Treatment

Biological Treatment Offers Lower-Cost Nitrate Removal Option

Using microbial biomass to treat groundwater provides new opportunities for US utilities to address widespread nitrate contamination, eliminate traditional waste streams, achieve greater water recovery, and save money.

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NITRATE IS ONE of the most common groundwater contaminants in the United States. Because of its ability to cause methemoglobinemia—also called blue-baby syndrome—nitrate has a US Environmental Protection Agency maximum contaminant level (MCL) of 10 mg/L as nitrogen. California has a similar MCL that’s stated in terms of nitrate (45 mg/L). Biological water treatment may be a promising alternative to traditional nitrate removal processes.

HISTORICAL PERSPECTIVE
In 2009, the California Legislature initiated a study of nitrate contamination in California’s agricultural areas, where groundwater provides much of the drinking water supply to communities and nitrate addition to the soil through fertilizer application and cattle operations is prevalent. The recently released study confirms widespread contamination of groundwater aquifers in these areas, particularly in the Central Valley and the Salinas Valley, in which many locations have nitrate concentrations in excess of twice the MCL.

More than 85 percent of California’s community drinking water systems rely on groundwater for some or all of their drinking water, and more than 1,800 of the state’s public potable water wells are contaminated with nitrate above the MCL. Similar problems occur across the United States in areas where agriculture contributes to a large part of the economy.

The use of microbial biomass for degradation of contaminants, nutrients, and organic matter has been used in the US wastewater field since the early 1900s. However, using biological treatment for drinking water in the United States has been limited, expanding only recently to include treatment of various organic and inorganic contaminants. In contrast, utilities in Europe have used biological treatment of groundwater for decades.

TRADITIONAL TREATMENT OPTIONS
Because accepted nitrate removal methods are costly and complex, MCL noncompliance is widespread. If the nitrate level in finished water can’t be diminished to an acceptable level through blending with other water supply sources, nitrate removal is usually accomplished through ion exchange (IX), reverse osmosis (RO), or electrodialysis reversal (EDR). However, these methods aren’t viable in many situations because of high costs and a need to treat and dispose of high-strength, highly saline concentrate waste. When the option is available to utilities, they often choose to shut down a problem well leaving a stranded asset, rather
One in 10 people living in California’s most productive agricultural areas is at risk for harmful levels of nitrate contamination in their drinking water, according to Addressing Nitrate in California’s Drinking Water, a March 2012 report released by the University of California and commissioned by the California State Water Resources Control Board. Nitrate is essential for plant growth and often added to soil to improve productivity.

than implement a traditional nitrate treatment technology. Clearly, utilities need a less-expensive, more environmentally sustainable solution to address nitrate challenges.

A NEW PARADIGM
During biological treatment of drinking water, bacteria indigenous to the local groundwater convert nitrate to innocuous nitrogen gas. In other words, biological treatment eliminates nitrate from the environment, a clear contrast to traditional nitrate removal processes. Several denitrification reactor configurations have been considered for drinking water applications, including fixed-bed (FXB) bioreactors, fluidized-bed bioreactors, and membrane-based bioreactors. Each is operated as a fixed biofilm system, meaning that the process includes a biogrowth support medium on which bacterial communities attach and grow.

FXB bioreactors use a stationary bed of media, such as sand, plastic, or granular activated carbon, on which indigenous bacteria form biofilms. Raw water is amended with an electron donor (e.g., acetic acid) and phosphorus and is pumped across the anoxic, biologically active media bed. Bacteria reduce nitrate to nitrogen gas, which is subsequently released to the atmosphere. Other contaminants can also be reduced in the bioreactor, including perchlorate, chromium (VI), selenate, some volatile organic compounds (VOCs), uranium, and arsenic.

Although the FXB denitrification process has been around for decades, much work during the last 10 years has honed the process for US drinking water applications. As shown in the accompanying figure, the result is a tailored FXB (T-FXB) treatment system that is robust and efficient. In the T-FXB system, once treated across the anoxic bioreactor, water is reoxygenated and dosed with a particle-conditioning agent. The water then goes through an aerobic biological filtration step, which provides oxidizing and filtration capacity. Effluent from the aerobic biofilter is disinfected and stored or distributed. The anoxic bioreactor is backwashed every 24–48 hours, and the aerobic biofilter is backwashed every 48–72 hours. Backwash wastewater can be treated to remove solids (i.e., sloughed bacteria), which can be discharged to a sewer or possibly land-applied, depending on the location. Recovered backwash wastewater is returned to the head of the T-FXB treatment system.

SYSTEM PERFORMANCE
Specific T-FXB system enhancements include specialized monitoring and chemical dosing algorithms, specialized nutrient addition, aerobic biofiltration, tailored media selection and configuration, and multiple biomass control tools. As a result, T-FXB systems have the following characteristics:

- **Robust.** Hydraulic and water treatment performance is independent of raw water quality and treatment goals and is insensitive to wide swings in operating conditions.
- **Green.** T-FXB is a low-energy system that eliminates nitrate from the environment rather than concentrating it, eliminates the generation of a high-strength brine stream and the addition of salt to a given watershed, and can achieve water recoveries greater than 96 percent.
- **Cost-effective.** Low-energy demand, the lack of salt regeneration, and the avoidance of a high-strength, nitrate-laden concentrate waste stream contribute to low operations and maintenance and life-cycle costs relative to IX and RO.
- **Flexible.** T-FXB systems can remove multiple contaminants in a single reactor and across a two-stage process. Nitrate, perchlorate, chromium (VI), selenate, some VOCs, uranium, and arsenic can be addressed without multiple add-on unit processes.
- **Straightforward.** T-FXB systems are comparable in design and operation with conventional granular media filtration. In addition, T-FXB systems are highly automated, so little operator attention is required.

POSITIVE OPTIONS
Nitrate contamination of drinking water sources is widespread, and options for disposing of high-strength, nitrate-laden waste streams are becoming scarce and more expensive. These realities are driving a paradigm shift for groundwater treatment. Consequently, T-FXB denitrification will be increasingly important for helping utilities provide safe drinking water in California and beyond.