# Advancing the adoption of artificial nitrogen sinks

Jill Raval[1], Elissa Monahan[1], Kelly Addy[1*], Dr. Art Gold[1], Dr. Mark David[2], Dr. Louis Schipper[3], and Dr. Brian Needelman[4]

[1]University of Rhode Island, [2]University of Illinois, [3]University of Waikato, [4]University of Maryland *kaddy@uri.edu

## Introduction

Constructed wetlands and denitrifying bioreactors are artificial "sinks" (hotspots of N removal) that are created to resemble natural systems that promote denitrification. When installed at the edge of an agricultural field, they can intercept groundwater or tile drainage water and reduce the nitrate-N content of agricultural discharge. The goal of our project is to advance the adoption and proper placement of denitrifying bioreactors and constructed wetlands in agricultural settings.

### Constructed Wetlands

Constructed wetlands (Fig.1) are artificial systems that provide ecological services, such as flood water storage, nutrient (nitrogen or phosphorus) storage and cycling, and erosion control. They are modeled after natural wetland systems. These systems are placed alongside ditches or streams where they retain water for hours or days to allow nitrate-N removal through denitrification.

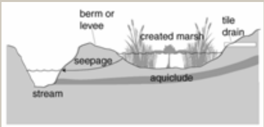



Figure 1: Conceptual diagram of constructed wetland treating tile drainage (Mitsch and Day 2006)

### Denitrifying Bioreactors

A denitrifying bioreactor (Fig.2) is an artificially constructed system that mimics selected functions of riparian wetlands. These systems are composed of an added source of carbon (often woodchips) that intercept groundwater or tile drainage. The wood chips create an anaerobic environment in which bacteria transform the nitrate-N in the water into nitrogen gas.



Figure 2: Denitrifying Bioreactors

The two main types of denitrifying bioreactors are beds (Fig. 2a) and walls (Fig. 2b). Beds are closed systems that receive tile drain inflow. Walls are placed in the natural flowpath of groundwater leaving from agricultural fields.

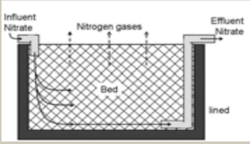



Fig 2a: Denitrification bed to treat tile drainage (Schipper et al. 2010)

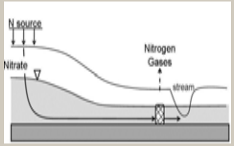



Figure 2b: Denitrification wall to intercept groundwater flow (Schipper et al. 2010)

## Outreach Approach

### www.artificialnsinks.org

This website, primarily targeting land managers and farm advisors, offers guidance, an International Atlas of constructed wetlands and denitrification bioreactors, fact sheets, case studies, presentations, videos and other resources.

We also have a listserv to share news on artificial N sinks and share project successes. To join our listserv, email kaddy@uri.edu.

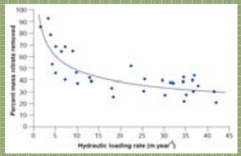

**The International Atlas** identifies artificial N sink research and demonstration sites from across the globe. The map not only gives information about where the systems are but also provides project contact information, links to case studies, papers, and websites with additional information. We welcome any additions to our atlas or website (email kaddy@uri.edu).


**Resources** include fact sheets, case studies, videos, workshop presentations and research summaries about constructed wetlands and denitrifying bioreactors. Research papers written by scientists are further studied and condensed into summaries in our case study section which highlights the situation, actions, and take-home messages. We also have videos and fact sheets that highlight similar subject matter.

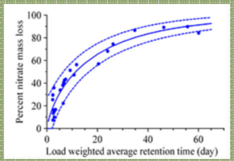

Another important feature of the website is the **Frequently Asked Questions (FAQs)** which provides basic information on the function and processes of artificial N sinks. Basic information about point source pollution, dead zones and other related details are also present on this page. Most questions have links to EPA definitions and videos which give a fuller understanding of the subject.

## Synthesis Approach

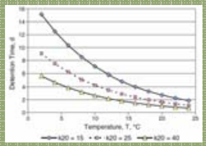
### Initial Synthesis: Factors controlling denitrification in constructed wetlands




**Hydraulic Loading**
While there is higher %N removal in summer and fall, there is also much less flow. Therefore, less total nitrate-N is removed at that time. (Crumpton et al. 2008)

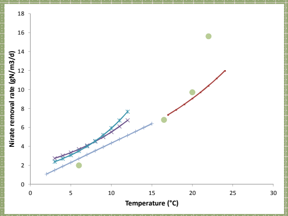


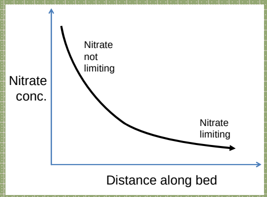

**Retention time**
Longer retention times can yield higher mass loss of nitrate-N. (Crumpton, Iowa State University)




**Temperature**
For a given retention time, more nitrate-N is removed as the temperature rises. (Kadlec 2012)

### Initial Synthesis: Factors controlling denitrification in denitrifying bioreactors




**Temperature:** Roughly, as temperature increases by 10°C, nitrate-N removal rates increase two-fold. (data from Warneke et al. 2011; Van Driel et al. 2006; Robertson and Merkley 2009; and misc. point studies)

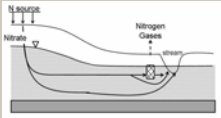
**Nitrate concentration:** Michaelis constant ($K_m$) will be important for removing the last bit of nitrate-N or when nitrate concentrations are low.

| Location | Study Type | Longevity of woodchips (years) | Source |
| --- | --- | --- | --- |
| Canada | Field Assessment | 15 | Robertson et al. 2008 |
| New Zealand | Field Assessment | 14 | Long et al. 2011 |
| Iowa, USA | Field Assessment | 9 | Moorman et al. 2010 |
| Western Australia | Extrapolation | 20 | Fahrner 2002 |
| New Zealand | Extrapolation | 39 | Warneke et al. 2011 |
| New Zealand | Extrapolation | 11 (carbon ½ life) | Long et al. 2011 |
| Florida, USA | Extrapolation | 23 | Schmidt and Clark 2012 |

**Carbon:** The longevity of denitrifying bioreactors is dependent on the continued lability of carbon in the woodchips, which may last 9 to 39+ years.

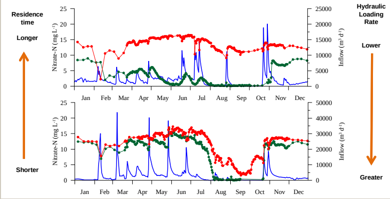
## Limitations & Next Steps

Artificial N sinks are not suitable for all locations and conditions. It is important to consider site conditions and hydrology at all sites to maximize N removal function.




**Flowpaths:** If a denitrifying bioreactor is intended to intercept natural groundwater flow, site hydrology must be understood. For instance, deep groundwater flow can bypass treatment. (Schipper et al. 2010)

**Cost and Social Barriers** to adoption are other important limitations for artificial N sinks.




**Residence time and hydraulic loading:** For high N removal in both constructed wetlands and denitrifying bioreactors, longer residence times need to be accommodated when hydraulic loading is high. (Crumpton, ISU)

**Next Steps**

- Conduct a formal meta-analysis to refine our synthesis of controlling factors and recommendations
- Explore geospatial data for improved siting of artificial N sinks
- Assess potential adverse effects: greenhouse gases, dissolved organic carbon, and methyl mercury

## Acknowledgements & References

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