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Chesapeake Bay Activities

Atmospheric nitrogen deposition in the Chesapeake Bay watershed: A history of change

Issue: Atmospheric deposition is one of the principal sources of nitrogen to the Chesapeake watershed with implications for patterns of nutrient loading, anoxia, and eutrophication in the Bay.

Reducing nutrients to tidal waters was an important goal of the Chesapeake Bay Program (CBP) when it was initiated in 1987, but the role of atmospheric nitrogen deposition as a nutrient source to the Bay was not well recognized at that time. However, publication of a pioneering 1991 study (Fisher and Oppenheimer, 1991) as well as subsequent investigations concluded that ¼ to more than ⅓ of the nitrogen load to the Bay originated as atmospheric deposition to the watershed and tidal waters. By 1992, the CBP partnership models used to guide management decisions on reducing nutrients began simulating atmospheric nitrogen deposition. Inclusion of atmospheric deposition in the Chesapeake Total Maximum Daily Load (TMDL) nutrient allocations in 2010, represented an unprecedented linkage of the Chesapeake TMDL to the national Clean Air Act's NOx emission reduction requirements.

By the mid- to late-1990s, implementation by Congress of the Clean Air Act Amendments of 1990 resulted in sharp decreases of oxidized nitrogen emissions within the Chesapeake airshed (see figure 1) which in turn resulted in declining atmospheric nitrogen deposition to the Bay watershed and tidal waters. Recent observations and model simulations have recognized the important contribution of declining levels of atmospheric nitrogen deposition to observations of declining nitrogen loads to the Chesapeake Bay.

USGS Study: The USGS, and science partners in the CBP Modeling Team, implemented this investigation to (1) document the history and evolution of atmospheric nitrogen investigations in the

Status - Completed

Contacts

Douglas Burns

Research Hydrologist (RGE)
New York Water Science Center
Email: daburns@usgs.gov
Phone: 518-285-5662

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Chesapeake Bay watershed and (2) to quantify the trends and patterns of nitrogen loads from the atmosphere relative to those of other nitrogen sources over a century-long time period. The specific objectives were to:

1. review and describe the history and evolution of knowledge and approaches used to estimate the relative importance of atmospheric nitrogen loads to the Bay,
2. describe trends in measured atmospheric nitrogen deposition from two monitoring networks and the policies responsible for those trends,
3. describe a new data set that provides past estimates (from 1950) and future projections (to 2050) of atmospheric nitrogen deposition.

Some considerations discussed in the journal article include:

- Although a broad consensus emerged regarding the role of atmospheric nitrogen deposition relative to other sources such as fertilizer and manure, results have varied due to a wide range of approaches and assumptions applied in past investigations such as the nitrogen chemical species included, whether deposition to the watershed and the Bay were both considered, and especially the years used in the analysis.
- The conclusions of recent investigations have differed regarding the relative role of decreases in atmospheric nitrogen deposition as a driver of declining nitrogen loads to the Bay. These differences have not been fully resolved but one factor identified in this paper as an important influence on conclusions is the extent to which a complete representation of transport and retention processes from deposition on the landscape to delivery to the tidal waters was considered.

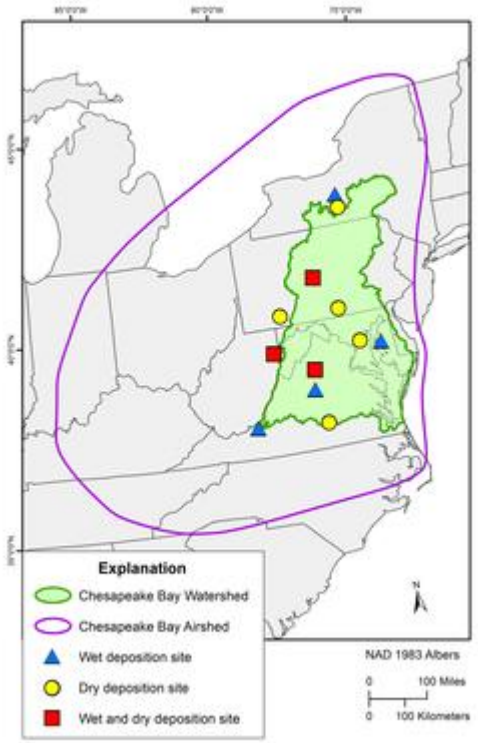

Figure 1. Map showing the Chesapeake Bay watershed, and the Chesapeake airshed. (Burns and others, 2021) https://doi.org/10.1016/j.atmosenv.2021.118277

Major Findings:

- Atmospheric deposition is an important nitrogen source to the Chesapeake Bay and was dominant among fertilizer, manure, and wastewater sources from about 1960 to 2000.

- Atmospheric nitrogen deposition was estimated to have peaked at about 15 kg/ha/yr in the year 1979.
- Implementation of Title IV of the Clean Air Act Amendments of 1990 has resulted in estimated decreases of 60% to 73% in wet and dry deposition of oxidized nitrogen and dry deposition of reduced nitrogen in the Chesapeake watershed during 1995 to 2019 (see figure 2).
- Wet deposition of reduced nitrogen in the form of ammonium has not changed significantly during 1995 to 2019, consistent with an assumption that ammonia emissions in the Chesapeake airshed have not changed during this period.
- Despite observed decreases, atmospheric nitrogen deposition was estimated to still contribute about 25% of the total nitrogen load to the Chesapeake watershed (not the Bay) as of 2015.
- A future projection based on planned implementation of Clean Air Act rules suggests that atmospheric nitrogen deposition to the Chesapeake watershed is likely to decline by an estimated additional 21% from 2015 to 2050.

Management Applications:

Reducing atmospheric nitrogen deposition is one approach to help the CBP jurisdictions meet their allocations for the TMDL. The additional decline in atmospheric nitrogen deposition of 21% projected from 2015 to 2050 highlights the potential for atmospheric deposition to further support declines in nitrogen loads to the Bay. However, these projections are dependent on assumptions about implementation of rules planned as part of Clean Air Act requirements as of the year 2011. Each administration typically proposes their own set of Clean Air Act rules, suggesting that projected declines could be greater or less than those projected, highlighting the opportunity for air quality management policies to affect future rates of atmospheric deposition.

For more information:

The journal article from the investigation is:
Burns, D.A., Bhatt, G., Linker, L.C., Bash, J.O., Capel, P.D., Shenk, G.W., 2021, Atmospheric nitrogen deposition in the Chesapeake Bay watershed: A history of change, Atmospheric Environment, 251: 118277, https://doi.org/10.1016/j.atmosenv.2021.118277.

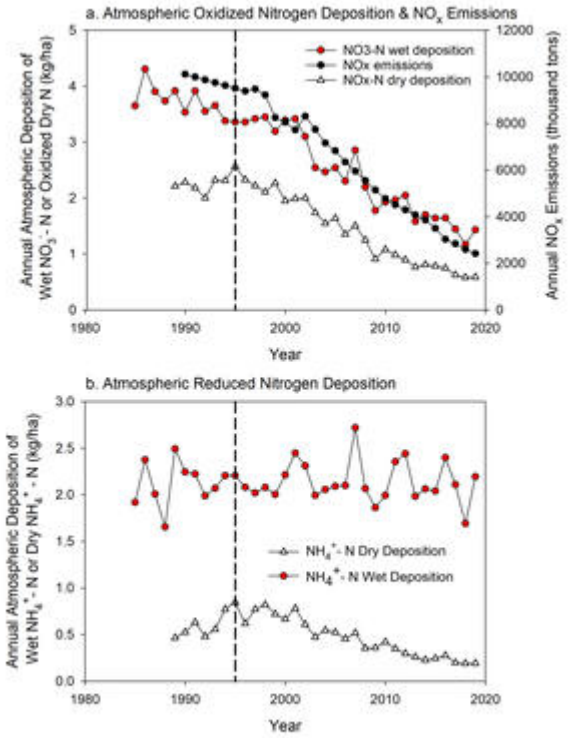

Figure 2. Annual atmospheric wet and dry N deposition at selected sites and NO_x emissions in the

Data that support the findings in this journal article are available in Hopple et al. (2020, 2021):

- Hopple, J.A., Bhatt, G., Bash, J.O., Burns, D.A., Capel, P.D., Jones, P.M., Linker, L.C., Terziotti, S., 2020. Estimates of atmospheric inorganic nitrogen deposition to the Chesapeake Bay watershed, 1950-2050. U.S. Geological Survey data release. https://doi.org/10.5066/P9AIZGLX.
- Hopple, J.A., Capel, P.D., Sekellick, A.J., Bhatt, G., Burns, D.A., Claggett, P.R., Clune, J. W., Jones, P.M., Kalk, F.K., Linker, L., Miller, M.P., Terziotti, S., 2021. Nitrogen sources to and export from the Chesapeake Bay watershed, 1950 to 2050. U.S. Geological Survey data release. https://doi.org/10.5066/P953SO6P.

The original study of atmospheric deposition in the Chesapeake is:
Fisher, D.C., Oppenheimer, M., 1991. Atmospheric nitrogen deposition and the Chesapeake Bay estuary. Ambio 20, 102–108.

Contact Doug Burns daburns@usgs.gov

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