Sulfate-Enhanced Bioremediation of Petroleum Sites in Alaska

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Background/Objectives. Parsons designed, installed, operates and monitors remediation systems at three petroleum-contaminated sites at the former Galena Forward Operating Location (FOL) in Alaska. Galena is a remote location without road or rail access. All electricity is generated locally using fuel delivered by barge. Remedial design included a green-and-sustainable sulfate-enhanced bioremediation component to minimize electrical demand.

Approach/Activities. Arctic diesel and JP-4 releases from pipelines and underground storage tanks occurred over many years. The water table fluctuates over 25 feet annually due to influence of the nearby Yukon River. The zone of water table fluctuation is referred to as the variably saturated zone (VSZ). The selected remedies included bioventing (for arctic diesel) and soil vapor extraction (for JP-4) in the vadose and upper VSZ, and sulfate-enhanced bioremediation for the lower variably saturated and permanently saturated zones where venting technologies would not be effective.

Sulfate was added to the subsurface in areas of the petroleum soil source area where methanogenic conditions predominated. A slurry of 7 to 10 percent gypsum ($CaSO_4 \cdot 2H_2O$) was injected over an interval from approximately 25 to 35 feet below ground surface. Gypsum was injected in boreholes aligned in rows to create sulfate dissolution zones perpendicular to the direction of groundwater flow. The mass of gypsum in each row was designed to dissolve over a five-year period (based on gypsum solubility and groundwater mass flux), and groundwater was expected to carry sulfate up to 110 feet downgradient before it was entirely consumed by sulfate-reducing bacteria in the petroleum-contaminated soil source area (based on literature derived sulfate utilization rates from cold water systems). A total of 194,000 pounds of gypsum were installed in 340 boreholes at three sites in 2017 and groundwater performance monitoring wells have been sampled annually for petroleum constituents, sulfate, and geochemical indicator parameters.

Results/Lessons Learned. Following injection, sulfate concentrations in source area groundwater increased to up to 1,000 mg/L near the injection zones, and concentrations remained elevated as far as 125 feet downgradient from the injection zones. Sulfate concentrations decreased over time and were nearly back to pre-injection levels after four years. Groundwater flux is believed to be greater than estimated during the design process and accounts for more rapid dissolution of gypsum. Concentrations of petroleum constituents such as benzene and naphthalene have decreased. Diesel-range organic concentrations in groundwater increased for two or three years following injection but have since decreased. The increased concentrations are attributed to more soluble polar metabolites detected with Method AK102. Soil in the source area for one site was sampled in 2021 and all contaminants of concern met Alaska human health cleanup levels. Sulfate-enhanced bioremediation was estimated to account for seven percent of the total reduction in petroleum contaminants at the sites. Although its contribution seems modest, it was in a zone where venting technologies were not effective.