Denitrifying bioreactors—an approach for reducing nitrate loads to receiving waters.

Review

Denitrifying bioreactors—An approach for reducing nitrate loads to receiving waters

Louis A. Schipper a, Stewart C. Cameron b

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Abstract

Low-cost and simple technologies are needed to reduce watershed export of excess nitrogen to sensitive aquatic ecosystems. Denitrifying bioreactors are an approach where solid carbon substrates are added into the flow path of contaminated water. These carbon (C) substrates (often fragmented wood-products) act as a C and energy source to support denitrification; the conversion of nitrate (NO₃⁻) to nitrogen gases. Here, we summarize the different designs of denitrifying bioreactors that use a solid C substrate, their hydrological connections, effectiveness, and factors that limit their performance. The main denitrifying bioreactors are: denitrification walls (intercepting shallow groundwater), denitrifying beds (intercepting concentrated discharges) and denitrifying layers (intercepting soil leachate). Both denitrification walls and beds have proven successful in appropriate field settings with NO₃⁻ removal rates generally ranging from 0.01 to 3.6 g N m⁻² day⁻¹.
ranging from 0.01 to 3.6 g N A m⁻³ A day⁻¹ for walls and 2–22 g N A m⁻³ A day⁻¹ for beds, with the lower rates often associated with nitrate-limitations. Nitrate removal is also limited by the rate of C supply from degrading substrate and removal is operationally zero-order with respect to NO₃⁻ concentration primarily because the inputs of NO₃⁻ into studied bioreactors have been generally high. In bioreactors where NO₃⁻ is not fully depleted, removal rates generally increase with increasing temperature. Nitrate removal has been supported for up to 15 years without further maintenance or C supplementation because wood chips degrade sufficiently slowly under anoxic conditions. There have been few field-based comparisons of alternative C substrates to increase NO₃⁻ removal rates but laboratory trials suggest that some alternatives could support greater rates of NO₃⁻ removal (e.g., corn cobs and wheat straw). Denitrifying bioreactors may have a number of adverse effects, such as production of nitrous oxide and leaching of dissolved organic matter (usually only for the first few months after construction and start-up). The relatively small amount of field data suggests that these problems can be adequately managed or minimized. An initial cost/benefit analysis demonstrates that denitrifying bioreactors are cost effective and complementary to other agricultural management practices aimed at decreasing nitrogen loads to surface waters. We conclude with recommendations for further research to enhance performance of denitrifying bioreactors.

Keywords
Denitrification; Bioreactor; Nitrate; Effluent
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