Biodegradation of 1,4-Dioxane in a Moving Bed Bioreactor

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Background/Objectives. 1,4-Dioxane is a common co-contaminant with chlorinated solvents. Treatment of 1,4-dioxane via enhanced biodegradation processes provides a viable remedial strategy. Both metabolic (i.e., energy producing) and cometabolic (i.e., fortuitous) biodegradation of 1,4-dioxane can occur. Metabolic biodegradation occurs under aerobic conditions, and cometabolic biodegradation must occur in the presence of both oxygen and a primary substrate (e.g., methane or propane) by microorganisms that utilize these primary substrates for growth. At the RACER Trust facility in Lansing, Michigan, historical use of chlorinated solvents resulted in up to approximately 3,300 micrograms per liter of 1,4-dioxane in groundwater. The initial remedial design called for ex situ treatment via advanced oxidation processes (AOPs), which is relatively expensive for long-term removal of 1,4-dioxane considering the power and chemical costs for operation. Instead, RACER Trust is exploring an ex situ biological treatment approach, using a pilot moving bed bioreactor (MBBR).

Approach/Activities. Three MBBRs were piloted to treat extracted groundwater prior to reinjection: one designed for metabolic biodegradation of 1,4-dioxane and two designed for cometabolic biodegradation of 1,4-dioxane (for concurrent testing of different hydraulic residence times [HRTs] and challenge conditions). The MBBR pilot system consisted of an aerated iron oxidation tank and clarifier, oxygen and/or propane cylinders, gas injection points, the three MBBR reactors filled with approximately 40 percent media in parallel, a biological solids settling tank, a bag filter, a lower explosive limit meter, and associated controls. The metabolic MBBR was seeded with a known 1,4-dioxane degrading organism, *Pseudonocardia dioxanivorans* CB1190 (provided by UCLA/Dr. Shaily Mahendra). The cometabolic MBBRs were seeded with a propanotrophic culture, *Rhodococcus ruber* ENV425 (provided by EOS Remediation, LLC). This culture utilizes propane as its primary substrate and has been used elsewhere to facilitate co-metabolic biodegradation of 1,4-dioxane. The MBBRs also received micro- and macronutrients to promote healthy bacterial colonization.

Results/Lessons Learned. The results of this pilot study provided valuable insights into operating these types of bioreactors – the first of their kind for 1,4-dioxane treatment. The optimal seeding and operating conditions were identified. Several challenges critical to establishing, and maintaining, the desired microbial community were vetted. Over the course of the three-month pilot test, 1,4-dioxane concentrations in one of the propane bioreactors was reduced from 240 µg/L to 40 µg/L – below the site-specific discharge limit. These pilot test bioreactors were set up as constant feed systems, or near-constant feed systems. The highest 1,4-dioxane removal was observed in the propane bioreactor where the propane was only fed into the bioreactor half of the time. This allowed propane concentrations to decrease and the microbiallly generated enzymes to degrade the 1,4-dioxane. Additional reductions could be expected with further refinement of operating parameters.