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Small Community Wastewater Issues Explained to the Public

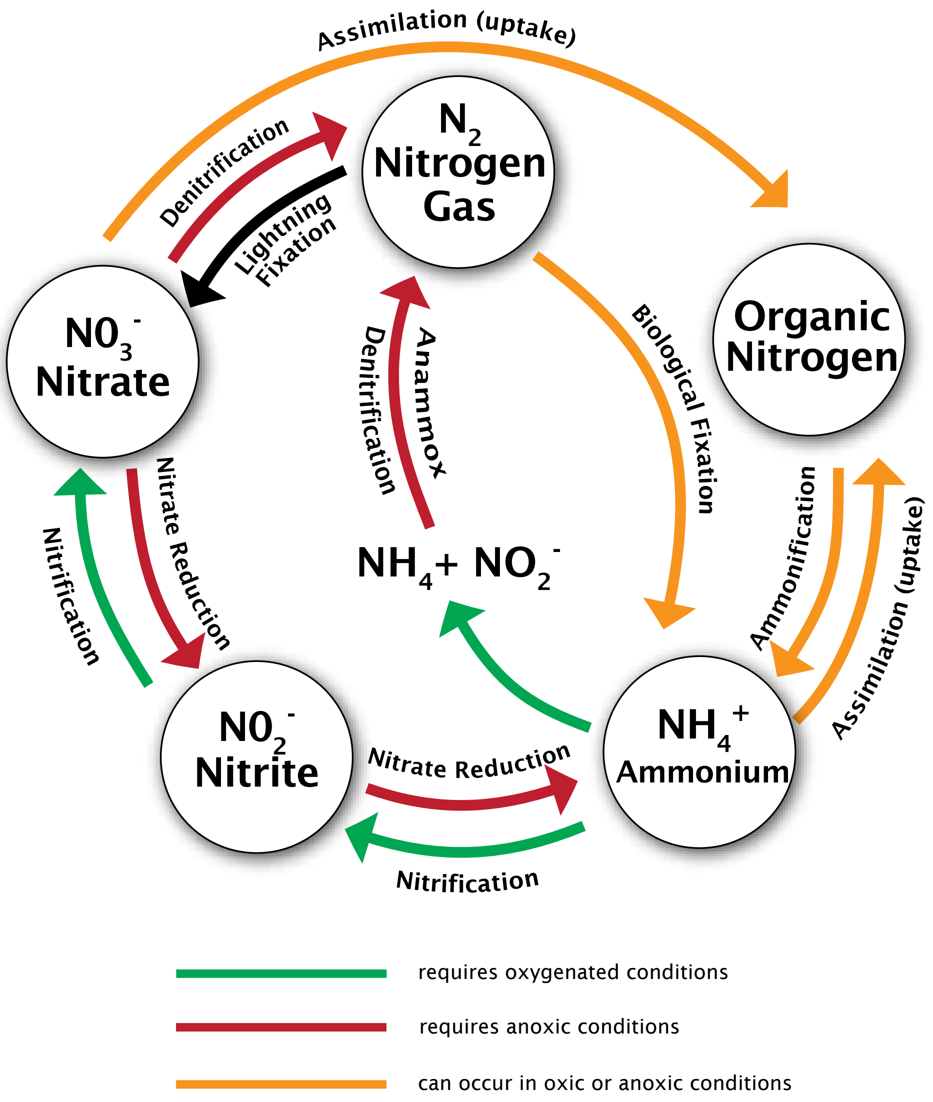
Minimizing Nitrogen Discharges from Onsite Wastewater Systems

Reducing the amount of nitrogen released from onsite wastewater systems has become a controversial issue in certain parts of the country. In some locales, property owners are being encouraged or even required to add nitrogen-reducing systems to new and existing septic systems. This *Pipeline* explores why controlling nitrogen is an issue and how the units work. Before discussing how nitrogen treatment systems work, however, it is worthwhile to cover some basic information about nitrogen.

Nitrogen in the Environment and the Nitrogen Cycle

Nitrogen is a common element that plays a crucial role in the biology of living organisms. It is a key component of DNA, RNA, and proteins. Along with phosphorus and potassium, it is considered one of the three major nutrients essential for healthy plant growth. It composes about 78 percent of the atmosphere as a colorless, odorless, tasteless gas (N_2) made up of two

Simplified Nitrogen Cycle



tightly bound atoms. Because the two atoms are connected by a triple chemical bond, nitrogen gas is relatively non-reactive or inert. However, nitrogen does cycle naturally through the soil/water environment in a variety of forms. Some of the most common forms of nitrogen and their chemical abbreviations include:

- Organic nitrogen – organic N
- Ammonia – NH_3
- Ammonium ion – NH_4^+
- Nitrogen gas – N_2
- Nitrous oxide – N_20
- Nitric oxide – NO
- Nitrite ion – NO_2^-
- Nitrate ion – NO_3^-

The graphic on the previous page shows a simplified diagram of the nitrogen cycle. Compared to nitrogen gas, the other forms of nitrogen are more reactive and transformations between different forms occur readily. Most of the transformations are assisted by the activity of microorganisms, mainly bacteria, and the transformations can occur in either direction depending on environmental conditions. Some of the key transformations are:

Nitrogen fixation is the process by which atmospheric nitrogen gas is converted to a form of nitrogen that can be taken up and used by plants. The primary natural fixation process converts nitrogen gas to the ammonium ion (NH_4^+). This type of fixation is carried out by microbes and can take place in either oxygenated or non-oxygenated conditions and in either soil or water environments. Some fixation to NH_4^+ takes place through the symbiotic or cooperative association of certain types of bacteria with the root systems of mainly leguminous plants, but also some non-legumes.

Another type of fixation occurs during lightning storms. Lightning is powerful enough to break the strong chemical bonds of nitrogen gas, converting it to nitrous and nitric oxides. These in turn dissolve in rain to eventually form nitrate, which is the other form of nitrogen that can be used by plants. Fixation by lightning contributes only about five percent of the nitrogen fixed annually on a global basis and is one of the only natural nitrogen transformations that does not involve living organisms.

Nitrogen is also fixed industrially through a process called the Haber-Bosch method, which converts nitrogen and hydrogen gases to ammonia under high pressure. The ammonia, which can also be converted to nitrate, can be used to produce synthetic fertilizers and other products such as explosives. The development of this process in the early 20th century is in part responsible for the dramatic increase in per acre crop yields and global agricultural output since then.

Assimilation or uptake is the process by which the ammonia is incorporated in organic biomass, first by being taken up by plants and in turn by plant-eating animals. Ammonia, NH_3, and its ionic form, ammonium, NH_4^+, exist in an equilibrium with the relative abundance of each dependent on environmental conditions, including pH levels. Ammonium is the form used by plants. Because plants can also use nitrate, the conversion of nitrate to organic biomass is also considered to be assimilation.

Ammonification is the biochemical conversion of organic material back to ammonia/ammonium. This can be thought of as a decomposition or decay process. Not all organic decomposition, however, results in the release of ammonia. Some organic nitrogen is tied up in material that is not completely biodegradable. At any given time in terrestrial

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environments much more organic nitrogen is incorporated in non-living organic debris than in living biomass.

Nitrification is the biochemical conversion of ammonium to nitrate. This occurs under oxygenated conditions in two steps, both mediated by different types of nitrifying bacteria. In the first, ammonium is converted to nitrite, which is then converted to nitrate in the second step. Because the second step proceeds more quickly than the first, nitrite is usually present only in small quantities under nitrifying conditions.

Denitrification is the process that converts reactive forms of nitrogen back to non-reactive nitrogen gas. There are two ways this conversion takes place, both requiring the involvement of bacteria. In the first, bacteria use nitrate as an energy source in a series of conversions to ultimately convert nitrate to nitrogen gas. This process must take place in an anoxic (no free oxygen present) environment. If any free oxygen is present the bacteria will preferentially use the oxygen for an energy source instead of nitrate and the nitrate will remain unconverted.

Within the past 20 years a second denitrification process has been discovered, referred to as the anammox process, which stands for **an**aerobic **amm**onia **ox**idation. (Note: Anammox also refers to a trademarked ammonia removal technology developed in Europe that uses this process.) The anammox process represents a short cut in the nitrogen cycle, allowing ammonia to be converted to nitrogen gas without needing to convert it first to nitrate. This process has been successfully used to remove nitrogen from municipal and industrial wastewater with significant energy savings. However, it is not clear at this time what potential it has for application at a small scale such as an individual household.

The nitrogen cycle is a natural process. However, as we have with the carbon cycle, human activity has disrupted the nitrogen cycle. And, just as there is a carbon footprint, there is also a nitrogen footprint. Worldwide, humans are estimated to introduce twice the amount of reactive nitrogen into the cycle annually than would occur through natural fixation alone. In the U.S. more than four times as much nitrogen is fixed and imported as would occur naturally. This happens through the industrial production of and subsequent use of nitrogen fertilizers, the human cultivation of nitrogen-fixing plants, and the burning of fossil fuels containing nitrogen. Much of the nitrogen used in agricultural fertilizers is incorporated into plants that are fed to farm animals leading to some nitrogen being passed through in the manure and urine. People also consume food that contains nitrogen and excrete feces and urine that contain nitrogen, so the fate of nitrogen in household wastewater is also a factor.

What's the problem with too much nitrogen?

Although nitrogen fertilizers help keep the world fed, excess reactive nitrogen in the environment can lead to environmental and public health problems. The primary public health issue connected with nitrogen is a condition called methemoglobinemia, a condition that occurs when infants ingest excessive nitrate. In the U.S. this has typically occurred when water from private home wells with elevated concentrations of nitrate was used to prepare baby formula.

The excess nitrate reduces the amount of hemoglobin present in the blood. Since hemoglobin is crucial for transporting oxygen throughout the body, oxygen deficiency results, which may be fatal. Babies suffering from this condition may have a bluish skin coloring so it is sometimes referred to as "blue baby syndrome."

The condition is restricted to infants of approximately six months of age and younger. Older children and adults produce an enzyme that prevents the condition. It has been estimated that at any given time there are approximately 40,000 infants in the U.S. of less than six months of age who live in homes with private wells with elevated levels of nitrate who may be susceptible. Fortunately, rural public health agencies and health care providers are usually familiar with the condition and fatalities have been rare in recent years.

In recent years there has been some discussion of whether nitrate alone is responsible for the condition. Some researchers believe that nitrate is a contributor but other co-factors such as high levels of bacteria in the water are also involved.

The federal standard for nitrate in drinking water under the Safe Drinking Water Act is 10 mg/l NO_3-N for nitrate. (This concentration is expressed as "nitrate as nitrogen," indicating that the weight only takes into account the weight of the nitrogen and not the weights of the attached oxygen atoms.) This standard was set expressly for the prevention of methemoglobinemia in infants.

Because nitrogen is a necessary nutrient it can stimulate the unnatural growth of algae in both freshwater and coastal waters. In some cases the resulting algal mats are no more than a nuisance. However, the algae that create red and brown tides in coastal waters can produce potent nerve and liver toxins. In shellfish that are filter-feeders, such as clams and oysters, the toxins can accumulate to levels that make them harmful and potentially lethal to people who may consume them.

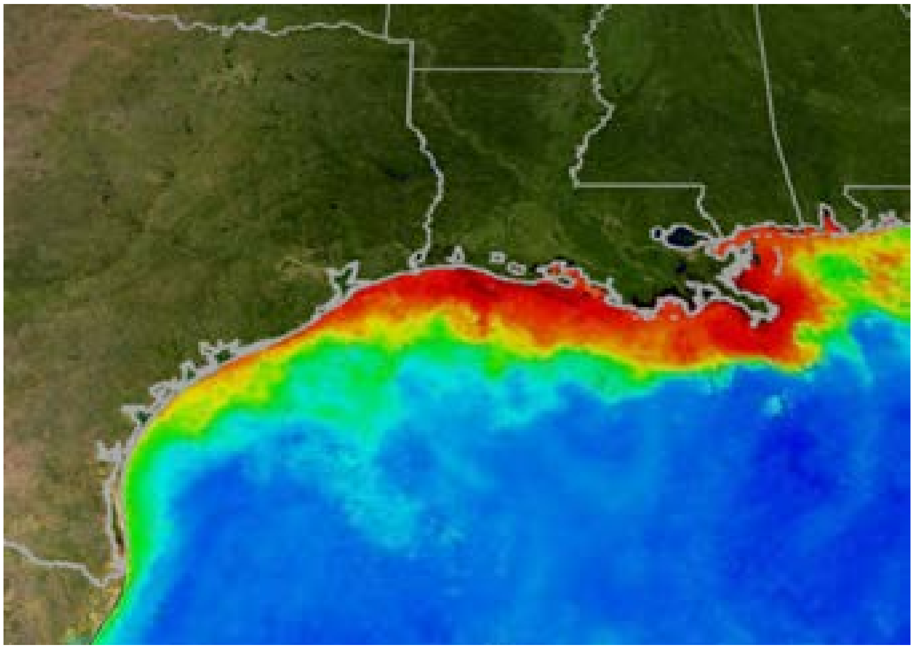
Other studies have linked excessive nitrate consumption to a variety of health conditions including miscarriages, birth defects, certain types of cancer, and hypertension. However, at this time, the studies are not considered to be conclusive.

Ecological Impacts of Nitrogen Contamination

An overabundance of reactive nitrogen in the environment leads to what has been described as a cascade of environmental changes. Accumulation of nutrients in the environment is referred to as "eutrophication," a level of nutrient enrichment that causes ecological changes. The effects of low-level eutrophication may be minor, but excessive eutrophication has widespread negative impacts.

Coastal environments such as estuaries, bays, and lagoons where the water moves slowly and has a limited rate of exchange with the adjacent ocean, are especially susceptible to undesirable changes. As mentioned, excess nitrogen and other nutrients can stimulate the growth of nuisance algae. In shallower coastal environments the algal blooms, if thick enough, may shade any rooted vegetation, such as seagrasses, causing their decline or elimination. Because seagrass beds serve as a key habitat for fish and shellfish, their loss leads to additional loss of aquatic life and an increase in sedimentation.

Algae consume oxygen during nighttime respiration and their microbial decomposition after death consumes additional oxygen. This can lead to water conditions of low oxygen (hypoxia) or no oxygen (anoxia). These conditions tend to be worse in warm weather when oxygen is less soluble. Nutrient pollution has contributed to the formation of a huge hypoxic area covering thousands of square miles near the mouth of the Mississippi River, where dissolved oxygen is too low to permit the survival of significant aquatic life.



Gulf of Mexico Dead Zone -- The red and orange colors in this NASA satellite image show the summertime extent of turbid waters at the mouth of the Mississippi River. The turbidity is due to suspended solids and algal blooms and correlates closely with low dissolved oxygen and elevated nutrient levels. The size of this hypoxic zone varies seasonally and from year to year but may cover 6,000 to 7,000 square miles in the summer.

The economic impact from the loss of fisheries is immense. Commercial and recreational fishing and shellfish harvesting are multi-billion dollar industries. When coastal areas become hypoxic or vital habitat is lost local economies are affected. Although problems in the Gulf of Mexico and the Chesapeake Bay are well known, more than 300 U.S. coastal areas are documented as suffering from hypoxia.

How Much Nitrogen Do Septic Systems Contribute?

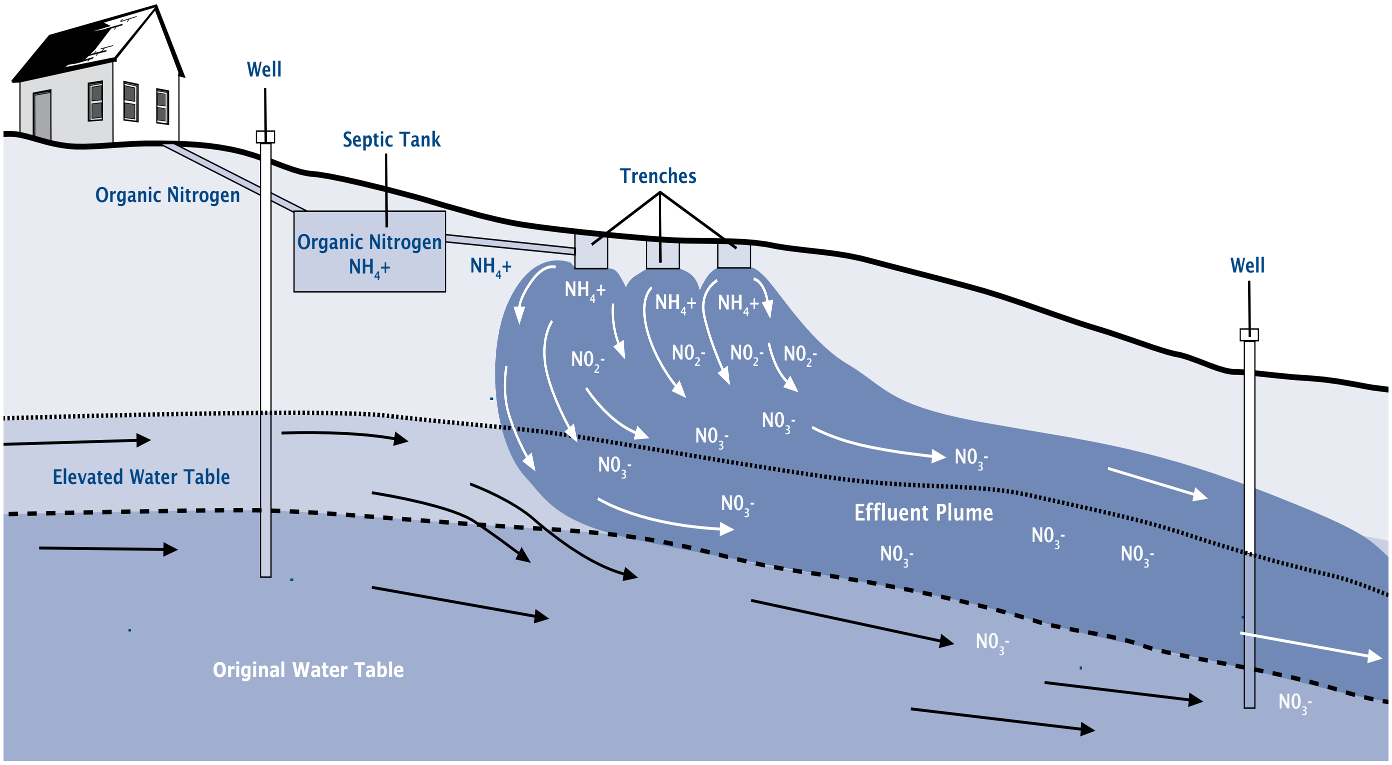
An average-sized household on a septic system generates about 20 to 25 pounds of nitrogen annually. For all onsite systems nationally this amounts to about 260,000 to 270,000 tons of nitrogen released per year, which may sound like a lot but, compared to the major sources of nitrogen in the U.S., it is relatively minor. Agricultural fertilizers produced in and imported into the U.S. annually amount to more than 12 million tons of reactive nitrogen. The combustion of fossil fuels, natural biological nitrogen fixation, and cultivated biological nitrogen fixation account for roughly 6, 7, and 8.5 million tons respectively of reactive nitrogen released each year.

This raises the question of why some septic systems are being targeted for nitrogen reduction when the amount contributed is such a small percentage of the whole. To borrow a real estate expression, the answer is “location, location, location.” According to the U.S. Census, more than half of the U.S. population lives in what are considered to be coastal counties (including the Great Lakes). As we have seen, estuaries and other coastal environments have been greatly affected by nitrogen pollution so, in many situations, the proximity of septic systems to an impaired water body is a concern. Of the 420,000 septic systems in the state of Maryland, 52,000 are within 1000 feet of tidal waters, which is considered the critical zone.

In other places, including areas far from the coasts, protection of shallow unconfined aquifers used for drinking water supplies may be a driving factor. Nitrogen reduction may be required within wellhead protection areas for municipal drinking water systems. In some areas, nitrogen control may be required for homes located along high quality streams or rivers. Reports of harmful algal blooms in freshwater lakes, many of which have been attributed to failing septic systems, have been increasing in recent years. This may lead to requirements for nutrient control for lakeside communities. In general, although septic systems are not one of the primary contributors of nitrogen contamination nationally, in specific areas they may be a significant source.

Nitrogen Transformations in Conventional Septic Systems

As wastewater flows through a conventional gravity-flow septic system, nitrogen undergoes a series of biological and chemical changes. About 75 to 90 percent of nitrogen in household wastewater comes from toilet wastes with the remainder coming from other fixtures—sinks, showers, and tubs. About 90 percent of the nitrogen in toilet waste is contained in urine, the rest in feces.



This illustration shows the nitrogen conversions that typically take place in a conventional septic system. Nitrogen in the raw wastewater is in the form of organic nitrogen, most of which is convertd to ammonium (NH_4^+) in th septic tank. In well-aerated drainfield soil, most of the NH_4^+ is converted to nitrite (NO2-), which is then quickly converted to nitrate (NO_3^-).

Most of the nitrogen in wastewater comes from the digestion of proteins and other nitrogen-containing compounds in food. The use of garbage disposals to grind food scraps introduces additional nitrogen. In untreated wastewater entering the septic tank, nitrogen is mainly in the form of organic nitrogen compounds, primarily urea. Urea is readily converted to ammonium in the septic tank and the nitrogen content of wastewater exiting the tank, referred to as septic tank effluent, is typically about 85 percent ammonium and 15 percent organic nitrogen. The concentration of total nitrogen in septic tank effluent is quite variable, ranging from 20 to 200 mg/l. The median value is roughly 50 to 60 mg/l.

After the wastewater exits the septic tank and flows to the unsaturated soil of the drainfield, further transformations occur. The remaining organic nitrogen is converted to ammonium (ammonification). Most of the ammonium is converted first to nitrite and then to nitrate (nitrification). In sufficiently alkaline soils some of the ammonium may be converted to ammonia and lost to the atmosphere as ammonia gas. Some ammonium may attach to soil particles and be consumed by soil microbes.

Under certain conditions, such as the presence of saturated, anaerobic, organic-rich soil below the unsaturated zone, natural denitrification may take place. However, in the vast majority of conventional septic systems this combination of conditions is not present. As a result, denitrification does not take place to any significant extent and the final nitrogen product is mostly nitrate. The concentration of nitrate in shallow groundwater below the drainfields of conventional systems typically indicates that only about 10 to 25 percent of total nitrogen is removed from the wastewater, mostly by the settling of solids in the septic tank. This compares with 90 to 99.99 percent removal of other wastewater constituents.

Because of the generally low rate of nitrogen removal, nitrate concentrations in shallow groundwater in the vicinity of drainfields frequently exceed the drinking water standard of 10 mg/l, often considerably. And, because nitrate is considered to be a mobile ion—it doesn't adhere to soil particles as many other ions do—plumes of nitrate contamination can travel away from septic system drainfields in the direction of groundwater flow. This puts owners of wells that tap shallow groundwater at risk. Where nitrate contaminated groundwater reaches surface water it can degrade streams and lakes. This may be especially true in areas where septic systems are densely sited so that dilution from groundwater and precipitation is insufficient to reduce the overall nitrate concentration.

Onsite Wastewater Nitrogen Reduction Methods

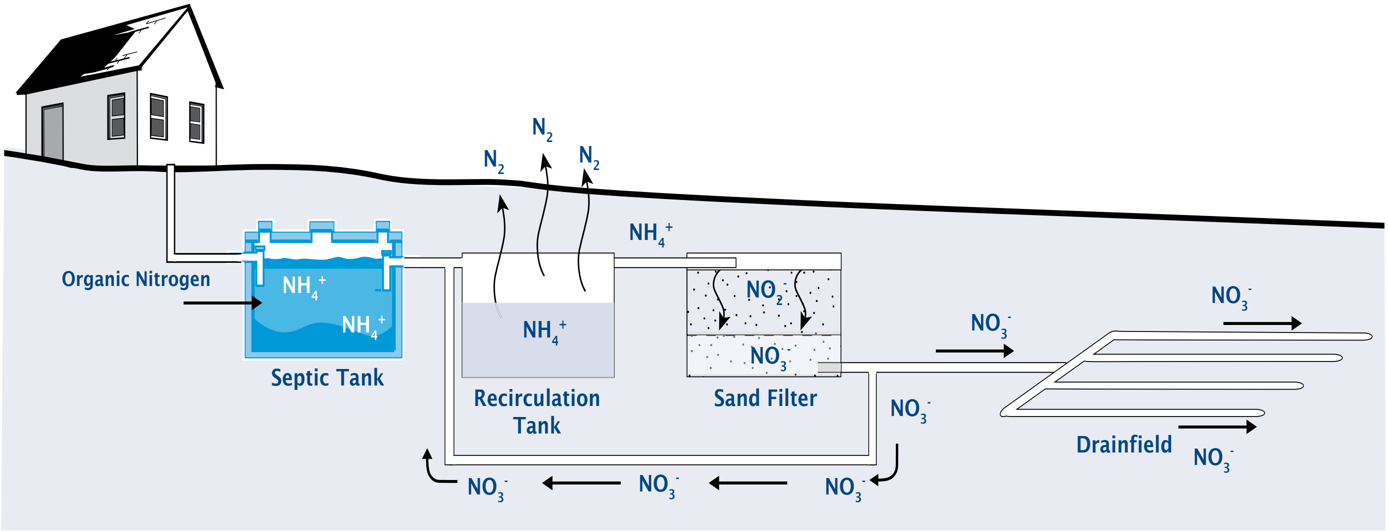
Processes for reducing concentrations of nitrogen in discharges of treated sewage from centralized wastewater treatment plants are well developed. However, the processes used at larger facilities are often not practical for use at onsite systems serving individual residences. Potential and existing methods for onsite treatment can be roughly grouped into four main categories: (1) coupled biological nitrification and denitrification, (2) source separation of urine, (3) physical/chemical removal, and (4) removal by natural systems. There is some overlap among the categories.

Biological Nitrification/ Denitrification

Of the four categories, biological nitrification/denitrification (N/D) processes are the most commonly used. There are a wide variety of these systems available, most of which are commercially manufactured. They can be categorized in different ways and the same types of systems are sometimes referred to by various names creating confusion. This article briefly describes some of the most commonly used approaches, but is not exhaustive.

As noted earlier, nitrogen goes through a series of transformations in a standard septic system beginning mainly in the form of organic nitrogen, which is changed first to ammonium, then nitrite, and finally nitrate. However, the transformations typically stop short of converting the nitrogen back to nonreactive nitrogen gas. Despite the wide variety of biological N/D processes, the common goal is to create conditions conducive for both processes to occur so nitrate can be converted to atmospheric nitrogen gas, reducing groundwater and surface water contamination.

Unfortunately, creating and maintaining the environments to allow both nitrifying and denitrifying bacteria to do their work is quite challenging. Nitrification is an acid-producing reaction. If sufficient alkalinity is not



Use of recirculating sand filter (RSF) to reduce nitrate discharge: Ammonium is nitrified in the sand filter. A portion of the nitrified sand afiter effluent is returned to a recirculation tank, which maintains conditions favorable for denitrification where some nitrogen gas is released. Because not all sand filter effluent can be recycled, some nitrate will still be released to the drainfield.

present to neutralize the acid, the nitrifying bacteria may be eliminated. Nitrifying bacteria require an aerobic or oxygenated environment. Denitrifying bacteria require an anoxic environment in which no oxygen is present. Maintaining both environments, while simultaneously providing traditional wastewater treatment (separation of solids, and sufficient reduction of decomposable organic matter, suspended solids, and pathogens) is difficult and nitrogen removal rates for many units are only in the 25 to 50 percent range. Below are the main categories of commonly used systems.

Suspended Growth Reactors, also referred to as activated sludge reactors, are systems in which athe bacteria that provide the treatment are in suspension in the wastewater. Many of these aerated units have been used for some time to provide enhanced onsite wastewater treatment, but not necessarily for nitrogen removal. The aeration helps achieve effective nitrification. By pulsing the aeration—intermittent periods of aeration followed by no aeration—anoxic conditions develop temporarily that allow for some denitrification to occur.

Sequencing batch reactors operate similarly except the treatment occurs in a timed batch in one vessel. This requires the system to have at least two vessels, one for treatment to take place in while the other accepts incoming wastewater. SBR processes are typically computerized.

In both systems, denitrification can be limited by the amount of organic carbon present in the anoxic phase. The denitrifying bacteria require some organic carbon for energy and cell growth. However, organic carbon can become depleted during the aerobic phase of the process. In fact, since that is a primary goal of wastewater treatment, decomposable carbon should be in short supply. To partially overcome this limitation, a recycle loop between the aerobic phase and the septic tank (or separate mixing tank), where organic carbon is plentiful, may be included. Recycling increases the amount of nitrogen removed but, because not all wastewater can be recycled, some nitrogen must leak or slip through the system without being denitrified.

Attached Growth Reactors, also referred to as fixed-film reactors or media filters, consist of a contained bed of porous media. Settled wastewater is distributed over the top of the bed and percolates through the media. Filtered wastewater is collected in an underdrain and can be further treated or discharged. A biofilm or bacterial slime layer grows on the surface of the media and provides much of the treatment. Treatment occurs through a combination of biological and physical processes.

Historically, inert materials like sand or gravel have been used for the media. However, a wide range of other materials are now being used, mostly in proprietary systems. These media include peat, textiles, open-cell foam, broken glass, tire crumb, plastics, and coir, a fiber from coconut husks

Wastewater can be dosed to the media filter once or multiple times. Filters receiving one dose are called single-pass or intermittent filters. Filters receiving multiple doses are called recirculating filters. Single-pass filters can be effective at nitrifying the wastewater but do not generally provide sufficient conditions for denitrification to follow. Recirculating filters typically provide better denitrification by recycling a portion of the wastewater collected in the underdrain back to either the septic tank, a mixing tank where it is mixed with septic tank effluent, or to another unit with anoxic conditions. As a result, recirculating media filters provide better total nitrogen removal than single-pass filters—in the 50 to 75 percent removal range.

Integrated Fixed-Film Activated Sludge (IFAS) are systems that combine characteristics of both attached growth and suspended growth systems. There are a number of variations of IFAS systems. In some the attached growth biomass forms on freely moving media such as porous sponges or plastic cylinders. In others, the biofilm grows on non-moving plastic support structures through which the unattached biomass is circulated. IFAS systems offer some advantages. One is that by combining the effectiveness of suspended growth and the resilience of attached growth systems they provide reliable treatment that is resistant to shock loadings. Because these systems allow for a generally higher density of bacterial populations, the treatment modules have a generally small footprint, making them attractive for use on small lots.

Anoxic Media Reactors, also referred to as anoxic packed-bed reactors, use a different strategy to achieve a higher rate of nitrogen removal. In the previously discussed systems, a percentage of the nitrified wastewater was recycled back to either the septic tank or a mixing tank to take advantage of an anoxic environment that contained organic carbon, both of which are needed for denitrification. However, because only a portion of the wastewater can be recycled, some wastewater must be discharged without being denitrified. Anoxic reactors overcome this limitation by eliminating the need to recycle.

Anoxic reactors use a bed of reactive media that provides an energy source and an attachment site for the denitrifying bacteria. The entire wastewater flow is passed through the reactor, usually in a single pass. The media may be wood-based, which provides a carbon source for the bacteria to use in the denitrifying process. Some types of denitrifying bacteria can use chemical elements or compounds other than carbon and mixtures of sulfur and oyster shell or limestone having been studied as well. Total nitrogen removal rates are in the range of 75 to 95 percent.

The effectiveness of the process depends on achieving complete nitrification of the wastewater before it enters the reactor, maintaining anoxic conditions in the reactor, and providing sufficient alkalinity to maintain the denitrifying bacteria. Because the reactive medium is gradually consumed over time the reactor must be built to provide a sufficient lifespan for the system.

Urine-diverting toilets or no-mix toilets have a vertical barrier in the bowl that separates urine (front section) from other toilet waste.

Source Separation/ Urine Diversion

In residential wastewater, both nitrogen and phosphorus are concentrated in toilet waste, with the majority of the nutrients found in urine. Approximately 75 percent of all nitrogen in the domestic wastewater stream is found in urine, which represents a very small volume of the total wastewater flow. By separating the urine, the majority of the nitrogen can easily be removed from the wastewater flow. There is no net benefit in simply removing the urine from the wastewater flow unless the removed nitrogen, which is mainly in the form of urea and ammonium, is beneficially reused to take the place of other nitrogen-based fertilizers. The urine can be used directly as a liquid agricultural fertilizer or processed to make solid fertilizers.

Urine diversion requires the use of specially designed urine-diverting toilets, waterless urinals, tanks to store the collected urine, and piping to connect the fixtures to the tank. Urine diversion has been used successfully in both developed and developing nations but is only beginning to be used in the U.S. Implementation in the U.S. is limited by its unfamiliarity and the lack of an established system for collecting and appropriately reusing the urine. However, urine harvesting is getting serious consideration and some implementation in facilities, such as schools and highway rest areas, that generate wastewater with a high urine content.

If all toilet waste is captured through the use of composting toilets, more than 90 percent of the nutrients are removed from the wastewater stream. As with urine, the composted waste must be used in a way that doesn't simply re-release the nitrogen to the environment.

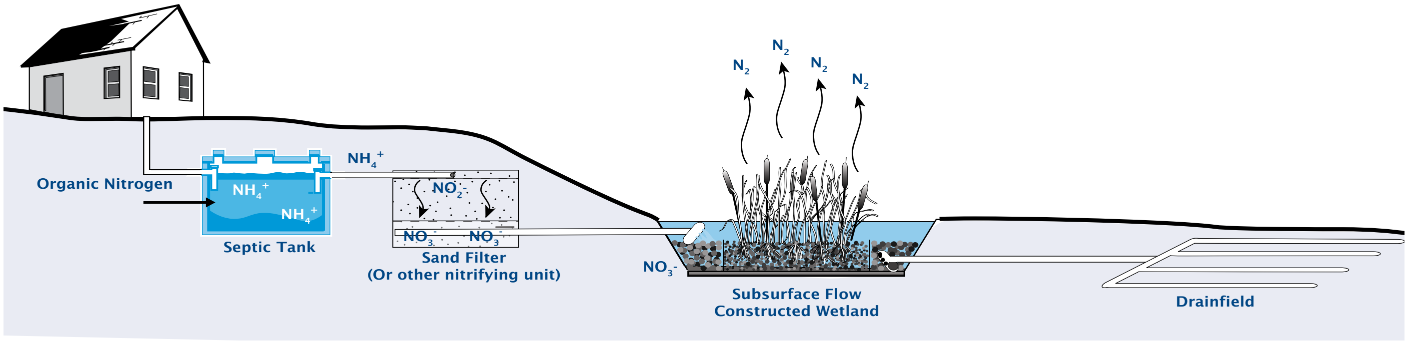
Physical/Chemical Treatment

Physical processes rely on some type of barrier to filter contaminants from the wastewater. Chemical processes involve the use of chemicals to either change the form of the contaminant of concern or to adsorb the contaminant and remove it from the wastewater stream. These types of processes have not been widely used for onsite wastewater treatment but some are beginning to be marketed.

Membranes bioreactors (MBRs) have gained acceptance for larger decentralized applications and some MBRs are available for use at individual homes. MBRs make use of either hollow fiber or flat plate membranes with very small pore sizes (0.3 to 1.5 microns) that allow water to be pulled through under suction that is of high enough quality to be reused for approved applications

MBRs also incorporate a biological suspended growth/ activated sludge treatment process and can therefore be considered to be a hybrid of biological and physical treatment processes. Not all MBRs are necessarily designed for nitrogen removal but those that are have reportedly achieved removal rates in the 75 to 95 percent range.

One promising chemical treatment technology is ion exchange, in which ions, in this case ammonium or nitrate, are attracted to and exchange place with other ions when the wastewater stream is run through a column of appropriate medium. The process is similar to that used in a typical water softener. With zeolite as a medium this process has worked effectively to remove ammo-



Use of constructed wetlands to reduce nitrate dischrge: Subsurface flow wetlands have been shown to be effective at denitrification as long as the wastewater entering the wetland is completely nitrified first. Some nitrogen is taken up by plants but much of the nitrogen is released as nitrogen gas.

nium. Its use has so far been limited by the need for pretreatment to avoid clogging of the column.

Natural Treatment

Natural systems mainly use soil, plants, and associated biota to provide nitrogen removal. Some may have other added media to further enhance treatment. Although they share many similarities with biological nitrification/denitrification units, natural systems are not used as frequently. This is because these systems tend to have a wider variability in effectiveness, are more difficult to monitor, and, when not operating optimally, are more difficult to adjust. However, they are attractive because they are generally passive and can potentially be used in combination with other systems to provide more effective treatment.

As mentioned, some nitrification/denitrification has been shown to occur naturally in conventional drainfields. However, the conditions for this to occur, including the presence of fine-grained soils, sufficient alkalinity and organic matter, and a relatively shallow, fluctuating groundwater table, are not usually present. Some natural treatment systems attempt to replicate these conditions in the drainfield.

One way this has been done is to apply timed, intermittent dosing of wastewater to the drainfield. The alternating cycles of wetting and drying mimic fluctuating groundwater levels and allow both nitrifying and denitrifying bacteria to survive and provide treatment. The use of intermittent dosing in combination with another treatment unit, such as a recirculating sand filter, has the potential to be effective at removing nitrogen.

Most conventional drainfields in well-drained soils are able to achieve high rates of nitrification but little or no denitrification. Some experiments have been conducted to add material to the drainfield to encourage denitrification. Sawdust or wood chips are added as a layer to provide a carbon source and to maintain saturated conditions that promote the anoxic environment needed by denitrifying bacteria. A layer of sand is added above the woody materials to provide the aerobic environment needed by nitrifying bacteria. Total nitrogen removal rates of 60 to 95 percent have been achieved in field trials. The use of other types of media to encourage denitrification is being studied.

Subsurface-flow constructed wetlands have shown potential for use in nitrogen removal systems. Because these systems are intended to consistently have saturated flow conditions they maintain an anoxic environment needed for denitrifying bacteria. Microorganisms associated with the root zone of the wetland plants provide the necessary organic matter. Because subsurface-flow constructed wetlands are not effective at nitrification it is important that the wastewater entering the wetlands is already well nitrified. If treatment to provide complete nitrification precedes the wetlands, nitrogen removal rates of 75 to 90 percent may be achieved.

The Need for Nitrogen Management Brings Change

Historically, minimizing nitrogen discharges from septic systems has not been a major consideration. The main goals of onsite wastewater treatment were to protect the public health by providing basic treatment and dispersing the effluent underground so that people did not come into contact with possible disease-causing organisms. It is only relatively recently that the extent to which nitrogen from septic systems can contribute to environmental problems has become apparent.

As the awareness of the impact of the accumulation of reactive nitrogen in the environment grows, difficult decisions will need to be made about how to better manage nitrogen. The extent to which those decisions affect onsite wastewater systems will almost certainly increase. Currently, about half of the states regulate nitrogen from onsite systems, with another handful of states considering regulation.

In some states, only larger septic systems serving multi-unit residential buildings or commercial buildings are regulated for nitrogen. In those states that regulate nitrogen from single-family homes with septic systems, regulations typically apply only to homes in specific areas that have been determined to be problem areas or areas that are near a nitrogen-sensitive water body. States and, sometimes, local health departments may designate what types of nitrogen control systems are permitted.

Because the need to manage nitrogen from septic systems is fairly recent, the technologies are still developing. Although systems are available that provide consistent treatment, there is room for improvement. The number of treatment options can be expected to increase in the next decade. Treatment effectiveness is also likely to improve as system design advances.

In some cases, changes may need to be made at the community level. For some communities or neighborhoods in critical areas, it may make more economic sense to extend sewers so that wastewater can be treated at a centralized facility. These decisions will need to be made on a case-by-case basis. In other situations, onsite nitrogen systems may make more sense but communities may recognize the need to establish a management system to ensure onsite systems continue to function well enough to protect environmental and public health.

Ultimately, the challenge will be how to continue to use nitrogen beneficially for agricultural use while minimizing the undesirable side effects. This will require changes in all nitrogen-generating sectors, including many residential septic systems.

References

Committee on Environment and Natural Resources. 2010. *Scientific Assessment of Hypoxia in U.S. Coastal Waters*. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC. Accessed at: *http://www.whitehouse.gov/administration/eop/ostp/nstc/oceans*

Fewtrell, Lorna. 2004. “Drinking Water Nitrate, Methemoglobinemia, and the Global Burden of Disease: A Discussion.” Environmental Health Perspectives 112(14): 1371-1374. Accessed at: *http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1247562*

Galloway, James, et al. 2008. “Transformations of the Nitrogen Cycle: Recent Trends, Questions, and Potential Solutions.” Science, Vol. 320, No. 5878, pp. 889-892. Accessed at: *http://www.sciencemag.org/content/320/5878/889.full*

Hazen and Sawyer, prepared for Florida Department of Health. 2009. “Literature Review of Nitrogen Reduction Technologies for Onsite Sewage Treatment.” Accessed at: *http://www.myfloridaeh.com/ostds/research/Nitrogen/Task_A-Lit_Review.pdf*

Larsen, Tove, et al. 2009. “Source Separation: Will We See a Paradigm Shift in Wastewater Handling?” Environmental Science and Technology 43, 6121-6125. Accessed at: *http://pubs.acs.org/doi/pdfplus/10.1021/es803001*

Lopez, C.B., Jewett, E.B., Dortch, Q., Walton, B.T., Hudnell, H.K. 2008. *Scientific Assessment of Freshwater Harmful Algal Blooms. Interagency Working Group on Harmful Algal Blooms,* Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC. Accessed at: *http://www.cop.noaa.gov/stressors/extremeevents/hab/habhrca/FreshwaterReport_final_2008.pdf*

U.S. EPA Office of Water, 2002. *Onsite Wastewater Treatment Manual*. EPA/625/R-00/008. Accessed at: *http://www.epa.gov/owm/septic/pubs/septic_2002_osdm_all.pdf*

Washington State Department of Health. 2005. “Nitrogen Reducing Technologies for Onsite Wastewater Treatment Systems.” Accessed at: *http://www.doh.wa.gov/ehp/ts/ww/n-red-tech.pdf*

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