PlumeStop® Technical Bulletin 3.1

Post-Sorption Contaminant Biodegradation

Quick Reference:

- Demonstration of post-sorption contaminant biodegradation
- Net acceleration of contaminant biodegradation rate

Background

PlumeStop® Liquid Activated Carbon™ is composed of very fine particles of activated carbon (1- 2 μm) suspended in water through the use of unique organic polymer dispersion chemistry. Once in the subsurface, the material behaves as a colloidal biomatrix, sorbing to the aquifer matrix, rapidly removing contaminants from groundwater, and expediting permanent contaminant biodegradation.

Wide-Area Dispersive Distribution

Unlike any other sorbent technology, PlumeStop can be installed in the subsurface through dispersive flow from low-pressure injection (without fracturing the formation), providing a wide-area, thin-film coating of the aquifer matrix. It does not create preferential flow pathways, plug the formation, or compromise monitoring wells through extreme carbon loading, as is often the case with pressure-emplaced powdered activated carbon products.

More information on low-pressure ease of distribution and dispersive emplacement of PlumeStop can be found in PlumeStop Technical Bulletin 1.1: Distribution through a Permeable Medium.

Rapid Removal of Contaminants from Groundwater

PlumeStop rapidly sorbs organic contaminants from aqueous solution within the timescale of hours. Pollutants partition directly into the PlumeStop particles that are sorbed to the soil formation, thereby removing the pollutants from groundwater. Contaminant advection in the aqueous phase is therefore eliminated, and partitioning into the vapor phase is also reduced (Henry's Law). Results can be dramatic, with groundwater cleanup objectives often met within days of PlumeStop application.

Information on the sorption of contaminants by PlumeStop can be found in PlumeStop Technical Bulletin 2.1: Sorption of Contaminants from Solution.

Acceleration of Contaminant Biodegradation

Once sorbed to the soil and with contaminants partitioned onto its surface, PlumeStop is colonized by contaminant-degrading bacteria. These may be naturally present or applied as an inoculum. The concentration of the contaminants and the degradative microflora on the PlumeStop surface reduces mass-transfer kinetic constraints and supports greater speed and efficiency of degradation compared to solution-phase bioremediation.

The net result is a substantial increase in the instantaneous rate and extent of contaminant destruction. Post-sorption biodegradation and rate acceleration by PlumeStop is the topic of the present technical bulletin.

Biodegradation Study

Study Objective

The present study provides an illustration of the synergy of sorption and degradation of PlumeStop. Both post-sorption degradation and the net effect on degradation rate are evaluated.

Test Procedure

Batch-equilibrium samples were prepared in 227 mL (8 oz.) amber serum bottles sealed with Mininert™ valves (Figure 1). All bottles contained 10 g of site soil and 70 mL of water spiked with 3 mg of benzene, thereby filling approximately one third of the container volume.

The resulting headspace in the bottles provided adequate oxygen to maintain aerobic status throughout the study. The four conditions tested are summarized in Table 1.

Table 1. Batch-Equilibrium Study – Conditions tested

Condition	Description
Sterile control	Autoclaved soil and sodium azide (abiotic control)
Live control	Natural soil (biotic control)
PlumeStop Treated	Soil and PlumeStop (biotic test)
Sterile PlumeStop Treated	Autoclaved soil, PlumeStop and sodium azide (abiotic test)

The conditions were tested in parallel and run over a period of 28 days. Microcosms were sampled destructively in triplicate on days 1, 7, 14, 21, and 28. Benzene was quantified in the aqueous phase and also as a mass-balance extract of the total soil-water system (i.e. the aqueous and solid-phase microcosm contents together).

Figure 1. Batch-Equilibrium Study – Experimental Set-up

Test Results

Aqueous-phase concentrations of benzene are presented graphically in Figure 2. Data from the total system extractions are presented in Figure 3.

Figure 2 illustrates a rapid and nearly equal reduction in aqueous-phase benzene concentration in both the biotic and abiotic PlumeStop systems within the first sampling period. Thereafter, the aqueous benzene concentration in the biotic PlumeStop system continued to decrease to non-detect levels, whereas that in the abiotic PlumeStop control remained broadly static.

Benzene concentrations in the soil-only control (biotic, no PlumeStop) changed little in the first week, suggestive of an acclimation period, and thereafter declined steadily. Benzene concentrations in the soil-only sterile control did not change significantly for the first 21 days but showed a minor decrease thereafter.

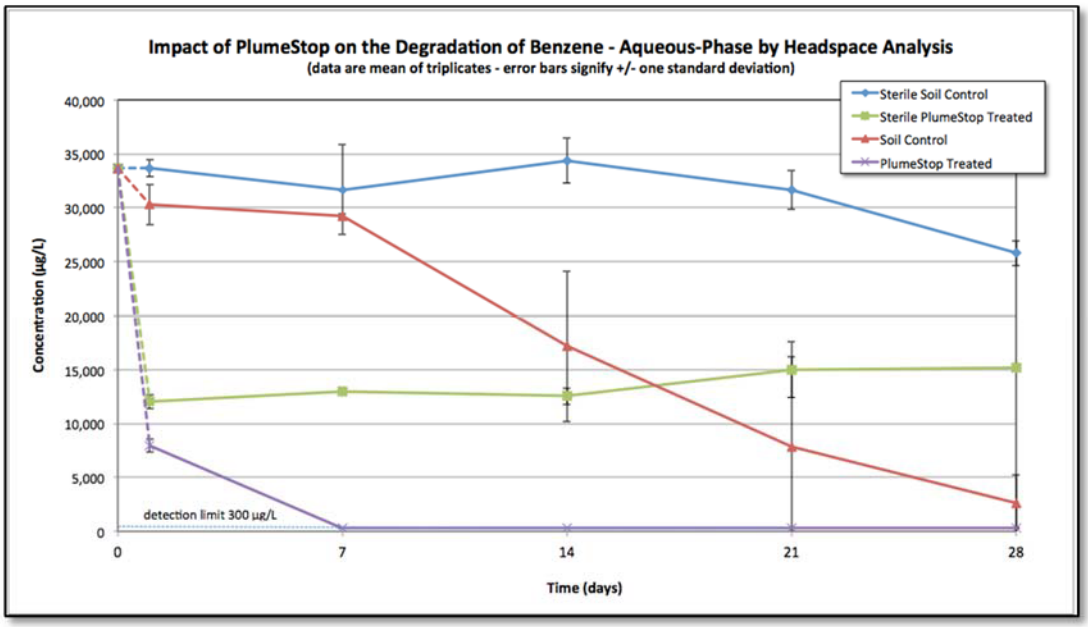

Figure 2. Batch-Equilibrium Study – Aqueous-Phase Results

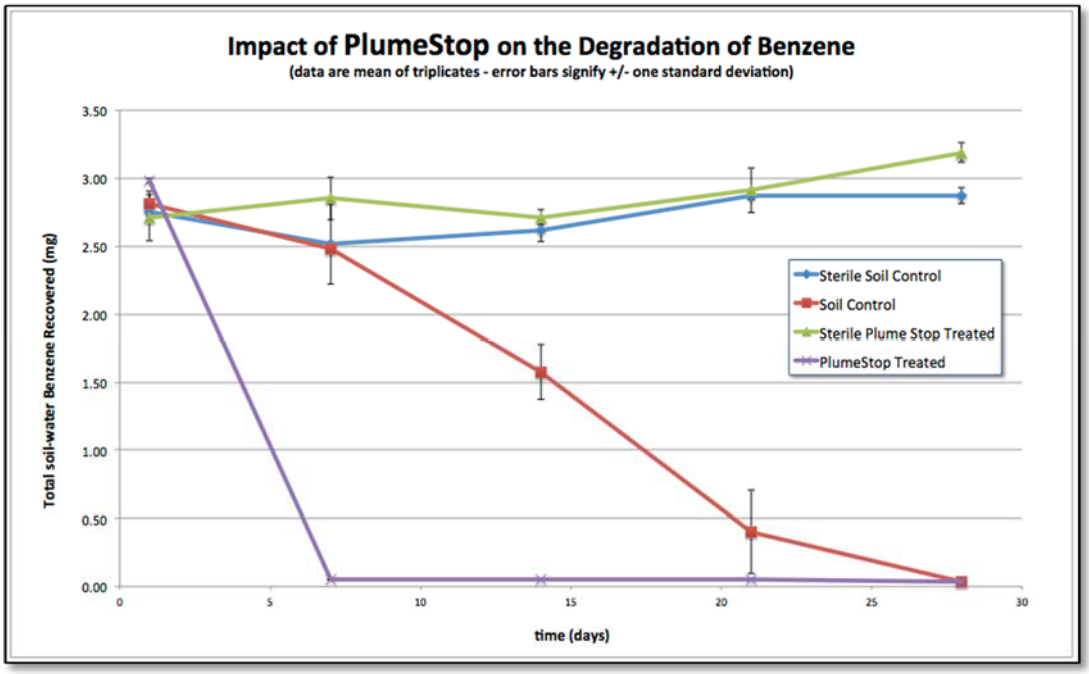

Figure 3. Batch-Equilibrium Study – Total System Extraction

Total system extract data (both aqueous-phase and soil-phase microchosm combined) are presented in Figure 3. In both the sterile control and the sterile PlumeStop treated samples, the total benzene mass remained constant at approximately 3 mg throughout the entire experiment. In contrast, the benzene concentrations in both biotic systems declined through the course of the experiment, with a markedly sharper decline in the PlumeStop-treated system; the treated system reached the detection limit by the seven-day time point compared to a 90% reduction at 28 days for the soil-only system.

Test Conclusion

The rapid and significant reductions in the aqueous-phase benzene concentrations over the first sampling period in both the biotic and abiotic PlumeStop systems may reasonably be attributed to abiotic sorption processes (Figure 2). The continued aqueous-phase concentration reduction in the biotic PlumeStop system is consistent with a destructive process as opposed to further sorption, since the aqueous benzene concentration in the analogous abiotic PlumeStop control remained constant after the initial sorption process.

The destruction of benzene in the biotic PlumeStop system is further confirmed in the total system extractions (Figure 3), in which the full initial mass of benzene was recovered from the abiotic PlumeStop control, confirming non-destructive abiotic sorption (and also validation of the extraction method).

In contrast, the mass-balance of benzene in the biotic systems with and without PlumeStop describes a destructive reduction that is consistent with biodegradation. Benzene was fully degraded in the biotic PlumeStop system within the first seven days of the test, in contrast with 12.5% degradation over the same period in the biotic soil-only control. This approximates to a half-life of less than one day in the biotic PlumeStop system as compared to ten days in the biotic control and represents a >10x rate increase based on the first-order approximation. Note that the half-life estimated for the biotic soil-only control is consistent with aqueous biotic rates that are published in the literature[i].

Summary

The above study shows clearly that sorption of contaminants onto PlumeStop does not inhibit their subsequent biodegradation, but rather, the rate of degradation is significantly stimulated by amendment with PlumeStop.

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[i] P. H. Howard, R. S. Boethling, W. F. Jarvis, W. M. Meylan, E. M. Michalenko, Handbook of Environmental Degradation Rates,Lewis Publishers, Inc. ISBN 0 87371, 3 (1991).