

BioSolve[®] Activator Column Test Results

Activator, the newest addition to the BioSolve portfolio of hydrocarbon remediation products, was developed through four years of formulation trials and testing. The design objectives were to: i) formulate a readily biodegradable product; ii) optimize mobilization and emulsification performance for aggressive NAPL mass removal from the subsurface; and iii) achieve a performance level equal to or better than our established remediation surfactant, BioSolve Pinkwater.

Laboratory testing of developmental Activator formulations was undertaken by Dr. Andrew Ramsburg, Director of the Integrated Multi-Phase Environmental Systems (IMPES) Laboratory at Tufts University (Medford, MA). One-dimensional column tests were run to model the performance of Activator for use during in-situ soil remediation. Parallel column tests were run with our traditional product, BioSolve Pinkwater. Results from early tests were used to select from alternative Activator formulations; later results helped “fine tune” the final product formulation.

Columns for testing were prepared by filling the pore space in the column with NAPL, then draining the column by gravity and finally rinsing the column with 2 PV of background solution (water with 500 ppm of calcium chloride) to confirm NAPL saturation had been reduced to “residual” level. For these tests, residual saturation was established as 14% of pore volume. In early column tests toluene was used as the NAPL source and in later testing, a synthetic gasoline mixture was used to better simulate field conditions.

During actual testing, a peristaltic pump, with a flow rate of 1 cm³/min, was used to treat the column with one additional PV of background solution followed by 7 PV of 5% Activator solution and finally another 2 PV of background solution. Effluent samples were taken every 7 minutes for analysis on a gas chromatograph.

NAPL recovery from the final column test using the final commercial formulation for BioSolve Activator, are shown graphically in Figure 1. As the figure indicates, the results



The BioSolve Company worked with the original inventor of BioSolve Pinkwater and the IMPES Lab at Tufts University over a period of four years to develop a new surfactant formulation. Our objective was a product that would at least match the NAPL mass removal performance of BioSolve Pinkwater as well as comply with OECD requirements for “ready biodegradability”. The outcome of that process is “BioSolve Activator”, now available for commercial use

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were excellent: over 50% mass removal after one pore volume of 5% Activator solution, reaching almost 90% removal after four additional pour volumes.

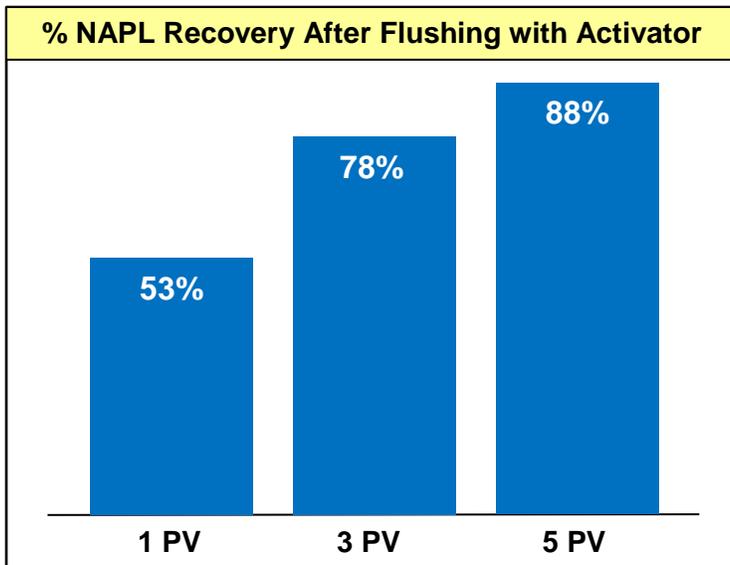


Figure 1. BioSolve Activator one-dimensional column test results

Furthermore, the studies demonstrated that switching from Activator solution to background solution after three pore volumes had negligible impact on total mass recovery. Mobilization of residual NAPL had already occurred such that additional removal required only displacement with water.

Since completing our work with Tufts, The BioSolve Company has conducted treatability studies with customers and used Activator at a number of commercial sites with

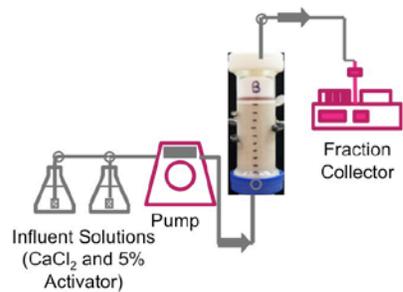
excellent results. Clearly field conditions vary significantly, but column and field testing confirm that if Activator solution flows through a contaminated zone, mobilization and emulsification will occur leading to accelerated recovery of NAPL.

BioSolve Activator is a proprietary blend of alcohol ethoxylates (nonionic surfactants) and other ingredients specifically formulated for soil remediation applications.

BioSolve Activator is formulated to comply US EPA's **Safer Choice** program, requiring both competitive performance and an improved health and environmental profile. All ingredients in Activator have been designated "products of low concern" on EPA's Safer Chemicals Ingredients List. Activator also meets criteria for **ready biodegradability** as established by US EPA and European REACH regulations.

For professional use at the user's discretion and risk. Instructions provided herein are not intended for site specific applications. Do not use BioSolve products without proper permits, approvals and authorization by appropriate regulatory agencies. Use in compliance with all federal, state, and local rules and regulations. For SDS, application protocols or additional information contact The BioSolve Company.

Design Parameters of Column Experiments



Column Length = 10 cm
Column Inside Diameter = 4.8 cm
Matrix: Medium Sand (Federal Fine)
Matrix Bulk Density = 1.68 g/cm³
Porosity = 0.39
Pore Volume = 70 mL
Flow Rate = 1 cm³/min
Background Solution: 500 mg/L CaCl₂
LNAPL: Synthetic Gasoline Mixture (SGM),
Density = 0.78 g/mL

- Benzene 2.3% by mass
- Toluene 6.5%
- M-xylene 13.5%
- Trimethylpentane 44.0%
- Trimethylbenzene 33.7%

Testing Protocol

Columns were prepared with a residual saturation of NAPL. Each column experiment started with a 1 pore volume (PV) flush using a background solution of 500 ppm calcium chloride to simulate groundwater. This was followed by up to 7 PV of Activator solution and finally another 2 PV of background solution to wash out residual surfactants. Samples were taken every 7 minutes, representing about 0.1 PV.

Mobilization and Emulsification

Whereas Pinkwater is known to achieve NAPL removal through emulsification, the objective for Activator is to remove NAPL through a combination of both mobilization and emulsification. During the column tests, Dr. Ramsburg's team observed significant mobilization of NAPL in the column during the first two pore volumes of Activator solution. Recovery of mobilized NAPL was also observed in the sample vials collected during the experiments. Further testing of the sample vials confirmed that about 40% - 50% of NAPL recovery can be attributed to mobilization.