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Pump and Treat Groundwater Remedy Optimization Using In Situ Bioremediation at Naval Base Kitsap, Bangor Site F

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Background/Objectives. Explosives-containing wastewater disposal to unlined lagoons contaminated groundwater at the Naval Base Kitsap, Bangor Site F (Site F). Less mobile explosives including trinitrotoluene (TNT) generated a small plume whereas highly mobile hexahydro-1,3,5-trinitro-s-triazine (RDX) formed a very large plume (52 ha) in site groundwater. In situ bioremediation is currently being considered for optimizing the increasingly inefficient pump and treat groundwater remedy at Site F. Anaerobic in situ biostimulation has been shown to effectively reduce comingled explosives contamination including RDX, TNT and other explosives concentrations in groundwater (e.g., Michalsen et al., 2013). A novel bioaugmentation approach, involving addition of aerobic RDX-degrading bacteria, has been recently demonstrated to effectively reduce RDX concentrations in both the laboratory (Fuller et al., 2015) and in field-scale demonstrations completed at the Umatilla Chemical Depot in Umatilla, Oregon (Crocker et al., 2015; Michalsen et al., 2016). This project involved demonstrating both anaerobic biostimulation and aerobic bioaugmentation for cleanup of RDX-contaminated groundwater at Site F.

Approach/Activities. Anaerobic Biostimulation: A series of small (0.57 m^3) and large (5.7 m^3) in situ push-pull tests (PPTs) were performed to measure RDX degradation rates following anaerobic biostimulation. Groundwater amended with growth substrate (24 mM fructose or 50-100 mM ethanol) was injected into select wells up to eight times over a period of months to stimulate growth and activity of indigenous anaerobic microbes. When anaerobic conditions were achieved, PPTs were completed by injecting groundwater amended with 24 mM fructose, 4.5 µM RDX, and 1.3 mM bromide as a conservative tracer, followed by time-series monitoring of bromide and RDX concentrations. Sorption- and dilution-adjusted RDX concentrations measured during each test were used to estimate the apparent first order RDX degradation rate coefficients for each test. Bioaugmentation: A previous laboratory column study performed using repacked Site F aquifer material (NESDI Project 499) demonstrated effectiveness of bioaugmentation with aerobic RDX-degrading for RDX treatment. In preparation for the field-scale bioaugmentation trial at Site F, a forced-gradient tracer test was performed by injecting 61 m^3 groundwater amended with 1.3 mM bromide into a well, followed by time-series monitoring in the injection well and two wells located 3 and 10 m downgradient from the injection well.

Results/Lessons Learned. Anaerobic Biostimulation: RDX transformation rates determined from small PPTs averaged 0.21 day^{-1} and 0.072 day^{-1} in wells that received fructose and ethanol, respectively. Appearance of RDX degradation products (e.g., MNX, DNX, TNX) confirmed that biotransformation of RDX occurred; however, RDX degradation rates were slow and RDX degradation products accumulated during the tests. Injected groundwater temperature during the small PPTs was ~3ºC (test performed in winter), ~10ºC colder than in situ groundwater. Slow RDX degradation and accumulation of degradation products was attributed to temperature/kinetic effects. Large injection PPTs were conducted using fructose only during spring and summer 2016. Results will be available in December 2016. Bioaugmentation: Forced-gradient tracer test results confirmed localized seepage rates within the tested area of the Site F aquifer; however, apparent preferential flow resulted in the majority of the tracer solution injected flowing around the downgradient monitoring locations. As a result, cell injection during the bioaugmentation pilot will be isolated to the bottom 3 m of the injection well screen. Measured RDX degradation rates were incorporated into a site-specific groundwater model to simulate how bioremediation could augment the pump & treat remedy to reduce cleanup timeframes. Results of all pilot testing and remedy optimization work will be presented. Lessons Learned: Strategic use of available funding sources, collaboration with regulatory agencies, and phased lab-to-field pilot testing has accelerated Site F remedy optimization, which may reduce remedial timeframe and costs by 10s of years and $M, respectively.