Biostimulation to Promote Total Nitrogen Loss in a Coastal Aquifer

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Background/Objectives. Groundwater impacted by nitrogen species (principally nitrate, nitrite, and ammonia/ammonium) can be transformed and released as nitrogen gas via multiple biologically mediated processes. Nitrification occurs as ammonium is converted to nitrate in the presence of oxygen. Denitrification takes place under reducing conditions and results in the release of nitrogen gas. Anaerobic ammonium oxidation (anammox) is performed by specialised bacteria; the process results in concurrent loss of nitrate/nitrite and ammonium and releases nitrogen gas. A field-based pre-design investigation (PDI) was undertaken at a site to assess naturally occurring nitrogen processes and the potential for stimulating further bioremediation of nitrogen in situ via an electron donor injectability assessment as a remediation option for nitrogen impacted groundwater.

Approach/Activities. The PDI approach involved baseline characterization of site conditions, including nitrogen species distribution, vertical profiling, geochemical evaluation, and microbiological community assessment (next generation sequencing [NGS] and quantitative polymerase chain reaction [qPCR]). Multiple lines of evidence were used to assess the current capacity for groundwater conditions to promote nitrogen transformation/loss. Long-term monitoring data were also reviewed to assess the potential mechanism(s) for nitrogen reduction occurring in situ over time due to reactive processes. Concurrently, injection of electron donor (lactate and emulsified vegetable oil [EVO]) was pilot tested in two locations at the site to assess the ability for biostimulation of native bacteria to further reduce nitrogen concentrations.

Results/Lessons Learned. Review of site data indicated multiple nitrogen transformation pathways with zones of nitrification, denitrification, and anammox occurring over time. Total nitrogen concentrations near the source area decreased by approximately half over a period of three years. Downgradient of the plume source area, the groundwater environment becomes carbon-limited, preventing complete loss of nitrogen along the downgradient edge of the site. Microbiological analyses indicated widespread presence of anammox-performing bacteria in groundwater and a diversity of bacteria capable of performing nitrogen reactions.

The addition of electron donor stimulated up to 90% degradation of remaining total inorganic nitrogen (nitrate, nitrite, and ammonium). Both lactate and EVO were successful at stimulating degradation within one week of injection. Degradation even occurred at elevated concentrations, indicating that the Site conditions are conducive to biodegradation despite the relatively recent and concentrated nature of the nitrogen release.

Near complete nitrate loss and concurrent decreases in ammonium concentrations support reactive loss via a combination of denitrification and anammox reactions. Nitrogen reductions have been sustained in the EVO injection well for more than 100 days after injection, with performance monitoring ongoing and electron donor remaining.