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Groundwater dating for understanding nitrogen in groundwater systems - Time lag, fate, and detailed flow path ways

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Nitrate contamination of groundwater is a problem world-wide. Nitrate from land use activities can leach out of the root zone of the crop into the deeper part of the unsaturated zone and ultimately contaminate the underlying groundwater resources. Nitrate travels with the groundwater and then discharges into surface water causing eutrophication of surface water bodies.

To understand the source, fate, and future nitrogen loads to ground and surface water bodies, detailed knowledge of the groundwater flow dynamics is essential. Groundwater sampled at monitoring wells or discharges may not yet be in equilibrium with current land use intensity due to the time lag between leaching out of the root zone and arrival at the sampling location. Anoxic groundwater zones can act as nitrate sinks through microbial denitrification. However, the effect of denitrification on overall nitrate fluxes depends on the fraction of the groundwater flowing through such zones.

We will show results from volcanic aquifers in the central North Island of New Zealand where age tracers clearly indicate that the groundwater discharges into large sensitive lakes like Lake Taupo and Lake Rotorua are not yet fully realising current land use intensity. The majority of the water discharging into these lakes is decades and up to over hundred years old. Therefore, increases in dairy farming over the last decades are not yet reflected in these old water discharges, but over time these increased nitrate inputs will eventually work their way through the large groundwater systems and increasing N loads to the lakes are to be expected. Anoxic zones are present in some of these aquifers, indicating some denitrification potential, however, age tracer results from nested piezo wells show young groundwater in oxic zones indicating active flow in these zones, while anoxic zones tend to have older water indicating poorer hydraulic conductivity in these zones. Consequently, to evaluate the effect of denitrification on nitrate fluxes it is insufficient to consider only the spatial distribution of oxic and anoxic zones; the flow through these zones needs to be quantified. If the majority of groundwater passes through the oxic zones rather the anoxic zones, insignificant N attenuation must be expected. Our results indicate about an order of magnitude lower vertical flow velocity and flux through anoxic zones compared to oxic zones. The age distribution of the groundwater allows identification of groundwater flow path ways, which in the Lake Taupo catchment is characterised by high piston flow, indicating groundwater flow between widely connected impermeable layers, probably paleosol layers.

Groundwater dating has become an important tool for management of nitrate contamination.