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Application of Bioreactors in 1,4-Dioxane Treatment: A Perspective

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Background/Objectives. 1,4-Dioxane (dioxane) is an emerging contaminant frequently found in groundwater at sites with historical chlorinated solvent use and liquids generated by or associated with waste disposal/recycling facilities (e.g., landfill leachate). Ex situ treatment systems, for a number of reasons, may have already been or need to be installed at these sites. Often, dioxane adds significant upgrade costs to these sites, because a cost-effective treatment is still lacking. For over 20 years, the industry has looked at bioreactors as a solution to this challenge, but only with isolated studies and very few documented full-scale systems. In addition, it is not clear whether or not bioreactors can treat dilute dioxane streams to low regulatory limits. The lack of demonstration/full-scale systems and evidence of effectiveness at meeting low regulatory limits needs to be overcome for bioreactors to be considered as a viable alternative to conventional ex situ treatment technologies for dioxane.

Approach/Activities. This presentation considers two factors that will likely impact the effectiveness of dioxane treatment in a bioreactor. The first factor is the microorganism(s). To date, a number of mixed and pure dioxane degrading cultures, through both metabolic and co-metabolic pathways, have been reported. Interestingly, many of them, including the model organism *Pseudonocardia dioxanivorans* CB1190, were isolated from bioreactors. It is important to recognize that the kinetics of the microorganisms will ultimately determine the rate of degradation, effluent concentration, and therefore the general applicability of such a system. A culture with a higher maximum specific degradation rate and a lower half-saturation concentration than the ones currently available would greatly improve prospects of using bioreactors to remove dioxane. A mixed culture from a full-scale landfill leachate treatment plant was used in our studies, which was preliminary characterized.

The second factor is reactor configuration. Dioxane degrading cultures, especially the ones metabolizing dioxane, are generally characterized by slow growth and sometimes sensitivity to environmental conditions (e.g., low DO). The reactor configuration must maximize biomass retention, supply co-substrates (for co-metabolic processes), and optimize other growth conditions, while supporting simple operation and consistent performance. Various bioreactor configurations in bench-, pilot- and full-scale studies were evaluated in our studies.

Results/Lessons Learned. We will first summarize the existing but limited literature on past bioreactor studies, focusing on microbial kinetics and the reactor features. Secondly, we will report a summary of results from our own studies, including evaluation results of various bench-, pilot-, and full-scale reactors (activated sludge, membrane bioreactor, moving bed bioreactor, biological granular activated carbon). Because dioxane can be in high concentrations in some waters (e.g., source zone groundwater and landfill leachate), and low concentrations in others (e.g., edge of plumes), we tested both concentration regimes (2~10 mg/L and <0.5 mg/L). For higher-concentration runs, the bioreactors demonstrated a removal between 97% and 99.5% in the field and a high removal rate with minimal optimization. In low-concentration runs, the initial laboratory results suggested that the removal was somewhat lower, and required longer hydraulic residence times. The laboratory bioreactors under low influent concentrations are currently being optimized.