Bioreactors for Drainage Water Treatment

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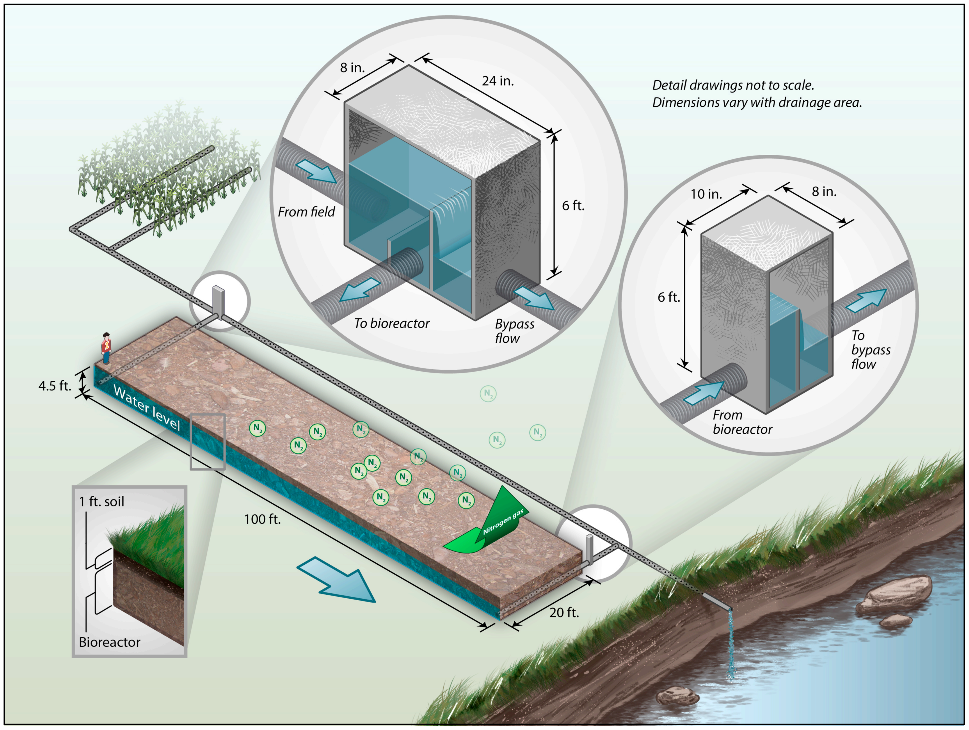

Diagram courtesy of Matt Helmers and Laura Christianson, Iowa State University. Illustration by John Peterson.

Photo courtesy of Mark Dittrich, Minnesota Department of Agriculture.

What is a bioreactor?

Bioreactors are one of a number of emerging conservation drainage practices (see Conservation Drainage box) for reducing the amount of nitrate in drainage water before it is released to surface waters. A bioreactor is a subsurface trench located along the edge of a field and filled with a carbon source, typically wood chips, through which the drainage water is passed. Control structures are used to control the flow of water through the bioreactor and to allow excess flows to bypass the system so that drainage isn't restricted.

How do bioreactors work?

The carbon source in the trench serves as a material for soil microbes to colonize. The microbes feed on the carbon source and 'breathe' the nitrate converting it into nitrogen gas. This process is called denitrification. The nitrogen gas is then released harmlessly into the atmosphere.

How effective are bioreactors?

Results of research on pilot scale and field scale bioreactors indicates that they can reduce nitrate levels in drainage water by 30 to 70%.

Advantages of bioreactors

- Based on proven technology
- Little or no land needs to be taken out of production
- Do not require a change in drainage practices
- Can be retrofitted to existing drainage systems
- No reduction in drainage effectiveness
- Require little maintenance (changing control structure levels a few times a year)

How much do bioreactors cost?

The average cost of field scale bioreactors installed by the Iowa Soybean Association for 40 to 80 acre drainage areas have averaged $8,000. Although there is currently no financial incentive for producers to install bioreactors, it is hoped that as more is learned about these systems, they will be considered worthy of public funding. In Iowa, the EQIP program currently offers a 50% cost-share for bioreactor installations.

How long do bioreactors last?

The wood chips in the bioreactor should last for 10 to 20 years. At that time the wood chips can be replaced to restore the bioreactor function, or if the producer chooses not to replace the chips, the stop logs can be removed from the control structures and drainage will continue normally.

Bioreactor design criteria

The USDA NRCS in Iowa has an interim conservation practice standard for denitrifying bioreactors (Interim IA-747) that provides some design criteria. The interim standard calls for a design capacity 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. Bioreactors should be designed to meet the capacity requirements with a hydraulic retention time (the time it takes for water to pass through the bioreactor) sufficient to achieve the desired nitrate reduction. Current recommendations are for a retention time of 4 to 8 hours. Iowa State University has developed a spreadsheet calculator to assist with bioreactor design (see example spreadsheet).

Why is nitrate in drainage water an issue?

- Although subsurface drainage generally reduces sediment and phosphorous pollution, it often increases losses of dissolved pollutants such as nitrate-nitrogen
- Nitrate is both a human health concern (drinking water) and a cause of surface water impairments
- Excess nitrogen from agricultural land in the Mississippi River basin, particularly from more heavily drained states in the Midwest, is a leading contributor to the hypoxic (dead) zone in the Gulf of Mexico
- EPA has a goal for a 45% reduction in annual nitrogen deliveries to the Gulf by 2015

Subsurface Drainage Bioreactor Design

Developed by M. Helmers, ABE Iowa State Unviersity

Instructions: Enter values in gray cells

Field Information:	
Tile Size (in)	5
Tile Grade (%)	1
Dual Wall	no
Velocity in Pipe (ft/s)	2.20
Peak Flow from Tile Size (cfs)	0.30
Media Information:	
Conductivity of Wood Media (ft/s) (K)	0.31168
Porosity of Wood (ρ)	0.7
Bioreactor Inputs and Calculations:	
Flow Length (ft) (L)	80
Trench Width (ft) (W)	30
Depth of Trench below Inlet (ft) (d_t)	0
Head Drop (ft) (DH)	1
Flow Depth (ft) (d)	0.5
Hydraulic Gradient (i)	0.0125
Results:	
Bioreactor Flow Rate (cfs) (Q)	0.06
Hydraulic Retention Time (hours) (HRT)	**4.0**
% of peak flow that can be passed through bioreactor	**19.5**

Example spreadsheet calculator for bioreactor design. Bioreactor dimensions and water control elevations are chosen such that at least 20% of the peak flow can be treated with a hydraulic retention time of 4 to 8 hours. Spreadsheet courtesy of Matt Helmers, Iowa State University.

Conservation Drainage

Conservation drainage is the use of practices designed to maintain the benefits of drainage while minimizing negative environmental impacts, including:

- Nutrient best management practices
- Shallow drainage
- Drainage water management (controlled drainage)
- Bioreactors
- Reduced drainage intensity
- Treatment wetlands and saturated buffers
- Cover crops
- Including perennials in the crop rotation
- Sediment trapping for surface inlets
- Two-stage ditches

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