Research into DENITRIFYING BIOREACTORS suitable for NZ conditions

An option for reducing nitrate discharges from artificial drainage to surface waters?

KEY INFORMATION on pilot-scale Hauraki bioreactor

Drainage area	0.65 ha
Design flow rate	0.9 m^3 hr^{-1}
Effective volume	60 m^3
Operation start date	31 July 2017
Duration of operation	3 years
Target reduction of nitrate load from the tile drain	50 %
Woodchip material	Untreated Pine

ON-SITE MONITORING

Rainfall, temperature, electrical conductivity, flows

AUTOMATED SAMPLING

Nitrogen, phosphorus and carbon species

MANUAL SAMPLING

Trace metals, dissolved gases (O_2, N_2O, CH_4)

Filling the pit with pine woodchips

BACKGROUND

Artificial drainage provides a pathway for fast and un-attenuated nutrient discharges from paddocks to streams. Denitrifying bioreactors promote conditions that support denitrifying bacteria to convert nitrate in water to harmless nitrogen gas using woodchips as a low-cost and easily available energy source. While denitrifying bioreactors are being used overseas (US, Europe) to reduce nitrate transfers to surface waters, overseas designs are not directly applicable to New Zealand conditions. This is largely due to differences in drainage system design, climate, and land use (particularly the predominance of all-year grazing in NZ). The implications of these differences need to be fully understood and taken into account in the design and operation of bioreactors before this technology can be confidently adopted in NZ as a viable option for treating drainage waters.

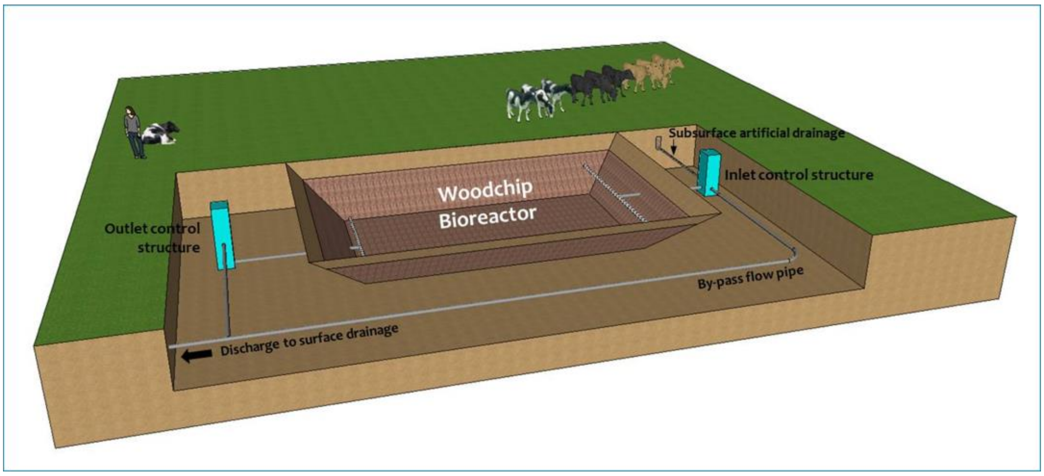
OBJECTIVES OF OUR WORK

- Determine the key factors affecting performance of denitrifying bioreactors for reducing nitrate loads from subsurface drains in New Zealand.
- Assess the full potential of the technology including quantifying any detrimental side effects.
- Determine how denitrifying bioreactors can be optimally designed and installed under New Zealand drainage conditions.

ADAPTING TO NEW ZEALAND CONDITIONS

NZ subsurface drains are typically installed at a depth of between only 0.6 to 0.8m, as compared to 1.8m common in the US. Consequently, bioreactors in NZ have to be installed beneath the depth of the drainage line. This necessitates different approaches for installing bioreactors and for ensuring sufficient passive flow through a bioreactor (without the need for costly pumping).

In the US, the emphasis has been on designing bioreactors that cope with expected hydraulic loads and retention times are not a key design criterion. In contrast, achieving sufficiently long retention times to ensure 50% reduction of the nitrate load discharged from the tile drain was our critical design criterion. This resulted in a much larger sized bioreactor to provide the longer retention time required for our high nitrate removal target.



Schematic of the woodchip denitrifying bioreactor

In the mid-west of the US, the main purpose of drainage systems is to remove a steady supply of surplus water in spring following snow melt. In contrast, drainage fluxes in NZ tend to be more episodic in their occurrence and highly variable in their flow rate, largely in response to rainfall excess. Accordingly, we need to find out how the more dynamic drainage fluxes in NZ affect the bioreactor operation and N removal efficiency.

NEW ZEALAND PERFORMANCE EVALUATION

Before denitrifying bioreactors can be added to the mitigations tool-box recommended for widespread application on NZ farms, it is critical to determine their effectiveness in terms of nitrate load reduction and to understand if there are any unwanted side effects. Accordingly, we will determine the N removal effectiveness of our pilot-scale bioreactor through flow-proportional automated sampling of the inflow and outflow water chemistry and also will investigate possibly occurring side effects.

- During the start-up phase of a bioreactor the most readily available woodchips fraction is quickly broken down, which can result in a short-lived pulses of carbon, nitrogen and phosphorus in the discharge from the bioreactor. We will ascertain the magnitude of these pulses, for how long they last, and determine approaches to reduce their potential impact.
- The woodchips provide the denitrifying bacteria with an ample energy source, which promotes complete denitrification of nitrate to environmentally benign dinitrogen gas (N_2). However, as incomplete denitrification may result in emissions of the greenhouse gas nitrous oxide (N_2O), we will monitor if, or how much, nitrous oxide gets produced and how a bioreactor can be optimised to minimise any emissions.
- If a bioreactor becomes more strongly anaerobic than what is required for denitrification, mobilisation of phosphorus and trace metals and hydrogen sulphide production (‘rotten egg smell’) may occur. Our research will therefore determine if and under what conditions these processes occur and, if required, develop strategies to reduce these unwanted effects.

COLLABORATORS

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