PLUME STOP®
Liquid Activated Carbon

PlumeStop® Technical Bulletin 1.1

Distribution through a Permeable Medium

Quick Reference:

- PlumeStop distribution through > 16' (5 m) packed medium readily achieved
- Even coating of sand matrix with PlumeStop secured
- Retained coating not subject to washout
- No detectable impact on permeability

Background

PlumeStop® Liquid Activated Carbon™ is composed of very fine particles of activated carbon (1-2µm) 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.

PlumeStop Flows through Permeable Media

PlumeStop is a very fine suspension of charged particles that resists clumping and has a very low viscosity that is similar to water. As a result, PlumeStop is easily applied to the subsurface through gravity-feed or low-pressure injection. Once applied, the material moves as a colloidal suspension through the permeable aquifer zones, coating the pore structures with a thin layer (ca.1µm) of PlumeStop particles.

Long Column Study - 16 Foot (5 meter)

Study Objective

In order to evaluate in detail the movement of PlumeStop through a simple permeable soil medium over field-relevant distances, an extended column study was undertaken in the laboratory.

Experimental Setup

A 16 foot (4.9 m) long by 2 inch (5 cm) diameter transparent PVC column was erected in a vertical position supported by a standing rack system (Figure 1). End-caps were affixed that were fitted with Viton® tubing (size 16; 0.12" / 3.1 mm ID). A white background was put in place with calibration marks every four feet (1.22 m). The column was then slurry packed with 35.4 lbs (16.1 kg) of Lapis Lustre #60 silica sand with particle size ranging from 210 µm to 420 µm (fine to medium sand). Based upon the volume and characteristics of the material packed within the column, the open pore volume (matrix total porosity) was calculated to be approximately 0.11 cubic feet (3.0 L) (30%).

Operation

A peristaltic pump was used to flow water and PlumeStop from a reservoir at the bottom of the column upward. Effluent leaving the top of the column was captured in a separate reservoir. Flow rates and pressures were measured at both the influent and effluent ports. Initially, water alone was pumped into the column at a target rate of 60 mL/minute (column seepage velocity 3.2 minutes per foot / 10.3 minutes per meter; = 0.16 cm/sec assuming unity of mobile and total porosity). Once the desired flow-rate was obtained and the system was tested for leaks, the influent reservoir was switched from clean water to a solution of PlumeStop. The system was operated until breakthrough of PlumeStop from the column was observed, and then continued at steady-state conditions for approximately 4 additional pore volumes before returning the influent to water only for approximately 9 pore volumes. Monitoring of influent and effluent PlumeStop concentrations proceeded until effluent concentrations declined to zero.

Figure 1. 16' Experimental Column.

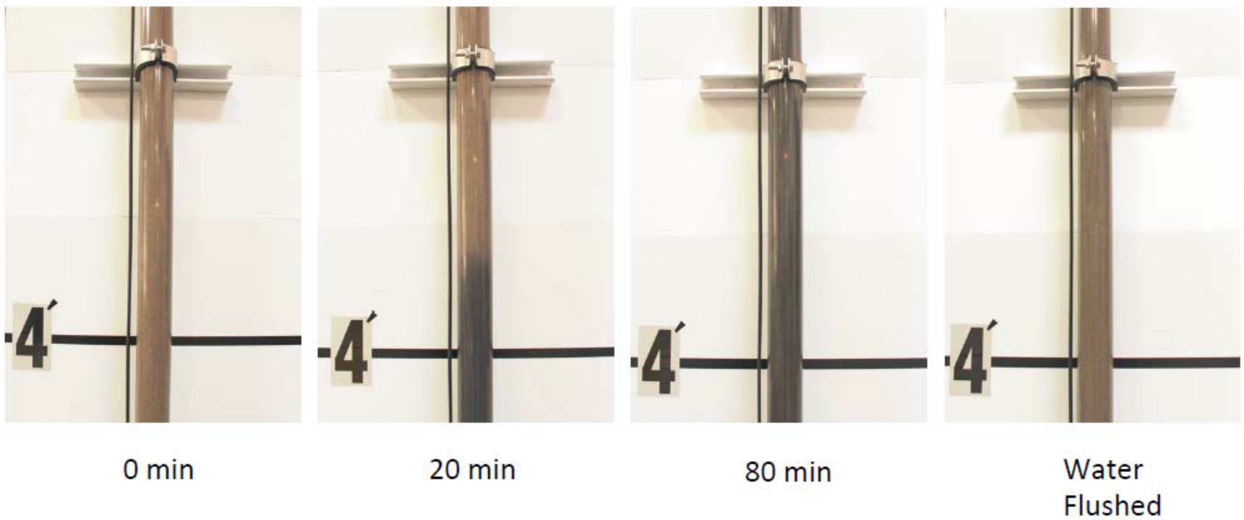

Figure 2. Visible PlumeStop migration front and coating residue following water-flush.

Results

The movement of the PlumeStop through the column was visually apparent, as the black color could be easily seen through the transparent PVC column casing (Figure 2). After 69 minutes or 1.2 pore volumes, PlumeStop had moved completely through the column at an even flow without fracture or visible fingering and was detected in the effluent. Shortly following breakthrough, the effluent PlumeStop concentration reached a steady state that equaled the influent concentration.

After approximately 4 additional pore volumes of PlumeStop were eluted at steady state, the influent solution was switched back to water only. PlumeStop concentrations in the effluent declined sharply after one pore volume of clean water and dropped beneath detection limits (0.1% of applied concentration) within 2 pore volumes. A total of 9 pore volumes of water were eluted post PlumeStop application. Data are presented graphically in Figure 3.

Carbon Retention Mass Balance

Mass balance calculations from the influent and effluent PlumeStop concentrations and the flow rate indicated that 5.7% of the applied PlumeStop carbon was retained within the column. This calculated value was further supported by elemental analysis of the column sand (analyzed destructively following the study and corrected against sand-only blanks), which revealed a consistent loading of 20 – 45 mg of elemental carbon per kg of sand throughout the column (Figure 4).

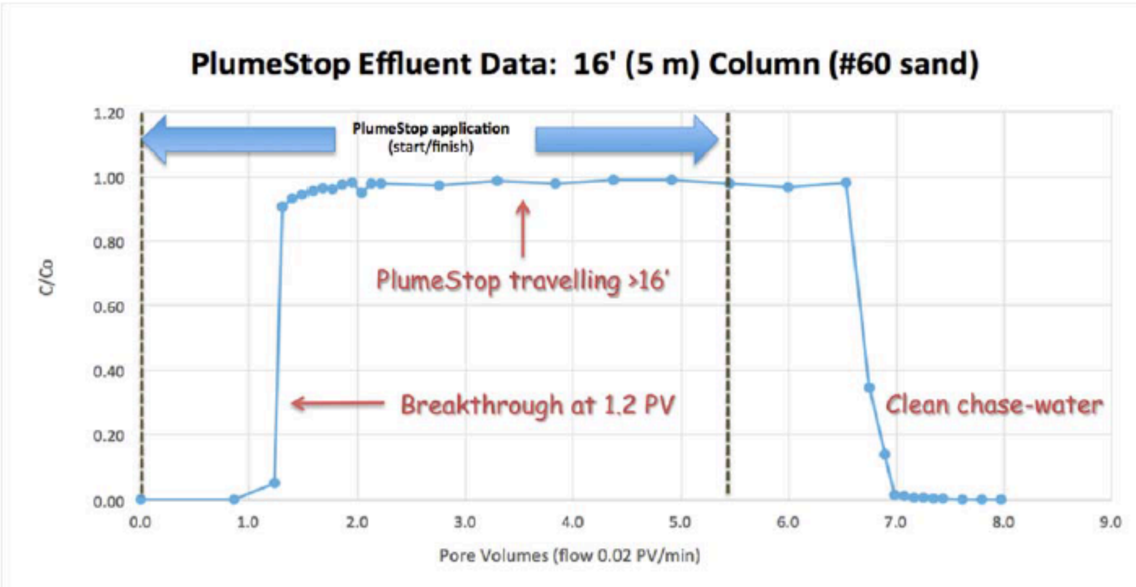

Figure 3. PlumeStop breakthrough dynamic – 16' (5m) column study.

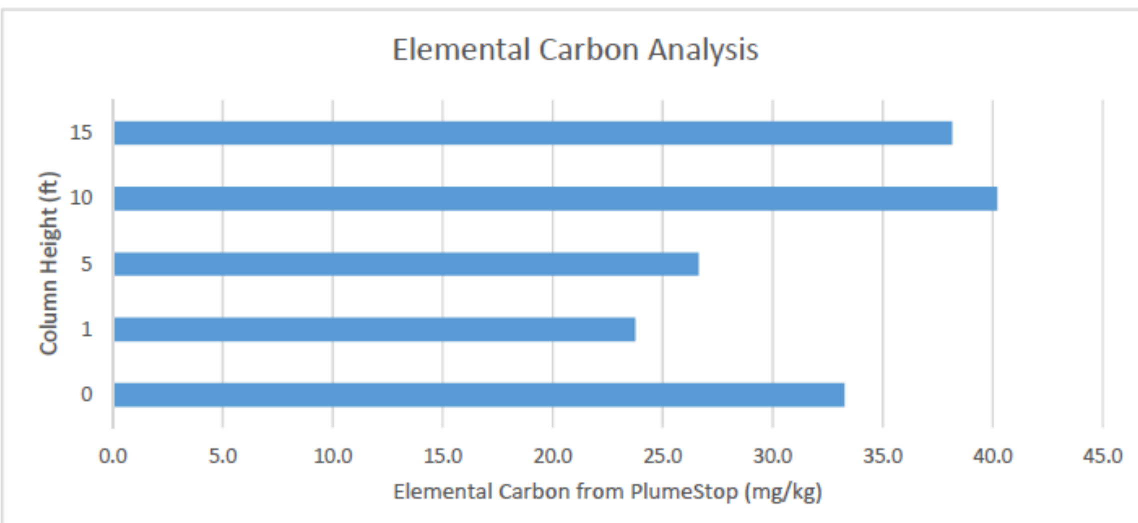

Figure 4. Elemental carbon (corrected against clean packing sand) at discrete depths.

Discussion

The ability to transport activated carbon as a liquid suspension through a permeable soil formation while leaving a dispersed bound residue that is resistant to washout was clearly demonstrated by this study. Breakthrough from the column following application of 1.2 pore volumes without visible soil fracturing or fingering illustrates the ease of distribution under low-pressure, advective flow.

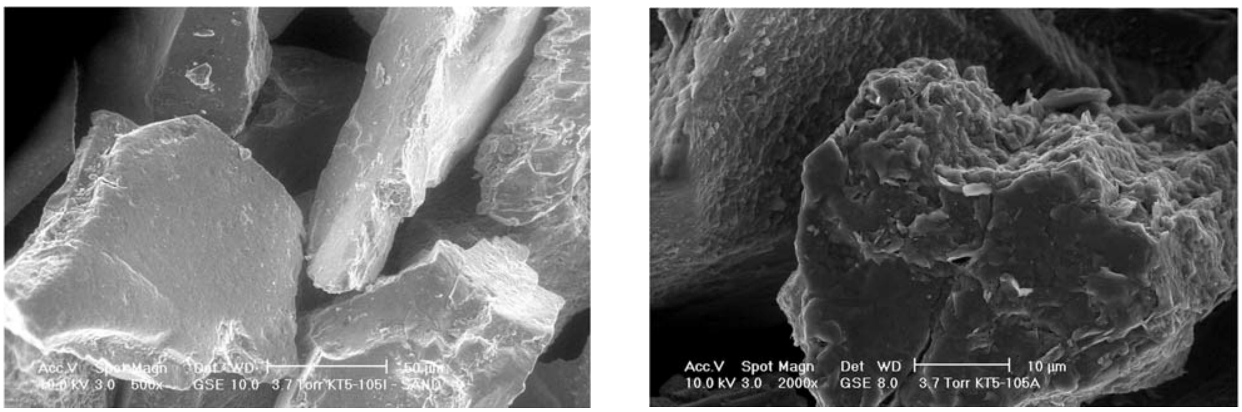

Figure 5. Scanning electron micrograph (SEM) of sand particles without PlumeStop (left) and coated with PlumeStop colloid (right) (Birnstingl et al., 2014).

Uniform retention of activated carbon on the soil matrix after extensive water flushing was visually apparent and was supported by elemental analysis of the sand after the study, which showed a loading of 20-45 mg per kg of sand throughout the column. An example of how activated carbon coats sand particles is shown in the scanning electron micrograph in Figure 5 (Birnstingl et al., 2014).

It should be noted that retention by other soil types will be different from that noted above – the present study is primarily intended to illustrate the principle of long-distance dispersive distribution and matrix-coating.

In field applications, the fraction of activated carbon retained per unit volume will be influenced both by soil type and volume, as well as by the manner of application. PlumeStop transport and retention through other soil types will be the subject of subsequent Technical Bulletins.

Conclusions

1. PlumeStop can be dispersed through at least 16’ (5m) of fine to medium sand.
2. 5.7% of the PlumeStop carbon (dry weight) was retained on the column of the present study, suggesting that significantly greater radial transport distances would be possible when the product is injected through a well into an aquifer environment.

3. The retained activated carbon coating of the matrix was evenly distributed throughout the column diameter and length (20 – 45 mg/kg range throughout the column), and plugging, clumping, fracturing, or fingering were not observed.

4. The retained coating was not subject to washout, even under vigorous flushing of 9 pore volumes within 24 hours.

5. Total volume occupied by the retained solids was <0.1% of the soil pore volume and presented no measureable impact on permeability.

Literature Cited

1. Birnstingl, J., Sandefur, C., Thoreson, K., Rittenhouse, S., and Mork, B. (2014). PlumeStop Colloidal Biomatrix – securing rapid contaminant reduction and accelerated biodegradation using a dispersive injectable reagent. San Clemente, CA: REGENESIS Bioremediation Products.