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Review

Denitrifying bioreactorsâ€"An approach for reducing nitrate loads to receiving waters

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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 ($NO_3^{â^'}$) 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 denitrifcation walls and beds have proven successful in appropriate field settings with $NO_3^{â^'}$ removal rates generally ranging from 0.01 to 3.6Â gÂ NÂ mâ ³Â dayâ ¹ for walls and 2â€“22Â gÂ NÂ mâˆ'3Â dayâˆ'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 NO_3âˆ' concentration primarily because the inputs of NO_3âˆ' into studied bioreactors have been generally high. In bioreactors where NO_3âˆ' 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 NO_3âˆ' removal rates but laboratory trials suggest that some alternatives could support greater rates of NO_3âˆ' 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.

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Keywords

Denitrification; Bioreactor; Nitrate; Effluent

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