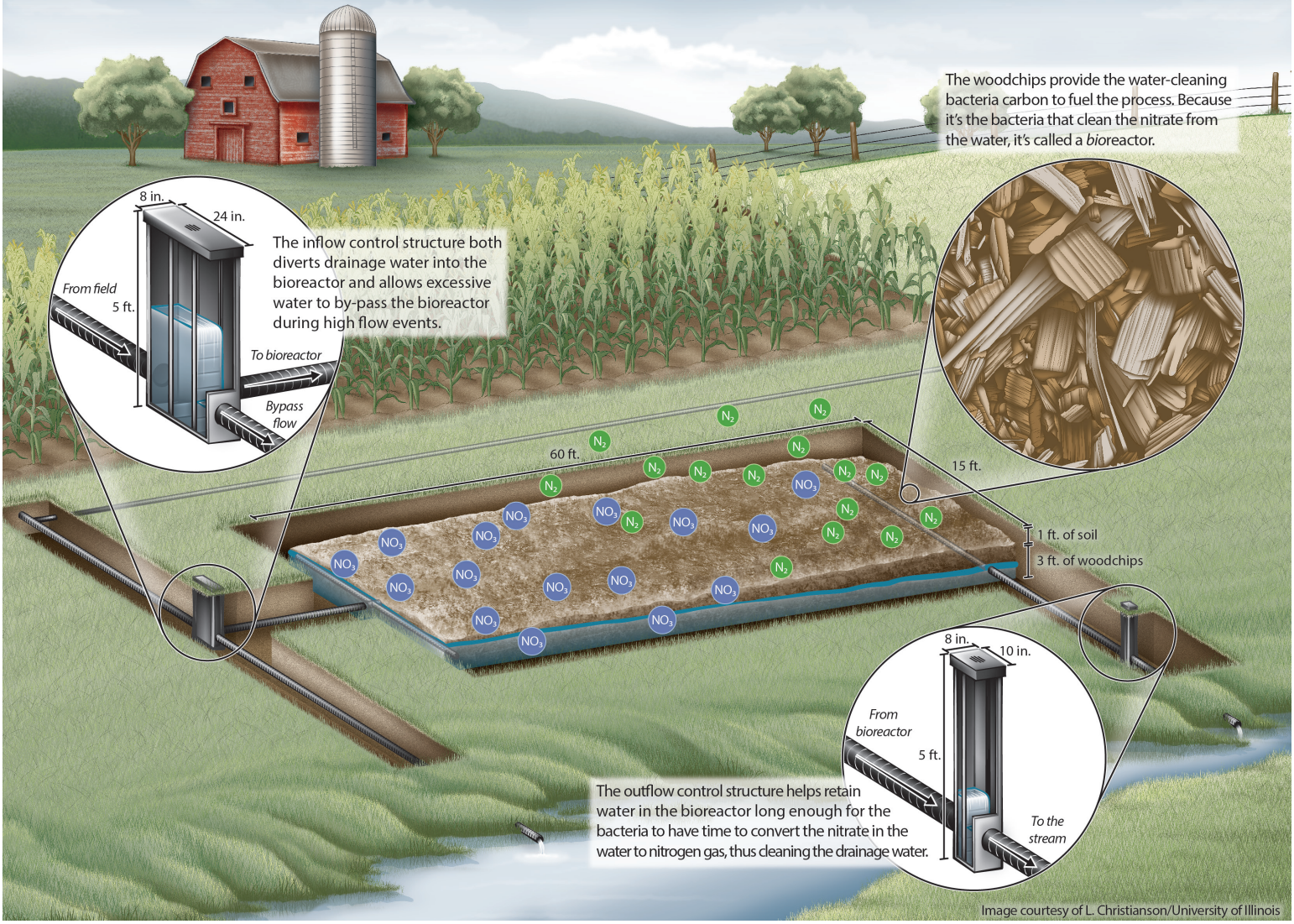
Woodchip Bioreactors

A science-based option to reduce nitrate loss

This fact sheet answers some of the most common questions about woodchip bioreactors using a recent survey of all published bioreactor research.

Woodchip bioreactors remove nitrate from subsurface ("tile") drainage water without significantly impacting production ground or crop yield. At the edge of a field or between adjacent fields, tile drainage water is routed to a carbon-filled excavated hole or trench—the bioreactor. The carbon media, typically woodchips, provides fuel for natural bacteria to convert nitrate in the water to harmless nitrogen gas. This conversion is a natural part of the nitrogen cycle called the process of *denitrification*. Water control structures, typically located at the inlet and outlet of the bioreactor, manage the water flow. These structures help to provide the anoxic (low-oxygen) conditions required to enhance the conversion of nitrate to nitrogen gas. Understanding and acceptance of woodchip bioreactors has grown rapidly in the past five years due to work by and interest from researchers, state and federal agencies, and private agricultural and environmental groups.



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What impacts how much nitrate a bioreactor can remove?

The amount of nitrate removed from the water entering a bioreactor often depends on the retention time—how long the water stays inside. Because denitrification is a biological process, the bacteria need enough time to do their job well. For instance, water that stays in a bioreactor less than 6 hours has less nitrate removed from it compared with longer time periods (see graph). Retention time depends on both how fast the water is flowing and the size of the bioreactor.

Water temperature also plays a major role in how quickly bacteria can remove nitrate. Cooler temperatures, like during springtime drainage, slow denitrification.

What kind of woodchips are best in a bioreactor?

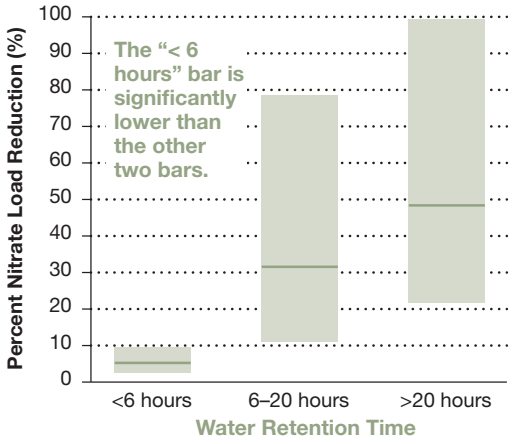
Softwood and hardwood chips have similar potentials to remove substantial nitrate in bioreactors. There is no significant difference between the two types (see graph). However, some kinds of wood, such as faster-growing species including willow, might leach more organics (that is, create more undesirable tea-colored outflow water) when a bioreactor is new. And some kinds of wood, such as cedar, may have antimicrobial or antifungal properties that have not fully been tested in a woodchip bioreactor.

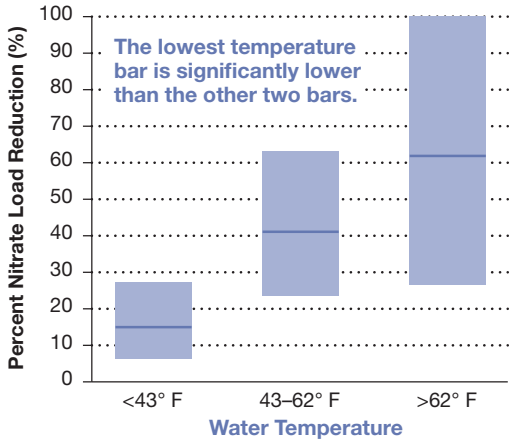
The size and shape of the woodchips used in a bioreactor are typically more important than the kind of wood. The best woodchips have these characteristics:

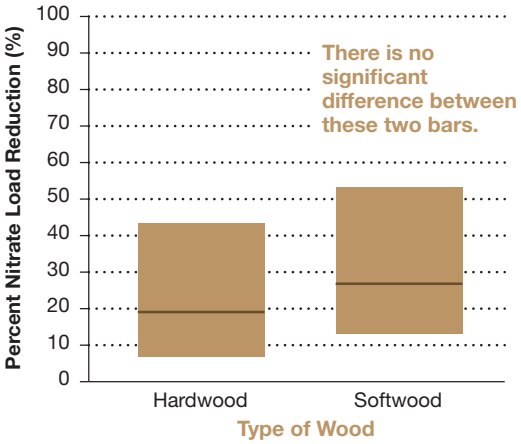
- Relatively free of fines and debris
- About 0.5–2 inches in size
- Square in shape

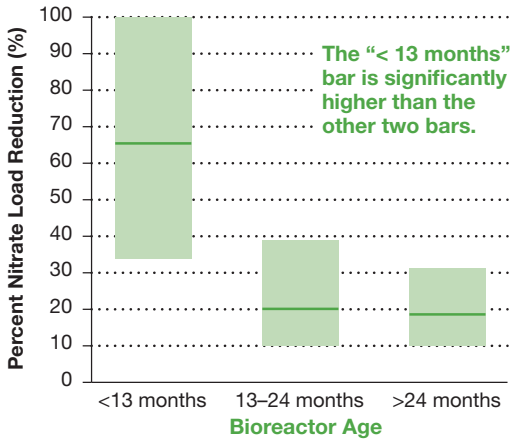
Does the age of a bioreactor matter?

Bioreactors within about one year of construction remove more nitrate than older bioreactors (see graph). When the woodchips are new, they initially contribute more carbon to fuel nitrate removal. First-year performance can be misleading, so bioreactors are designed with longer-term performance in mind.









Methods for Developing Scenarios

We assumed an average bioreactor size of 150 cubic yards, average bioreactor drainage treatment area of 50 acres, and average nitrate loss of 21 pounds of nitrogen per acre. Tile drainage was assumed to flow ten months of the year. We applied these assumptions to a wide inspection of the scientific literature that reported bioreactor nitrate removal in terms of the amount of nitrate removed from the water per the volume of the bioreactor per day (that is, pounds of nitrate-nitrogen removed per cubic yard of woodchips per day). This metric is useful to scientifically compare the performance of different bioreactors. We converted the scientific values using these assumptions to report values in terms of percent nitrate load reduction, a figure more useful for land owners, watershed planning, and creating policy. On the graphs, the line within the bars represents the average nitrate load reduction percent; the edges of the bars represent the 5th and 95th percentiles.

For more information on the original analysis, see this publication: Addy, K., A.J. Gold, L.E. Christianson, M.B. David, L.A. Schipper, and N.A. Ratigan. 2016. Denitrifying bioreactors for nitrate removal: A meta-analysis. J. Environ. Qual. 45(3): 873-881.

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