Colloidal Biomatrix Technology for In Situ Groundwater Contaminant Plume Treatment

Kristen Thoreson, Ph.D., Stephanie Rittenhouse, Joy Gravitt, Ryan Ferguson, M.S., Jeremy Birnstingl, Ph.D. and Ben Mork, Ph.D.

REGENESIS | 1011 Calle Sombra, San Clemente, CA 92673 | Ph: (949) 366-8000
kthoreson@regenesis.com, jbirnstingl@regenesis.com, bmork@regenesis.com

BACKGROUND

There are many risk factors associated with the migration of dissolved contaminant plumes in groundwater. While bioremediation agents are known to be effective at treating low concentration plumes, there is a need to accelerate the rates at which these treatment methods proceed. Regenesis has developed a new technology to address this limitation by coupling enhanced bioremediation with a colloidal and wide-distribution sorbent material in order to:

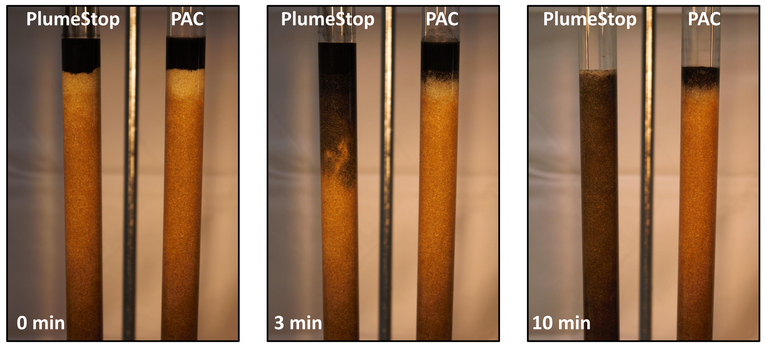
- **Adsorb contaminants and quickly reduce their groundwater concentrations**
- **Inhibit the transport of contaminants in the aquifer**
- **Provide a "biomatrix" for bacteria and contaminants that enhances biodegradation and results in site remediation**

PlumeStop™ is an easy to use, liquid colloidal remediation agent that was designed to distribute widely through the aquifer upon injection, adsorb a variety of contaminants, and provide a matrix for enhanced bioremediation. The environmentally friendly, patent-pending technology is based on activated carbon, is expected to last many years and have minimal impact on aquifer oxidation-reduction potential and geochemistry.

SUBSURFACE DISTRIBUTION

A key feature to the efficacy of PlumeStop is the ability of the sorbent material to distribute through the subsurface using low pressure, direct-push injection (DPI) techniques. This is in contrast to most well-known sorbents, e.g. powdered activated carbon (PAC), which are essentially immobile under low pressure injections. The unique chemistry of PlumeStop results in widespread coverage in the contaminated zones and leads to lower application costs for remediation practitioners.

Mobility through soil: PlumeStop vs. Powdered Activated Carbon (PAC)



Laboratory Demonstrations:

Column tests were conducted in order to demonstrate and quantify PlumeStop transport through soil. Both gravity (1"x12" bed, pictured above) and pressurized (2"x24" bed, 20-40 psi) columns were wet packed with a fine to medium-grain sand containing 11% (w/w) silt + clay. In each case, a known amount of PlumeStop was loaded onto the column and chased with 3-4 pore volumes of water. The effluent was then analyzed using a spectrophotometer to quantify the deposition rate of PlumeStop. Data analysis over multiple testing conditions indicated an expected radius of injection of 10 to 20 feet in sandy geologic settings.

The series of pictures above compare the mobility of equivalent quantities of PlumeStop (left) with powdered activated carbon (PAC, right) through soil under gravity flow conditions. It can be seen that PlumeStop uniformly distributes and deposits on the soil while PAC is effectively immobile.

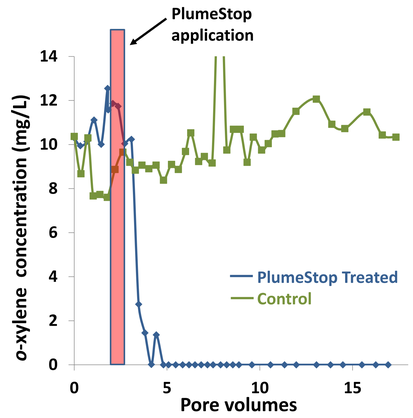
- **PlumeStop distributes uniformly through permeable zones for extensive coverage upon injection**
- **Column tests emulating low DPI pressures extrapolate to a field ROI of 10 ft. or more**
  - Performed at 30-40 psi
- **Upon injection a fraction of PlumeStop deposits permanently on the soil in order to provide sustained treatment over many years**

RAPID ADSORPTION

Treatment using PlumeStop™ results in very fast decreases in groundwater contaminant levels through physical adsorption to colloidal particles. Laboratory studies have shown that the PlumeStop formulation, which enables subsurface distribution and supports enhanced biodegradation, has no interference with the adsorption capacity for numerous contaminants relative to powdered activated carbon. This sorbent material is expected to remain for many years in situ for long-lasting performance.

Laboratory Demonstration:

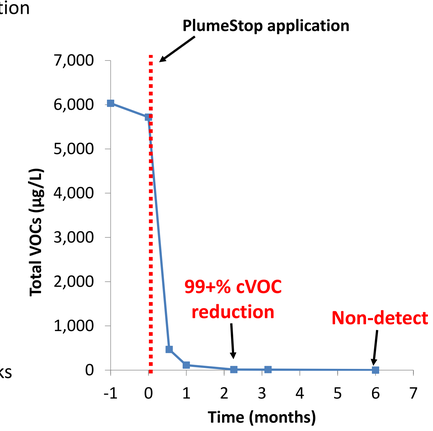
The efficacy of PlumeStop contaminant sorption in a typical site scenario was demonstrated in a laboratory column experiment. In this study, two columns (2" x 24" bed of sandy soil containing 11% fines) were equilibrated with a 10 ppm *o*-xylene water feed flowing at 0.1 mL/min over the entire course of the study. PlumeStop was applied to one column and the effluent o-xylene concentrations were monitored throughout. The graph at the right demonstrates the rapid and sustained decrease in contaminant water concentrations achieved with PlumeStop treatment due to physical adsorption.



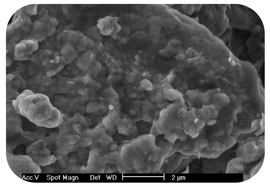
- **80-100% decreases in groundwater contaminant levels have been observed within weeks of PlumeStop field applications**
- **The fast acting sorption of PlumeStop technology is ideal for:**
  - Preventing plume migration and expansion
  - Protecting sensitive receptors (neighborhoods, rivers, etc.)
  - Controlling migration across property boundaries
  - Matrix back diffusion mitigation
- **PlumeStop is an effective treatment for numerous volatile and semi-volatile organic compounds including:**
  - Hydrocarbons
  - Halogenated compounds
  - MTBE

FIELD APPLICATION

- **Confidential Midwest industrial site**
  - Concerned with off-site migration of the dissolved phase plume
- **Contaminants of Concern:**
  - 3.5 mg/L TCA
  - 1.4 mg/L TCE
- **Treatment: PlumeStop with HRC™ controlled release electron donor**
  - 320 sq. ft. treatment area
  - 10 point direct push grid (PlumeStop)
  - 4 upgradient points (HRC™)
  - Water level: 10-13 ft. BGS
  - Sand to silty sand
- **Results:**
  - 92% cVOC reduction at 2 weeks
  - 99+% reduction at 2 months
  - Non-detect at 6 months



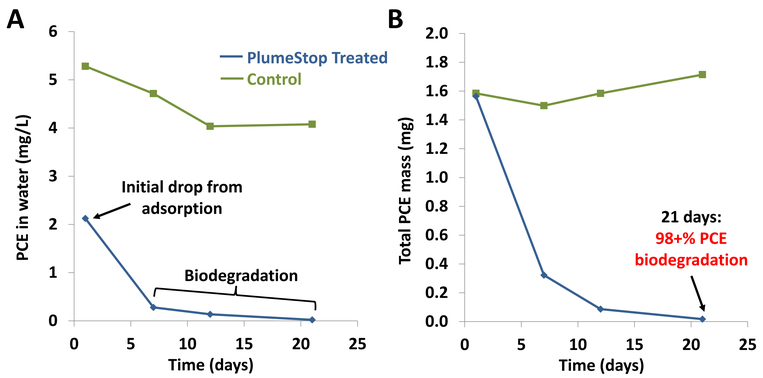
ENHANCED BIODEGRADATION



This colloidal amendment is composed of ingredients that create a biomatrix in order to facilitate enhanced biodegradation. The formulation functions by integrating contaminants and bacteria, thus increasing the efficiency of biodegradation. The end result is extremely rapid reductions in groundwater contaminant concentrations, followed by efficient contaminant destruction.

Laboratory Demonstration:
Tetrachloroethene (PCE) biodegradation studies were performed in batch systems. Control and PlumeStop™ treated sample sets were prepared with a 10:1 weight ratio of water to autoclaved or unmodified field soil, respectively. The PlumeStop treated samples were augmented with Bio-Dechlor Inoculum Plus™. At each sampling time point water concentrations were measured and the data is presented in Graph A. Additionally, sacrificial sample bottles were fully extracted in order to measure the total mass balance including aqueous and sorbed PCE, Graph B.

The initial PCE concentration drop observed in Graph A at Day 1 is attributed to adsorption of PCE to PlumeStop. Comparing the same time point in Graph B indicates that no biodegradation has begun since all of the PCE was recovered in the extraction. Later time points reflect active biodegradation of PCE up to 98+% remediation at Day 21.



- **The PlumeStop biomatrix fosters enhanced biodegradation of the contaminants collected on the sorbent material**
- **The formulation is compatible with both native consortia present in the aquifer and bioaugmented amendments**
- **Complete site remediation is accomplished with PlumeStop treatment**

SUMMARY

- **PlumeStop technology is a new colloidal remediation platform technology that can lead to rapid site closures through its formulations designed to:**
  - Distribute through soil at low injection pressures much more effectively than off-the shelf PAC
  - Quickly adsorb a wide range of contaminants that result in rapid reductions of groundwater concentrations
  - Enhance biodegradation of contaminants resulting in site remediation
- **Field scale tests showed 90+% cVOC groundwater reduction at 2 weeks, 99+% at 2 months and non-detect levels at 6 months**