Revealing groundwater's denitrification capacity

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PROJECT TIMELINE

January 2017 – December 2018

Key points

This research looked into groundwater's natural capacity to reduce nitrate concentrations (denitrification).

A new way to measure denitrification in groundwater has been proved, and could make analysing groundwater's denitrification capacity more accessible for regional councils and farmers.

The concept of spatially variable groundwater denitrification capacity has been proved, but further research is needed before the solutions and benefits of this capacity can be realised.

A national map of groundwater denitrification capacity is being developed over the next two years. This could be used to reduce the amount of nitrate entering rivers and other surface freshwater bodies from groundwater systems.

Why is this issue important?

Farmers, land users and the government are working to improve water quality by reducing losses of contaminants such as nitrate, which impact freshwater quality.

Nitrate is primarily lost from land via leaching through soil into groundwater, and eventually enters streams, lakes and other fresh waterbodies.

In some groundwater systems, microorganisms turn nitrate into harmless nitrogen gas (known as 'benign denitrification'), significantly reducing the amount of nitrate entering surface waterbodies.

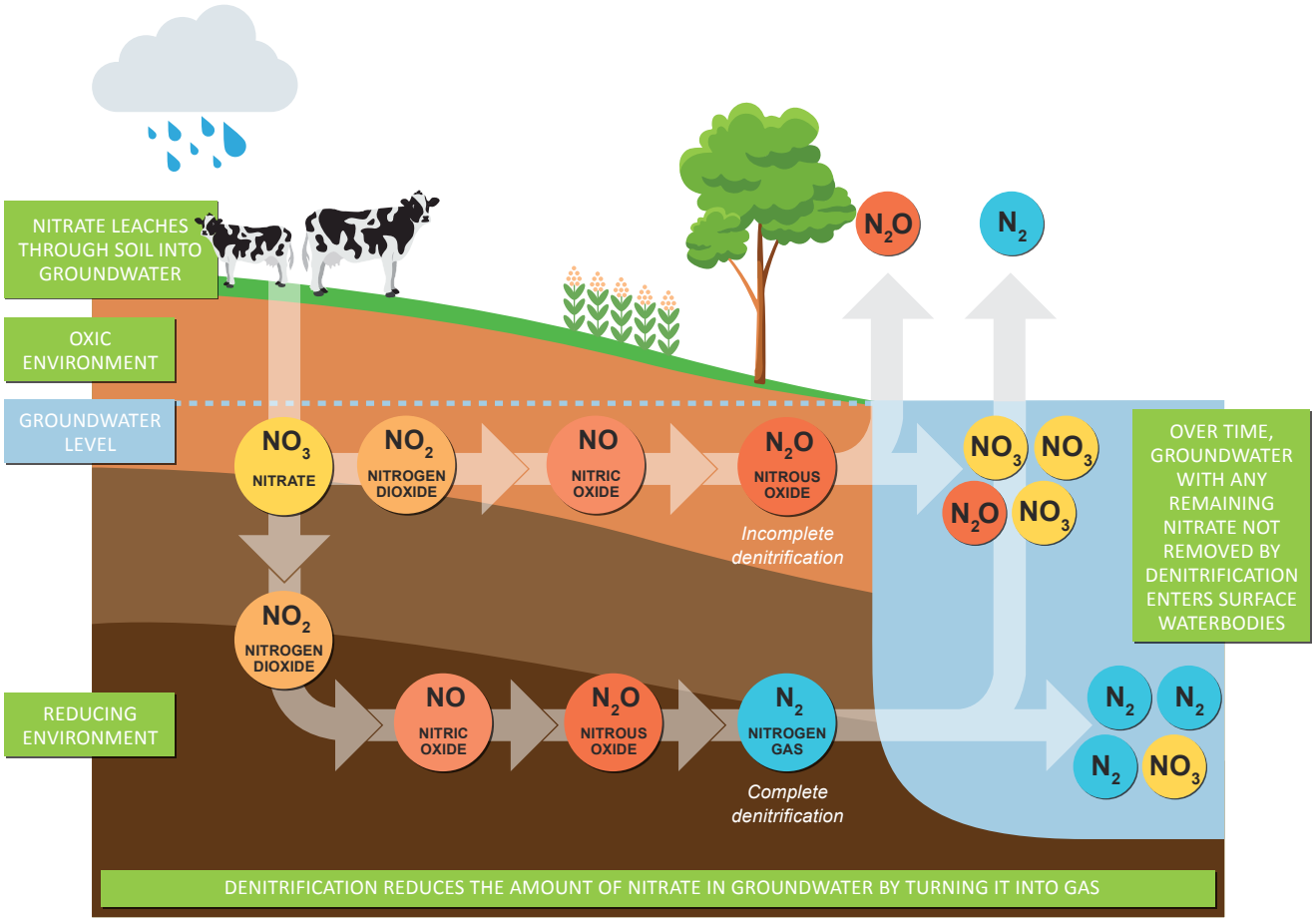
The capacity for microorganisms in New Zealand groundwaters to remove nitrate is currently unknown. If data from nutrient budgeting models such as OverseerFM, which determines nitrogen loss from the rootzone, was coupled with spatially specific groundwater denitrification rates, then more accurate estimates of nitrogen loads to surface water could be determined.

Denitrification capacity is variable across regions depending on the subsurface groundwater chemistry, but it is not yet known which locations have better denitrification capacity than others, or if there are seasonal variations.

A national map of groundwater denitrification capacity will help identify and prioritise areas to target with nitrogen-leaching mitigation measures. This will help land stewards avoid unnecessary investment to reduce rootzone nitrogen losses in areas where naturally existing groundwater denitrification processes reduce nitrate concentrations.

Integrating groundwater denitrification information with outputs from OverseerFM could help farmers to reduce the amount of nitrate entering surface waterbodies.

The denitrification process

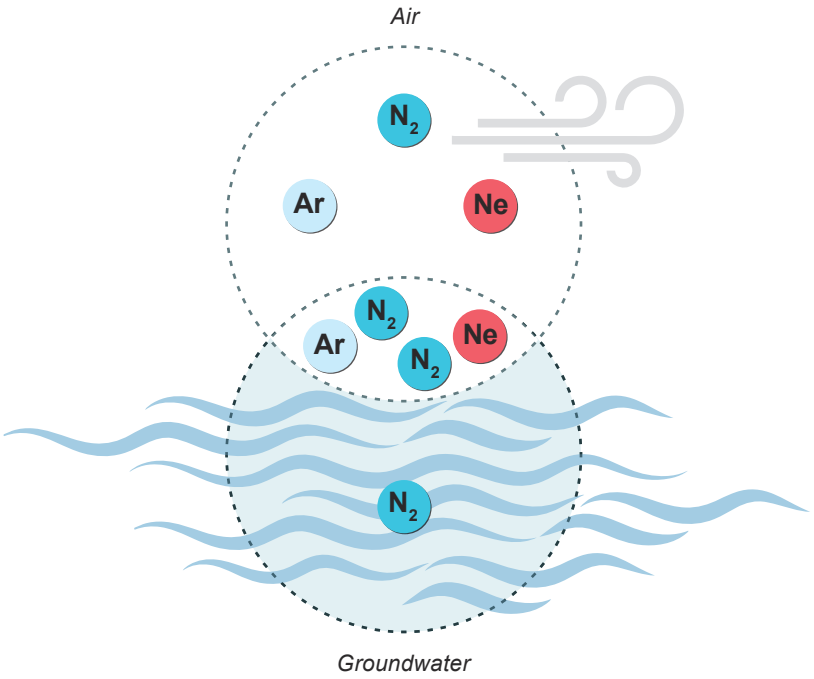


What did we find?

New, proven method for measuring denitrification in groundwater

Any 'excess' dissolved nitrogen gas (more than could originate from air) in groundwater can only be from denitrification. Excess nitrogen can be measured by comparing the amounts of dissolved nitrogen, neon and argon gases in groundwater.

The rate of denitrification can be calculated by identifying the groundwater's age (using water age tracers).

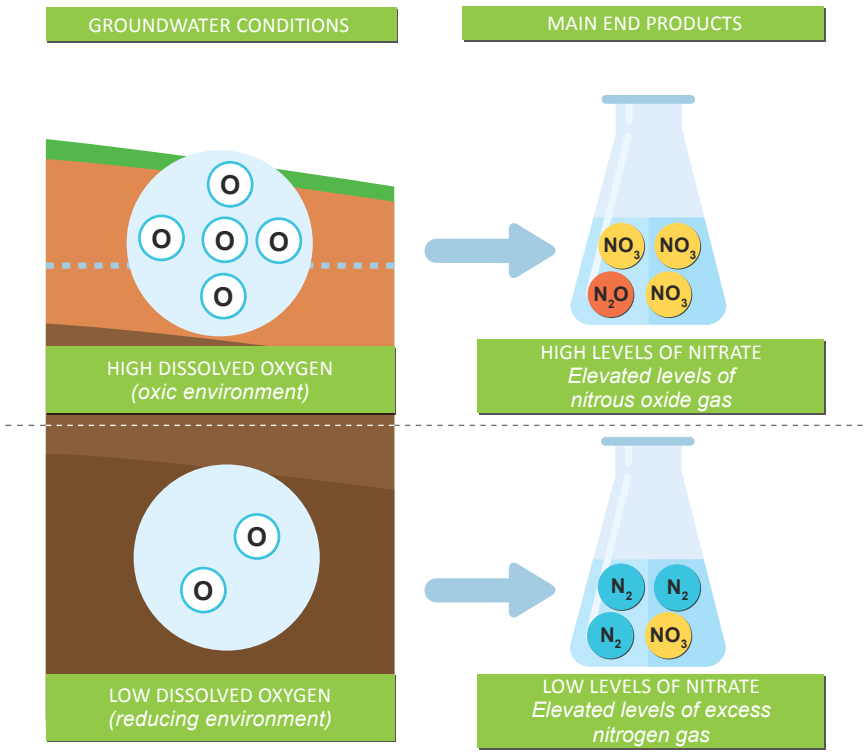


Groundwater contains dissolved nitrogen gas (from both the air and denitrification), and dissolved argon and neon gases (which come only from the air). By extracting these three gases and measuring their respective ratios, excess nitrogen gas (from denitrification) can be measured.

Denitrification completeness related to oxygen

Groundwater denitrification varied across the sites studied.

The main end product of groundwater denitrification (nitrogen gas or nitrous oxide) also varied, depending on the amount of oxygen in the groundwater.



LEGEND

- Ar — Argon
- Ne — Neon
- N_2 — Nitrogen gas
- NO_3 — Nitrate
- N_2O — Nitrous oxide
- O — Oxygen

What did we do?

We completed two related research projects:

Measuring Denitrification ran a pilot study to develop and test a new method for measuring denitrification in groundwater.

Benign Denitrification in Groundwaters ran field trials on six pastoral farms in the Manawatu and Rangitikei river catchments to check if denitrification processes in groundwater are complete, turning nitrate into harmless nitrogen gas (benign denitrification). Incomplete denitrification creates the greenhouse gas nitrous oxide. (This research arose from a Rangitikei catchment study, see case study below).

Denitrification is a natural process that reduces nitrate concentrations.

Subsurface denitrification capacity includes potential denitrification in soil below the rootzone as well as groundwater.

How can this benefit land, water and people?

The new method for measuring excess nitrogen could be used to locate and characterise groundwater denitrification sites, so spatial variability of sites and rates can be mapped.

Identifying the location and efficiency of groundwater denitrification sites can result in more effective nutrient loss regulations, more strategic nitrogen loss mitigation measures and improved land management.

Land use can be better matched to land suitability. Areas with high groundwater denitrification capacities may be suitable for more intensive land use, while other areas with less capacity could be used less intensively.

Reducing the amount of nitrate entering rivers and other freshwater bodies will improve water quality, providing greater opportunity for people to use rivers for swimming and other recreational pursuits, while safeguarding drinking water sources.

The outputs of further research into groundwater denitrification could be integrated with outputs from models such as OverseerFM to inform nutrient budgeting from farm to catchment scale.

Case Study

Rangitikei and Tararua river catchment modelling

The likely result of matching land use to land suitability – by intensifying land use in areas with high subsurface denitrification capacity and de-intensifying land use in areas with low capacity – has been modelled for the Rangitikei and Tararua river catchments.

Modelling indicates that relocating intensive dairy farming to areas with high subsurface denitrification capacity could reduce the amount of nitrate entering surface waterbodies from dairying by over 15% in the two catchments (supported by selective grazing and cut-and-carry on free-draining areas with low subsurface denitrification capacity).

Combining the subsurface denitrification capacity with purpose-built drainage management could reduce nitrate loads from dairying by over 25% in the catchments, according to the modelling.

This research was a project between Massey University and Horizons Regional Council, partly funded by Our Land and Water National Science Challenge

Next steps

The excess nitrogen method to measure groundwater denitrification has been developed and tested with Horizons Regional Council, Environment Southland and Waikato Regional Council. The next step is to partner with other regional councils to test it in larger catchments.

Our Land and Water is establishing a team to produce a national map of denitrification potential in the subsurface environment. This team will:

- analyse groundwaters in every region of New Zealand, to establish the relationship between low oxygen groundwaters and their denitrification capability
- predict relationships between catchment characteristics and subsurface denitrification processes
- refine a classification approach to tracing contaminant sources, providing confidence about the fate and impact of on-farm N, P, sediment and E. coli losses.

This map of denitrification will allow land stewards to identify whether their land's rate of nitrogen loss is impairing catchment water quality or largely being attenuated within the ground water. Both the map and classification approach will inform allocation by the Ministry of the Environment and regional councils.

Key publications

Assessment of excess N_2 for quantifying actual denitrification in New Zealand groundwater systems, Journal of Hydrology 2019; 58(1):1-17.
ourlandandwater.nz/excessN2

Quantifying actual denitrification in groundwater systems, NZ Hydrological Society Annual Conference 2019.
ourlandandwater.nz/actualdeN

Measurement of neon in groundwaters for quantification of denitrification in aquifers, GNS Science Report 2018/34.
doi: 10.21420/FR4XJ821

Benign denitrification in shallow groundwaters, Land Use and Water Quality Conference 2019.
ourlandandwater.nz/benigndeN

Water quality issues facing dairy farming: potential natural and built attenuation of nitrate losses in sensitive agricultural catchments, Animal Production Science 2019; 60(1): 67-77.
doi: 10.1071/AN19142

OUR LAND AND WATER | Toitū te Whenua, Toiora te Wai

National SCIENCE Challenges

Our Land and Water (Toitū te Whenua, Toiora te Wai) is working towards an agri-food and fibre system that enhances the vitality of te Taiao with a diverse mosaic of land uses that improve the health of land, water and people.

Our Land and Water is one of 11 National Science Challenges that focus on defined issues of national importance identified by the New Zealand public.

Our Land and Water is hosted by AgResearch, funded by the Ministry of Business, Innovation and Employment, and supported by 16 partner research organisations.

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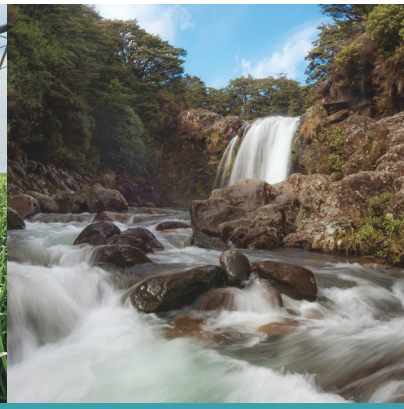
Research Findings Brief: Revealing groundwater's denitrification capacity, Our Land and Water (Toitū te Whenua, Toiora te Wai) National Science Challenge 2020



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