

## Why do we care about Nitrogen?

All life needs nitrogen (a nutrient and component of protein) for growth and survival. However, too much nitrogen can cause adverse health effects (in drinking water) or environmental degradation (especially in coastal waterways). In this fact sheet, we will discuss the many forms of nitrogen and how it cycles through the environment, the health and environmental effects of excess nitrogen, the water quality standards for nitrogen, and what you can do to minimize the amount of nitrogen released into the environment.

## Nitrogen and Its Forms

Nitrogen (N) exists in the environment in many forms. Nitrogen is the most abundant element in the atmosphere; nitrogen gas ( $N_2$ ) makes up 78% of the air we breathe. However, most organisms cannot use  $N_2$  directly.  $N_2$  is converted to more usable forms of nitrogen via *fixation* (Box 1). The three other major forms of nitrogen are: organic N, ammonium ( $NH_4^+$ ), and nitrate ( $NO_3^-$ ). Figure 1 depicts the nitrogen cycle, the processing of N into different forms.

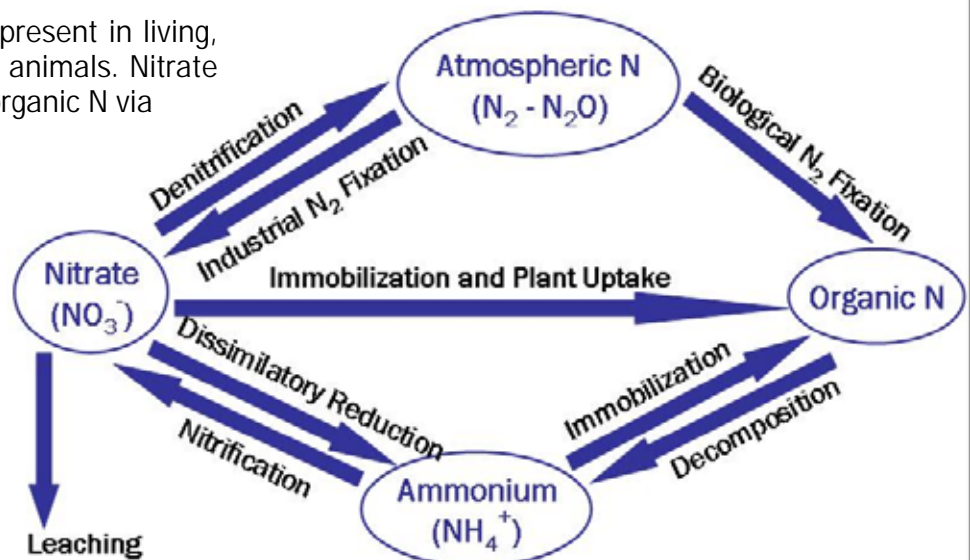
**Organic N** is simply the N that is present in living, dead, or decomposing plants and animals. Nitrate and ammonium get converted to organic N via

*plant uptake* and *immobilization* (microbial uptake of nitrogen). When abundant, ammonium is preferred by plants over nitrate. Animals consume plants and animals (which have fed on plants) to get their supply of N. When plants and organisms die and decompose, ammonium is released back into the environment.

**Ammonium** is the most reactive form of N in aquatic systems. Because it is positively charged, it readily adheres to soils and sediment. In addition to decomposition, ammonium levels can be increased by *dissimilatory reduction*, a process of microbes converting nitrate to ammonium when oxygen is not present. The reverse process also occurs—microbes can convert ammonium to nitrate in *nitrification*.

**Nitrate** is typically the most common form of inorganic N in lakes and streams. Unlike ammonium, nitrate generally does not bind to soils and sediment so it is likely to leach into groundwater where it will be transported to streams and coastal waterways. In addition to the processes listed above, nitrate is involved in *denitrification*, a process in which bacteria convert nitrate to gaseous N ( $N_2$  or  $N_2O$ ) under zero oxygen, or anoxic, conditions. Denitrification is the only process that completely removes N from the soil-water environment.

Figure 1: The Nitrogen Cycle



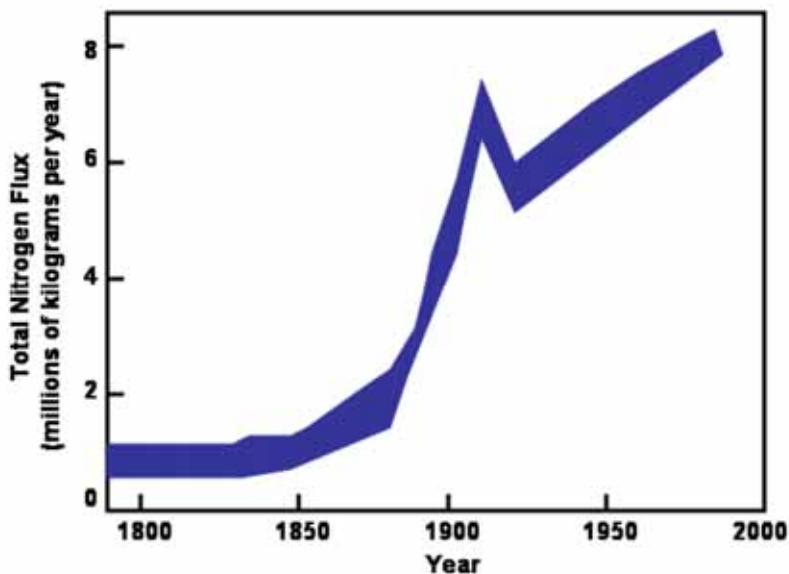
## Why Is There Excess N in the Environment?

Nitrogen in soil and water can originate from many sources, most notably commercial fertilizers applied to lawns, gardens and cropland, livestock manure, pet waste, septic systems, and leaking sewers. Some N enters water from the atmosphere, which carries N-containing compounds derived from automobiles and other sources. The advent of industrial N fixation has meant that American farmers routinely achieve levels of crop productivity that seemed improbable in the early 1900s. Before World War I, the world annually produced 0.6 million tons of nitrogen fertilizers. Today, the United States alone produces about 12 million tons of nitrogen fertilizers annually (Trautmann et al. 1998). Unfortunately, crop production gains through industrial fertilization may incur human health and environmental costs. If the amount of N applied exceeds the crop or lawn need, as is often the case, the extra N escapes to ground and surface waters (Fig. 2).

## What Are the Impacts of Excess N?

The primary health hazard from drinking water with high levels of nitrate-N (> 10 parts per million (ppm)) is "blue-baby syndrome," in which blood lacks the ability to carry sufficient oxygen to cells. Most adults are not susceptible to this condition, but infants under six months of age, pregnant women, nursing mothers, and the elderly may be at an elevated risk. For more information on nitrate-N in private drinking water wells, please refer to the following University of Rhode Island Cooperative Extension fact sheet: <http://www.uri.edu/ce/wq/has/html/Nitrate.pdf>.

*Figure 2: Nitrogen Levels in Narragansett Bay increased dramatically before 1900, after installation of a public water supply and sewer system. After 1950, fertilizer usage contributed to increased N. (Adapted from Nixon 1998)*



## Box 1: Nitrogen Fixation

1. Atmospheric fixation occurs when lightning breaks the N molecules apart and combines them with oxygen, often in the form of nitrate. Atmospheric fixation contributes only 5-8% of the total N fixed.
2. Biological fixation takes place in some naturally occurring bacteria. These particular bacteria often live in a symbiotic relationship (two dissimilar organisms living together to the benefit of both) with certain plants, including alders and the legume family (i.e., soybeans and alfalfa; which is why farmers use alfalfa as a cover crop - it helps to fertilize the soil naturally). In aquatic environments cyanobacteria, e.g., blue-green algae, fix N. The N from this process is quickly taken up by organisms.
3. Industrial fixation is a man-made process. Under high temperature and pressure, N<sub>2</sub> and hydrogen, usually from natural gas or petroleum, is combined to form ammonia (NH<sub>3</sub>). Often, it is processed further to nitrate for fertilizer use.

Excess levels of nitrate-N can cause environmental problems too. Nitrate-N is usually the most abundant form of N in lakes and streams. Nitrate-N concentrations > 1 ppm typically indicate human impact of some sort. Concentrations of nitrate-N are of particular concern in coastal or salt water systems where it is the nutrient that in excess can cause cultural eutrophication (Ryther and Dunstan 1971; Nixon 1993). When eutrophication occurs, algal and plant growth is stimulated, water clarity is decreased, deep waters become depleted of dissolved oxygen, and fish and shellfish death may result. A fish kill in the summer of 2003 received much attention spurring public interest (Fig. 3). Review RI DEM's report to the Governor for more information on that event: <http://www.ci.uri.edu/projects/pnb/Documents/Greenwich-Bay-Fish-Kill-Report-to-Governor.pdf>

## Nitrogen Standards

**Nitrate-N standards** take two forms: drinking-water standards - designed to prevent adverse human-health effects, and ambient-water standards - designed to prevent excessive eutrophication in lakes and streams.

1. Drinking Water Standards. EPA's drinking water standard for nitrate-N is 10 ppm (US EPA 1996). This standard is to prevent health risks associated with drinking water with elevated nitrate-N. As with most states, RI adopted the EPA guideline as its standard. For more information on drinking water standards in RI, visit the RI Department of Environmental Management (DEM) website at: <http://www.state.ri.us/dem/pubs/regs/REGS/WATER/GWQL8-96.PDF>.
2. Surface water quality standards. EPA recently set guidelines for determination of nutrient criteria for various types of water bodies in different regions (For more information on the ecoregional nutrient criteria, see the EPA website at: <http://www.epa.gov/waterscience/standards/nutrient.html>). These recommended water quality criteria can help states identify problem areas, serve as a basis for state water quality criteria for nutrients, and evaluate relative success in reducing cultural eutrophication. Rhode Island is in Ecoregion XIV where EPA suggests total N criteria of 0.32 and 0.71 ppm for lakes/reservoirs and rivers/streams, respectively. States are being encouraged to incorporate these criteria into state regulations. For Rhode Island's fresh and sea waters, N water quality standards vary by water body classification. The RI Department of Environmental Management (DEM) tries to prevent N concentrations that will impair usages for specific classes or cause undesirable or nuisance aquatic species associated with cultural eutrophication. For more information on surface water quality standards in RI, visit the RI DEM website at: <http://www.state.ri.us/dem/pubs/regs/REGS/WATER/h2Oqlty.pdf>.

For **surface ammonium-N water quality standards**, EPA is re-evaluating the current water quality criteria to determine if they should be revised to reflect new toxicity data. For more information see the EPA website at: <http://www.epa.gov/waterscience/standards/ammonia/>.

Figure 3: Excess levels of N in coastal waterways may cause nutrient overenrichment leading to lack of oxygen and fish kills (Photo from RI DEM).



### Box 2: Rhode Island Waterways

URI Watershed Watch (URI WW) typically does not monitor private drinking water wells, thus does not have groundwater data. Less than half of the URI WW lakes have detectable levels of nitrate-N, i.e., 0.04 ppm, and all lakes were below the drinking water standard. For total N, 80% of the lakes monitored by URI WW exceeded the EPA suggested EcoRegion criteria of 0.32 ppm indicating the impact of humans in the state. All streams and rivers monitored by URI WW were below the drinking water standard. For total N, 27% of the streams and rivers monitored by URI WW exceeded the EPA suggested EcoRegion criteria of 0.71 ppm. URI WW data on nitrate-N and total N can be found online at: [http://www.uri.edu/ce/wq/ww/html/ww\\_data.htm](http://www.uri.edu/ce/wq/ww/html/ww_data.htm) under parameter data for individual years.

Historically, no URI WW sites have shown ammonium-N concentrations considered toxic to aquatic organisms. Often, these sites have no detectable levels of ammonium-N. However, expanded mid-summer deep lake sampling found that some lakes contained high ammonium-N concentrations in the bottom waters. These deep locations were already known to be depleted of oxygen in mid to late summer (see fact sheet *Dissolved Oxygen and Temperature* <http://www.uri.edu/ce/wq/ww/resources/dotemp.pdf> for more info) and hence were already showing signs of cultural eutrophication. URI WW will conduct follow-up monitoring at these sites.

In 2004, RI DEM stated in its 305b Report (<http://www.state.ri.us/dem/pubs/305b/>) that the major impacts on designated uses for the estuarine waters of RI were due to bacterial contamination, low dissolved oxygen, and nutrient enrichment.

## Minimizing N Problems in RI

There are many ways to reduce N levels in the environment. First, N can be prevented from entering the environment - [source reduction](#). For instance, homeowners and farmers are being taught to have their soil tested so that they only apply as much fertilizer as their soil needs. Alternatively, treatment measures or [best management practices](#) (BMPs) can be implemented to remove N once it has entered the environment. In areas with sensitive groundwater resources and challenging soils, alternative septic systems, which reduce N concentrations more than conventional systems, are being researched and gaining popularity (see the URI Onsite Wastewater Training Center: <http://www.uri.edu/ce/wq/owtc/html/owtc.html>). Farmers or homeowners can create vegetated buffer zones to filter excess N before it reaches groundwater or waterways. Preventing excess N from leaching into ground and surface waters is typically much more cost effective than removing it after it has entered these environments.

In 2004, Rhode Islanders approved a referendum that authorizes Rhode Island to conduct anti-pollution projects and restoration activities benefiting Narragansett Bay and state watersheds. These funds will support open space, farmland preservation, recreational development, and acquisition of land for groundwater protection and supply. Much of the focus will be on preventing N from entering Narragansett Bay. Also in 2004, the Rhode Island Legislature passed an act to implement measures to achieve an overall goal of reducing N loadings from wastewater treatment facilities by 50% by 2008. For more information on these actions, see *Save the Bay*: <http://www.savebay.org/Advocacy/WastewaterPermits.asp>.

The R.I. Coastal Resources Management Council (CRMC) is coordinating with Warwick, East Greenwich, government agencies, and community groups to prepare the Greenwich Bay Special Area Management Plan (SAMP). The SAMP describes the present status of the bay, characterizes its watershed, identifies sources of pollution, and recommends steps to help government work with communities to restore, protect, and balance uses of Greenwich Bay. To learn more, visit the RI Sea Grant website at: [http://seagrant.gso.uri.edu/G\\_Bay/Management/SAMP/](http://seagrant.gso.uri.edu/G_Bay/Management/SAMP/).

## For more information:

Nixon, S.W. 1993. Nutrients and coastal waters: Too much of a good thing? *Oceanus* 36:38-47.

Nixon, S.W. 1998. Enriching the Sea to Death. *Scientific American Presents* 9: 48-53.

Rhode Island Department of Environmental Management. 2003. Greenwich Bay Fish Kill – August 2003: Causes Impacts and Responses. <http://www.ci.uri.edu/projects/pnb/Documents/Greenwich-Bay-Fish-Kill-Report-to-Governor.pdf>

Rhode Island Health Department and the University of Rhode Island Cooperative Extension. 2003. Nitrate-Nitrogen in Private Drinking Water Wells. Private Well Series. <http://www.uri.edu/ce/wq/has/html/Nitrate.pdf>

Ryther, J.H. and W.M. Dunstan. 1971. Nitrogen, phosphorus, and eutrophication in the coastal marine environment. *Science* 171:1008-1013.

Trautman, N.M., K.S. Porter, and R.J. Wagenet. Nitrogen: The Essential Element. Cornell Cooperative Extension. <http://pmep.cce.cornell.edu/facts-slides-self/facts/nit-el-grw89.html>

U.S. Environmental Protection Agency, 1996, Drinking water regulations and health advisories: U.S. Environmental Protection Agency report EPA-822/B-96/002, 11 p.

To learn more about the URI Watershed Watch program or Nitrogen monitoring, please contact:

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<https://web.uri.edu/watershedwatch>



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## *What YOU can do to prevent Nitrogen and Phosphorus contamination of our waterways*

- **Maintain your septic system** (For more information please see septic system fact sheets from URI Cooperative Extension: [http://www.uri.edu/ce/wq/has/html/has\\_septicfacts.html](http://www.uri.edu/ce/wq/has/html/has_septicfacts.html)):
  - \* Have it inspected every year or two;
  - \* Have it pumped regularly, every 1 - 3 years;
  - \* Replace an old system to meet new standards, and
  - \* Avoid using garbage disposals.
- **Manage lawn and garden fertilizer use:**
  - \* Have your soil tested. Only apply the amount of fertilizer your lawn needs (See the University of Massachusetts Soil and Plant Tissue Testing Laboratory: <http://www.umass.edu/plsoils/soiltest/>);
  - \* Use a mulching lawnmower (grass clippings recycle nitrogen to your lawn);
  - \* Use slow-release fertilizers;
  - \* Do not rinse spilled fertilizer off paved surfaces, instead sweep excess up or onto lawn;
  - \* Store fertilizer in a water-tight container on a concrete floor; and
  - \* Do not throw grass clippings or leaves into the water.
- **Plant a buffer strip of plants or shrubs between your lawn and lake/river;** this zone may absorb excess nitrogen before it can enter the waterbody.
- **Support maintaining wetlands in their natural states.** Wetlands help filter nitrogen as well as other nutrients and pollutants.
- **Properly dispose of pet waste (garbage).** Please remove your pet's waste, especially when walking your pet along a waterway.
- **Do NOT feed waterfowl.**
- **Direct roof downspouts to broad, grassy areas** so rain, along with sediments and nutrients, has a chance to seep into the ground rather than run off.
- **Conserve water.** For example, use low-flow shower heads or place a brick in the toilet tank.
- **Correct soil erosion problems immediately!** Steep, sloping banks and exposed soil should be seeded or terraced to prevent erosion.

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