Bench- and Pilot-Scale Testing of Aerobic Biological and Advanced Oxidation Process Treatment Methods for Chlorinated Constituents and 1,4-Dioxane in Steam-Enhanced Extraction Condensate

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Background/Objectives. Treatment of condensate and associated recovered groundwater from a steam-enhanced extraction (SEE) source remediation pilot was investigated at a former chemical manufacturing facility. Primary constituents of concern (COCs) include 1,2-dichloroethane (1,2-DCA), 1,4-dioxane, 2-chloroethanol, bis(2-chloroethoxy)methane (BCEM), and bis(2-chloroethyl)ether (BCEE). This presentation will provide a synopsis of the process development testing leading to a recommended treatment option.

Approach/Activities. Pilot testing was performed in conjunction with pilot SEE operations in a known source area which generated an authentic SEE condensate/recovered groundwater. Pilot testing evaluated advanced oxidation processes (AOPs) including UV / peroxide and ozone / peroxide targeting 1,4-dioxane, in tandem with granular activated carbon (GAC) adsorption to estimate utilization for 1,2-DCA, BCEM, and BCEE upstream and downstream of AOP. Pilot-testing was preceded by bench-scale studies to range-find AOP dosing and GAC utilization requirements in simulated SEE groundwater. Field pilot studies were followed by bench-scale aerobic biological treatment testing of pilot SEE groundwater to address removal of bulk organic content which was suspected of causing hydroxyl radical scavenging during pilot AOP testing. Subsequent bench-scale aerobic biological studies included operation of 4 and 16-liter fill-and-draw reactors. Biologically-treated effluent underwent bench-scale AOP testing to ascertain potential improvements compared to pilot results.

Results/Lessons Learned. Groundwater recovered during SEE pilot testing had increased background organic levels (400 mg/L SCOD versus 100 mg/L SCOD) compared to the non-source area recovered groundwater. In addition, a two-to-three order of magnitude increase in primary COC concentrations including 1,2-DCA (17,000 μg/L), 1,4-dioxane (5,000 μg/L), 2-chloroethanol (145,000 μg/L), BCEM (53,000 μg/L), and BCEE (360 μg/L) was observed. Pilot testing demonstrated significantly reduced performance of UV / peroxide and, to a lesser extent, ozone / peroxide, presumably due to the increased presence of hydroxyl radical scavengers in the SEE extract matrix. Aerobic biological pre-treatment removed 77% of the gross organic content; greater than 50% removal of 1,4-dioxane; and nearly-complete removals of 1,2-DCA, 2-chloroethanol, BCEM, and BCEE. Subsequent, confirmatory bench-scale AOP testing of biologically-treated effluent demonstrated successful treatment of residual target COCs and apparent reduction of competitive hydroxyl radical scavenging. In summary, aerobic biological pre-treatment was shown to (1) reduce overall organic strength and concentrations of specific COCs to less than treatment criteria, (2) improve AOP performance by reducing the concentration of hydroxyl radical scavengers, and (3) reduce GAC polishing utilization requirements for compounds not amenable to AOP.