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Field Gas-Sparging Tests for In Situ Aerobic Cometabolism of Trichloroethylene (TCE)

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Abstract

Single-well-gas-sparging tests were developed and evaluated for assessing the feasibility of in-situ aerobic cometabolism of trichloroethylene (TCE), using propane as a growth substrate. To evaluate transport characteristics of dissolved solutes [sulfur hexafluoride (SF6) or bromide (non-reactive tracers), propane (a growth substrate), ethylene, propylene (nontoxic surrogates to probe for CAH transformation activity), and DO], push-pull transport tests were performed. Mass balance showed about 90% of the injected bromide and about 80% of the injected SF6 were recovered, and the recoveries of other solutes were comparable with bromide and slightly higher than SF6. A series of Gas-Sparging Biostimulation tests were performed by sparging propane/oxygen/argon/SF6 gas mixtures, and temporal ground water samples were obtained from the injection well under natural gradient "drift" conditions. The decreased time for propane depletion and the longer time to deplete SF6 as a conservative tracer indicate the progress of biostimulation. Gas-Sparging Activity tests were performed. Propane utilization, DO consumption, and ethylene and propylene cometabolism were well demonstrated. The stimulated propane-utilizers cometabolized ethylene and propylene to produce ethylene oxide and propylene oxide, as cometabolic by-products, respectively. Gas-Sparging Acetylene Blocking tests were performed by sparging gas mixtures including acetylene to demonstrate the involvement of monooxygenase enzymes. Gas substrate degradation was essentially completely inhibited in the presence of acetylene, and no production of the corresponding oxides was also observed. The Gas-Sparging tests supports the evidences that the successive stimulation of propane-oxidizing microorganisms, cometabolic transformation of ethylene and propylene by the enzyme responsible for methane and propane degradation.

Introduction

The objective of this study was to develop a series of rapid, low-cost Gas-Sparging tests for use in evaluating the site-specific potential for aerobic

cometabolism of TCE. The tests were conducted in a single well to assess the site-scale spatial variability in these processes. The test series consists of: (1) Push-pull Transport test to evaluate the mobility of the gaseous substrates, TCE surrogates (ethylene and propylene), and tracers (SF6 and bromide) in the absence of biological activity, (2) Gas-Sparging Biostimulation tests to evaluate the ability of propane additions to stimulate propane-utilizers, (3) Gas-Sparging Activity tests, to evaluate the abilities of the stimulated microorganisms to utilize propane and TCE surrogates, and (4) Gas-Sparging Acetylene-Blocking tests to evaluate the involvement of monooxygenase enzyme system in the growth propane degradation and transformation of TCE surrogates.

Materials and Methods

Biostimulation test by gas mixture sparging. The sequential biostimulation tests were performed to evaluate if the propane-utilizers could be stimulated in the aquifer. The propane/oxygen/argon gas mixture for sparing was formulated to stimulate indigenous propane-utilizers, while maintained the gas below the LEL. Propane and oxygen injection ratios were maintained to result in complete utilization of both gases.

Gas sparging activity test. The propane/ethylene/propylene/oxygen/argon gas mixture sparing activity tests were performed to evaluate relative degradation rates of propane, ethylene and propylene under natural gradient conditions. After sparging, temporal groundwater samples will be taken and analyzed for all of gaseous compounds, DO, TCE, CO_2, and potential metabolic products such as ethylene oxide, propylene oxide.

Gas sparging inhibition tests. Inhibition tests were performed as another demonstration that the observed uptakes of propane, ethylene and propylene and TCE transformation are biologically catalyzed reactions and not the result of abiological processes (e.g. sorption or volatilization). Acetylene that acts as a mechanism-based inactivator for most of the oxygenases expressed by methane- and propane-oxidizing bacteria (Hamamura et al., 1999; Prior and Dalton, 1985) was used. The effect of acetylene on uptake of both propane and ethylene uptake was tested in a series of inhibition tests.

Results and Discussion

Gas sparging biostimulation tests. The sequential biostimulation tests were performed. By the third test, propane was completely consumed (a well sparged with propane) (Figure 1), while oxygen was partially consumed. Incomplete utilization of oxygen resulted from the background oxygen concentration of regional groundwater that mixed with the injected solution. With repeated gas sparging tests depletion time of propane decreased from 10 to 5 days, while SF6was depleted after 20 days (Figure 1). The decreased time for growth substrate depletion and the longer time to deplete SF6 as a conservative tracer indicate the progress of biostimulation.

Gas-sparging activity tests. Complete utilization of propane, ethylene, and propylene was observed 7 days after injection, while SF6 concentration reduced about

20%. By-products having the same retention time on the GC as ethylene oxide and propylene oxide were detected. The stimulated propane-utilizers cometabolized ethylene and propylene to produce ethylene oxide and propylene oxide, as cometabolic by-products. The activity test results showed that propane-utilizers stimulated with repeated gas sparging tests were able to cometabolize ethylene and propylene, resulting in the formation of the by-products ethylene oxide and propylene oxide.

Gas-sparging inhibition tests. Propane utilization and ethylene and propylene oxidation were essentially completely inhibited in the presence of acetylene, and no production of the corresponding oxides was also observed. The results when compared with those obtained in the activity tests further demonstrate propane and methane monooxygenase enzymes were responsible for the transformation of ethylene and propylene.

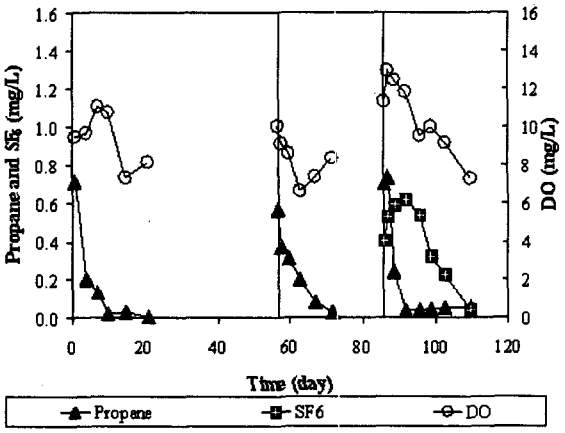

Figure 1. Temporal concentrations of propane, DO and SF6 during the Biostimulation Drift tests.

Conclusion

Direct gas-sparging of a gaseous substrate/oxygen mixture into an aquifer results in a prolonged release of the dissolved gaseous substrate and oxygen. Thus the direct gas-sparging method for the biostimulation would be more effective and less time intensive than injecting propane and oxygen as dissolved components of ground water.

References

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