



Wet Deposition/Acid Rain

Resource Brief

Importance

Atmospheric deposition is the process in which airborne particles are deposited to lakes, streams, plants, and soils. Particles, including pollutants, can be deposited through rain, snow, clouds, and fog (wet deposition) and through dust, fine particles, and gases (dry deposition). Deposition affects ecosystems in a variety of ways, including acidification, fertilization, or eutrophication. Wet deposition of nitrogen (N) and sulfur (S) compounds is commonly known as acid rain.

Deposition of N and S compounds affects freshwater lakes, streams, and watersheds. Changes in water chemistry can affect algae, fish, submerged vegetation, and amphibian and aquatic invertebrate communities. Deposition can also cause changes in soil that affect soil microorganisms, understory plants, and trees. Excess N deposition can cause unwanted fertilization effects, leading to changes in plant community structure and diversity. Changes are driven by both the amount of air pollutants deposited

and the sensitivity of the place where the pollutants land. Materials including limestone, marble, bronze, and brass are also vulnerable to N and S deposition.

Sources of human made atmospheric S include power plants and industries. Sources of human made atmospheric N include power plants, industries, vehicle exhaust, oil and gas production, fertilized crops, livestock production, and municipal and residential activities.



Photo: NPS/Lehman

The rain drops that dot this jewel weed (*Impatiens capensis*) may carry dissolved airborne pollutants.

Monitoring

Wet deposition is monitored through cooperation with the National Atmospheric Deposition Program/National Trends Network (NADP/NTN). Precipitation samples are collected weekly at monitoring stations across the country. Samples are analyzed for S (as sulfate [SO₄]), for N (as nitrate [NO₃] and ammonium [NH₄]), and for calcium, chloride, potassium, magnesium, and sodium.

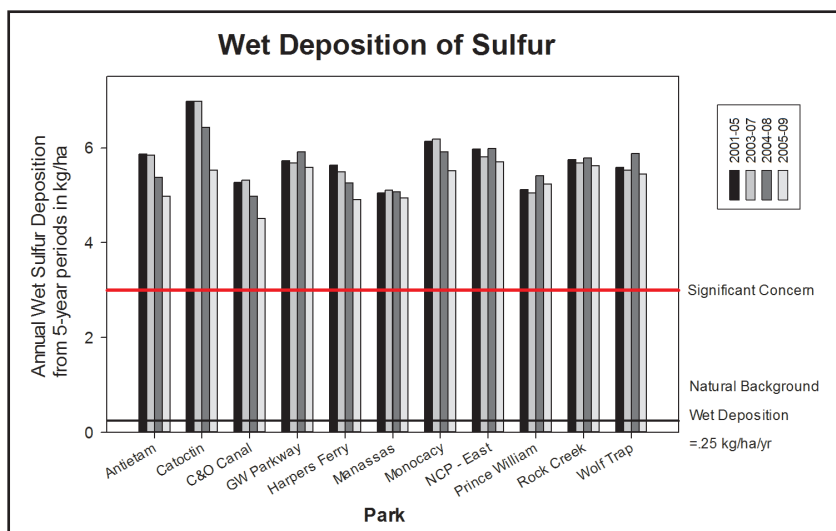
The monitoring sites in and nearby to the National Capital Region Network (NCRN) are: MD07 located at Catoctin Mountain Park; MD99 at Beltsville, MD; MD03 at Finksburg, MD; WV18 at Parsons, WV; MD13 at Wye, MD; VA28 at Shenandoah National Park, VA; and PA00 at Arendtsville, PA. Data from these sites and others are interpolated to estimate wet S and N deposition at the center of each NCRN park. Estimates are based on a five-year average to smooth out year-to-year variability.

Dry deposition is monitored by the Clean Air Status and Trends Network (CASTNet). There is one NCRN site at Beltsville, MD (BEL116).

Sensitive Ecosystems

In general, ecosystems in the NCRN are more susceptible to acidification than to nutrient enrichment and eutrophication, especially the more northern NCRN parks of Antietam, Catoctin, C&O Canal, and Harpers Ferry.

Lower, more acidic pH levels in lake and stream waters



Wet sulfur deposition rates in the NCRN are of "significant concern" and can cause acidification that affects plant health and water quality.



increase the bioavailability and toxicity of aluminum which can lead to asphyxiation of fish and amphibians. Plants like sugar maple and red spruce are especially sensitive to acid rain. These and other plants can exhibit visible death of plant tissue, break down of the waxy covering on leaves, faster leaching of leaf nutrients, and in conifers, reduced seed germination and seedling growth. Some lichens are also especially sensitive, with documented effects occurring in the deposition range of 1 to 2 kilograms of N or S per hectare per year (kg/ha/yr).

Results

Compared with other I&M networks, emissions, atmospheric deposition, and pollutant exposure in the NCRN are among the highest in the country. Total atmospheric deposition rates (a combination of both wet and dry deposition) are very high in the NCRN but actual levels are difficult to calculate. Dry deposition data is very limited in many parts of the country, including the NCRN, so NPS uses wet deposition data to evaluate trends.

Although there are large uncertainties associated with dry deposition estimates, models* suggest that dry deposition in

the NCRN may be twice as high as wet deposition. When combining wet deposition NADP data from 2002 and modeled dry deposition estimates for the same time period, total S deposition within the NCRN generally ranged from 10 to 20 kg/ha/yr, with several smaller areas in the range of 20 to 30 kg/ha/yr. Total N deposition within the network generally ranged from 10 to 15 kg N/ha/yr to as high as 15 to 20 kg N/ha/yr, with the higher values mainly in and around Washington, DC.

NCRN wet deposition rates between 2001 and 2009 for N exceeded 3 kg/ha for every five year period calculated. Rates of wet deposition of S in the same periods exceeded 4 kg/ha (see graph). Wet deposition rates of more than 3 kg/ha/yr are considered to cause an elevated risk for impacts to plant health and water quality. (Natural background levels of N and S wet deposition in the east are about 0.25 kg/ha/yr.)

While current wet deposition levels are elevated, trends in the NCRN are improving. Since 2001, wet deposition of N has decreased at 7 NCRN parks and wet deposition of S has decreased at 10 NCRN parks. Additionally, NADP/NTN monitoring stations in Beltsville and Catocin, MD, show that from 2004-2010, the average pH of precipitation, although still more acidic than typical rainwater (5.6) has slowly risen (gotten less acidic). In 2010, the average pH of precipitation at both stations was ~4.85.

*Dry deposition was estimated with the CMAQ (Congestion Mitigation and Air Quality improvement) model. CMAQ takes into account more forms of nitrogen than actual wet deposition monitoring.

References

- Lawrey, J.D. 2011. A lichen biomonitoring program to protect resources in the National Capital Region by detecting air quality effects. Natural Resource Program Center, Fort Collins, CO. NRTR NPS/ NCRN/NRTR -- 2011/450. https://nriinfo.nps.gov/Reference.mvc/DownloadDigitalFile?code=428476&file=Lawrey_2011_Lichen_Bioindicators_Final_Report.pdf
- Environmental Protection Agency. Measuring Acid Rain. <http://www.epa.gov/acidrain/measure/index.html>. Accessed 12/22/11.
- National Park Service, Air Resources Division. 2010. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, Colorado. http://www.nature.nps.gov/air/Pubs/pdf/gpra/AQ_Trends_In_Parks_2009_Final_Web.pdf
- National Park Service, Air Resources Division. 2011. Technical guidance on assessing impacts to air quality in NEPA and planning documents: January 2011. Natural Resource Report NPS/NRPC/ARD/NRR—2011/289. National Park Service, Denver, Colorado.
- National Park Service, Air Resources Division. Air Quality Estimates. http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm. Accessed 12/22/11.
- Peterson, M.A. 1982. Effects of air pollution and acid rain on fish, wildlife, and their habitats urban ecosystems. Report No. 10. FWS/OBS-80/40,10.
- Sparling, D. W., T. P. Lowe, and P. G. C. Campbell. 1996. Ecotoxicology of aluminum to fish and wildlife. Page 47. *in* Yokel, R.A. and M.S. Golub, editors. Research issues in aluminum toxicity. Taylor & Francis, Washington, DC.
- Sullivan, T. J., et al. 2011. Evaluation of the sensitivity of inventory and monitoring national parks to acidification effects from atmospheric sulfur and nitrogen deposition: National Capital Region Network (NCRN). Natural Resource Report NPS/NRPC/ARD/NRR—2011/367. National Park Service, Denver, Colorado. http://www.nature.nps.gov/air/Pubs/pdf/acidification/ncrn_acidification-eval_2011-05.pdf
- Sullivan, T. J., et al. 2011. Evaluation of the sensitivity of inventory and monitoring national parks to nutrient enrichment effects from atmospheric nitrogen deposition: National Capital Region Network (NCRN). Natural Resource Report NPS/NRPC/ARD/NRR—2011/317. National Park Service, Denver, Colorado. http://www.nature.nps.gov/air/Pubs/pdf/n-sensitivity/ncrn_n_sensitivity_2011-02.pdf