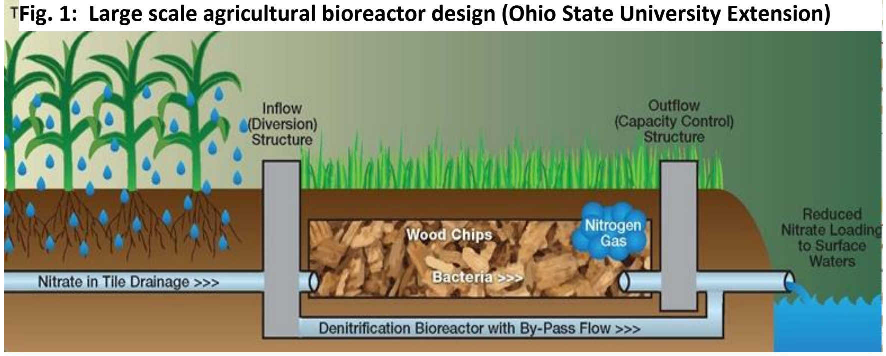
Using Scaled-down Woodchip Bioreactors in Roadside Ditches to Filter out Dissolved Nitrate *(Draft Nov. 2018)*

Excess dissolved nitrogen, along with phosphorus, leaches from septic systems and from fertilizers and manure spread on agricultural fields. Dissolved nitrate is transported during storms in overland runoff and in subsurface groundwater, into our streams, lakes and eventually transported to bays and estuaries where it contributes to pollution, algal blooms, and anoxic zones. To address this problem, farmers in the Midwest have been redirecting farm runoff and tile drainage into large-scale, woodchip bioreactors. This method has proven to be an effective tool for removing the dissolved nitrate before it enters a stream.

What is a Bioreactor?

Fig. 1: Large scale agricultural bioreactor design (Ohio State University Extension)



Wood chip bioreactors are large pits filled with wood chips that are used to treat nitrogen-polluted water. Large bioreactors can be up to 150 feet long, 50 feet wide, and up to 10 feet deep. Dissolved oxygen drops rapidly within the bioreactor, creating conditions which favor denitrifying bacteria that naturally grow in organic media, such as the wood chips. The bacteria form biofilms around the chips which intercept the flowing water and filter out significant quantities of dissolved nitrogen compounds by converting the nitrate to N_2 gas.

Scaled-down Wood Chip Bioreactors for Ditches

Our previous research has shown that extensive networks of roadside ditches criss-cross every landscape. These ditches are efficient conduits of water and contaminants, intercepting ~20% of the runoff from each small watershed, and rapidly shunting it to nearby streams, contributing to floods and pollution[1-3]. Viewed as an opportunity, these networks of ditches have the potential to serve as the basis for a watershed-wide filtration system. We have been monitoring dissolved nitrate in roadside ditches adjacent to manure-spread ag fields in c. New York, and documented consistent NO_3+NO_2 concentrations of 10-35 mg/L and a total load of 900 kg over 5 months associated with a 10 ha farm field. In 2016, we began testing out the viability of using scaled down bioreactors placed directly in roadside ditches as a cheap, easily installed method for removal of dissolved nitrates from storm water runoff.

Fig. 2: Ditch bioreactor TC1 in Tompkins County NY

Our bioreactors (nick-named “socks”) are designed to be easy and quick to install, cheap to make, easily monitored, and flexible to fit a variety of different ditch conditions (Fig. 2, 3). They are installed within existing ditches that do not require extensive excavation and have frequent water flow. Our research sock dimensions are consistently 5m (length) x 1m (width) x 0.2m (depth), though a sock can be modified to fit the shape of the ditch in which it is installed. Each sock is constructed in place, using polypropylene mesh and zip ties to contain the wood chips. Rebar is pounded through the sock and into the ditch to hold the sock in place.

Fig. 3: Construction of paired bioreactors in PA.

To install: *First scrape down an inch or two into the ditch bottom, to clear vegetation, level the substrate, and create a small depression that captures water. Lay the mesh lengthways on the ditch bottom, add woodchips and rake them out evenly, then fold the extra mesh over the top. Close the sock by rolling the top and bottom pieces together on all sides until taut, and secure the rolled edges with zip ties every 8 inches. Finally, pound 6-8 short pieces of rebar through the sock into the ground to secure it. Fill in along the sides with dirt as needed to eliminate side flow. Total installation time: 2 hrs.*

How well do they work?

We have thus far evaluated four ditch bioreactors: TC1 was piloted in 2015 in Tompkins County NY; and in May 2018 two bioreactors (PA1, PA2) were installed in Bradford Co, PA, as a series separated by 25 cm to determine if removal rates would be increased. The fourth (PA3) was installed in July 2018 in a separate ditch (Bradford Co., PA) to experiment with different engineering designs to increase water residence time. Our data thus far indicate that these trial socks work best during low flow conditions (Fig. 4) with nitrate removal efficiencies up to 100%. Nitrate is still removed at lower efficiencies during high flow conditions, but much of the total N load bypasses the socks as water quickens and flows over the top.

The double sock system (PA-1, PA-2) successfully exhibited increased removal compared to a single sock (Figs. 5 and 6). These findings suggest that installing multiple socks, back-to-back, increases removal, and additional socks can be added in line to accommodate the conditions of each site.

Fig. 4: Reduction of NO3+NO2 concentrations as a function of flow rate of water in each ditch.

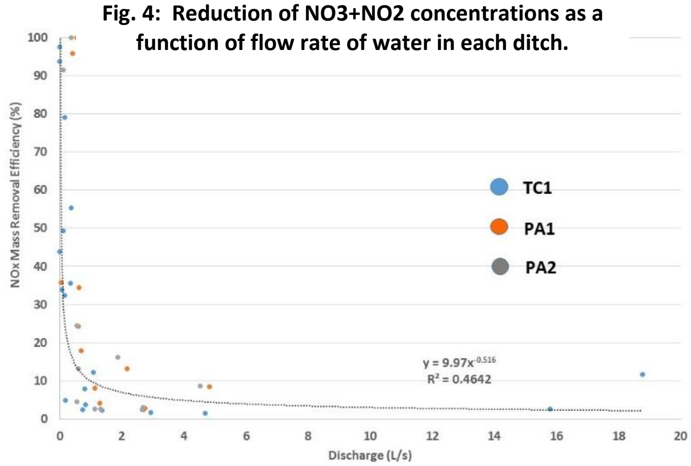


Fig. 5: Water sampler located between double socks.

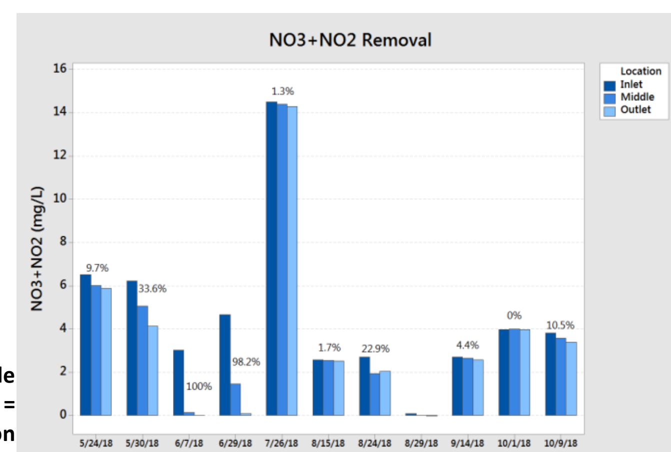


Fig. 6: Reduction of NO3+NO2 concentrations in the double bioreactor system in Bradford County PA in 2018 (Middle = between the two socks). Overtopping occurred during storms on 7/26, 8/15, 9/14, and 10/1.

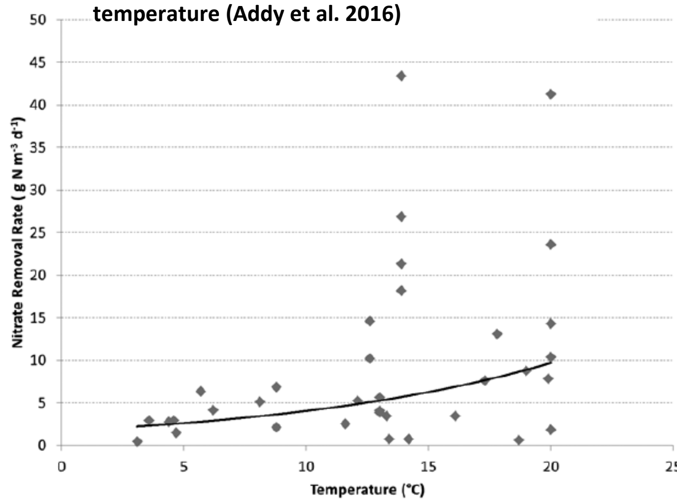
Additional Considerations

Ditch bioreactors are best placed in a long section of gently sloping, medium depth ditch. Steep slopes (>5-10 %) cause water to pass through the sock more quickly, which can reduce residence time and overall efficiency. The denitrification process which drives the nitrate removal is also sensitive to various factors, including contact time, temperature (Fig. 7), extended periods of drought and aerobic conditions, and to a lesser extent, wood chip species and age.

Unintended Consequences

Contrary to our expectations, the bioreactors did not contribute significant levels of dissolved organic carbon (DOC) into stream flow. An average increase of one mg/L DOC leached from the paired socks for several weeks associated with the initial flush of the system. Electrical conductivity and pH also remained relatively constant in the NY and PA socks. However, dissolved oxygen dropped by ~70% between the inlet and outlet of the paired sock system, which could be detrimental to ponds or streams located immediately downstream. We suggest that a simple gravel riffle can be placed after the bioreactor to increase turbulence and expedite aeration.

Fig. 7: Bioreactor removal rate as a function of temperature (Addy et al. 2016)



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Acknowledgments

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