Enhancement of Intrinsic 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 pilot-scale study to assess the efficacy of adding gases 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 field pilot-scale study is currently being performed to evaluate the effectiveness of injected oxygen and nutrients to enhance intrinsic, aerobic treatment of 1,4-dioxane. In addition, propane may also be added in the injection stream in the future to further enhance 1,4-dioxane biodegradation. The pilot-scale study is being conducted using a pseudo-recirculation approach in which 1,4-dioxane impacted groundwater is extracted from a well and augmented with gas. Gas is infused in extracted groundwater using a Venturi jet injector to supersaturate the gas and subsequently re-injected into the subsurface to maximize the radius of influence as compared to traditional biosparge approaches. Biweekly performance groundwater monitoring is being 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 will be completed 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. In particular, 1,4-dioxane degradation was observed within the first month of the study. These results were used to guide the design and implementation of the pilot-scale study, which will be discussed in detail and contrasted with traditional gas biosparge remedial approaches. 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. The effect of the injections on the microbial community structure and activity of 1,4-dioxane degraders will also be presented.