Bioremediation of a Dissolved Ammonia and Nitrate Plume Through In-Situ Reduction

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Background/Objectives: A retail petroleum site in central Alberta, Canada has been in operation since the 1930's, and has a history of widespread petroleum hydrocarbon (PHC) contamination in both soil and groundwater. Previous attempts to enhance the biodegradation of the PHC contaminants using alternative electron acceptors through the addition of nitrogen based liquid fertilizer resulted in a reduction in PHC concentrations and plume area. However, incomplete utilization of the electron acceptors resulted in the creation of a nitrate and ammonia plume. The site has sandy lithology and is naturally aerobic, which indicates that natural carbon sources are low, and anaerobic denitrification is unlikely. The goal of the investigation was to facilitate the in-situ reduction of nitrate and ammonia through the addition of an electron donor solution, in this case ethanol. It was anticipated that the nitrification of ammonia would decrease the dissolved oxygen concentrations and produce anaerobic conditions. Subsequently, denitrifying bacteria would utilize nitrate as an electron acceptor during anaerobic respiration, through which nitrogen gas would be produced. Alternatively, we may see simultaneous reduction of both ammonia and nitrate via the anammox process.

Approach: Carbon source amendment to create in-situ anaerobic conditions is most commonly achieved through the addition of a high fructose corn syrup, molasses, or similar product. The proposed use of ethanol was considered for the site due to its low viscosity and high availability, as well as the simplicity of the carbon source. A mass balance calculation was completed to quantify the volume of ethanol required to complete nitrification and denitrification. Consideration was also given to overcoming potential scavenger electron acceptors such as iron (Fe^{3+}) and carbon assimilation during de-oxygenation for biomass production. Approximately 19,000 L of 15% ethanol solution was direct injected into injection wells throughout the plume area via a gravity feed system. A pre-injection, baseline groundwater sampling event was completed approximately one month prior to injections and a post injection sampling event was completed approximately six weeks post injections, with further sampling events scheduled.

Results: The oxygen reduction potential (ORP) decreased to a reducing environment throughout the plume area following the injection of ethanol. PHC concentrations remained relatively static between the sampling events. Ammonia concentrations were reduced throughout the plume area by greater than 99%, with the majority of wells reporting non-detectable or near non-detectable concentrations. Nitrate concentrations were reduced throughout the plume area by greater than 67%. A 21% rebound in nitrite concentrations was measured and expected, as nitrite is produced through the denitrification of nitrate. Additional groundwater monitoring and sampling events are planned for the site four and eight months post injection to confirm the initial post injection results and to document any trends in ORP, ammonia, nitrate and nitrite concentrations. Overall, the in-situ denitrification program using ethanol as a carbon source amendment has proven to be a successful method for the bioremediation of in-situ ammonia and nitrates in groundwater.