Role of Temperature and Nitrate Concentration in Controlling Denitrification in Field Scale Denitrification Beds

Anna M Carter, David M Zweig and Louis A Schipper, University of Waikato, New Zealand*

* Presenter: Schipper@wakato.ac.nz Website: www.waiber.com

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Introduction

Denitrifying beds are a promising approach for reducing nitrate loads to receiving waters. These beds are constructed by filling a large container with a solid carbon source, such as wood chips, which are loaded with effluent or agricultural runoff containing nitrate. The wood chips act as an energy source to support denitrification. To allow appropriate design and sizing, environmental factors that control the rate of nitrate removal need to be quantified. We determined how nitrate removal rate was controlled by nitrate concentration and temperature.

Methods

Field sites.

Two denitrifying beds were sampled: Karaka and Motutere, New Zealand. Karaka is 140m long by 1.5m deep and 7.8m deep loaded with effluent from a glasshouse while Motutere is 28m long by 1m deep and 1.5m deep and loaded with domestic effluent.

Temperature control.

Wells along the Karaka bed was sampled for nitrate concentration on multiple occasions along with flow rate and temperature measurements. Nitrate removal rates were determined from the product of flow rate and decreases in nitrate mass along the length of the beds (Warneke et al. 2011) and plotted against temperature. Temperature sensitivity was calculated as Q_{10} (the ratio of rates measured 10°C apart).

Nitrate control.

Wood chips were taken from both beds and incubated under anaerobic conditions with different nitrate concentrations. Acetylene was added into the headspace and accumulated N_2O measured by gas chromatography to calculate denitrification rate (Warneke et al. 2011).

The Michaelis-Menten kinetic parameter K_m was calculated by non-linear regression of denitrification rate against nitrate concentration. The K_m value is the concentration of nitrate at which the rate of nitrate removal is half the maximum value.

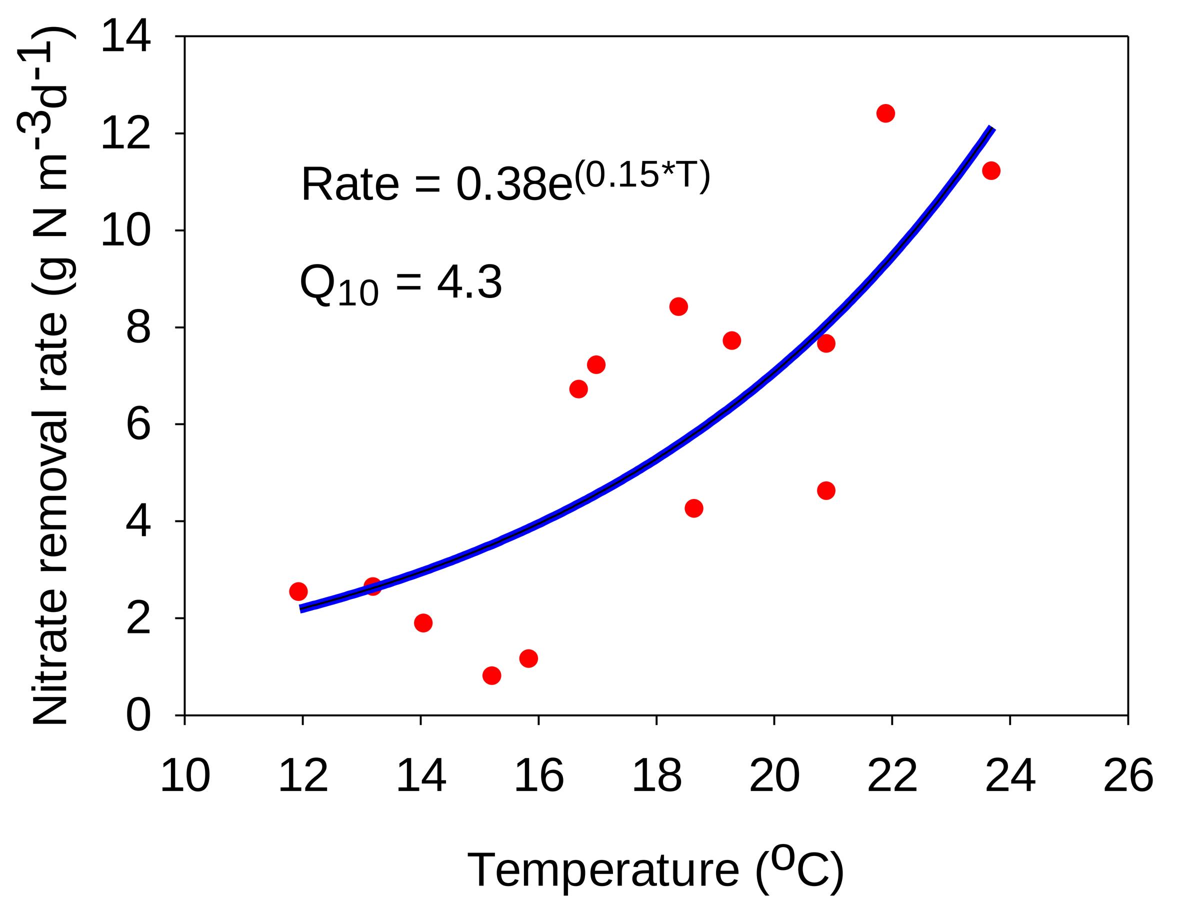

Fig. 1. Nitrate removal as a function of temperature at Karaka.

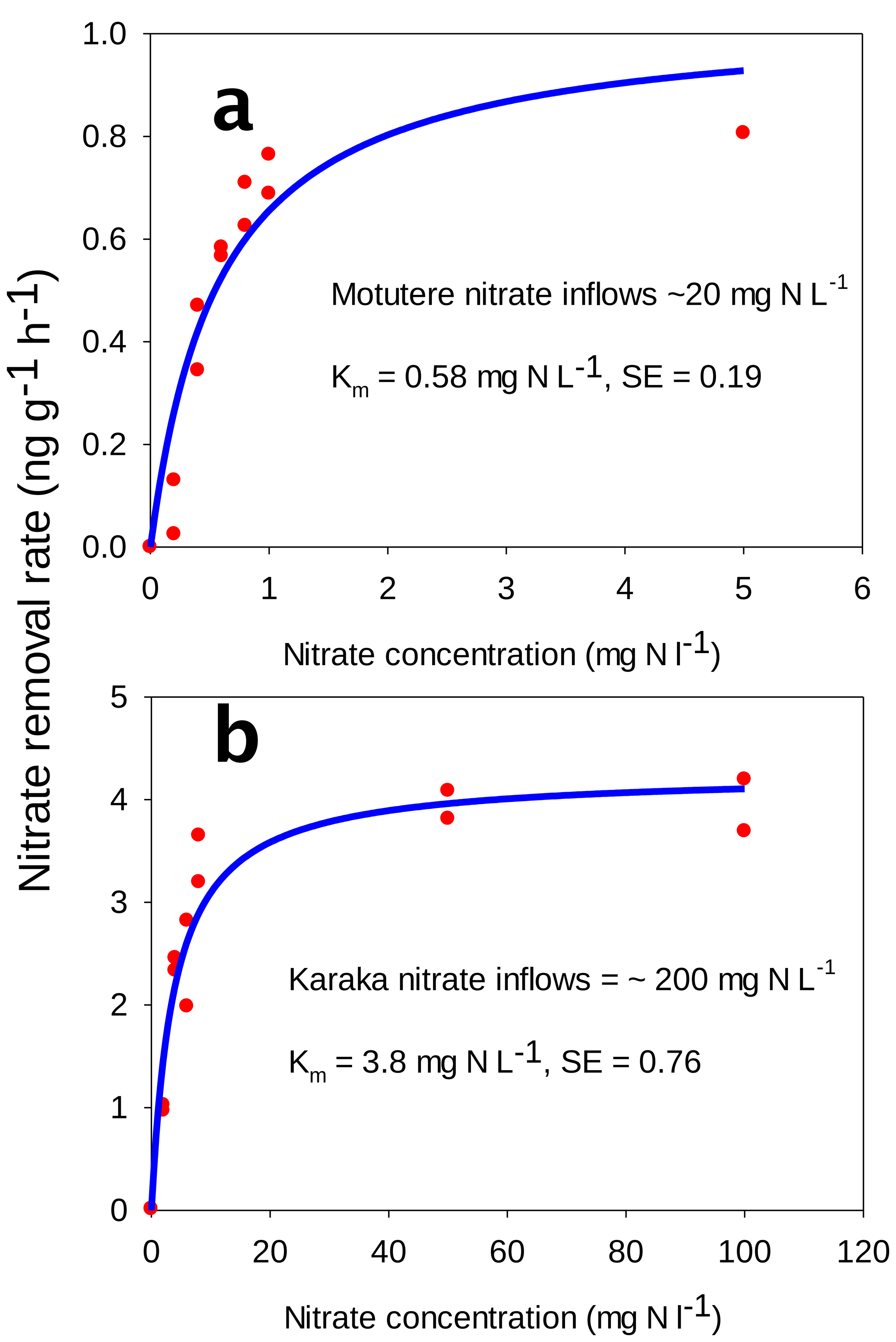

Fig 2. Dependence of nitrate removal on nitrate concentration from two denitrification beds (a) Motutere and (b) Karaka. K_m values are given on each plot. Note difference in nitrate concentrations between beds.

Results

Temperature control.

The Q_{10} value at Karaka was 4.3 (**Fig 1.**) and higher than most previous studies of denitrification beds where typically Q_{10}s range from 1 to 3 (Christianson et al., 2012) (**Table 1**). A difficulty in determining nitrate removal at this site was the highly variable flow rate.

Table 1. Q_{10} values derived from different denitrifying bioreactors

Study	Q_{10}
Robertson et al., 2000. Ground Wat 38: 689-695	1.7
Robertson and Merkley, 2009. JEQ, 38: 230-237	3.2
Elgood et al., 2010. Ecol. Eng., 36: 1575-1581.	2.1
Warneke et al., 2011. Ecol. Eng., 37: 511-522.	1.7

Nitrate control.

The K_m value at Karaka was relatively high at 3.8 mg N L^{-1} and was lower at Motutere (0.58 mg L^{-1}) (**Fig. 2**). Inflow concentrations of nitrate at Motutere was about 20 mg N L^{-1} and was completely removed whereas nitrate concentrations at Karaka were about 200 mg N L^{-1} declining to about 150 mg N L^{-1}. Both K_m values were within the range measured in previous studies from a variety of ecosystems (**Table 2**).

Table 2. K_m values for denitrification in various sediments

Study	K_m (mg N L^{-1})
Ambus, 1993. Fems Microbiol Ecol.102: 225-234	0.06
Schipper et al., 1993. Soil Biol Biochem 25: 925-933	2.1
McCrackin & Elser, 2012. Biogeochem 108: 39-54	4.1
Laverman et al., 2006. Fems Mbio Ecol. 58: 179-192	2.8-11.2

Discussion

K_m values varied depending on nitrate inputs suggesting that microbial populations adjusted to inflow nitrate concentrations and is potentially why nitrate removal appears be zero order in most denitrification beds.

Q_{10} values seemed high in comparison to previous studies of denitrification and along with K_m need to be measured in a broad range of denitrification beds to develop simple predictive models of bed performance that allow appropriate sizing for a range of environments and nitrate loadings.

References:
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Christianson, L.E.; Bhandari, A.; Hailers, M.J. (2012) Appl. Eng. Agricult. 28, 861-874.
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