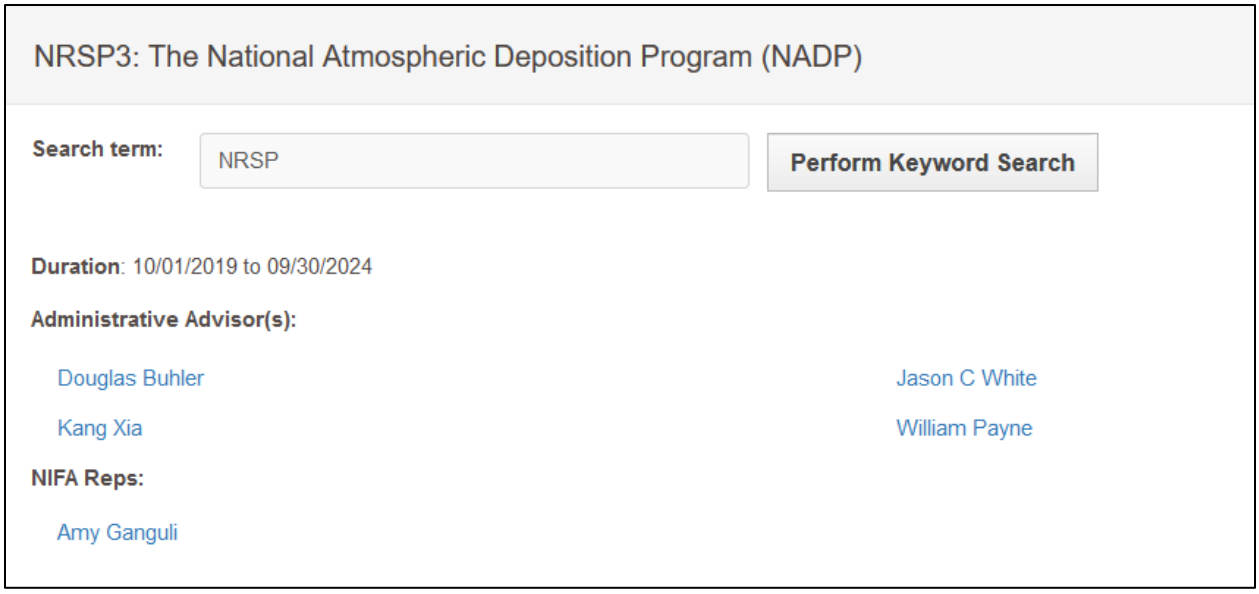

Annual Report

NRSP #3 The National Atmospheric Deposition Program (NADP)
2023

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

The movement of pollution into any ecosystem, whether a managed agricultural system or a natural and unmanaged system, changes the chemical nature of this ecosystem. Many pollutants move through the atmosphere from a pollution source to an endpoint ecosystem, and this change is a very important to monitor, track, and understand.

The National Atmospheric Deposition Program (NADP) monitors the nation's precipitation and the atmosphere for a range of chemical constituents to determine the rate or flux of atmospheric pollutants moving into the biosphere as wet-deposition of pollution (and dry deposition of pollution). With continued measurement, NADP provides the data necessary to determine whether spatial and temporal trends in concentration and wet/dry deposition exist, understand the direction and magnitude of chemical deposition trends and impacts of regulatory control measures, and understand

the impacts on agricultural systems. These research measurements and data are used by researchers to study and determine the impact this pollution flow has on all ecosystems in North America. The NADP measures the concentration and deposition rates of the following constituents: pH (H ion), specific conductance, sulfate, nitrate, ammonium, ortho-phosphate, chloride, calcium, magnesium, sodium, potassium, and mercury in precipitation; and mercury gases and ammonia in the atmosphere (for dry deposition estimates).

This project specifically provides management and coordination of NADP's five nationwide (with some international sites) networks: the National Trends Network (NTN), the Mercury Deposition Network (MDN), the Atmospheric Mercury Network (AMNet), the Ammonia Monitoring Network (AMoN), and the Mercury Litterfall Network (MLN). This agreement also provides site support, chemical analysis, and data validation for the 48 SAES National Trends Network sites (of 259 total sites) covered in this agreement.

The goals of the NADP are to:

1. Using best practices, conduct measurements of atmospheric and precipitation chemistry;
2. Use standard methods and procedures to ensure that the measurements are made with the utmost quality and are equivalent between sites and over time;
3. Make these measurement freely available to all users, with a particular emphasis on the research community and educators; and
4. Strive to advance environmental measurement science through discussion, testing of new methods, assisting others making similar measurements, general outreach, and data accessibility.

The NADP operates with technical and administrative guidance from the NADP Executive Committee and from cooperators (researchers, etc.) and subcommittees in a cooperative manner. All work described here is conducted in accordance with the NADP Quality Management Plan (https://nadp.slh.wisc.edu/quality-assurance/). All NADP data are available free of charge to any and all users.

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.

The National Research Support Project – No. 3 (NRSP-3) provides a framework for cooperation among State Agricultural Experiment Stations, the USDA-NIFA, and other cooperating governmental and non-governmental organizations. 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 and through dry deposition of several of these compounds.

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. Researchers also use NADP mercury data to examine the link to environmental and dietary mercury and human health (agriculture research priority of food safety).

In support of our measurement goals, the NADP's principal output is the collection of samples from it's constituent networks. During this reporting period (~9/30/2023), analytical data was reported for 13,400 NTN samples, 4,250 MDN samples, 2,400 AMON samples, and 100 MLN samples. AMNet sites operate very differently from these networks, and use onsite instruments. Each NTN sample has ten separate analytes (pH (H ion), specific conductance, sulfate, nitrate, ammonium, o-phosphate, chloride, calcium, magnesium, sodium, potassium). All analytical results undergo an extensive quality assurance review before release, so all data will be released when completed.

As a National Research Support Project, our principal goal/responsibility is to produce data that the research community uses. To track performance of this goal, the NADP counts the number of research journal and report publications each year that use NADP data. During 2023, we identified 191 publications (including many dissertations and theses) that used NADP data in some important way to further their research (183 articles in 2022). These publication counts will continue over the life of the program (complete lists here: https://nadp.slh.wisc.edu/pubs/nadp-bibliography/). We are also adding a searchable database of all NADP related publications, which will soon be complete and available.

For researchers to use and trust our data, quality assurance of this data is necessary. The NADP uses standard operating procedures for all sampling, laboratory, and data processes. The NADP has established best practice methods over the 45 years of program existence (https://nadp.slh.wisc.edu/siteops/). The NADP continually evaluates and updates the standard methods and procedures through guidance of the NADP Network Operations Subcommittee (NOS). We have quality assurance staff (1.3 FTEs) that continually review methods and data to ensure quality, and ongoing performance. Copies of any SOP and available upon request (https://nadp.slh.wisc.edu/quality-assurance/).

NADP laboratories and the Program Office typically undergo external review annually in rotation to identify systemic problems, improve performance, and provide external checks to the program. Audit team members are a mix of NADP members (not part of the paid staff) and external experts. During the project period, the Program Office was audited and responses provided.

To support the research data use goals of NADP and the NRSP program, NADP provides data access and availability to everyone at no charge from the NADP website (http://nadp.slh.wisc.edu). This 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. Downloads of data remained strong during 2023, with ~20,000 comma-delineated data file downloads (12,000 from the NTN), and about 50,000 pdf map images downloads. Internet availability of NADP data is the primary dissemination route. A NADP website redesign is now essentially complete.

In 2022, the Executive Committee made a decision to release precipitation measurements as a new and independent data set (without chemistry, ~350 sites). This task should be completed during early 2024. This will essentially be a new product available without additional funds.

The NADP annual map series of atmospheric concentrations, wet deposition fluxes, and report was developed and compiled in the fall of 2023 for the 2022 data and maps. The 2022 Map Summary was released in October 2023. For each summary, NADP produces a series of 23 national maps of wet deposition concentration and flux for all analytes, and summary figures for each gaseous network. Individual maps are filed by network, year, and constituent, and can be downloaded in several formats (http://nadp.slh.wisc.edu/data/annualmaps.aspx, http://nadp.slh.wisc.edu/lib/dataReports.aspx).

The NADP also strives to advance environmental measurement science (another goal) through discussion, testing of new methods, assisting others making similar measurements, and new approaches. Here are a few examples to meet this goal.

The NADP hosted and organized three meetings where these ideas were discussed: the Fall Scientific meeting, the Spring Business meeting, and the Summer Budget meeting. A diverse group of participants attended these meetings, including university researchers, SAES researchers, NIFA, a variety of federal agencies (EPA, USGS, NPS, Forest Service, FWS, BLM, and NOAA), many state government organizations, and Native American tribes. All meeting proceedings, minutes and most presentations are available on our website (https://nadp.slh.wisc.edu/conferences/).

Here are a few specific examples of new measurements/procedures being considered by NADP.

- PFAS Subnetwork: in Fall 2023, a new pilot network was approved for the monitoring of Per- and Polyfluoroalkyl Substances (PFAS) in precipitation. Planning and discussion of this network has occurred over the last several years. A final decision on longterm network permanence will be made in the next year. This network will be of particular interest to the SAES/USDA due to the fact that atmospheric loading of PFAS to agricultural lands can be substantial and these compounds are being identified in U.S. crops (e.g., Lesmeister et al., 2021, Science of the Total Environment 766: 142640).
- New MDN Collection Bag: initial work has begun on a redesign of the MDN sampling equipment. Currently, samples for mercury are collected in clean glassware, but this is quite expensive. The goal is to evaluate whether MDN samples can be collected in an entirely plastic sampling train (bag), that will be easier to use and much less expensive. Testing should be completed soon.
- Total Nitrogen Sampler: the effort continues to add total nitrogen capability (and by subtraction, organic nitrogen (ON)) to the regular NTN analyte suite. This required the development of a supplemental precipitation sampler that is affixed to the side of a standard NTN sampler – an effort that is essential complete. A TN/ON analysis in precipitation should be of interest to agricultural scientists, since many ON sources are thought to be of agricultural origin.
- Total Phosphorus Sampler: NADP has developed a method to measure Total P in the same Total N sample mentioned above. The NTN currently only measures ortho-phosphate, which represents only a small fraction of Total P. A total P measurement is important to those interested in the increase of algal blooms in lakes and rivers. Again, this topic has obvious connections to the agricultural community.

- The NADP is testing a measurement of Black Carbon (BC) in precipitation. BC in the atmosphere is related to wildfires, diesel emissions, and in prominent in urban airsheds, is important in climate energy balance, and has public health implications. During November 2022, all NTN samples from 14 sites were analyzed for BC. A journal article on these findings will be forthcoming. This idea has particular impact to the forestry community.

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

The NADP's target audience is primarily researchers (research support), but have three general target audiences for our data: researchers, policy professionals; and educators and students. Beyond our stated research support mission, we provide quality data to also help make informed decisions on environmental and agricultural issues related to precipitation and deposition chemistry, as well as promoting better science measurement and understanding (educators and students).

In brief, here are a list of the products that we have produced during the previous 12 months that benefit our target audiences:

Research data support

- 13,400 NTN measurements/observation of wet deposition of 10 analytes (pH {H ion}, specific conductance, sulfate, nitrate, ammonium, o-phosphate, chloride, calcium, magnesium, sodium, potassium);
- For all years (1978 through 2023), approximately 600,000 samples for 10 analytes;
- ~20,000 comma-delineated data records (12,000 from the NTN) downloaded and distributed;
- 50,000 pdf files of flux maps and map summaries downloaded and disturbed;
- Longer-term averages, in data format and in map products, including trends graphics by site and chemical component;
- Strict quality assurance of all data records, with each record classified as valid or invalid;

- Unrestricted data access to all;

All of this data is currently being used to do research and make better policy decisions

- 191 research publications during 2023 (182 in 2022);
- This total includes 11 dissertations and 10 theses (1 undergraduate);
- 15 Agricultural connected articles/topics (includes 3 extension documents);

Education

Although we are still improving our tracking of educational uses of our data, we do have some indications:

- As mentioned previously, there were 11 dissertations and 10 theses (1 undergraduate
- During the year, our data was used in a Chemistry text: Mosher, M., & Kelter, P., 2023. Acids and Bases. In An Introduction to Chemistry (pp. 693-742). Cham: Springer International Publishing (ISBN 978-3-030-90266-7), doi.org/10.1007/978-3-030-90267-4, Cham, Switzerland.

Here are five examples of the use of this SAES funding to support agriculturally-relevant research journal articles (NRSP goal):

1. Hagedorn, J., 2022. Examination of Soil Greenhouse Gas Fluxes and Denitrification to Assess Pollution Swapping in Agricultural Drainage Water Management. Doctoral Dissertation, Department Marine, Estuarine, and Environmental Science, University of Maryland, College Park.

   Hagedorn used the nitrogen input from fertilizer, atmospheric deposition and several other sources to estimate increases in nitrate (NO3) soil emissions due to fertilizer addition. Hagedorn used estimates of N deposition from several NTN sites over many years near the Chesapeake Bay.

2. Guo, X. 2022. Doctoral Dissertation, Environmental Eng., Princeton University.

   and

Guo, X., Pan, D., Daly, R.W., Chen, X., Walker, J.T., Tao, L., McSpiritt, J. and Zondlo, M.A., 2022. Spatial heterogeneity of ammonia fluxes in a deciduous forest and adjacent grassland. Agricultural and Forest Meteorology 326: 109128.

Guo et al. undertook the development of a fast response ammonia sensor based on laser adsorption to measure both emission and deposition of gaseous ammonia, which is an important atmospheric emission from agricultural fertilizer application and animal feeding operations. The authors used several of NADP's Ammonia Monitoring Network (AMoN) locations (principally NC30) and measurements over the time period of the study.

3. Stops, M.W., Sullivan, P.L., Peltier, E., Young, B. and Brookfield, A.E., 2022. Tracking the hydrologic response of agricultural tile outlet terraces to storm events. Agricultural Water Management 263: 107382.

   The authors investigated the management practice of Tile-Outlet-Terraces (TOT) management practice, and the chemical behavior of agricultural flow for three agrosystems in Kansas. The authors used 3 years of several NADP site wet deposition data of all analytes to define the wet deposition of all of these compounds.

4. Vira, J., Hess, P., Ossohou, M., & Galy-Lacaux, C., 2022. Evaluation of interactive and prescribed agricultural ammonia emissions for simulating atmospheric composition in CAM-chem. Atmospheric Chemistry and Physics 22(3): 1883-1904.

   The authors took a global approach to accounting for global atmospheric ammonia concentrations, with the largest contribution being from agricultural fertilizer and animal feeding operations. The authors used all of the NTN and AMON sites from NADP in their model simulations. They used a six-year period of observations, along with other continental networks for a global approach.

5. Benish, S. E., Bash, J. O., Foley, K. M., Appel, K. W., Hogrefe, C., Gilliam, R., & Pouliot, G., 2022. Long-term Regional Trends of Nitrogen and Sulfur Deposition in the United States from 2002 to 2017. Atmospheric Chemistry and Physics 22: 12749–12767.

   The authors determine both nitrogen and sulfur deposition trends (wet and dry deposition) for the continental United States, using a host of NADP and CASTNET observations of wet and atmospheric concentration measurements. The authors used all of NADPs observations for all observational years for sulfate, nitrate and ammonium, and also our AMON measurements of ammonia from the beginning of the network.

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

Given that NADP data is made available to all, and that our data is fundamental, it is used for a very wide variety of issues important to the Nation. The research impacts have been noted previously.

But additionally, our data is used by many government agencies (federal, state, tribal) to make more informed policy decisions. The NADP (in addition to SAES) is heavily funded by federal and state agencies, and is used by these agencies in a variety of ways by improving the science of deposition and pollution flow through ecosystems. We feel that we can make a strong case that the NADP data goes to many areas of scientific research that affects and improves policy decisions for the United States.

For educational purposes, It is clear that NADP provides data that get used in many different dissertations and theses, improving the quality of graduate education in many areas (agriculture, environmental, geographical, engineering based upon the departments listed with these documents). We typically have supported these efforts in 15 or so each year. Occasionally, we also record an undergraduate thesis. Although we have little documentation, we do know that our data support undergraduate education (understanding environmental problems, real world observations for projects, statistical education, text book materials). So primarily, we support education in science and science, technology, engineering and mathematics (STEM) classwork.

With to the leadership of the SAES scientists, and the highly diverse nature of this NRSP, there are many nationally-important issues that NADP data and information can and do contribute toward.

Agricultural Issues
Grand Challenges (from the *Science Roadmap for Food and Agriculture).*

- Grand Challenge 1 "*.. enhance the sustainability… of U.S. food and agricultural systems.",* through the monitoring of pollutants that are emitted from and deposited to agricultural land, feeding operations, and fertilizers (Nitrogen in particular).
- Grand Challenge 2 "*adapt to and mitigate the impacts of climate change...*", by monitoring precipitation at 300 sites, and the changes in pollution in precipitation with fuel changes and restrictions, as climate fchanges occur, and specifically the changes in air pollutant flow with increased cooling needs.

- Grand Challenge 3 "… *energy security and the development of the bioeconomy*…", by tracking the movement of Sulfur, Nitrogen, and Mercury compounds (all associated with energy production), we are documenting the change in atmospheric chemistry and deposition to lands as the evolution of energy production occurs, and monitor for air quality changes with increased biofuel production and increased electric generation.
- Grand Challenge 4 *"… leadership role to ensure a safe, secure, and abundant food supply...*", where NADP could support this challenge through the tracing of agricultural disease movement through the atmosphere (our samples have been used for this purpose, unofficially, with soybean rust spores), and through the increased need/use of fertilizers (i.e. potential pollutants).
- Grand Challenge 6 "… *heighten environmental stewardship through the development of sustainable management practices*.", where NADP easily supports this challenge by monitoring the emission of and the deposition to agricultural lands, with current and new practices for a large number of pollutants.

Overall, one of the principal advantages of the NRSP-3, is that it is a science-based observation network that can be restructured with additional techniques to look for a variety of pollutants (herbicides, pesticides, etc.), disease vectors, physical bodies (plastic) and others moving through the atmosphere.

<u>Other Challenges Addressed:</u>

- <u>Mercury</u> contamination is U.S. fish, through monitoring the main addition of mercury to a water body (precipitation), which also addresses Grand Challenge 4 (and 5, sustainable food supply);
- <u>General Air Pollution</u>: Documenting the presence and removal of inorganic pollutant gases and aerosols in the atmosphere (i.e., US "chemical climate"), all very useful in policy decisions, research modeling, source and sink relationships;
- Assessing the accelerated chemical weathering of material and cultural resources (limestone buildings, monuments;
- Evaluating the effectiveness of current Clean Air Act (CAA) and Clean Water Act (CWA);
- <u>Acidic Precipitation,</u> following the issue of acidic deposition, continued following of reduction of precipitation pH and acidification of soils and waters;
- <u>Nitrogen Fertilization;</u> with increased N deposition, NADP data is used in the research of <u>invasive species</u> in national parks, forests, and lakes.

- Algal Blooms has become a major environmental problem in recent years, and these are associated with both N and P atmospheric deposition (and fertilizer use). NADP supports this issue with both the NTN and AMON measurements, and possible future Total N and P measurements in wet deposition.
- Ammonia increases in the atmosphere; NADP data used to understand the shift from oxidized N compounds to a majority of reduced N compounds (NH3) which drives a shift in atmospheric chemistry and particulate levels. Note that agricultural sources of ammonia are very important.
- Studies have connected atmospheric N deposition to estuarine eutrophication and related low dissolved oxygen concentrations in lakes and rivers. NADP measures both wet deposition measurements of nitrate and ammonium.

These bullets only briefly describe a number of research areas where NADP has been used to address agricultural and environmental problems. The reader is encouraged to review the list of publications using NADP and the associated research issues addressed (https://nadp.slh.wisc.edu/pubs/nadp-bibliography/).

It is also important to note that NADP cooperates with similar organizations in Canada and Mexico, to evaluate similar issues on a continental scale, and with similar organizations in Europe and Asia to help evaluate similar issues in the Northern Hemisphere and around the Earth.

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.

The NADP is a monitoring cooperative, and strives to make the same measurements year in and year out with the same methods in a consistent way. No substantive changes are planned for operation of the network. Outside of normal issues with inflation and budget, the networks are operating well.

We are continually considering ways to make the network operation more efficient, and increase the throughput of samples and reduce the costs of laboratory services. Several methods we are considering is an improved mercury collection vessel (plastic bags, mentioned previously), automation of several laboratory steps, and improved data review system. More of these efforts will be reported in forthcoming year reports.

And as mentioned above, we will continue to make ourselves more relevant to the current research direction, by pursuing these new ideas (as mentioned previously):

- PFAS Subnetwork: the monitoring of Per- and Polyfluoroalkyl Substances (PFAS) in precipitation.
- Total Nitrogen Sampler: a new added sampler to measure total nitrogen and organic nitrogen in precipitator.
- Total Phosphorus Sampler: a new added sampler to measure total phosphorus in precipitator.
- Black Carbon analysis: a measurement of Black Carbon in precipitation.

<u>Training Opportunities:</u>

The NADP is constantly training operators on our equipment and methods, through a variety of means. NADP holds online video meetings, has video presentations, and

provides onsite and training over the phone of our operators. This basic training is for approximately 60-70 operators per year, and is constantly being repeated.

The NADP also, at times, holds special meetings that provide professional development on topics not covered at our two annual meetings. One example was the Spring 2022 Meeting, where the Mercury in the Environment and Links to Deposition (MELD) ad hoc Scientific Committee held an organizational meeting (minutes and attendees online).

Additionally, we have hired a series (currently 4) Association of Public Health Laboratories interns that were employed over the past year to assist (and learn) the various analytical as well as data management activities of the NADP. We have found them to be quite engaged and good students.

Additional Dissemination of Data

The primary route of data dissemination for the NADP is through its website, its databases, and its series of maps, all mentioned in the previous sections. NADP provides data access and availability for all; scientists, policymakers, educators, students, and others are encouraged to access data at no charge from the NADP website (nadp.slh.wisc.edu). Currently, the data is available through mid 2023 (quality assurance procedures require this normal delay) and the maps for 2022 were produced on schedule. 2023 maps will be drawn in the Summer, 2023.

Finally, the annual Fall NADP Scientific Symposium, in addition to other conferences, fosters the dissemination of NADP data to key stakeholders and researchers. In 2023 (hybrid), the meetings included a total of 41 oral presentations and approximately 20 posters. Details of the meeting are here (https://nadp.slh.wisc.edu/conferences/).