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Hydraulic Performance of the Denitrification Bioreactor

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Abstract
Denitrification bioreactors, also known as woodchip bioreactors, are a new strategy for improving drainage water quality before these flows arrive at local streams, rivers, and lakes. A bioreactor is an excavated, woodchip-filled pit that is capable of supporting native microbes that convert nitrate in the drainage water to nitrogen gas. The idea of these edgeof-field treatment systems is still relatively new, meaning it is important for investigations to be made into how to design these "pits" and to determine how drainage water moves through the woodchips. Because the bioreactor at the ISU Northeast Research Farm (NERF) is one of the best monitored bioreactor sites in the state, it provided an ideal location to not only monitor bioreactor nitrate-reduction performance, but also to investigate design hydraulics.

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Hydraulic Performance of the Denitrification Bioreactor

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Introduction

Denitrification bioreactors, also known as woodchip bioreactors, are a new strategy for improving drainage water quality before these flows arrive at local streams, rivers, and lakes. A bioreactor is an excavated, woodchip-filled pit that is capable of supporting native microbes that convert nitrate in the drainage water to nitrogen gas. The idea of these edge-of-field treatment systems is still relatively new, meaning it is important for investigations to be made into how to design these "pits" and to determine how drainage water moves through the woodchips. Because the bioreactor at the ISU Northeast Research Farm (NERF) is one of the best monitored bioreactor sites in the state, it provided an ideal location to not only monitor bioreactor nitrate-reduction performance, but also to investigate design hydraulics.

Materials and Methods

The NERF bioreactor was installed in April 2009 with the flow monitoring equipment and the transect wells installed in Fall 2009 and Spring 2011, respectively. The trapezoidal cross-section bioreactor (120 ft long × 3 ft deep × 15 ft top width) was filled with hardwood chips, the majority of which fell between the 0.3 and 1.0 in. particle size (by mass, based on visual comparisons). Beginning in October 2009, bypass and bioreactor flow were calculated from water depths recorded by logging pressure transducers in the two control structures. Water grab samples were collected twice weekly from both the inflow and outflow structures.

Based on preliminary nitrate-removal performance, a tracer test was done at the bioreactor in May 2011. Approximately five gallons of a bromide tracer solution was poured into the inflow control structure while no by-pass was occurring and samples were collected at regular intervals from the outflow structure. To have an increased level of sampling frequency compared with the routine inflow/outflow sampling scheme, two automated sample collection devices (Teledyne Isco 6712 Portable Samplers) were temporarily installed near the outflow control structure to collect samples on a timed basis. The routine monitoring samples and the tracer samples were analyzed for nitrate-nitrogen and bromide, respectively, at the Iowa State University Agricultural and Biosystems Engineering Water Quality Laboratory (Lachat Quick-Chem 8000).

Results and Discussion

In these early years of operation, the NERF bioreactor's nitrate-removal performance was poor compared with other bioreactors in the state. The annual nitrate-nitrogen load reduction for waters that passed through the bioreactor and for the total drainage water (that is, bioreactor treated water plus untreated bypass water) showed reductions less than 15 percent for both years (Table 1). This was less than total overall reductions ranging from 27 to 33 percent and 49 to 57 percent at two other bioreactors in central Iowa.

The tracer testing provided insight into reasons for this reduced performance. Tracer testing data from a reactor operating under theoretically ideal conditions would reflect no dispersion of the tracer as it moved through the reactor and would reflect complete elution of the tracer solution at the time when one pore volume of water passed through the reactor (curve A in Figure 1). By comparison, the narrow shape of the NERF tracer data curve (curve B in Figure 1) showed there was very little dispersion of the tracer solution throughout the bioreactor in this test. However, the peak tracer solution concentration arrived at the outlet before the theoretically ideal one pore volume. This was an indication of a non-ideal flow regime caused by short circuiting and inadequate use of bioreactor volume. In other words, the poor performance of the NERF bioreactor was likely due to short circuiting rather than dispersion or the lack of plug-flow conditions. In coming years, different outlet structure management at this site should be attempted to maintain water at deeper depths in the bioreactor to facilitate greater volume utilization and, it is thought, improved performance especially at higher flow rates.

The NERF bioreactor not only provides an excellent opportunity to collect high-quality, continuous monitoring data but also to additionally explore design hydraulics. Similar testing at other poorly- and well-performing bioreactor sites will help refine design and operational parameters for future bioreactors. It is hoped continued efforts such as these will lead to better, more effective bioreactors and improved water quality in the U.S. Midwest.

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Table 1. ISU Northeast Research Farm bioreactor-only and total flow nitrate-nitrogen load reductions for 2009 through 2011.

Year	Bioreactor-only	Total (bioreactor + bypass flow)
	------------------------- % NO_3^--N load reduction	---------------------
Oct. 2009 – Sept. 2010	14.6	13.6
Oct. 2010 – Aug. 2011	11.7	11.5

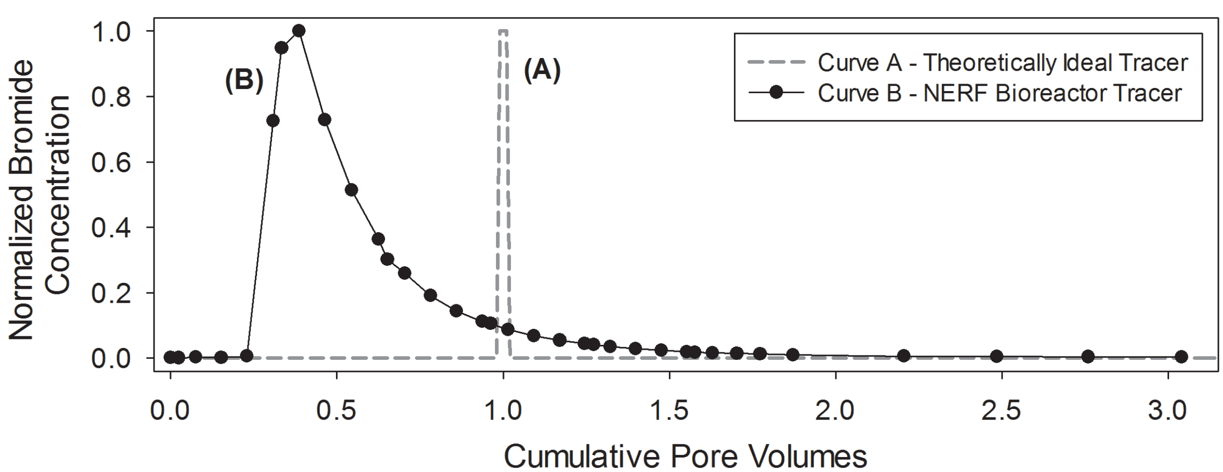

Figure 1. Tracer testing curve for a theoretically ideally performing reactor (A) and for the ISU Northeast Research Farm bioreactor test in May 2011 (B). Bromide concentration normalized to peak concentration in each case.