

BIOREACTORS: A New Approach to Managing Nutrient Loss from Agricultural Lands

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INTRODUCTION

Wetlands serve as a natural purifying and filtering system for contaminated and nutrient rich waters from nearby agricultural fields. As surface, subsurface and tile drainage waters flow into wetlands, excess nutrients are removed through plant absorption and bacterial digestion. Other contaminants, such as suspended solids, chemicals, heavy metals, and organic matter sources, are also filtered out of the drainage waters by deposition onto the wetland detrital floor¹, flocculation, precipitation or plant chemisorption². Wetlands also provide an additional benefit to the area by acting as a viable environment for wildlife and aquatic animals, and by providing a significant environmental benefit to landowners and agricultural producers through nutrient removal as mentioned above.

A modern alternative to wetlands, bioreactors are advantageous to the agriculture sector as they also provide the purifying capabilities of wetlands, but do not reduce overall cropland acreage, as they are located underground.

WHAT IS A BIOREACTOR AND HOW IS IT CONSTRUCTED?

A bioreactor (also known as a biofilter) is a constructed purifying system for subsurface drainage waters from agricultural lands. As tile drainage flows through the bioreactor, the total nutrient load is reduced prior to being released to surface or groundwater. The total nitrate-nitrogen ($\text{NO}_3\text{-N}$) load is reduced as denitrifying microorganisms convert $\text{NO}_3\text{-N}$ into gaseous byproducts through the process of denitrification³. The microbes are naturally occurring bacteria within this system, but are sustained by the addition of carbon-rich organic substrates that provide the microbes with energy (i.e. wood chips, tree bark, leaf litter, corn cobs, etc.).

Current studies have shown that the best organic substances for bioreactors include woodchips ranging in size from $\frac{1}{4}$ "-1", as they are a consistent source of carbon that is considered the most resistant to decomposition over time in comparison to other sources³.

The bioreactor is composed of an inlet pipe, the chosen carbon source, an outlet pipe, and two control structures with stop logs to control the flow of influent and effluent water (Figure 1).



Figure 1. Biofilter construction. A. Dig trench B. Place and level control structures. C. Backfill pipes and control structures. D. Line trench with plastic liner, ensuring inlet and outlet pipes will have good contact with woodchips. E. Fill trench with woodchips, cover with plastic liner, and backfill leaving a 12" minimum soil cover. F. Seed overtop of biofilter.

HOW EFFECTIVE ARE BIOREACTORS AT REDUCING NUTRIENTS?

Bioreactors have demonstrated significant reduction in $\text{NO}_3\text{-N}$ loads (ranging from 12 to >99% $\text{NO}_3\text{-N}$ reduction in numerous studies)³, and are largely affected by four main factors:

Influent water volume: Greater flow of influent water into the system can mean a decrease in the total amount of $\text{NO}_3\text{-N}$ reduced. A recent study showed that surges of rainfall events led to a decline of 27-50% in $\text{NO}_3\text{-N}$ reduction, due to the increase in water flow and decrease in retention time⁴.

Temperature/Seasonality: Removal of $\text{NO}_3\text{-N}$ is often greatest at warmer temperatures due to increased microbial activity for microbial denitrifiers³. Nitrate removal has been shown to increase linearly with temperature; for every 10°C increase the $\text{NO}_3\text{-N}$ removal rate has an average 2 fold increase⁵. Seasonality plays a large role in the effectiveness of bioreactors due to the change in drainage water volume caused by large precipitation events and flood surges. The size of bioreactors should be carefully planned out to accommodate these events, as this can affect the amount of drainage water that can be processed.

Influent Retention Time: Generally, the greater the retention time of influent within the bioreactor, the greater the total $\text{NO}_3\text{-N}$ load is reduced⁶. Recommended retention times for influent are 4-8 hours. Retention times above 8 hours, can potentially lead to the production of unwanted byproducts such as methane and methylmercury, due to sulfur reduction processes⁷.

Age of the Bioreactor: The longevity of a bioreactor is still uncertain, however, some studies anticipate woodchip bioreactors can last from 10 to 20 years^{8,9,10,11}. At some point, the carbon source of the bioreactor will need to be replaced to ensure efficient activity within the system.

ARE THEY EXPENSIVE?

Biofilters can range in price and are dependent on the materials used for the carbon source, and the size of the biofilter (which is also based on the expected flow volume into the biofilter). The typical cost of a biofilter can range from \$1500 to \$2500. Currently there is no economical incentive program on PEI to offset the costs of biofilter construction, however, continued work showing the benefits of these structures may lead to future funding sources.



BIOREACTORS ON PEI

In the fall of 2012, through the work of the Kensington North Watershed Association, along with funding and technical support through the Environment Canada Eco-Action Program, the PEI Department of Agriculture and Forestry, and Agriculture and Agri-Food Canada; an underground wood chip bioreactor was constructed within a small tributary of the Darnley Basin. The bioreactor measures 40 feet in length, 4 feet wide and 4 feet deep.

Preliminary data from the bioreactor within the Darnley Basin shows NO₃-N reductions from inlet to outlet sources ranging from 16-95% over a 7 month period (Figure 2), with large nutrient reductions observed during early winter thaws (January- February), and during the planting period (late May-early June).

Another bioreactor has been constructed on the Agriculture and Agri-Food Canada Research Farm in Harrington, PEI, below a tile drained 10 acre field. Current data from this bioreactor has shown similar nutrient removal results to the bioreactor of Darnley Basin, with more results to be produced within the 2014 season under potato production.

HOW EFFECTIVE ARE BIOREACTORS AT REDUCING OTHER CONTAMINANTS?

Few studies have identified the ability of bioreactors to absorb pesticides and chemical contaminants that could potentially be transported with agricultural drainage waters.

Some preliminary studies based out of the mid-West USA under soybean and corn rotations using the herbicides, atrazine and acetochlor, showed an average 54% decrease in atrazine, and a 70% decrease in acetochlor^{4,12} from use of bioreactor devices. As these are preliminary studies, it would be beneficial to further explore this potential benefit to bioreactors here on PEI.

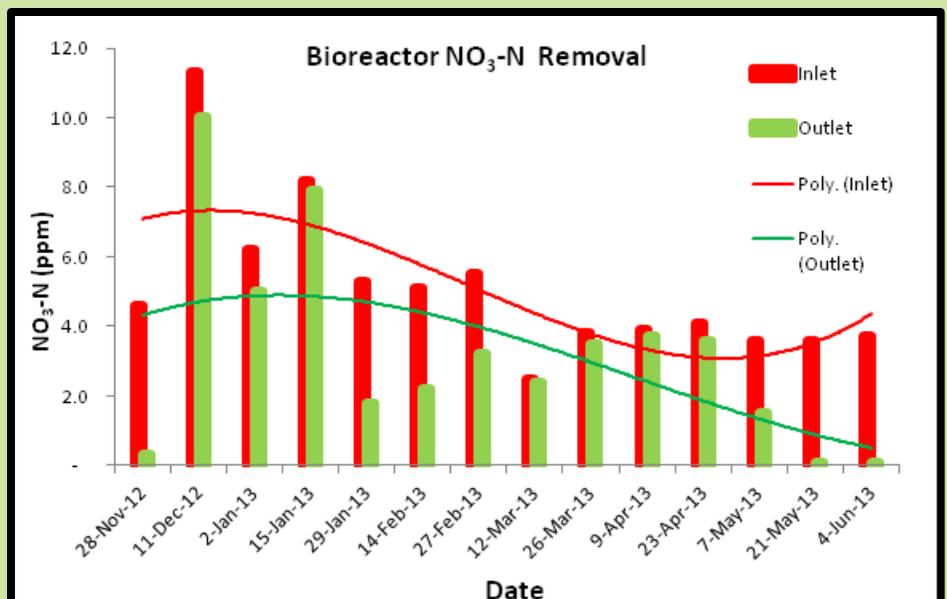


Figure 2. NO₃-N removal rates from the KNWSA biofilter in Darnley Basin. Curved lines are based on third order polynomials of bioreactor data.

CONCLUSION

The construction of bioreactors within agricultural areas may be a viable solution to reducing excess nutrient contamination without affecting current fertility practices within agricultural lands. If you are interested in more information on bioreactors, please contact: **Kyra Stiles** (PEI DAF) at kstiles@gov.pe.ca, OR **Scott Anderson** (AAFC) at scott.anderson@agr.gc.ca.

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