Natural Resources

NIMSS Project Information

NRSP3: The National Atmospheric Deposition Program (NADP)

NIMSS project details: NRSP3

Collaborating/Performing States

TX, KS, MN, NE, MA, NY, UT, CA, MI, WI, NH, CO, LA, PA

Objectives

- Characterize geographic patterns and temporal trends in chemical or biological atmospheric (wet and dry) deposition
- Support research activities related to: (a) the productivity of managed and natural ecosystems; (b) the chemistry of surface and ground waters, including estuaries; (c) critical loads in terrestrial and aquatic ecosystems; (d) the health and safety of the nation's food supply; and (e) source-receptor relationships
- Support education and outreach through the development of informational materials and programs aimed at people of all ages.

Non-Technical Summary

Acidic atmospheric deposition continues to be a serious environmental concern. Sulfur oxides and nitrogen compounds are emitted from industrial and transportation sources,

Part 1: In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Atmospheric chemical constituents or air pollutants are continually being transferred from the atmosphere to the managed and natural ecosystems at the earth's surface through both wet and dry deposition.

Many of these pollutants are transferred in amounts large enough to change the ecosystem that they are deposited into, and result in significant problems such as acidic precipitation, nitrogen fertilization and changing species composition, eutrophication of waters (algal growth and low oxygen), etc.

The National Research Support Project – No. 3 (NRSP3) provides a framework for cooperation among State Agricultural Experiment Stations (SAES), the U.S. Department of Agriculture-National Institute of Food and Agriculture, and other cooperating governmental and non-governmental organizations to measure and monitor these transfers of chemical pollutants, and share the data with research scientists and policy professionals.

Specifically, researchers use NADP data to investigate the impacts of atmospheric deposition on the productivity of managed and natural ecosystems; the chemistry of estuarine, surface, and ground waters; and the biodiversity in forests, shrubs, grasslands, deserts, and alpine vegetation.

Part 2: Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

At the end of September 2021, NADP supported sample collection in almost all of the US States, Puerto Rico, the Virgin Islands, and Canada. Operational support included 257 NTN, 80 MDN (7 sites also collecting methyl mercury), 12 AMNet, 117 AMoN, and 22 mercury litterfall monitoring sites across North America. Particularly for the NTN network, we have very good coverage of all lands in the United States. Currently, 48 NTN sites are operated by and located on SAES areas (sites specific for this report). In

addition, there are quality assurance and testing sites in Colorado and Wisconsin (SAES).

The NTN provides the only long-term nationwide record of base ion wet deposition in the U.S. Sample analysis includes free acidity (H+ as pH), specific conductance, and concentration measurements for calcium, magnesium, sodium, potassium, sulfate, nitrate, chloride, and ammonium. NADP also measures orthophosphate ions in the inorganic form, but for quality assurance purposes. The MDN offers the only long-term and routine measurements of mercury in North American precipitation. These measurements are used to quantify mercury flux primarily to water bodies.

The NADP operates two gaseous atmospheric chemistry networks: the Atmospheric Mercury Network (AMNet) and the Ammonia Monitoring Network (AMoN). The goal of these networks is to provide atmospheric concentrations of mercury and ammonia, respectively, to estimate the rate of dry deposition (without precipitation), and to support the measurements required to understand atmospheric chemical processing and total deposition of nutrients and pollutants. Fourteen AMNet sites were collecting five-minute measurements of gaseous elemental mercury and (for a subset of sites) two-hourly average concentrations of gaseous oxidized mercury and particulate bound mercury. The AMoN measures two-week average concentrations of atmospheric ammonia using passive sample cartridges, at 110 sites. These data are particularly important to the agricultural community, since many sources of ammonia are related to agricultural processes and ammonia deposition contributes to the total nitrogen deposition.

During the performance period, all three NADP goals were met. Our major accomplishment was smooth and consistent operation of the monitoring networks. Operation, maintenance, management, quality assurance, and data distribution from these networks is the major outcome of this grant and project.

The principal NADP deliverable is the database of precipitation chemistry and deposition rates, along with atmospheric gaseous concentrations intended for the development of dry deposition fluxes. This database is available free to all users (http://nadp.slh.wisc.edu/data/).

Principal Outcomes of the NADP for the project period include the following.

Samples Collected: NADP's principal output is the collection and analysis of precipitation and atmospheric chemistry samples obtained from network operations. As of Sept. 2021, total network analytical samples consisted of 12,982 NTN samples, 4016

MDN samples (and 58 methyl mercury samples), and 4,149 AMON samples for the previous 12 months. The AMNet measured approximately 90,000 hourly and two-hourly ambient mercury concentrations. All analytical results undergo an extensive quality assurance procedure prior to release to the public via the NADP website. Sample results are now available all of 2020 and well into 2021.

The NADP provides full technical support to data users and site operators. All program participants (supervisors, operators, funders) have direct access to technical experts at NADP via the web, email, and our toll free number (1-800-952-7353). Through this, we can address site operator's questions, offer technical expertise on data interpretation, and repair inoperable equipment. Hundreds of inquiries are answered each year.

NADP Database: Data access and availability is a key accomplishment of NADP, allowing support of continued research and outreach. Scientists, policymakers, educators, students, and others are encouraged to access data at no charge from the NADP website. This website offers online retrieval of individual data points, seasonal and annual averages, trend plots, concentration and deposition maps, reports, manuals, and other data and program information. The NTN has the chemical analysis for approximately 510,000 precipitation samples and 112, 687 MDN observations for all years. As of today, the 2020 calendar year data are complete, final, and online, and the 2021 data are posted through generally August, with final QA to be completed in the next few months (final data QA is completed after the full calendar year).

Map Summary: The 2019 annual map series of atmospheric concentrations, wet deposition fluxes, and report was developed during fall of 2020 after all of the data and quality assurance checks were completed. The 2020 map summary was completed and printed in October 2021. Map summaries are available here: https://nadp.slh.wisc.edu/pubs/Annual-Data-Summaries/). These maps and summaries are used widely. NADP prints 1500 copies of the Summary, and distribution occurs throughout the year to sites, at scientific meetings, and for education and outreach activities. For each summary, the NADP produces a series of 23 national maps of wet deposition concentration and flux maps for all of our analytes, and summary figures for each gaseous network. Individual maps are filed by network, year, and constituent, and can be downloaded in several formats.

Fall Scientific Symposium and Business Meeting: The Fall meetings were held online (for pandemic reasons) over Oct 25-26 and Nov 1-2, 2021 (just after the project period), with the Symposium was held Oct 27-29. There were 194 registered attendees (for the Symposium), and we recorded that 284 actual attendees present for some part of the meetings. Meeting information can be found online. The symposium was highlighted

by a talk from Dr. D. Farmer (Colorado State Un.) entitled "Masters of their Fate: Revisiting Atmospheric Particle Dry Deposition and Lifetimes", and a video is available. The symposium included 7 sessions, 55 presentations, and a special session on the Clean Air Act of 1970 at 50 years. Business sessions were held for all of NADP's subcommittees, and a special session on multi-network cooperation. Approved committee minutes are online (https://nadp.slh.wisc.edu/committees/).

Spring 2021 NADP Business Meeting (Technical Committee, subcommittees, Executive Committee): The Spring Meeting was held online between May 10-14, 2021, with Executive Committee following on May 19th. All subcommittees met during the period. Total attendance for all days was 208 individuals (i.e. logged in and attending at least one session). Details of this meeting can be found in the subcommittee minutes organized under each committee.

Summer 2021 Budget Meeting: also a digital meeting, and was held on July 20 and 21, 2021. Approximately 20 members were in attendance.

The NADP supported 223 journal and report publications during the 2021 calendar year (our research support role and goals), following 219 in 2020. The full list of publications can be found here (https://nadp.slh.wisc.edu/pubs/nadp-bibliography/), and a few examples of more agriculturally-related publications in the section.

Additional Notable Outcomes include the ongoing testing of total nitrogen and total phosphorus in NTN samples. This new analyte would be very important to both agricultural and non-agricultural uses. Additionally, we completed a full rework of the NADP website, to make updating and downloading of data easier. Finally, the NADP is working with a WSLH laboratory to measure Per- and Polyfluoroalkyl Substances (PFAS) compounds in precipitation. PFAS is also of interest to agricultural scientist, given that at least one paper has shown uptake of PFAS compounds in cover crops and vegetables (Ghisi et al, 2019 Environmental Research V169 326-341).

Part 3: Briefly describe how your target audience benefited from your project's activities.

NADP samples are collected to support research of atmospheric transport, ecosystem impacts, documentation of spatial and temporal trends, assent of air pollution mitigation success, development of computer simulations, and for community and educational outreach. With NADP's national research support designation, publications

that use our data are the best example that our target audience (researchers) are benefiting from our project.

NADP tracks the number of journal and report publications for each calendar year that use NADP data in their research. During CY2020, we found 219 publications (almost all refereed articles) that used NADP data in some important way to further their research (our objective). During CY2021, we found 223 publications. The complete list of articles using NADP data can be found here: http://nadp.slh.wisc.edu/lib/bibliography.aspx.

The following are a subset of 2020 and 2021 journal articles using NADP data that should be of particular interest to agricultural researchers.

1. Brahney, J., Wetherbee, G., Sexstone, G. A., Youngbull, C., Strong, P., & Heindel, R. C. (2020). A new sampler for the collection and retrieval of dry dust deposition. Aeolian Research, 45, 100600.

The measurement of dry deposition continues to be a difficult and highly inaccurate measurement. These authors (including SEAS scientists) are developing a new method for a direct and accurate measurement of dry deposition. They are particularly interested in the dry deposition of phosphorus, which is clearly important as a source term and as a deposition product for agriculture. The authors report on their measurement technique and results here. This method in particular collects unadulterated particulates allowing for further analysis. This new design was tested at 15 western sites, and was found superior to many current designs for retention and retrieval of samples, even under windy conditions. The NADP has cooperated with the authors extensively, with measurements being made at NADP sites and with NADP sampling equipment. NADP also hopes to use these samples in future sampling, for sampling that will complement our NADP goals of deposition monitoring.

2. Byrnes, D. K., Van Meter, K. J., & Basu, N. B. (2020). Long-Term Shifts in US Nitrogen Sources and Sinks Revealed by the New TREND-Nitrogen Data Set (1930–2017). Global Biogeochemical Cycles, 34(9), e2020GB006626.

The authors use modeling techniques to determine estimates for the amount of excess nitrogen that remains in landscapes and soils from anthropogenic additions (including agriculture) for each county in the contiguous United States between 1930 and 2017. The major source of this excess N is different by county, as predicted by the Trajectories

Nutrient Dataset for nitrogen [TREND-nitrogen] model. A large range of N balances exist given differences in land use and management and particularly in complicated urban areas. Agricultural sources dominate the Midwest and plains, along with many other county areas. The authors use NADP's nitrogen deposition data for wet deposition (1986–2017) and dry deposition (2000–2017) for all sites over these multiple years.

3. Chen, Y., Shen, H., Shih, J.S., Russell, A.G., Shao, S., Hu, Y., Odman, M.T., Nenes, A., Pavur, G.K., Zou, Y. and Chen, Z. (2020). Greater contribution from agricultural sources to future reactive nitrogen deposition in the United States. Earth's Future, 8(11), p.e2019EF001453.

The authors used wet deposition observations to estimate current and future impacts to areas in the US from reactive nitrogen compounds (nitrate, ammonium measured in NADP). Agricultural actives are important sources of many of these compounds. The Community Multiscale Air Quality model was used, Future nitrogen emissions from mobile and power generation should reduce this deposition. However, intensive fertilizer use areas and animal feeding operation areas could see significant increases of reactive nitrogen deposition, based upon economic estimates. Reactive nitrogen emissions from agriculture should continue to have important impacts on background areas, with agricultural emissions being the dominant source at several locations. The authors used NADP observations of nitrate and ammonium wet deposition from about 100 of our sites for the year 2010 as a baseline for the model.

4. Hinckley, E. L. S., Crawford, J. T., Fakhraei, H., & Driscoll, C. T. (2020). A shift in sulfur-cycle manipulation from atmospheric emissions to agricultural additions. Nature Geoscience, 13(9), 597-604.

These authors note that over the past 50 years, sulfur dioxide emissions and deposition rates from traditional combustion sources have peaked and are now nearing background levels. However, it is noted that agricultural additions of sulfur are now larger than combustion sourced sulfur (a main driver of acidic precipitation), and are now an important anthropogenic modification of the sulfur cycle. They show four case studies of high input of agriculture sulfur fertilizer and some of the environmental perturbations in soil and waterways as a result. The authors used NADP sulfur

deposition over time at many sites for measured deposition to the agricultural lands of these case studies.

5. Khan, M. S., Koizumi, N., & Olds, J. L. (2020). Biofixation of atmospheric nitrogen in the context of world staple crop production: Policy perspectives. Science of The Total Environment, 701, 134945.

The authors of this paper evaluate policy perspectives of the need for nitrogen fertilizer versus the impact upon natural ecosystems. They evaluate different solutions to fixing excess nitrogen, they suggest that biological fixation (BF) for staple crops, or designing of a microbiome that fix natural nitrogen in situ through genetic engineering. They provide a roadmap and recommendations for action by the agricultural community, including some very specific options to move forward. The authors used the National N picture of deposition using all of our sites and map products for the year 2016.

6. Tan, J., Fu, J. S., & Seinfeld, J. H. (2020). Ammonia emission abatement does not fully control reduced forms of nitrogen deposition. Proceedings of the National Academy of Sciences, 117(18), 9771-9775.

Agricultural emissions of reactive nitrogen (N) are well documented over the years. The authors used atmospheric chemistry models to estimate the impact of ammonia reduction on the reduction of nitrogen deposition over the U.S. The authors note the relatively straightforward reduction to NOx emissions and resulting depositional reductions. However, the authors conclude that a straightforward reduction in N deposition with ammonia emission restrictions will not likely occur. They report that significant reduction in NHx deposition is unlikely in the early reduction stages, and at best expect a 60-80% reduction of each N emission unit. The authors used both our observations of ammonia gas (AMON network) and our observations of ammonium wet deposition (NTN) in their analysis. Multiple years (2001-2010) of all of our sites were used.

7. Hu, C., Griffis, T. J., Frie, A., Baker, J. M., Wood, J. D., Millet, D. B., ... & Czarnetzki, A. C. (2021). A multiyear constraint on ammonia emissions and deposition within the US corn belt. Geophysical Research Letters 48(6): e2020GL090865.

The authors used tower-based and biweekly atmospheric measurements (NADP) of atmospheric ammonia and emissions estimates over the US corn belt combined with an atmospheric chemical model to model ammonia concentrations through several years. The authors conclude that NH3 emissions peak in early summer, were larger than typical emission estimates, were similar year to year, that meteorology and land management could have very large impacts on these emissions, and that roughly 40% of corn belt emissions were dry deposited locally leaving 60% to move away from corn growing areas. The authors used NADP's AMON concentration measurements within the corn belt for 3 years.

Part 4: Briefly describe how the broader public benefited from your project's activities.

Primarily, the public benefits from the scientific research that is conducted in part using our data. Our data is used in many different research projects primarily for environmental impacts. As these environmental issues are identified and understood through research, the changes made to alleviate these problems are a direct benefit to the broader public. A brief review of our publications list shows that our data is used towards many different research ends. Two examples are the impact of agricultural chemical/fertilizer use on the surrounding areas, and the impact upon agriculture lands from pollution deposition. These are typical types of data uses show examples of a direct impact upon the broader public.

NADP provides scientifically-sound measurements that many different government bodies (federal, state, local) can use to make more informed decisions. Many of our membership organizations (such as NOAA, National Park Service, Bureau of Land Management, etc.) use our data for their respective management practices on federal lands to help them make scientifically based policy decisions. For example, EPA's Office of Air uses our data to estimate the rate of sulfate removal from the atmosphere to help them track compliance with specific aspects of the Clean Air Act (acid rain issues). A second more recent example is that some agriculture extension services have begun to note that sulfate deposition has dropped so drastically over the past 40 years that some farmers need to consider adding sulfur as part of their fertilizer applications. Overall, better policy decisions by numerous agencies benefit the broader public.

Researchers use our samples and data to both identify environmental problems, and to track these issues for change over time. The public benefits from both the understanding of a problem and policy decisions meant to solve or alleviate the issue.

We provide our data, maps, trends and statistics to all users, beyond scientists and researchers. NADP provides data access and availability everyone at no charge from the NADP website, and all are welcome to use our data in any reasonable manner. The website offers online retrieval of all individual data points (weekly and biweekly), seasonal and annual averages, trend plots, concentration and deposition maps, reports, manuals, etc. Many different groups use our data (we track some information from downloads) including many different school districts for educational purpose, many college students and professors, environmentally related organizations, companies, and other organizations. One example is that educators often use our data for real-world scientific data for understanding environmental information and questions and for statistical applications.

Part 5: Comments (optional), Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

We have really had no major problems during the year with network operation, outside of issues presented by the pandemic, such as remote work, employee turnover, inflation, etc. However, during the COVID period, we only missed a few sample collections (about 6%) and this was mostly due to policies that did not allow people to enter federal lands/areas. Throughout, the NADP labs and Program Office continued to operate and had no work stoppage. Other than this, no major problems occurred out of the normal operational issues, so no major changes are planned in the next few years.

Distribution of data is free to all, and occurred normally. Distribution of the printed materials to other scientists and policy professionals that usually occurs at scientific meetings and talks was curtailed during the pandemic, but we do expect that this will return to normal as travel begins again.

We are continually looking for new and valuable measurements that can be made with our samples, with little additional costs (efficiency of funding). The following are being tested now.

a) NADP continued to collaborate with Utah State University scientists to develop methods to measure dry deposition accurately and correctly. This study continues to expand and will generate valuable dry deposition data, and perhaps expand the capabilities of the NADP to make dry deposition measurements directly (see Brahney, et al., 2020, A new sampler for the collection and retrieval of dry dust deposition, Aeolian Research, 45, 100600).

b) The NADP has begun a testing procedure to determine if we can accurately determine both total nitrogen and total phosphorus in our wet deposition samples from the NTN. With total N, our wet deposition nitrate and ammonium values will be subtracted, giving us a "measurement" of organic nitrogen compounds. The sampler will also be able to provide a total phosphorus deposition value, which is currently not reported (NTN measures orthophosphate only by request). Over the year, we have developed a separate wet deposition sampler that attaches to the NTN bucket sampler (since acid precharge is required). After the sampler design phase, initial testing of the idea has begun, and the sampler is collecting a quality precipitation sample. Now, we are testing the accuracy of our TN and TP measurements. TP is clearly being measured accurately. TN accuracy is good, but we have identified a few outlier observations that are being further reviewed. Once the accuracy determination is final, then we planning on considering the TN/TP measurement for general measurement within all NTN sites as a regular sampling analyte.

c) The NADP is working with a WSLH laboratory to evaluate whether Per- and Polyfluoroalkyl Substances (PFAS) compounds are found in precipitation. We are currently surveying precipitation at 8 sampling locations for these compounds, and find different compounds at detectible levels. This work will continue through the current year with expected publications coming soon. PFAS analysis is one option of future work identified within our Strategic Plan effort last year. PFAS is also of interest to agricultural scientist, given that at least one paper has shown uptake of PFAS compounds in cover crops and vegetables (Ghisi et al, 2019 Environmental Research V169 326-341).

d) The NADP is testing the accuracy of pollen grain capture in its NTN precipitation samples. We are comparing pollen capture efficiency and speciation

against the traditional measurement used by state health networks, a more traditional air quality high volume sample, and a new automated sampler ("PollenSense", using an automated microscopic method). This comparison is occurring at several NTN sites. The samples will show if the NTN network can be used as a pollen-monitoring network.