Development of Design Criteria for Denitrifying Treatment Wetlands

Nitrate has been identified as a constituent of concern for many small and decentralized wastewater systems because of potential impacts on groundwater. Elevated levels of nitrate in drinking water have been linked to methemoglobinemia in infants, a medical condition that interferes with the oxygen-carrying capacity of blood (U.S. EPA, 2006). Due to this health concern, the U.S. EPA has set the maximum contaminant level for nitrate in drinking water at 10 mg N/L and some regulatory agencies are mandating control of nitrogen discharges to groundwater. In some aquifers, nitrate concentrations above the drinking water limit have been found to extend more than 100 meters from small septic systems. There are limited options available for decentralized wastewater systems to remove nitrogen. The lack of effective treatment options has resulted in the centralization of the wastewater systems for some communities with capital intensive collection and treatment systems.

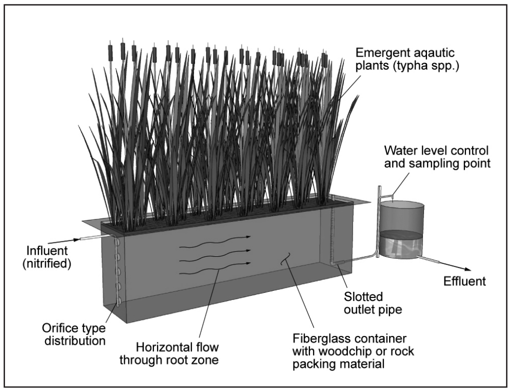

Illustration of Experimental Wetland Unit Used in the Study.

Research Background

This project assessed the effect that aquatic plants, temperature, length of operation, and nitrate concentration have on nitrate removal performance in subsurface flow constructed wetlands filled with a readily available organic media. An illustration of the experimental units is shown above. Nitrate removal was found to be effective and rapid, with denitrification described by first-order kinetics. Removal rate constants and temperature coefficients ranged from 0.33 d^{-1} to 4.10 d^{-1} and 1.14 to 1.21, respectively. First-order removal rate constants and temperature coefficients deceased as length of operation increased. Aquatic plants accounted for about 5 mg/L of the nitrate removal.

The experimental treatment included wetland units with (a) gravel packing with plants started on 7/2008, (b) woodchip packing with plants started on 7/2007, (c) woodchip packing without plants started on 7/2007, (d) woodchip packing without plants started on 7/2008, (e) woodchip packing with plants started on 7/2008, and (f) gravel packing without plants started on 7/2008.

Challenges for Nitrogen Removal in Small Wastewater Systems

In general, biological nitrogen removal systems are complicated by the variability in wastewater characteristics and inherent limitations in the processes used for denitrification. Most denitrification processes that have been used with onsite wastewater systems attempt to utilize the carbon contained in wastewater as the carbon source in the denitrification reaction, which must be preceded by nitrification. Unfortunately, in the process of accomplishing nitrification, much of the carbon required for denitrification is removed through aerobic reactions, leaving insufficient residual carbon for the denitrification reaction. Several proprietary post-anoxic denitrification processes have been developed to overcome this limitation, such as using a liquid carbon feed or solid phase carbon filters, however, most nitrogen removal processes used in practice are based on the modified

BENEFITS

- Outlines inexpensive solutions to remove nitrogen from water in anoxic constructed wetland environments.
- Provides design requirements needed to size the process for any desired level of nitrogen removal.
- Confirms that waste organic materials can be used for the development of denitrification systems that minimize operation and maintenance requirements.

RELATED PRODUCTS

Residential and Commercial Source Control Programs to Meet Water Quality Goals (95IRM1)

Small-Scale Constructed Wetland Treatment Systems: Feasibility, Design Criteria, and O&M Requirements (01CTS5)

Improving the Efficacy of Wastewater-Polishing Reed Beds (DEC11U06)

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Ludzack-Ettinger (MLE) process, which is not well suited for decentralized wastewater systems where high variability in loading results in unreliable performance.

Need for a Supplemental Carbon Source

Liquid carbon feed systems are well adapted to larger scale systems, such as those that benefit from daily operation and maintenance activity. For remote and small scale decentralized systems, however, chemical feed systems are subject to a number of challenges, including the need to replenish the chemical source on a regular basis and difficulty in applying the correct chemical dose for wastewater of variable quality. A variety of solid-phase organic materials have been used successfully as the electron donor in denitrification reactions, including sawdust, wheat straw, compost, and woodchips. While there is evidence that these systems can operate for extended periods of time without replenishment of the media, it is anticipated that replacement of the carbon supply will be required at some point, e.g., five to 10 years.

Development of Anoxic Constructed Wetlands for Nitrate Removal

Conventional constructed wetland technology, while having among the lowest carbon footprint of any wastewater treatment system (NAWE, 2007), is marginally successful in the removal of nitrogen. The nitrogen removal that does occur results from plant uptake and biological reduction using carbon sources in the influent and from the production of internal carbon through plant growth and decay. Free water surface (FWS) wetlands are better adapted to the input of plant debris as the vegetation can simply fall back into the water, resulting in high seasonal nitrogen removal. Subsurface flow (SSF) wetlands are more appropriate for many decentralized wastewater systems because of access and mosquito issues. Unfortunately, conventional SSF wetlands inhibit carbon cycling because the inert gravel packing used in the design separates the plant debris from the wastewater (Kadlec and Knight, 1996). Further, another recent study sponsored by WERF recommends augmenting treatment wetlands with waste organic matter for enhanced nitrogen removal (Liehr et al., 2000). Therefore, the creation of SSF wetlands utilizing a carbonaceous packing material has the potential to address all of the challenges presented above and needed to be evaluated as a viable technology for nitrogen removal in decentralized wastewater systems.

Research Demonstrates Simple System for Passive Nitrate Removal from Wastewater

The treatment system that was developed and evaluated consists of a lined subsurface flow treatment wetland with an organic (e.g., waste woodchips) packing material. The woodchips served as the initial carbon source for denitrification. The bed was planted with emergent aquatic plants that are expected to serve as a long-term regenerative carbon source through fixation of atmospheric carbon. In addition, visual and olfactory indicators of system performance were identified, a key advantage for treatment processes applied in remote areas where operation and maintenance are carried out on an infrequent basis. It was found that the nitrate concentration in the treatment unit could be qualitatively assessed by the height of the wetland plants, where growth was roughly proportional of nitrate concentration in the water. Little plant growth was observed at the system outlet where nitrogen concentration was typically non-detect. In addition, the presence of a hydrogen sulfide odor in the effluent was correlated with non-detect nitrate due to the highly reduced condition in the treatment wetland. It should be noted that, for optimal performance, a robust nitrification process is required upstream of the treatment wetland.

The anoxic wetland treatment system is applicable to decentralized residential, commercial, and institutional wastewater systems where a low effluent nitrogen limit has been imposed. The system will also be applicable to wastewater streams that have high nitrogen but insufficient internal carbon for denitrification. Applications where high nitrogen content wastewaters are common, such as landfill leachate and industrial process wastewater, are also target applications for anoxic treatment wetlands.

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