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Denitrification Bioreactor in Northeast Iowa

Laura E. Christianson
Iowa State University

Matthew J. Helmers
Iowa State University, mhellers@iastate.edu

Carl H. Pederson
Iowa State University, carl@iastate.edu

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Abstract

Denitrification bioreactors for removal of nitrate in tile drainage are new water quality technology that has rapidly gained interest in Iowa. A bioreactor is composed of an excavated trench filled with woodchips that are colonized by denitrifying bacteria. As drainage waters containing nitrate flow by these “good” bacteria, they convert the nitrate in the water to nitrogen gas. A critical component in evaluating the performance of these treatment systems is the documentation not only of nitrate concentrations in the drainage water, but also the flow rate and volume of the water treated in the bioreactor.

Keywords

RFR A1099, Agricultural and Biosystems Engineering

Disciplines

Agricultural Science | Agriculture | Bioresource and Agricultural Engineering

Denitrification Bioreactor in Northeast Iowa

RFR-A1099

Laura Christianson, research assistant
Matthew Helmers, associate professor
Carl Pederson, research associate
Department of Agricultural and Biosystems
Engineering

Introduction

Denitrification bioreactors for removal of nitrate in tile drainage are new water quality technology that has rapidly gained interest in Iowa. A bioreactor is composed of an excavated trench filled with woodchips that are colonized by denitrifying bacteria. As drainage waters containing nitrate flow by these “good” bacteria, they convert the nitrate in the water to nitrogen gas. A critical component in evaluating the performance of these treatment systems is the documentation not only of nitrate concentrations in the drainage water, but also the flow rate and volume of the water treated in the bioreactor.

Materials and Methods

A denitrification bioreactor was installed at the Northeast Research and Demonstration Farm in April 2009 with flow monitoring equipment installed later that fall. A unique feature of this bioreactor was that it was constructed with a trapezoidal cross-section, the first to do so in the state. The bioreactor’s dimensions were 120 ft long \times 3 ft deep \times 15 ft (top width) to 8 ft (bottom width). Hardwood chips from a local supplier were used as fill material. Water depths were monitored with pressure transducers in the inlet and outlet control structures and were converted to flow rates using rectangular weir flow equations from Chun and Cooke (2008). Area velocity meters (ISCO brand) were used to verify inlet and outlet flow data. Water samples were taken from the control structures by farm staff at least twice weekly starting in

October 2009. The samples were analyzed for nitrate-nitrogen using a cadmium reduction method (Lachat Quick-Chem 8000) at the Iowa State University Agricultural and Biosystems Engineering Water Quality Laboratory.

Results and Discussion

Initial sampling results show consistent, albeit small, differences in influent and effluent nitrate concentration (Figure 1b). Even during the winter months of early 2010 when biological activity by the denitrifying bacteria may have been reduced due to low temperatures (Figure 1c), nitrate removal was occurring. This small amount of nitrate removal continued during most of the spring and summer. To increase removal, in summer 2010 the downstream control structure was adjusted to increase the retention time of drainage within the bioreactor. In fall 2010, nitrate removal in the bioreactor was complete with the nitrate concentration in effluent samples reduced to nearly 0 mg NO₃⁻-N/L.

Regarding flow data, there was a correlation between several drainage events and precipitation in the area. There also seemed to be correlation between flow in the bioreactor and nitrate removal. For example, precipitation events on October 23 and 29, 2009 caused large drainage events at the bioreactor on those dates—approximately 600 gallons per minute (gpm) at the inlet (Figures 1a and 1c). A precipitation event on May 10–13, 2010 caused high bioreactor flow (about 800 gpm at inlet) and a decline in nitrate removal. Before this event, the bioreactor nitrate concentration reduction was 21 percent (inflow: 9.4 mg NO₃⁻-N/L, outflow: 7.4 mg NO₃⁻-N/L), while during the event nitrate removal was only 5 percent (inflow: 9.6 mg NO₃⁻-N/L, outflow: 9.2 mg NO₃⁻-N/L). Lastly, a rain event on November

12, 2010 resulted in reduced bioreactor performance as the effluent nitrate levels changed from less than 1 mg NO_3^- -N/L to over 6.2 mg NO_3^- -N/L on November 11 and 15, respectively.

This is the first bioreactor in the state with such comprehensive flow monitoring. This monitoring is a critical component of evaluating bioreactor performance in terms of nitrate loadings, not simply concentration changes. Further collection and analysis of this data will help strengthen the body of evidence for this technology. Continued

research at this site will contribute to more complete understanding of bioreactor performance and will potentially increase the positive impact these treatment systems can have on water quality in the Midwest.

Acknowledgements

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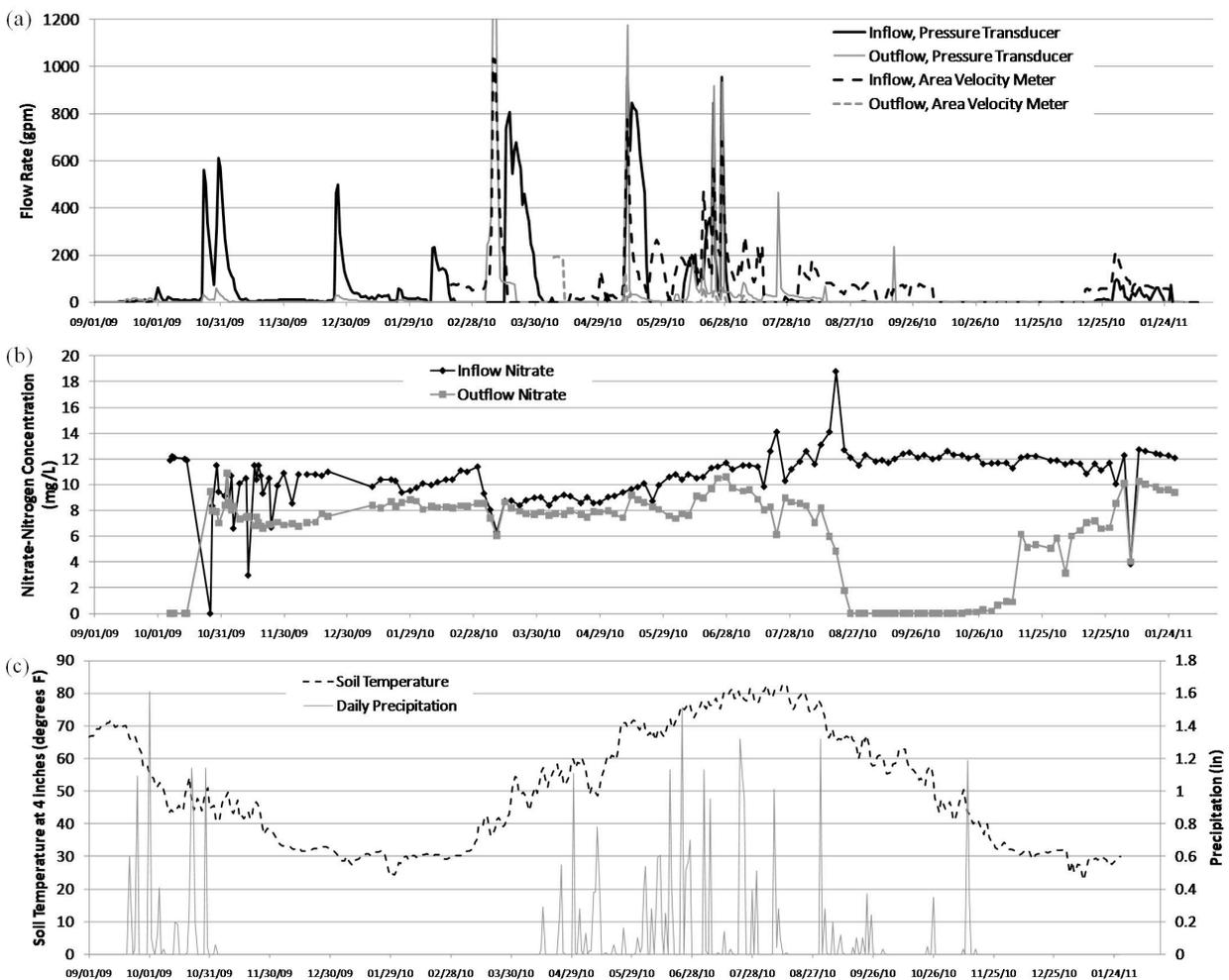


Figure 1: Northeast Research Farm bioreactor flow rates in and out (a), nitrate concentrations (b), and four inch soil temperature and precipitation (c).