Aerosol Delivery for Biostimulation/Bioaugmentation of Contaminated Vadose Zones

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Background/Objectives. The inability to effectively distribute liquid- or solid-phase amendments in unsaturated materials has limited the application of many remediation approaches for contaminated vadose zones. Among these remedial approaches is *in situ* bioremediation, which typically requires introducing amendments and/or microbes into the contaminated zone to achieve optimal microbiological reaction rates.

Aerosol delivery is a promising new approach for distributing amendments in contaminated vadose zones. The amendments are aerosolized, creating a cloud of micron to sub-micron-scale liquid droplets held suspended in a gas by Brownian motion. During injection into porous media the aerosol particles are transported along with the gas until they impact a solid surface and deposit. The process is continued until appropriate amendment concentrations are achieved, ideally resulting in a radially and vertically broad distribution. Such a distribution could not be achieved by injecting pure liquid-phase solutions.

The objectives of this work were A) to evaluate biodegradation of TCE under partially saturated conditions when amendments and/or microbes are delivered as aerosols; and B) to characterize transport and deposition of aerosols in partially saturated conditions.

Approach/Activities. Stimulation of TCE biodegradation using aerosolized amendments was investigated by constructing anaerobic microcosms in 160 ml serum bottles. Headspace samples were analyzed for TCE, cDCE, VC, and ethene to determine the rates and extent of biodegradation within each bottle. Multiple sets of microcosms were created to determine differences based on water saturation, electron donor, and amendment delivery method.

Aerosol transport and deposition processes were investigated by conducting lab-scale injection experiments. The lab experiments involved injection of aerosols through 1.5-m-tall, sand-filled columns constructed with sampling ports at 15-cm intervals. A particle-size analyzer was used to measure aerosol particle distributions along the column with time. Sand samples were taken through the ports following injection and analyzed for amendment content.

Results/Lessons Learned. Microcosm results have shown that anaerobic biodegradation of TCE can occur in unsaturated systems. No statistical differences in degradation activity were observed based on whether amendments in aqueous solution were added directly or as an aerosol. Addition of microbial culture as aerosols resulted in complete conversion of TCE to ethene, however, initial reaction rates were typically slower as compared to when culture was added directly.

Results of column tests involving NAPL (vegetable oil) aerosol injection show that significant liquid saturations could be readily achieved throughout the 1.5-m-long columns. Tests involving transport and deposition of aqueous aerosols did not produce measurable changes in liquid saturation away from the point of injection, a difference that most likely results due to evaporation. However, amendments precipitated from the aqueous solution are found to deposit throughout the 1.5-m-long columns. The process appears to be capable of transporting and depositing aqueous amendments (electron donor, pH buffer, etc.) in sandy formations at concentrations that are appropriate for bioremediation purposes. Overall, the results indicate that bioremediation of the vadose zone using aerosol delivery of substrates and enrichment cultures is a promising treatment strategy.