Bioremediation of 1,4-Dioxane Using Cometabolic Bioreactors

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Background/Objectives. 1,4-Dioxane is a groundwater contaminant that is a growing concern and is commonly associated with chlorinated solvent plumes. Removal of 1,4-dioxane using traditional physical-chemical water treatment technologies can be difficult, and many existing groundwater pump and treat (P&T) systems are not equipped to remove chlorinated solvents and 1,4-dioxane. While advanced oxidation processes (AOPs) can reliably remove 1,4-dioxane, other treatment methods are emerging – with bioremediation serving as a reliable, safe, sustainable, and economical alternative to AOPs. Bioreactors are an attractive option for retrofitting existing P&T systems when 1,4-dioxane treatment is required, or as a technology to incorporate into new construction. The focus of this ESTCP project (ER22-7226) is the biodegradation of 1,4-dioxane using propane as a primary substrate in an aerobic membrane biofilm reactor (MBfR).

Approach/Activities. This project will combine two previously demonstrated remedial technologies: propane-mediated biodegradation of 1,4-dioxane and MBfRs. 1,4-Dioxane biodegradation occurs via aerobic pathways. Engineered bioremediation approaches have been implemented at the pilot- and full-scale level and commonly have utilized propane as a primary substrate. Using gaseous species to foster biologically mediated reactions in conventional engineered bioreactors can be challenging, specifically related to achieving adequate gas transfer. An MBfR eliminates this challenge by utilizing pressure-controlled gas-transfer membranes to provide a gaseous substrate directly to the biofilm by diffusion through the membrane. The gas supply to the biofilm is driven by the concentration gradients caused by biochemical demand, making the MBfR a self-regulating system. This work begins with bench-scale testing to configure commercially available membranes for 1,4-dioxane biological treatment.

Results/Lessons Learned. The bench-scale work is evaluating the ability to deliver propane via commercially available bubble-free hollow-fiber membranes; specifically, the flux of propane as a function of propane pressure in the membrane lumen for a polypropylene membrane. This work is also determining the required ratio of propane-to-1,4-dioxane to support biomass growth and maintenance, along with the cometabolic biodegradation of 1,4-dioxane. *Rhodococcus ruber* culture ENV425 is being used as a seed culture in the MBfR and changes to the microbial community over time documented. 1,4-Dioxane levels in the MBfR are being evaluated at environmentally relevant concentrations (e.g., 100 µg/L). Lastly, the bench-scale work is determining the optimal way to configure the membranes to deliver propane and oxygen: separate membrane bundles for each gas, mixing the gases for delivery through the same membrane, or saturation of one gas outside the membrane. These configuration components will then be carried over to a future field demonstration.