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Novel Approach to Enhance Solubilization of Gaseous Substrates in Contaminated Groundwater to Promote Aerobic Cometabolic Biodegradation

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Background/Objectives. Aerobic cometabolic biodegradation (ACB) has been shown to be capable of treating contaminants, such as TCE, cDCE, MTBE, TBA, 1,4-dioxane, and NDMA to levels below their cleanup goals. Many gaseous substrates (e.g., methane, propane, butane, and oxygen) that are useful to stimulate and maintain the in situ ACB activity are commercially available and stored in pressurized gas tanks or cylinders. Because these gaseous substrates are not very soluble, most field ACB applications to date use sparging to deliver gaseous substrates in contaminated aquifers. The performance of sparging has been known to be sensitive to aquifer heterogeneity. To help enhance ACB's implementability for aquifer restoration, a reliable alternate method to supply gaseous substrates into contaminated aquifers is desirable.

Approach/Activities. Three gas absorption technologies, including gas diffusion emitters, bubble diffusers, and Venturi injectors, were reviewed and their efficiencies were compared. The use of the Venturi principles for fast gas absorption was found to be promising because of its relatively small reactor size and scalability. A literature review was performed to determine engineering principles needed to use the Venturi injector technology for a field ACB demonstration project that required solubilization of propane and oxygen into recirculated groundwater for in situ ACB of 1,4-dioxane and 1,2-dichloroethane.

Results/Lessons Learned. Gas diffusion emitters require diffusion of substrate molecules through plastic or silicone tubing, which generally limits the mass loading from emitters. The efficiency of a bubble diffuser system is usually less than 20% (assuming a 10 feet water column), and thus it is difficult to be scaled up for applications that require a high groundwater recirculation rate. In contrast, a Venturi injector system was found to regularly achieve a solubilization efficiency between 60% and more than 95%, depending on operation conditions. The significantly higher efficiency achieved by a Venturi injector is attributed to a high degree of shear forces occurring at the Venturi throat, which results in the production of microbubbles. The overall solubilization efficiency is generally controlled by the degree of turbulence occurring in the injector throat and in the downstream pipeline and the total contact travel time in the pipeline before entering the aquifer. The Reynolds number, which characterizes the degree of turbulence, is desirable to be more than 10,000. The field test results indicate that the Venturi injector based approach can achieve the solubilization efficiencies of more than 60% and 90% for propane and oxygen, respectively. The Venturi-based substrate addition system coupled with groundwater recirculation successfully established an in situ ACB bioreactor to concurrently treat 1,4-dioxane and 1,2-dichloroethane in contaminated groundwater at an efficiency more than 98% and to the levels below their respective cleanup goals.