



Mid-Project Preliminary Research Report:

**Optimization of denitrifying
bioreactor performance with
agricultural residue-based filter
media**

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Project Objectives

1. Identify agriculturally derived materials that will maintain required hydraulic properties in a bioreactor.
2. Improve the nitrate-N removal rate of bioreactors using agriculturally derived materials rather than wood chips, including at temperatures just above freezing.
3. Investigate the cost for bioreactors using agriculturally derived materials and compare to the cost for wood chip bioreactors.

Background

Wood-chip denitrifying bioreactors are one promising technology to mitigate subsurface drainage nitrate-N losses. Drainage water is routed through these denitrifying bioreactors, where anaerobic microbes reduce nitrate-N to nitrogen gas that ultimately escapes to the atmosphere (Figure 1). We seek to demonstrate that agricultural residue-based materials (e.g., stover, straw, cobs) used as filter media can improve the performance and decrease the size of bioreactors, and potentially lower their cost. Additionally, a large fraction of annual subsurface drainage and nitrate-N loss occurs during the spring snowmelt when soil temperatures are just above freezing (Jin and Sands, 2003). The cold temperatures tend to reduce microbial activity and negatively affect reactor efficiency. We propose to test the cold-temperature effectiveness of bioreactors with agricultural residue-based materials, in which the carbon is more labile than in wood chips.

Overview of Methods and Procedures

A laboratory approach is being used to investigate the flow and nitrate-N reducing properties of agricultural residue-based biofilter media—corn cobs, corn stover, and barley straw—compared to wood chips. PVC pipe columns (6-in. dia. by 19 in. long) were packed with soaked media and held vertically by steel racks in a temperature-controlled chamber (Figure 2). The media was inoculated with soil taken from crop land with a manure history. The columns were plumbed to a positive displacement pump that pumped water with a nitrate-N concentration of 50 mg/L up through the media. The water that passed through the columns was weighed daily. Water samples were taken three times per week and tested for nitrate-N concentration and pH. The oxidation-reduction potential in each column was measured continuously with a data logger; the temperature of each column, inlet water, and room air were also measured continuously. Dissolved gases within each column were sampled at 4-week intervals by withdrawing water through valve ports with a syringe.

The hydraulic conductivity of each medium was tested with a device known as a permeameter (Figure 3). The permeameter consisted of a 12-in. diameter by 8-ft long PVC tube. The tube was filled while in the vertical position by repeatedly pouring a fixed volume of material into it, and then compacting the material with a dropped weight. The material was weighed and the moisture content was determined, so that the dry bulk density for each replicate packing of the tube could be calculated. The tube was closed with a sealed end cap that was plumbed to a constant-head water supply tank. Water was pumped to the constant-head supply tank at an elevation 2 feet above the tube and routed down through the tube. The water flow rate was controlled by a valve on the outlet pipe. The pressure loss

that occurred along the length of the permeameter was measured by manometers connected at the top and bottom of the column. The relationship between the flow rate and the differential manometer reading was recorded for a range of flow rates. Each material was tested a number of times.

Description of Work Performed to Date

Eighteen column bioreactors have been constructed, instrumented, filled, and operated for 25 weeks at a temperature of 62°F. A system was developed to fill two water holding tanks in the controlled temperature chamber, to mix the chemicals in them, and to transfer the water to a single, larger inlet tank. More than 2000 water samples have been obtained, processed, stored, analyzed, and archived. More than 430 gas samples have been processed and analyzed. At the completion of the 25-week run, each column was unpacked and media samples were collected for DNA testing of the microbial biomass. The media masses for each column were weighed before and after each run to determine the rate of carbon loss. The columns have been emptied, cleaned, re-packed, and racked in preparation for the second experimental run, which will be conducted at 36°F.

The permeameter was designed and built on the turf grass research plots on the University of Minnesota - St. Paul campus during June and July. The permeameter has been filled and emptied 13 times.

Results to Date

Preliminary results show differences among the material candidates with respect to reduction in nitrate-N concentration. However, we have not completed the analysis that will take into account the actual residence time of the water in the column, which was nominally 12 hours but varied among treatments. Thus, the apparently higher denitrification rate of the corn cob treatment is yet to be substantiated.

The hydraulic conductivity test data has also yet to be fully analyzed. The major factor that needs to be considered is the temperature of the water during each test. Since the permeameter installation was outside and tests were conducted from August to October, the water temperature and viscosity, which affected flow, varied substantially. We can note, however, that the compressibility of the straw negatively affected the flow rate compared to the other materials.

Potential Benefit to Minnesota Economic/Environmental Development

Testing these materials is being conducted to determine if the wood chip bed material that is currently used in denitrifying bioreactors can be replaced with readily available agricultural residues. The potential benefits include cost and availability. Materials with a higher denitrification rate would

require a smaller size to perform the same task. However, the materials with a higher denitrification rate would need to be replenished more often than wood chips, which presents engineering and cost challenges.

Future Needs/Plans

At the conclusion of the second experimental run, the information from the two aspects of the project will be combined. A logical next phase of the project would be to select the most promising material and build a pilot scale bioreactor at a field location.

References

Jin, C.-X., G.R. Sands. 2003. The long-term field-scale hydrology of subsurface drainage systems in a cold climate. *Trans. ASAE* 46(4):1011-1021.

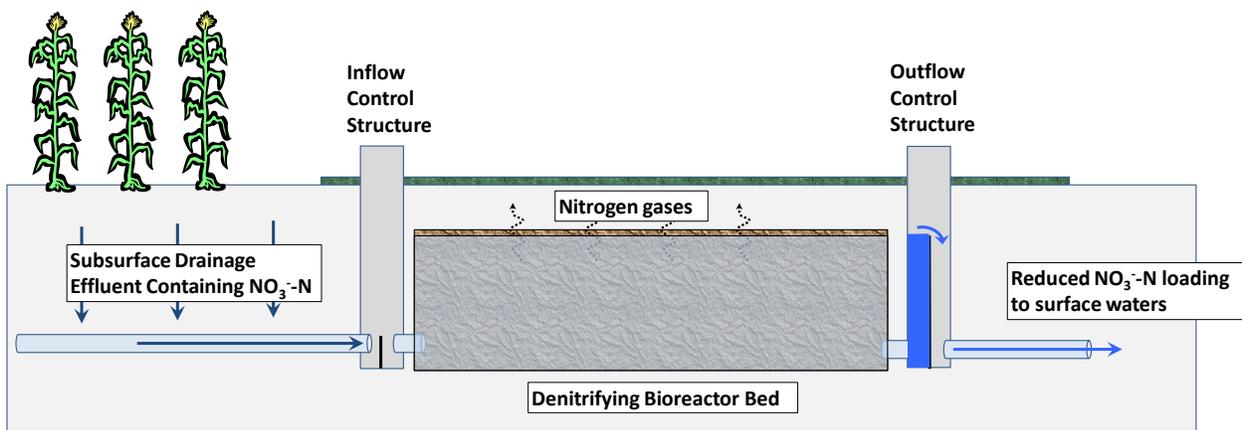


Figure 1. Schematic of a denitrifying bioreactor designed to reduce the nitrate-N concentration of agricultural drainage water.



Figure 2. Eighteen bioreactor columns racked and plumbed in a temperature controlled chamber.



Figure 3. Permeameter built in June and July 2012 for hydraulic conductivity testing. Insets: Column packed with corn cobs (A) and corn stover (B); column laid horizontally for removal of barley straw (C).