

# Evaluating woodchip bioreactors for mitigating drainage nitrate levels from a municipal wastewater land treatment site



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[Low Environmental Impact]



# Context

## Nitrogen pollution

Major global environmental issue, contributing to water eutrophication and endangering both aquatic life and human health.

## Domestic wastewater

While agriculture is often seen as the main source of nitrogen pollution, inadequately treated domestic wastewater is also a major contributor to nitrification of waterways

## Land application wastewater

In New Zealand, land application is becoming a common method to remove excessive N from pretreated domestic wastewater. However, significant daily volumes of wastewater can lead to high application rates, resulting in  $\text{NO}_3^-$  losses.

## End-of-drain treatment

Need to identify end-of-line treatment systems applicable to drainage water of land treatment areas.



Waitatapia farm - Manawatu



Massey Dairy 4 Farm - Manawatu

# Denitrification woodchip bioreactors

Studies have demonstrated that woodchips bioreactors can achieve consistent  $\text{NO}_3^-$  removals from water.

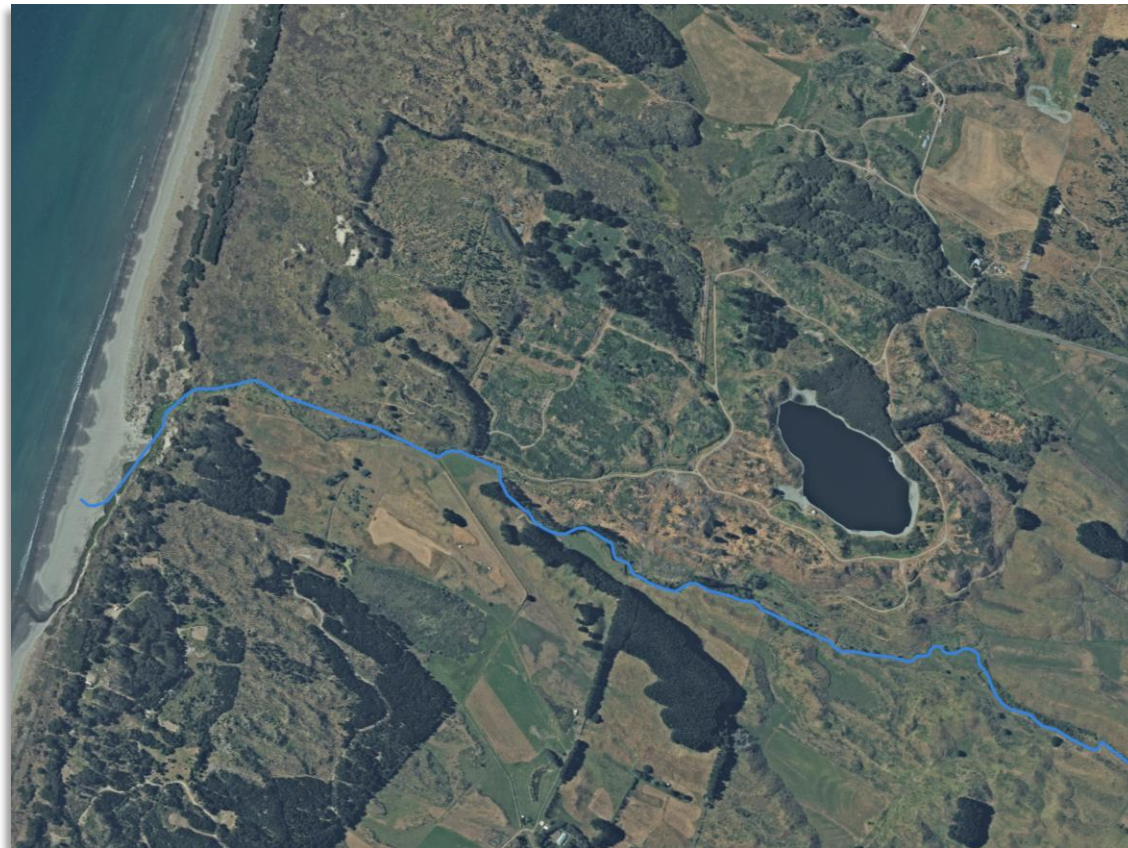
Well-established technology that has been widely applied to reduce  $\text{NO}_3^-$  discharges from agricultural drainage water.

Opportunity: denitrification bioreactors perform better under conditions of consistent water flows and  $\text{NO}_3^-$  concentrations compared to their use primarily in the winter or early spring seasons on farms.

Disadvantage: labile carbon production from the woodchips declines over time and at low temperatures.

# Research problem

## Levin Wastewater Land Treatment Site (LWLTS)



<b>Total wastewater managed:</b>	<b>2.3 million m<sup>3</sup>/year</b>
Storage pond:	425,000 m <sup>3</sup>
Seepage from unlined pond:	450,000 m <sup>3</sup> /year
Wastewater applied by irrigation:	1.9 million m <sup>3</sup> /year
Land application area:	40.5 ha.
<b>Wastewater application depth:</b>	<b>4,600 mm/year</b>
<b>Total nitrogen load in wastewater:</b>	<b>88,543 kg/year</b>

# Research objective

Evaluate the potential use of woodchip bioreactors for treating drainage water from the LWLTS, including assessments of soluble C dosing of woodchip bioreactors to enhance  $\text{NO}_3^-$  removal.

**Small-scale  
column  
bioreactors**

**Pilot-scale  
woodchip  
bioreactors**

**Full-scale  
woodchip  
bioreactor**

# Research objective

Evaluate the potential use of woodchip bioreactors for treating drainage water from the LWLTS, including assessments of soluble C dosing of woodchip bioreactors to enhance  $\text{NO}_3^-$  removal.

**Pilot-scale  
woodchip  
bioreactors**

Assess the ability of pilot-scale woodchip bioreactors to reduce  $\text{NO}_3^-$  levels in drainage water from the LWLTS and evaluate how  $\text{NO}_3^-$  removal efficiency varies with water temperature and HRT. Evaluate the ability of ethanol dosing to enhance  $\text{NO}_3^-$  removal, particularly during the cooler season.

# Pilot-scale woodchip bioreactors



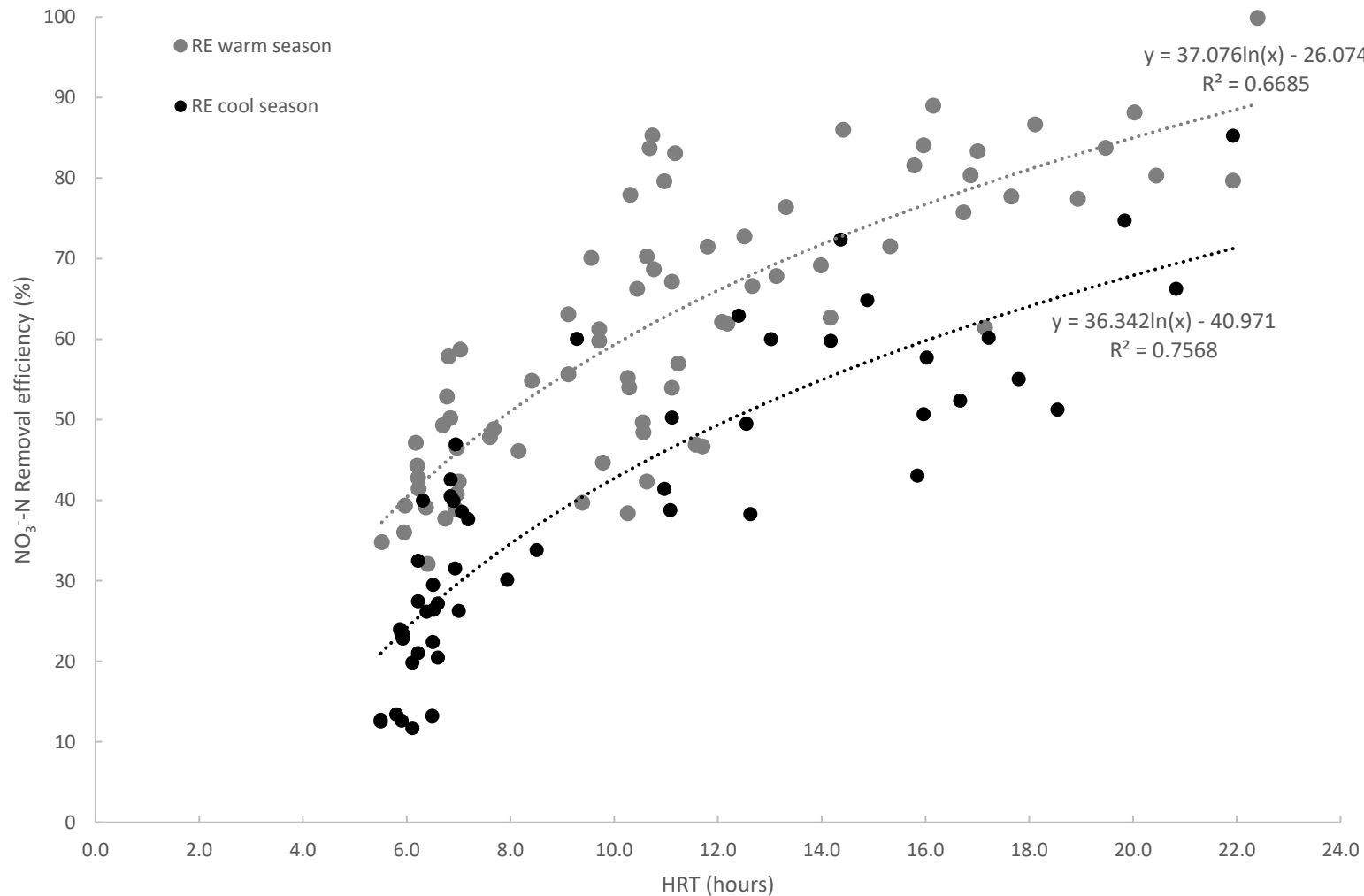
**Objective 1:** assess the ability of pilot-scale woodchip bioreactors to reduce  $\text{NO}_3^-$  levels in drainage water from the LWLTS and characterise how  $\text{NO}_3^-$  removal efficiency varies with hydraulic residence time and temperature.

**Objective 2:** evaluate the ability of ethanol dosing of pilot-scale woodchip bioreactors to enhance  $\text{NO}_3^-$  removal, particularly during the cooler season.

**Experiment design:** four pilot-scale woodchip bioreactors measuring 5 m x 1 m x 1 m, lined with heavy-duty plastic liner, drain water pumped to a 5000 L storage tank, then gravity fed into the bioreactors.

**Experiment procedure:** bioreactors monitored over a 12-month period. The performance of the bioreactors was evaluated using a range of HRTs (5.5 – 22.5 hours), and with the addition of ethanol at a range of C:N ratios (0.5 - 1.5).

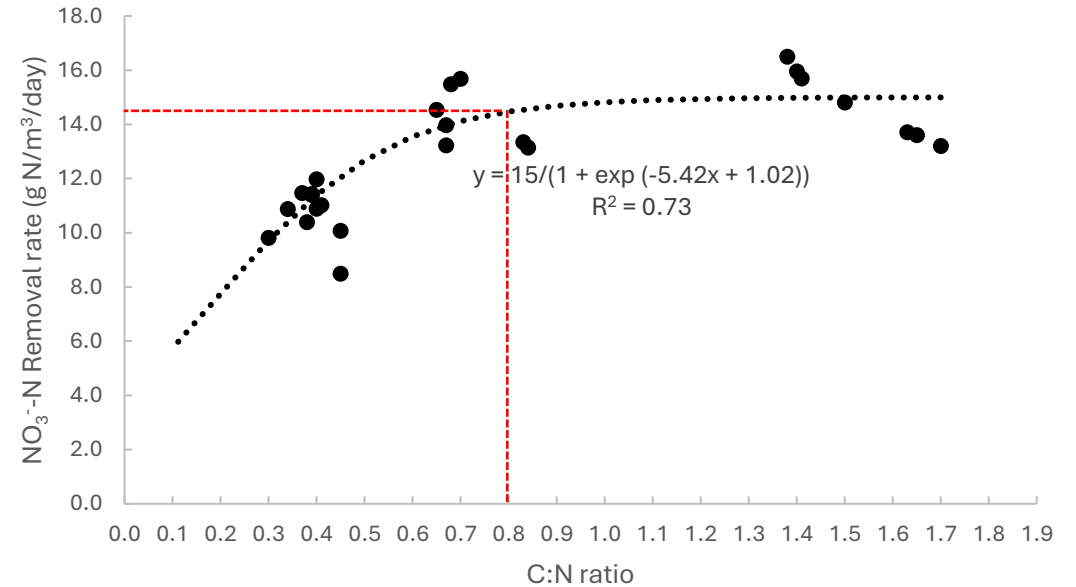
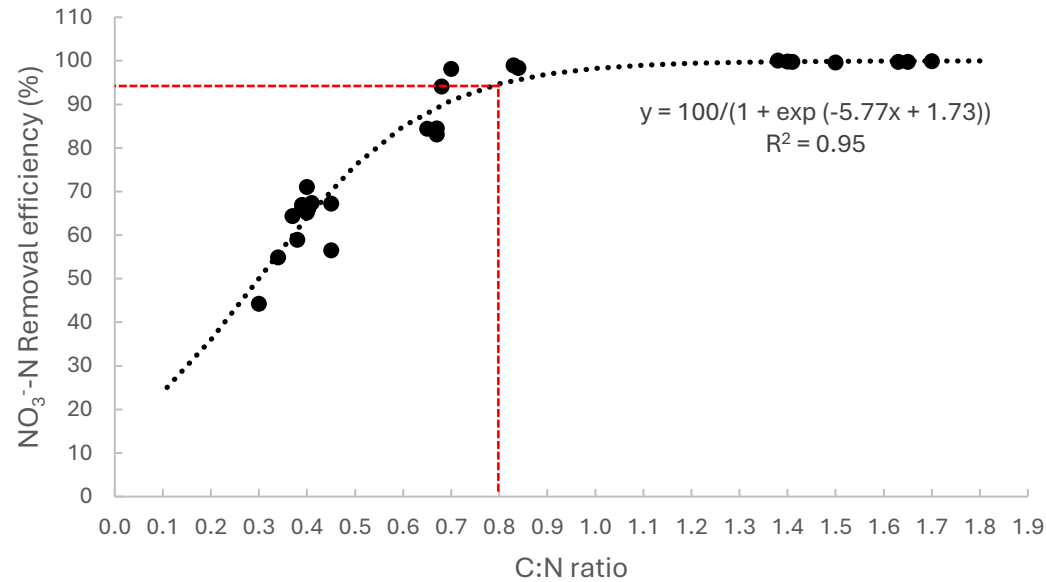
# Pilot-scale bioreactors: HRT effect



HRT	RE Warm	RE Cool	RR (g N/m <sup>3</sup> /d)
6 hours	40%	24%	4.2
10 hours	59%	43%	4.2
15 hours	74%	57%	4.0
20 hours	85%	68%	3.5

**Temperature effect:** under cooler conditions, the bioreactors presented approximately a one-third decrease in removal efficiency compared to warmer conditions. In terms of removal rate, during both season, remained relatively consistent across changes in HRT.

# Pilot-scale bioreactors: EtOH C:N ratio



## Operation conditions:

HRT: 6.6 hours

Cool season: average 13.2 °C

C:N ratios	RE	RR
No dosing	24%	4.2
0.5:1	76%	12.7
0.75:1	93%	14.3
1.5:1	99.9%	15.0

Removal efficiency showed a diminishing marginal improvement with increases in the C:N dosing ratio above **0.8:1**.

# Final takes

Temperature **seasonal variability** is a key control on bioreactor performance. Increasing HRT during cooler periods can improve removal efficiency, but not necessarily removal rates. Longer HRT also reduces the volume of water that can be treated at a time for a given bioreactor size. Highlighting the importance of **designing for treatment capacity per unit time**.

**Ethanol dosing was proved to be an effective strategy** for enhancing the performance of woodchip bioreactors during the cooler periods of the year. The **optimal C:N ratio**, however, **is site specific** and it needs to be determined based on the characteristics of the drainage water being treated.

**Future research** on woodchips bioreactors treating drainage water from a wastewater land application site should focus on the long-term supply of carbon under continuous use.

# Thank you!



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