Enhancement of Intrinsic, Cometabolic 1,4-Dioxane Biodegradation

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Background/Objectives. 1,4-Dioxane is an emerging contaminant at industrial and waste sites with physical and chemical properties that promote transport in the environment. As it is mobile in the subsurface, groundwater contamination by 1,4-dioxane can sometimes result in large, dilute plumes that can only be treated by a limited set of remedial technologies. Thus, natural in situ strategies are promising alternatives to remediate 1,4-dioxane in impacted environments. A strategy to enhance the intrinsic capacity for biodegradation of 1,4-dioxane via injection of gases and nutrients was applied to a former industrial waste landfill site located in the Midwestern US. A previous multiple lines of evidence evaluation that examined groundwater monitoring data, fate and transport modeling as well as biological analyses and compound-specific isotope analysis (CSIA) demonstrated that intrinsic biodegradation of 1,4-dioxane is occurring within the groundwater plume. Additionally, detailed bench-scale studies indicated that the intrinsic 1,4-dioxane biodegradation could be enhanced with addition of oxygen and/or alkane gases (propane and isobutene) and nutrients. These data were used to design a field pilot-scale study to assess the efficacy of adding oxygen, propane and nutrients to the subsurface to enhance intrinsic 1,4-dioxane biodegradation at the site.

Approach/Activities. Bench-scale studies were conducted to evaluate the effectiveness of different gas substrates (oxygen, propane, ethane, methane and isobutene) and nutrients for aerobic treatment of 1,4-dioxane. Based on these results, a phased field pilot-scale study was performed to evaluate the effectiveness of injecting oxygen and nutrients (Phase I) and oxygen, propane and nutrients (Phase II) to enhance intrinsic, aerobic treatment of 1,4-dioxane. The pilot-scale study was conducted using a pseudo-recirculation approach in which 1,4-dioxane impacted groundwater was extracted from a well and augmented with gas and subsequently re-injected into the subsurface to maximize the radius of influence as compared to traditional biosparge approaches. Biweekly performance groundwater monitoring was conducted within and downgradient of the injection area to evaluate the treatment efficacy. Gene abundance and expression of biomarkers related to metabolic and cometabolic biodegradation of 1,4-dioxane were completed for performance monitoring and compared to baseline levels to assess the impact of the injection on 1,4-dioxane degraders.

Results/Lessons Learned. The bench-scale studies demonstrated that the addition of oxygen and nutrients, and the addition of propane, oxygen and nutrients stimulated 1,4-dioxane degradation by native microorganisms within 30 days. The initial phase of the pilot-scale study, which included injection of oxygen and nutrient amended groundwater, demonstrated that aerobic conditions that favored enhanced 1,4-dioxane degradation could be achieved; although there was little measurable effect on 1,4-dioxane levels during this phase. During the second phase of the pilot, weekly injection of oxygen, propane and nutrient augmented groundwater resulted in greater than 90% reductions in 1,4-dioxane concentrations within the treatment zone in less than 3 months. Gene abundance and population count data indicated that propanotroph bacteria (known 1,4-dioxane degraders) increased above baseline levels during the study. The effectiveness of this remedial approach to enhance natural 1,4-dioxane biodegradation will be presented based on the pilot test as well as potential applicability as a larger-scale 1,4-dioxane treatment approach.