Highlights

Enhancing Nitrate Removal in Denitrifying Woodchip Bioreactors: A Comprehensive Analysis of Enhancement Strategies and Environmental Trade-offs

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Research Highlights

- Systematic review of 70 studies on enhanced woodchip bioreactor strategies
- Alternative media achieve 12.8–15.2 g N/m^3/day vs 5.1–8.6 for carbon addition
- Temperature sensitivity varies by strategy (Q_{10} = 1.8–3.0) with aged chips
- Cost-effectiveness ranges \$10.56–86/kg N removed across enhancement methods
- Mitigation strategies address GHG emissions, DOC leaching, P dynamics trade-offs

Practical Significance

This work provides the first standardized framework for comparing woodchip bioreactor enhancement strategies, enabling informed decision-making for water quality management applications. The comprehensive analysis addresses critical knowledge gaps in environmental trade-off assessment while providing practical implementation guidance for diverse stakeholder groups.