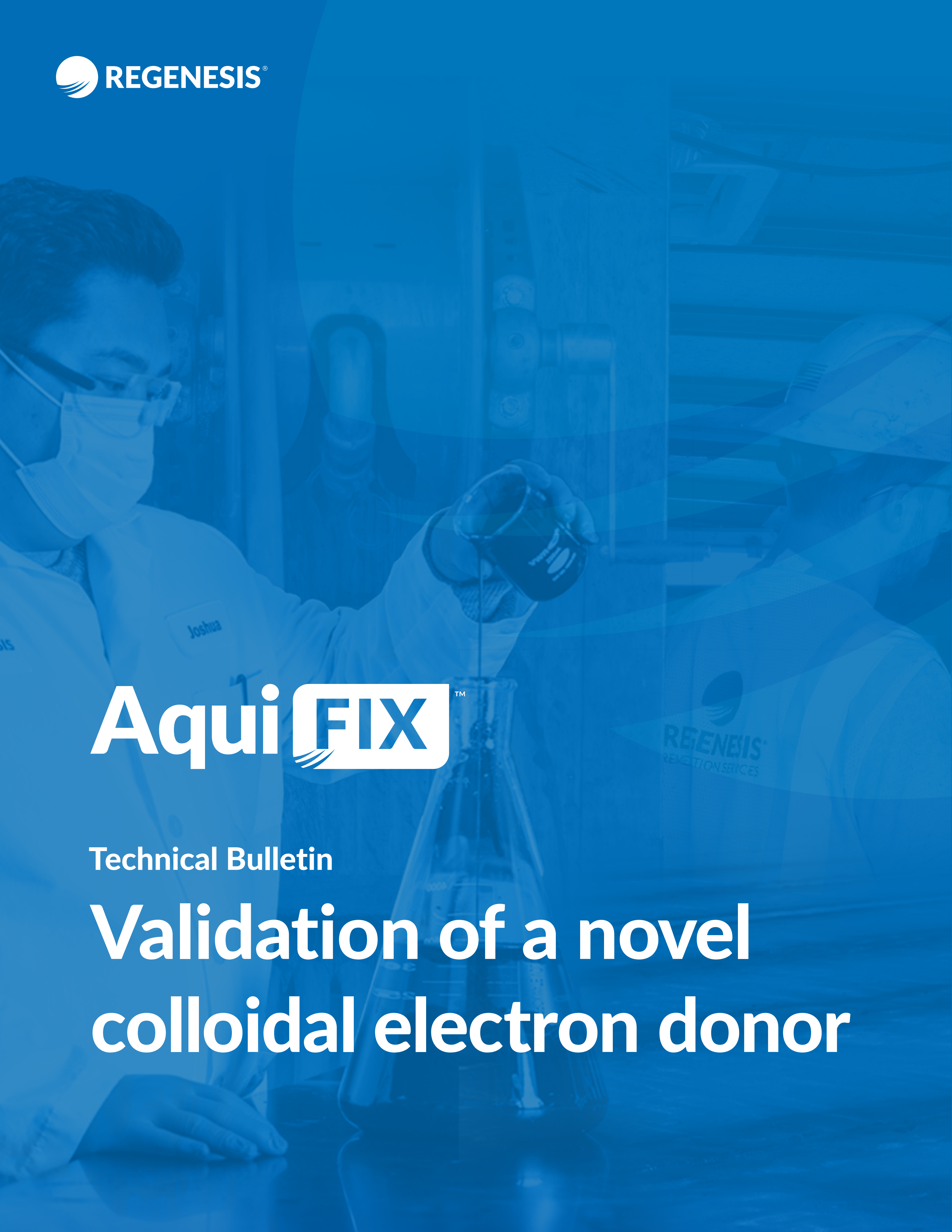
REGENESIS®



AquiFIX™

Technical Bulletin

Validation of a novel colloidal electron donor

Summary

AquiFix™ is an organic remediation amendment engineered to promote *in situ* anaerobic biodegradation of toxic groundwater contaminants. AquiFix contains an engineered mixture of fast and slow-release organic compounds. The slow-release component is composed of fine, solid-phase, plant-based particles (<0.5 µm) suspended in water using polymer dispersion chemistry. The rapid release organic compound is dissolved within the aqueous matrix. Once applied to the subsurface, AquiFix binds to the soil matrix and the soluble organic donor quickly establishes reducing conditions. The solid phase component slowly degrades to produce volatile fatty acids and molecular hydrogen that sustain long-term anaerobic bioremediation. AquiFix is fully compatible with, and does not interfere with the performance of complimentary remediation amendments, including PlumeStop® colloidal activated carbon (CAC) and S-MicroZVI®.

Background and Objectives

Organic bioremediation amendments are used to support the metabolism of anaerobic microbes which biodegrade chlorinated hydrocarbons and other toxic groundwater contaminants *in situ*. Existing commercially available bioremediation amendments have fundamental shortcomings. Water soluble compounds such as sodium lactate are highly effective for short periods, but offer limited persistence and can require frequent reapplication. Liquid oil emulsions are known to have better longevity but interfere with the performance of activated carbon products used to immobilize groundwater contaminants. AquiFix is engineered to address these shortcomings by providing an extended-release organic bioremediation amendment fully compatible with PlumeStop CAC.

The soluble component in AquiFix activates shortly after application and quickly establishes reducing conditions facilitating the acclimation of anaerobic bacteria. The solid phase component slowly ferments to produce shorter chain water soluble organic compounds (e.g., propioniate, acetate) and molecular hydrogen. This unique combination provides the strongly reducing environment needed for anaerobic bioremediation while providing a long-term supply of organic carbon to sustain degradation of groundwater contaminants.

Another key feature of AquiFix is its compatibility with PlumeStop CAC and other solid phase remediation amendments. Liquid oil-in-water emulsions competitively adsorb to activated carbon particles adversely affecting their ability to adsorb and immobilize groundwater contaminants. The solid phase component of AquiFix has a negligible effect on the absorptive capacity of the CAC allowing for a co-application of both products into contaminated soil and groundwater.

Successful remediation outcomes are also predicated on delivering and distributing the amendments into and within the contaminated aquifer. AquiFix has sub-micron particles that fit within the pore throats of most soil environments and can be applied using low injection pressures minimally disrupting the soil matrix. The distribution profiles are comparable to PlumeStop resulting in a homogeneous product distribution when the two products are co-applied. This increases the probability of contact with the contaminants and ensures a more successful outcome.

Experimental: Batch and Column Study

Sterile Abiotic Control Microcosms *240 mL Amber Glass Bo. le*	
90 Mesh Silica Sand	20 g
Tap Water	230 g
1% Sodium Azide	4.6 g

Active Biotic Microcosms *240 mL Amber Glass Bo le*	
90 Mesh Silica Sand	20 g
Tap Water	230 g
AquiFix	1.3%

A batch study was performed to evaluate the ability of AquiFix to promote the anaerobic bioremediation of chlorinated ethenes. This test included an active biotic microcosm paired with a sterile abiotic control. The sterile abiotic control microcosms used duplicate 240 mL amber bottles containing 20 g of 90 mesh silica sand, 230 g of tap water and 4.6 g of 1% sodium azide to prevent bacterial growth. The active biotic bottles contained 1.3% of AquiFix (25% solid phase organic and 6% soluble organic in water) without the sodium azide biocide. Each bottle received 10 mg/L of TCE and was placed on a shaker for 24 hours before adding 230 µL of the BDI Plus (1.0 x 10^{8} cell Dhc/mL) anaerobic microbial culture. An additional 10 mg/L TCE was added into the bottles four times between days 45 and 70. Degradation progress was evaluated by periodically withdrawing samples and using GCMS.

Control Column (PlumeStop Only) *Omni Fit 25 x 500 mm*	
90 Mesh Silica Sand	315 g
20 Mesh Silica Sand	20 g
PlumeStop	25 g
Tap Water	425 g
BDI	50 g

Omni Fit 25 x 500 mm columns were assembled to determine if adding AquiFix to PlumeStop had an adverse effect on the ability of the activated carbon to adsorb TCE. Two columns were filled with 315 g of 90 mesh silica sand and capped with 10 g of 20 mesh sand on the top and bottom. The control column (PlumeStop only) received 1 pore volume (~85 mL) of a mixture containing 25 g of PlumeStop (20% activated carbon in water), 425 g of tap water, and 50 g of BDI (10^{10} cell Dhc/L).

AquiFix Column *Omni Fit 25 x 500 mm*	
90 Mesh Silica Sand	315 g
20 Mesh Silica Sand	20 g
PlumeStop	25 g
AquiFix	20 g
Tap Water	405 g
BDI	50 g

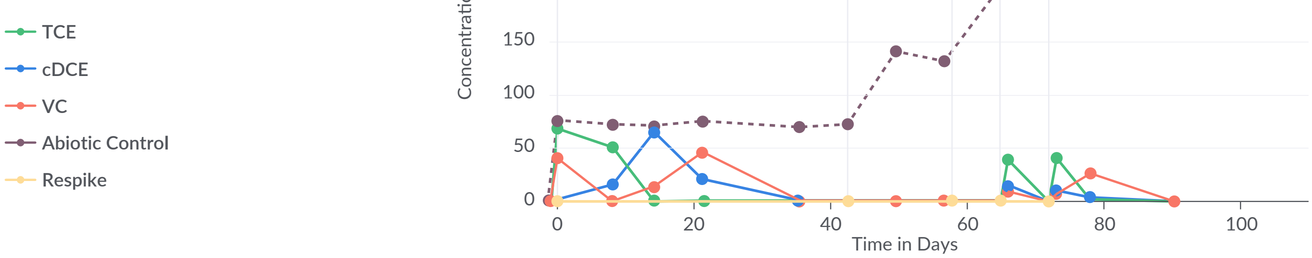
An estimated 0.85 g of activated carbon was added to the column. The other column received 1 pore volume (~85 mL) of a mixture containing 20 g of AquiFix, 25 g of PlumeStop, 405 g of tap water and 50 g of BDI (10^{10} cell Dhc/L). After adding the amendments, each column received a continuous influx on 2 mg/L of an half oxic TCE solution, added into the bottom of the column at a rate of two and a half pore volumes per every 2 weeks. The influent TCE concentration was increased to 10 mg/L after 40 pore volumes. A total of 10.2 mg of TCE were added to the column during the experiment. The total amount of TCE added to the column is below the adsorptive capacity of the activated carbon within the column (0.85 g) so little contaminant breakthrough was expected in the effluent where concentrations of TCE and daughter products in the effluent were measured using GCMS.

Results and Discussion: Batch Study

Figure 1 provides concentrations of TCE and daughter products as solid lines with TCE concentrations in the sterile abiotic control as a dashed line. Approximately 35 days was required to acclimate the system and accomplish the complete biodegradation of the initial 10 mg/L dose of TCE and its daughter products. The degradation pathway followed sequential reductive dechlorination route with transient increases in cDCE and VC. Less time was required to accomplish complete contaminant degradation for the re-spiked contaminant presumably because the system was already sufficiently acclimated. This result demonstrates AquiFix promotes the complete anaerobic biological reduction of environmentally relevant concentrations of chlorinated ethenes.

Figure 1 — AquiFix

Concentrations of TCE, cDCE and VC concentrations (solid lines) in the Aquifix batch microcosm study. The dashed line is the concentration in the sterile abiotic control and the vertical lines depict additional spikes of TCE. AquiFix promoted the complete biodegradation of TCE and its daughter products.



Results and Discussion: Column Study

Figure 2 provides concentration of chlorinated ethenes in the column effluent for the control column containing PlumeStop alone (solid line) and the influent (dashed line). Similarly, Figure 3 provides concentrations of chlorinated ethenes in the effluent for the column containing both PlumeStop and AquiFix. No breakthrough was detected in the control column; this result was consistent with what is expected for a column containing this concentration of PlumeStop. Similarly, no breakthrough was detected in the column containing both PlumeStop and AquiFix indicating that the solid phase organic donor did not interfere with the sorption of chlorinated ethenes on the activated carbon particles.

Figure 2 — PlumeStop

Effluent concentrations in the PlumeStop control column. The influent concentration is shown by the dashed line. No breakthrough was detected, indicating that the TCE was completely adsorbed onto activated carbon.

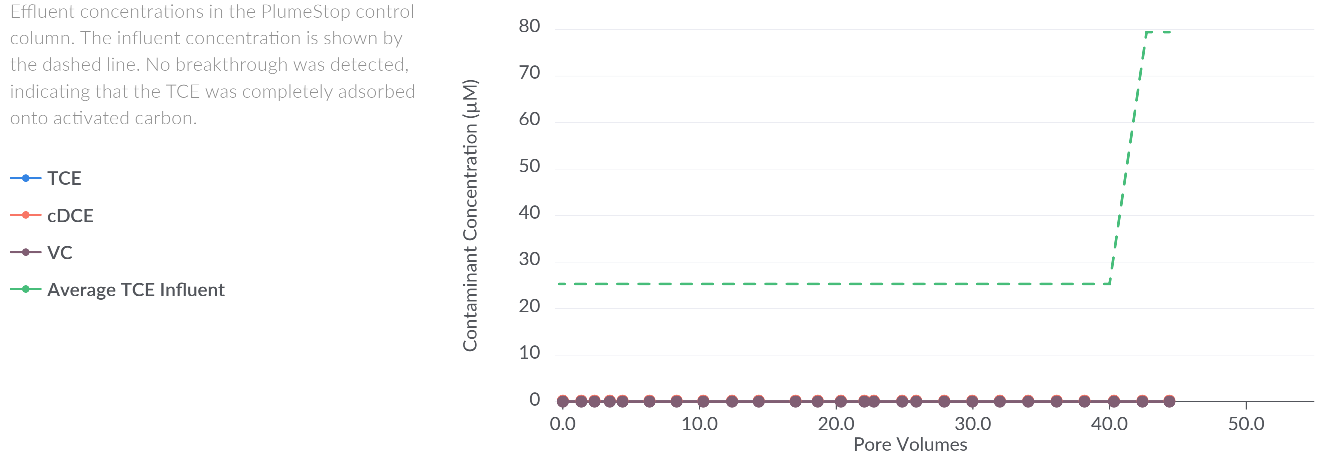
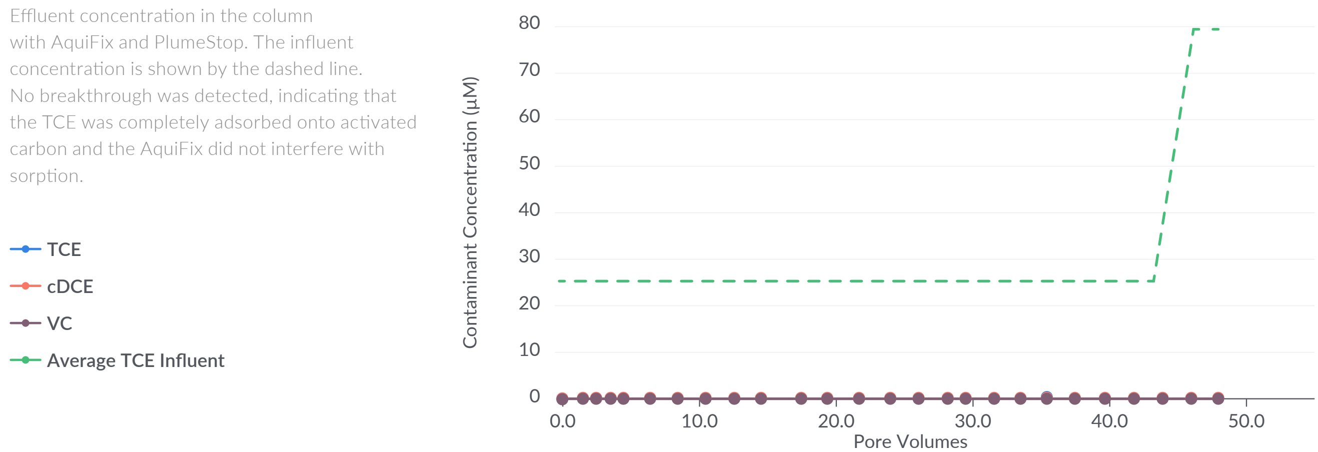


Figure 3 — PlumeStop and AquiFix

Effluent concentration in the column with AquiFix and PlumeStop. The influent concentration is shown by the dashed line. No breakthrough was detected, indicating that the TCE was completely adsorbed onto activated carbon and the AquiFix did not interfere with sorption.



REGENESIS®

www.REGENESIS.com