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Evaluation and Enhancement of Intrinsic 1,4-Dioxane Biodegradation

Andrew Madison and Timothy Richards (Golder Associates Inc., Mt. Laurel, NJ, USA)
Phillip Gedalanga and Shaily Mahendra (UCLA, Los Angeles, CA, USA)

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 such, establishing the intrinsic capacity for biodegradation of 1,4-dioxane and evaluating remedial strategies to enhance 1,4-dioxane biodegradation is an important consideration when evaluating remedial alternatives. This remedial alternative framework was applied to a former industrial waste landfill site located in the Midwestern US. Previous investigations identified the occurrence and extent of a large, dilute groundwater plume primarily comprised of 1,4-dioxane and tetrahydrofuran that emanates from the former landfill area and extends downgradient for more than 2 miles. Groundwater monitoring data indicate the 1,4-dioxane groundwater plume extent is generally stable, while some portions of the plume are contracting. Fate and transport modeling indicate that nondestructive physical processes alone do not account for 1,4-dioxane attenuation within the groundwater plume. State-of-the-art molecular biological analyses and compound-specific isotope analysis (CSIA) were employed in concert with traditional data approaches to evaluate the intrinsic biodegradation potential of 1,4-dioxane. These data were used to guide and design bench-scale studies to evaluate a remedial approach to enhance intrinsic 1,4-dioxane biodegradation at the site.

Approach/Activities. Gene and transcript abundance of biomarkers related to metabolic (ALDH and DXMO) and cometabolic (sMMO) biodegradation of 1,4-dioxane were applied to nucleic acid extracts from groundwater samples at the site. 1,4-Dioxane CSIA was also applied to groundwater samples for supporting evidence of biodegradation. Treatability microcosms were established from groundwater and soil collected within the groundwater plume at one location where metabolic 1,4-degradation biomarkers (DXMO and ALDH) were most abundant and another location where cometabolic biomarkers (sMMO) were most abundant. Microcosms were constructed to evaluate the effectiveness of gas substrate additions (oxygen, ethane, isobutene, methane and propane) with and without nutrient augmentation to enhance and/or stimulate metabolic and cometabolic biodegradation of 1,4-dioxane.

Results/Lessons Learned. Quantification of functional gene targets (DNA) and their transcripts (RNA) demonstrated that microorganisms capable of both metabolic and cometabolic degradation of 1,4-dioxane were present and active throughout the groundwater plume. The CSIA data also provided supporting evidence of biodegradation. These data support the traditional data analyses and demonstrated that intrinsic biodegradation of 1,4-dioxane is occurring within the groundwater plume. Microcosms were constructed to evaluate if the metabolic and cometabolic 1,4-dioxane biodegradation activities may be enhanced by subsurface amendment addition of gas substrates and nutrients. The effectiveness of the substrate additions in the microcosms to enhance and stimulate 1,4-dioxane will be presented, including a focus towards development of remedial alternatives.