Future Proofing Groundwater Systems

Excess Nitrogen

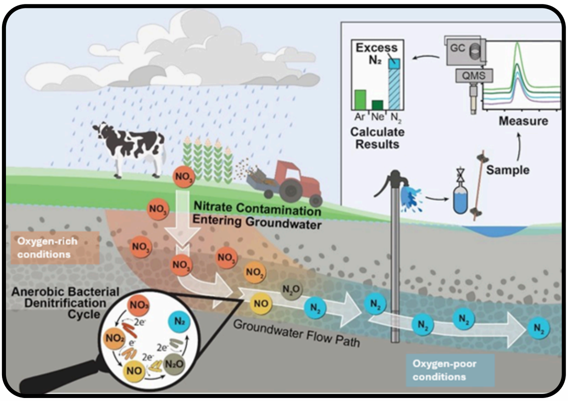
Factsheet 3

Nitrate is the most pervasive freshwater contaminant in New Zealand (NZ) and poses a significant risk to human and environmental health. Nitrate is derived primarily from land-use activities and can leach through soils into groundwater systems, where it may persist for decades before discharging into streams and lakes. In some settings, nitrate can be naturally attenuated through microbial denitrification - a process where bacteria convert nitrate into benign nitrogen gas (N_2). A current challenge is lack of understanding regarding which groundwater systems have the capacity to buffer nitrate loads through denitrification and which are vulnerable to contamination. Importantly, this knowledge will enable identification of resilient and more vulnerable aquifers.

During sample collection, specialised techniques to preserve the original gas composition are used. Water is pumped directly into airtight containers, carefully excluding any contact with the atmosphere. Exposure to air would alter the dissolved gas concentrations and compromise the accuracy of laboratory analyses. Analysis of gas concentrations are then undertaken at the ESNZ state-of-the-art noble gas facility.

Excess Nitrogen

The accumulation of N_2 in groundwater provides a direct indicator and quantification of denitrification. In anoxic groundwater systems, bacteria use nitrate as an electron acceptor to successively reduce nitrate (NO_3), to nitrite (NO_2^-), nitrous oxide (N_2O), and dinitrogen gas (N_2). However, groundwater also contains atmospherically derived N_2 introduced through the dissolution of air in rainwater. Measurements of noble gases (e.g., argon, neon) are used to distinguish background N_2 from that produced by denitrification. Like atmospheric N_2, noble gases are derived from dissolved air but remain unaffected by biological processes. These gases allow us to accurately quantify the atmospheric component of dissolved N_2. By subtracting this fraction from the total measured N_2, we determine the "excess N_2" generated by denitrification. As a world first, this method is applied at catchment scales to quantify and map denitrification in the FPG Programme.



When combined with knowledge of groundwater flow paths and age, this approach enables reconstruction of the timing of historical nitrogen inputs, as well as the delayed impacts of land-use practices and management actions. Understanding the denitrification capacity of groundwater systems is critical for predicting their resilience to nitrate loading. This knowledge supports informed land-use decisions and helps avoid unintended adverse impacts, particularly as land-use pressures intensify under changing climatic conditions.