Enhancing 1,4-Dioxane Bioremediation at Low Concentrations by Combining a Metabolic Degradation Culture with Adsorbents

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Background/Objectives. This presentation will provide an overview of a series of laboratory tests to evaluate the potential of combining commercially available and inexpensive adsorbents with a mixed 1,4-dioxane metabolizing culture to enhance 1,4-dioxane bioremediation. Previous kinetic characterization efforts suggested the mixed culture was able to support growth-linked metabolism at a few hundred µg/L; however, the 1,4-dioxane concentrations in groundwater is often <100 µg/L and the regulatory levels are in general even lower. Although 1,4-dioxane only adsorbs weakly, it was hypothesized that the interactions between a biofilm and concentrated and potentially more readily available substrate on the adsorbent can enhance substrate degradation.

Approach/Activities. Considerations were made to conduct all tests at representative operating conditions, including 1,4-dioxane concentration, reactor flow/sizing, method for bioaugmentation, and adsorbent type. Initial columns were constructed with granular or pellet forms of the adsorbents, effectively making the columns analogous to ex situ fixed bed bioreactors. Synthetic or site groundwater containing up to 100 µg/L of 1,4-dioxane was used as influent. Multiple adsorbents were tested, including activated carbon, biochar, and zeolite. Empty bed contact time ranged from <1 to 4 hours. The flow-through reactors were operated for 6-24 months (and some still ongoing). Effluent 1,4-dioxane samples were analyzed periodically to confirm steady state. In select studies, the microbial communities as well as the adsorbed 1,4-dioxane on the adsorbent were analyzed after the column test. One site groundwater contained detectable TCE and high concentrations of perchlorate. For this groundwater, the reactor consisted of an activated carbon layer (not bioaugmented) followed by a downstream layer of another adsorbent (bioaugmented).

Results/Lessons Learned. In virtually all of the column studies so far, the effluent 1,4-dioxane was non-detect (<0.5 or 1 µg/L) at steady state. In the site groundwater that contained TCE and perchlorate, the 1,4-dioxane biodegradation was not affected. TCE was 100% removed by the activated carbon, presumably through adsorption only, and never broke through during the test. Unexpectedly, approximately 50~80% of the influent 1,4-dioxane was also removed at steady state by the non-bioaugmented activated carbon. Extraction of adsorbed 1,4-dioxane indicated that only 1~3% of the removed 1,4-dioxane remained on the activated carbon after the column study, whereas an isotherm-based calculation estimated the adsorbed proportion to be approximately 18%. Taken together, the main 1,4-dioxane removal mechanism on the activated carbon was due to enhanced biodegradation rather than adsorption. Similar conclusions can be drawn for the downstream adsorbent layer for each of the adsorbents tested. For example, about 6% of the 1,4-dioxane removed by zeolite was shown to be attributable to adsorption while the remaining 1,4-dioxane was biodegraded. While the microbial community analysis for this specific column study is not available, similar studies showed a diverse microbial community with multiple putative 1,4-dioxane metabolizing bacteria, consistent with our previous published batch and kinetic characterizations. Current efforts are focused on evaluating additional adsorbents, effects of other CVOCs, and adapting the concept to in situ remediation with powdered form of adsorbents.