ENVIRONMENT

Wastewater Is Key to Reducing Nitrogen Pollution

Upgrading wastewater treatment plants can dramatically reduce a municipality's nitrogen footprint

By Susan K. Moran on June 2, 2016

Dead zones are often caused by the decay of algae during algal blooms. Above, a girl looks at an algal bloom at Clovelly Beach in Sydney, Australia. Credit: Photo by Edwina Pickles/The Sydney Morning Herald/Fairfax Media via Getty Images

Nitrogen is a vital nutrient for crops, but soils rarely produce enough of it to sustain the relentless farming needed to feed a world population that has more than doubled in the past 50 years. For almost a century synthetic fertilizer has made up the difference, driving up crop yields. Yet we have overindulged, creating vast quantities of waste. Globally, more than 90 percent of the nitrogen used to produce meat and dairy products, along with 80 percent used to grow plant-based foods, is lost to the environment. It contaminates streams, lakes and oceans as well as drinking water, and fuels the growth of algae and other organisms that can suffocate fish and kill plants. And much of the nitrogen that crops and livestock do absorb, and we thus consume,

exits our bodies as sewage, a significant source of nitrogen pollution when it is not sufficiently treated.

"Nitrogen pollution is one of the biggest environmental challenges that we face," says James Galloway, a biogeochemist at the University of Virginia who has been studying the issue for nearly 40 years. "Nitrogen is critical for food security but it is clearly harming human and environmental health."

Among the consequences is the Gulf of Mexico, a poster child of nitrogen pollution, where agricultural runoff that seeps into the Mississippi River and flows into the Gulf has created "dead zones" where no fish can live. Nitrogen fertilizer also contributes to climate change; nitric oxide, a by-product of fertilizing fields, is a potent and long-lived greenhouse gas. And nitrogen fumes from fertilizer combine in the air with industrial emissions to form tiny, solid particles that can creep into our lungs and cause heart or pulmonary disease. Nitrate, the soluble form of nitrogen, at high concentrations in drinking water can cause infant methemoglobinemia, a disease known as "blue baby syndrome," which can be fatal.

As a pollutant, nitrogen has not been on the radar like carbon (dioxide) has for individuals, organizations, cities or nations. But that is beginning to change, thanks in part to emerging regulations and scientific tools that are increasing awareness of the problem and helping people solve it. Agriculture, including both the production and consumption of food, is the big player. In the U.S. it accounts for 65 percent of nitrogen pollution, followed by emissions from vehicles and power plants (20 percent) and industry (15 percent), according to the U.S. Environmental Protection Agency.

Galloway and other researchers are trying to help solve the problem. For instance, he and his colleague, Allison Leach, have developed an online tool called N-Print, a

nitrogen footprint calculator that is designed to help individuals and institutions measure the amount of pollution they emit from their food and energy consumption so they can then apply that knowledge to shrink their nitrogen shoe size. By compiling average, per capita data, nations could eventually calculate their imprints as well. A per capita footprint is defined as the total amount of reactive nitrogen—all nitrogen compounds except inert nitrogen gas (N2) like that in our atmosphere—that is released into the environment from all sources.

Beyond farming changes, municipalities in recent years have increasingly focused on improving how wastewater, or sewage, is treated. Upgrading wastewater treatment facilities as well as household septic systems can be expensive, but such measures can dramatically return bodies of water to health. "Wastewater treatment is clearly part of the solution, especially in limiting outflow of nitrogen to estuaries," says Jan Willem Erisman, a professor of integrated nitrogen studies and CEO of the Louis Bolk Institute in the Netherlands. He notes that roughly one half of nitrogen that is lost to the environment when humans excrete what they eat can be reduced by proper wastewater treatment.

THE SEWAGE SOLUTION

It may come as no surprise that the average person's footprint in the U.S.—41 kilograms per year per person—is much larger than that of many European countries, such as the Netherlands (24 kilograms) and Austria (20 kilograms), according to research led by Leach. A key factor in the Netherlands is improvements in wastewater processing. Advanced treatment converts reactive nitrogen (Nr) into N2 in a process called denitrification, which can remove up to 78 percent of nitrogen, a huge improvement over the 5 percent removal rate in the U.S. The rate in many other countries is similarly bad.

Some U.S. regions and cities are making progress, however. The Clean Water Act, which mandates that states maintain healthy waterways, has given regulators and conservationists a legal tool in the fight against nitrogen pollution from "point sources" like wastewater treatment plants. Chesapeake Bay, which has been notorious for its nitrogen-induced dead zones, massive fish kills and dwindling income for crab and fishing industries, has made great strides, thanks in part to upgraded wastewater

treatment facilities. Nitrogen pollution from treatment plants has plunged by 43 percent—from 28 percent of the total load in 1985 to 16 percent in 2015, according to the Chesapeake Bay Foundation, a nonprofit organization focused on preserving the bay. The improvements have also reduced phosphorus pollution. "Wastewater [treatment] is definitely the shining star in terms of progress. It's where the bulk of progress has come," says Beth McGee, chief scientist for the foundation.

A worker at the Wastewater Treatment Plant in Walkerton sprays water into a newly emptied holding tank. *Credit: Photo by Peter Power/Toronto Star via Getty Images*

State and federal agencies have set a goal of reducing the total nitrogen load entering Chesapeake Bay by 39 percent from all sources—to some 87,000 metric tons in 2025 from more than 143,500 metric tons in 1985. That's the year when the Chesapeake Bay Program, a regional alliance of state governments and other political entities, along with local agencies, nonprofit groups and the EPA, began tracking nitrogen and other

pollutants. As of 2014 the multistate region was at about 112,400 metric tons, or a little more than halfway to achieving its goal, according to McGee. The foundation has been using a nitrogen calculator, developed with the help of Galloway and Leach, to raise awareness among residents of their personal nitrogen footprint, including what goes down the toilet. For example, eating less meat will lower the footprint because it is so nitrogen-intensive to produce.

Another locale that has made progress through sewage treatment is West Falmouth, Mass., part of the touristy town of Falmouth, home to about 30,000 residents (around 90,000 in the summer) tucked in the southwestern corner of Cape Cod. In 2002 Falmouth received a designation no town wants: entry on the "dirty waters list" under the federal Clean Water Act. Nitrogen pollution was the main culprit, especially nitrate from human effluent after it had been treated at a centralized plant. (The plant treated the wastewater and then discharged it into large sand beds. The treated effluent then seeped into the groundwater and ultimately into the harbor.) The West Falmouth plant accounted for 70 percent of the nitrogen pollution flowing into the harbor, compared with 30 percent from septic systems. Among the casualties were native eelgrass and bay scallops.

The listing triggered a stringent nutrient limit slapped on the West Falmouth part of town. In 2005 the town upgraded its treatment plant so that it would remove nitrogen, which it had not done previously, surprisingly common in the U.S. Improvements in water quality in adjacent Buzzards Bay are expected soon, according to Korrin Petersen, senior attorney for the Buzzards Bay Coalition. The original permit for the plant allowed for up to 50 parts per million, or 50 milligrams per liter, of nitrogen discharge—a limit that reflects previously weaker regulations and poor water treatment technology.

The new permit sets the limit at three ppm, which is roughly where levels hover currently. The town is also working on upgrading household septic systems within 90 meters of the harbor. "This is not something that's going to turn itself around in one

year, but we're seeing significant reductions in nitrogen pollution into the bay already," Petersen says. "I'd characterize it as a success story because this community has put a lot of effort into upgrading." A small but growing number of U.S. municipalities are following suit.

CALCULATING NITROGEN PLUS CARBON

Galloway hopes that individuals, organizations, cities and nations become part of the solution once they better understand, measure and ultimately alter their ecological impact via tools such as a nitrogen footprint calculator. For instance, at the Paris climate talks last December, several major corporations pledged to aggressively slash the greenhouse gas emissions generated by their products and services by cleaning up their whole supply chain, which includes nitrogen.

Better calculators could help. The one designed by Galloway and Leach mainly measures individuals' and institutions' nitrogen footprints from food consumption, including related food production and processing. But the two researchers, as well as other scientists, are also developing combined calculators that give a more complete picture of environmental impacts, because many pollutants interact with one another. For example, the duo is devising a combined nitrogen and carbon calculator for universities. "If institutions already calculate their carbon footprint, they can use much of the same data to calculate their nitrogen footprint and make better management decisions," Leach says.

Other researchers and organizations are creating models for calculating combined pollutants from agricultural and other sectors. Field to Market, for example, is a nonprofit that aims to make agriculture more sustainable. Using a tool called a Fieldprint Calculator, the organization is working with producers of several crops,

including corn, cotton, rice and soybeans. The online tool estimates performance at a specific field on eight "sustainability indicators," including two—water quality and greenhouse gas emissions—that specifically address nitrogen. Water quality includes nitrate runoff into surface water and leaching through the soil; greenhouse gases include nitrous oxide emissions from soil related to fertilizer application rates and farm management practices.

Producers could use the tool to compare their performance with local, state and national averages. Field to Market's customers include soybean growers who supply soy oil to Unilever's Hellmann's Mayonnaise. Rod Snyder, chief executive officer of Field to Market, says, "It's going to be increasingly important going forward to go upstream and ask farmers to participate."

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