Edge of Field Practice

Denitrifying Bioreactors

A denitrifying bioreactor is an edge-of field-nitrogen management practice that involves a trench in the ground packed with carbonaceous material such as woodchips that facilitate colonization of soil bacteria that convert nitrate in drainage water to nitrogen gas; see figure 1 for a generalized schematic. Bioreactors are most suitable for 6”-10” tile lines and most current bioreactor designs in use in Iowa have been successful at treating nitrate in drainage areas from 30 to 80 acres in size and have life spans of at least 15 years (before material fill need replacing/or control structures need significant maintenance). Because this is an edge-of-field practice, in-field yields will not be affected. Likewise, bioreactors will have no impact on soil quality. Regional research regarding the effectiveness of bioreactors has demonstrated nitrate reduction in drainage water between 30 to 70% (Christianson and Helmers, 2011).

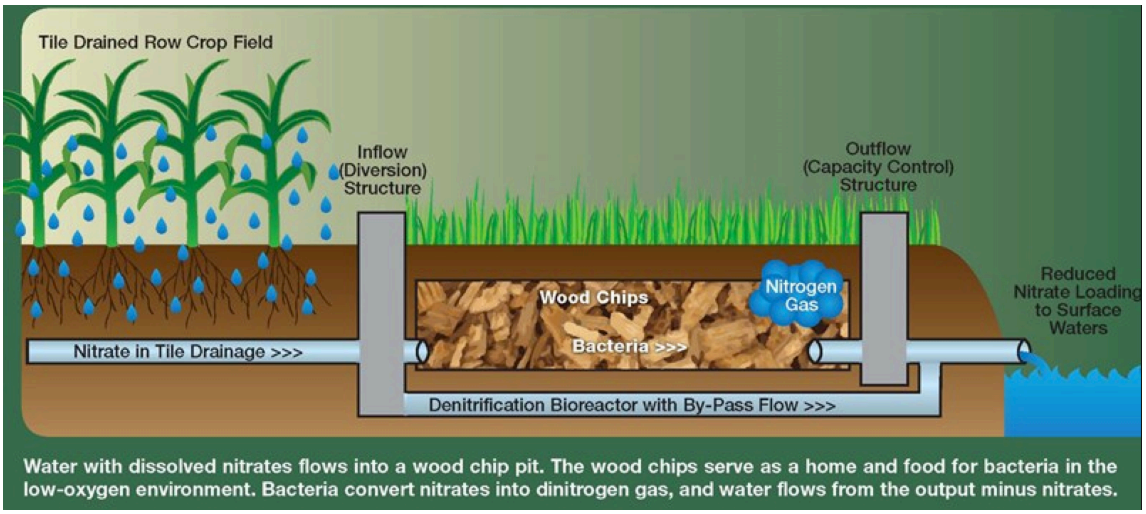

Figure 1. Simplified diagram demonstrating the basic bio-physical principles of a denitrifying woodchip bioreactor and its structure. Design, scale, and function of denitrifying bioreactors are site-specific and contingent upon site conditions and management goals. Image: Christianson, 2014

Woodchip Bioreactor Cost Overview and Example:

The primary cost of a woodchip bioreactor is associated with planning and design, excavation, control structures and obtaining, transporting, and handling fill material; these represent upfront costs that occur in years 0 and 1; see table 1. There are no land-use opportunity costs associated with the utilization of bioreactors. The functional lifespan of this practice is estimated to be between 15 to 20 years (though it could be longer) after this time period, control structures and the fill may need to be replaced.

Table 1. General practice characteristics of bioreactors as used in Iowa and basic cost parameters. This practice can be cost shared with the NRCS via the EQIP program.

Best Management Practice (NRCS practice standard code)	**General use of the BMP: For the most part this information comes directly from NRCS practice standard information.**	**Basic Cost Parameters: Varies considerably from site to site and depends on initial conditions, hydrology, soil, crop, practice design, and management characteristics.**
Bioreactors (Practice Code 747) [1]	Reduction in nitrogen load from tile drainage system	Design and planning; excavation; tile pipe, wood chip, and control gate purchase, installation and yearly adjustment/maintenance; site surface planting; seed mix (usually 1-2 species); annual grounds keeping, replacement costs at end of practice lifespan.

1. NRCS Practice Standard for Bioreactors, Practice Code 747: https://efotg.sc.egov.usda.gov/references/Agency/IA/Archived_Denitrifying_Bioreactor_747_STD_2014_04_151015.pdf

Because the total costs of a bioreactor are use specific and contingent upon the overall scale/ drainage area being treated, below is an example cost assessment for a bioreactor suitable for a 50-acre drainage treatment. Basic bioreactor parameters for cost example: 40-acre drainage treatment. Design capacity is to treat a flow equivalent to a drainage coefficient of 1/8″per day or 20% of the calculated peak flow from the drainage system. Four-hour hydrologic retention time. The annualized costs over a 20-year period come to slightly over $800 per year. Total upfront costs for design and full installation come to $10,250. Table 2 below summarizes the outcome of this example. The Iowa NRCS Environmental Quality Incentives Program (EQIP) will pay $24.85 per cubic yard of pit excavation. The bioreactor in this example has an excavated pit volume of 333 cubic yards (e.g. 6 feet deep, 15 feet wide and 100 feet long) and would pay $8,275 or 80% of the total installation costs. Table 3 overviews all the custom rate costs associated with this practice.

Table 2. First year and annualized costs of a denitrifying bioreactor designed for a 50-acre drainage area. Annualized using a 4% discount rate. Costs are in 2016$.

First year costs (Design and installation)	$10,150 [1, 2]
Annualized costs over 20 year lifespan	$675 [3]
Annual management costs	~ $50

1. No productive land is removed from production so opportunity costs are negligible. The vast majority of total costs are in installation and in chip replacement after 20 years; **2.** Iowa 2016 EQIP program will pay $24.85 per cubic yard of bioreactor pit excavation assuming the practice is maintained for at least 10 years. (The Iowa 2016 EQIP payment schedule: http://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd420279&ext=pdf (Bioreactors, page 108); **3.** Costs were calculated and annualized using standard discounted cashflow procedures for structural water quality Best Management Practices. For more detail see Tyndall and Roesch, 2014.

Important caveat: Please note that the direct and indirect cost of any Best Management Practice can vary considerably from site to site and are largely contingent on: initial conditions, hydrology, soils, crop, practice design, management characteristics and experienced opportunity costs (which can be highly variable). As with all of these types of financial assessments, the costs presented here are simply baseline numbers and are meant to be informative rather than prescriptive.

References

Christianson, Laura. (2014) Bioreactors: Benefits and potential challenges. Iowa Learning Farm Webinar Series. November 2014. Available at: https://iowalearningfarms.wordpress.com/2014/11/17/top-ten-webinars-4-bioreactors-benefits-and-potential-challenges/

Christianson, L. and M. Helmers. (2011) Woodchip Bioreactors for Nitrate in Agricultural Drainage. Iowa State University Extension & Outreach. PMR 1008. October 2011. Available at: https://store.extension.iastate.edu/Product/13691

Christianson, L., Tyndall, J.C., Helmers, M. (2013) Financial Comparison of Seven Nitrate Reduction Strategies for Midwestern Agricultural Drainage. *Water Resources & Economics*. http://dx.doi.org/10.1016/j.wre.2013.09.001

Tyndall JC, and G. Roesch (2014) A Standardized Approach to the Financial Analysis of Structural Water Quality BMPs. *Journal of Extension*. Vol. 52, Num. 3, 3FEA10.

Table 3. Custom rate costs associated with bioreactors installed in Iowa; primary goal is nitrogen reduction in tile drainage. Costs presented in 2016 dollars. All data updated from Christianson et al. 2013.

Cost Activities [1]/ items	Year(s) cost incurred	Average cost (per bioreactor)	Average cost (per year; 20 years)	Notes/ Assumptions
Bioreactor design	0	$1000	$61	Bioreactor design is generally available without cost from a government service agency (such as the NRCS); however, more complex designs may require an engineering firm (~ 10 hours at $100/hr).
Control Structures	0	$2630	$161	Cost and installation of control structures (2 for every 50 drainage acres at $530 - $2100 per structure).
Connection pipe/tile	0	$1650	$101	1000' of connection pipe (at $0.30 - $3.00 per foot).
Trenching (backhoeing)	0, 20	$1140	$70	Bioreactor trenching (backhoeing); at average cost of $95/hour for 12 hours. In year 20 the woodchips may need replacing. A backhoe may be used to remove old woodchips
Woodchips (with transportation)	0, 20	$3600	$220	Two semi loads of woodchips at $1600 per load, $200 transport ea. There may be locally available woodchips at significantly reduced cost. Ideally, woodchips are should be uniform in size and free of debris. Bulk sales of woodchips from retail outlets can cost ~ $30/ cubic yard, or about $10,000. In year 20 it is possible that the woodchips will need to be replaced.
Grass cover seed	0	$60	$4	$0.02/ft^2 bioreactor area; total area < 3,000 square feet.
Planting grass cover	0	$10	$1	Includes broadcast seeding from a tractor or ATV.
Mow bioreactor grass cover	0-20	$10	$10	$0.01 to $0.09/ drainage acre. This management action will likely be incremental to mowing activities in the edge of field. The bioreactor's grass cover should be mown at least once per year.
Bioreactor maintenance – adjust control gates	0-20	$40	$40	$20.00 per hour labor. Control gates must be adjusted seasonally to account for crop growth and field operations.
Bioreactor maintenance – replace control gates	8, 16	$75	$7	Every 8 years, the gates within the control structures must be replaces to maintain correct operation. 5 Gates per structure ($15.00 per ea. for 15 cm structure) 2 structures per 50 acres drainage area.
Impacts on crop yield	0	$0.00	$0.00	The impact of bioreactors on corn and bean yields is assumed to be negligible.