How are Nitrogen Compounds Attenuating at Your Site? Implications for Site Remediation and Climate Change

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Nitrogen compound contamination of surface water and groundwater can originate from many sources including fertilizer application and production, human and livestock waste, and mining operations. Anthropogenic nitrate, ammonium and their breakdown products, such as nitrous oxide, have substantial negative environmental effects. Nitrate and nitrite are toxic to humans and are regulated in drinking water in Canada. Ammonium and nitrate contribute to eutrophication of natural water bodies. Nitrous oxide is produced by partial denitrification and comprises approximately 6% of global warming emissions.

Microbial processes can convert problematic compounds into inert nitrogen gas, primarily via denitrification and anammox. Nitrification is also critical, functioning in tandem with denitrification to remove nitrogen mass. Dissimilatory reduction of nitrate to ammonium

(DRNA) can reduce nitrogen mass in water or soil via volatilization of ammonia.

To understand and optimize nitrogen compound remediation it is important to monitor not only the forms of nitrogen, but also microbial groups and functional genes critical to nitrogen metabolism. Multiple microbial and functional gene targets for nitrogen pathways are routinely monitored by quantitative polymerase chain reaction (qPCR) tests and next generation sequencing including denitrification, anammox bacteria, nitrification and DRNA. Other useful tests include compound specific isotope analysis (CSIA) which provides compelling evidence for ammonium and nitrate transformation. Also total organic carbon and volatile fatty acids analysis can be used to determine if sufficient electron donor is available to drive denitrification or DNRA.

A former dry blend fertilizer plant, site near the Cape Fear River in North Carolina was characterized using a suite of molecular, analytical and isotopic tests (NitroGen™) to assess intrinsic nitrogen removal processes. The site was contaminated with petroleum hydrocarbons, naphthalene, metals and ammonia in groundwater at concentrations above Groundwater Quality Standards. Ammonia exceeded the standard of 1.5 mg/L in all samples, with the highest concentration of 30.8 mg/L. The presence of nitrification, denitrification and anammox functional genes in groundwater at the site was confirmed by qPCR tests, and indicated multiple pathways for nitrogen mass removal that varied according to location. The potential for transformation of ammonium was confirmed by the detection of nitrification functional genes and anammox bacteria and was confirmed by 15N enrichment in CSIA. Even though nitrate was undetected, denitrification genes were detected as were electron donors, supporting the possibility for denitrification.

The data set provided compelling evidence that ammonia remediation was ongoing at the site and likely utilized multiple pathways.

Once the existing pathways for nitrogen metabolism are understood at a site, a variety of approaches can improve remediation performance including electron donor addition, to enhance denitrification and oxygen addition to enhance nitrification. Bioaugmentation has potential to introduce microbes with complete nitrogen pathways to enhance mass removal and reduce nitrous oxide emissions and global warming impacts. Effective monitoring of nitrogen metabolism and related parameters is an important first step to understand intrinsic bioremediation processes and to determine enhanced bioremediation could improve system performance.

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Phil Dennis is Principal Scientist at SiREM where he has worked for over 20 years. Phil holds a Masters of Applied Science in Civil Engineering from the University of Toronto, and an Honours Bachelor of Science, Molecular Biology and Genetics from the University of Guelph. Phil has almost 30 years of experience in research and development and management of molecular biology, microbiology, and environmental remediation laboratories. Phil currently manages molecular genetic testing services and is innovation lead for SiREM's research and development program and leads multiple research and development projects.