

Real Alchemy

Donald Pryor

In the Middle Ages, alchemists tried to convert matter from one form to another, especially base metals into gold. It's one of history's ironies that until recently, the goal of modern environmental management has been to do the opposite—convert a valuable resource into waste. That is, the nutrients processed and excreted by humans and animals have been considered waste products to be hidden and disposed of as quickly as possible. But these days we're catching up to the alchemists; we recognize that nutrients, especially nitrogen, move through the environment along many different paths and produce both advantages and disadvantages. More and more, environmental managers are looking at whole systems and seeking to optimize the nutrient cycle.

The history of wastewater management in Narragansett Bay provides a fascinating case study of this paradigm shift. In Providence from 1840–1870, 14% of all deaths were caused by cholera, diarrhea, dysentery or enteritis—diseases we now recognize as carried primarily by sewage-contaminated water, although that was only an emerging scientific concept at the time. Profiting from their foresight in planning for a public water supply, city officials by 1871 were bringing clean water to Providence from a then-uncontaminated stretch of the Pawtuxet River. But at the same time, they also realized the need to address the other end of the system. In that same year, they hired J. Herbert Shedd to design a system of pipes to carry wastewater and stormwater away from the population. It was 1882 before construction began and 1892 before this system was completed enough to deliver the first sewage to be discharged at Fields Point. The sewage was discharged untreated; but in 1882, the year they started construction, the city had already charged the city engineer, Samuel Gray, with designing a treatment system based on the latest developments in Massachusetts and Europe. Chemical precipitation began in 1901. Unfortunately, this period of visionary municipal oversight did not continue. Despite intermittent advances in treatment systems over the next 60 years, the plants fell victim to disrepair and poor maintenance. By the 1970s, even with passage of the Clean Water Act, conditions had deteriorated to the point where nearly 65 million gallons of untreated or partially treated sewage were discharged into Rhode Island's waters everyday. Grease deposits the size of soccer balls were a favorite report of travelers on the Bay; long-time residents tell of

swimming through floating human waste. It took enabling state legislation, creation of the Narragansett Bay Commission (NBC), and overwhelming passage of an \$87.7 million bond issue in 1980 to rescue the city's wastewater management system. By 1995, just 15 years later, the city's Field's Point plant received an EPA award as the best large secondary treatment facility in the country

Justifiably proud as the city and NBC were of this accomplishment, the late 1990s brought a dawning realization that treatment levels were not adequately protecting aquatic life in the bay. Nutrient levels, primarily nitrogen, from treatment plants (but from other sources as well), were overstimulating phytoplankton growth and the resulting decaying matter was using up oxygen in the water. Dissolved oxygen concentrations occasionally, and in some areas chronically, dropped to levels that stunted or killed marine organisms. A dramatic fish kill in Greenwich Bay in 2003 raised public attention. By 2005, the Rhode Island Department of Environmental Management (RIDEM) had devised a "Plan for Managing Nutrient Loadings to Rhode Island Waters." Today, major progress has been made in implementing this plan and by 2014 most upgrades will be completed, reducing nutrient levels significantly.

Nitrogen is an essential element in the proteins that humans and animals need to live. It's also the nutrient exerting the greatest control over primary growth in marine waters (Phosphorus is the other major nutrient, but its effects are much more pronounced in fresh water.) Unfortunately, humans



The Narragansett Bay Commission Fields Point Wastewater Treatment Facility. Photo: NBJ.

aren't particularly efficient in assimilating nitrogen—20 to 30% of it passes through our systems, more in many domestic animals. Modern sanitation systems send our domestic wastes to wastewater treatment facilities where organic nitrogen is broken down into simpler inorganic forms (ammonia and nitrate) by decomposing bacteria. Microorganisms can also transform nitrate into nitrogen gas, which is then released into the atmosphere. The combination of these and other transformations is called the nitrogen cycle.

What we have found is that this kind of treatment can exacerbate the effect of nitrogen on the bay ecosystem by converting more of it to forms that are more easily assimilated by phytoplankton. On the other hand, natural processes can remove nitrogen quite efficiently, and many facilities have adopted an additional treatment stage, often called tertiary treatment, that mimicks these natural processes but does so at an accelerated pace and under conditions where oxygen can be controlled.

But in yet another instance of unintended consequences, this process has led to concerns about its contribution to greenhouse gas emissions. Nitrous oxide (N_2O) is a greenhouse gas, it is 300 times more potent than carbon dioxide. And if that were not enough, the other concern often raised about treatment to remove nutrients from wastewater is the fear of higher energy costs and resulting CO_2 emissions.

Kartik Chandran and associates at Columbia University have been measuring N_2O emissions from plants throughout the country. Their results indicate that partial nitrogen removal (particularly ammonia removal only, as is practiced in many US plants) produces high N_2O emissions, whereas well-operating systems that also remove nitrates produce lower emissions. Further, the level of N_2O emissions can serve as a useful indicator for plant engineers on how well their plant is operating. In cooperation with Kartik, industry leader Glenn Daigger, and Steve Hamburg and James Wang of Environmental Defense Fund, we have estimated that, if a greenhouse gas trading system were in place, good control of N_2O emissions could offset up to 70% of operating and maintenance costs of biological nutrient removal in wastewater treatment. Fortunately, plants in the Narragansett Bay area already are being designed to remove both ammonia and nitrates, but if rugged and simple instrumentation can be developed for N_2O monitoring it would assist with optimizing process control.

Similarly, plants that remove both forms of nitrogen are also more energy-efficient than those that remove only ammonia. An exciting finding is that wastewater treatment can be a net energy producer. Facilities in Europe are approaching this goal and EPA has been working with treatment

plants in this region to demonstrate similar potential here. Throughout the wastewater industry there is increased interest in the potential for energy generation and efficiency. The Massachusetts Water Resources Authority (MWRA), the Boston-area wastewater treatment system, self-generated 40% of its energy needs in 2009 and is implementing plans to increase that percentage. NBC's Bucklin Point plant is planning to generate biogas and use it to fuel a generator to partially power that plant. NBC's Fields Point plant will use its site advantage to install wind turbines to help power that plant.

More broadly, wastewater plants are interested in conserving and recycling as much as possible. For example, phosphorus, the primary cause of nutrient problems in freshwater and a key material for agricultural fertilizer, is anticipated to be in short supply because it cannot now be produced artificially. Some treatment facilities are now capturing it from wastestreams as struvite, a phosphate that can be recycled into fertilizer. Although there is growing interest in digesting sludge for biogas, it too can be recycled by using it as a fertilizer. Locally, Jamestown's wastewater treatment plant has used some of its treated effluent to water and fertilize a golf course. Cranston's treatment plant has used some of its treated effluent for power plant cooling water.

Like the alchemists of old, we are looking to transmute base materials into more valuable ones. But unlike their efforts, ours will be successful. Capturing and recycling nutrients, as well as other materials from wastewater, will increasingly make sense and cents.

~Donald Pryor is a visiting scholar with Brown University's Center for Environmental Studies.

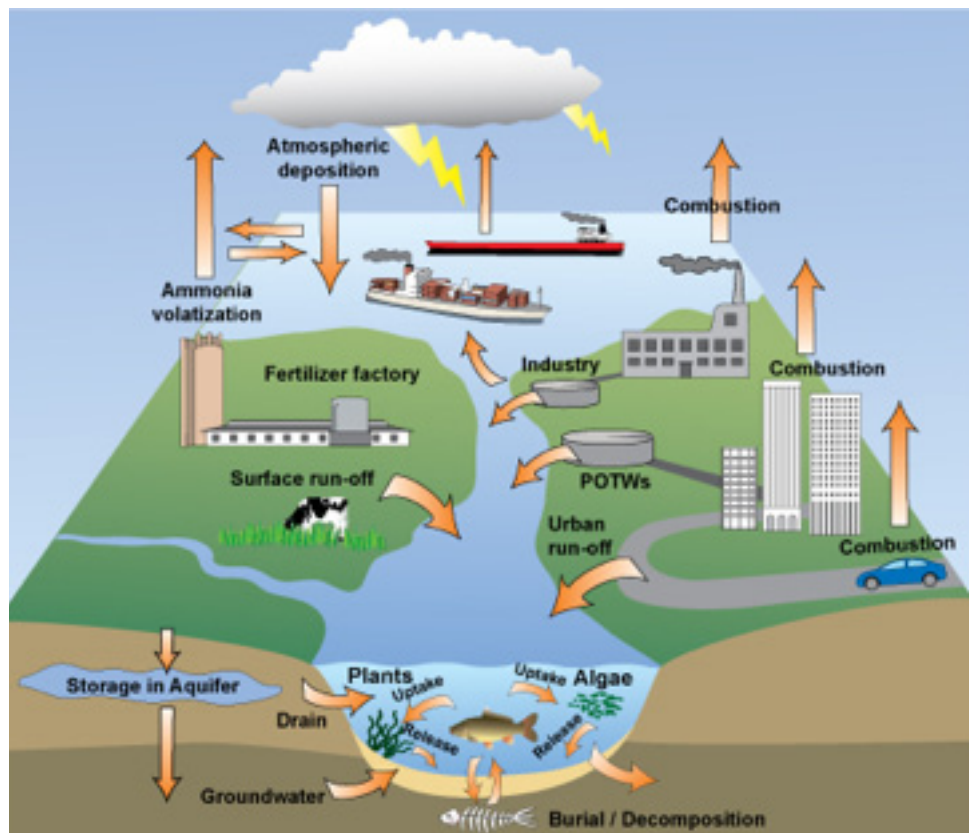


Image from: Southern California Coastal Water Research Project.