Sequester and Destroy: A Multi-Site Performance Review of Liquid Activated Carbon for Groundwater Treatment

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REGENESIS
Technology-Based Solutions for the Environment

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Outline

• Introduction
• Background on Technology Development
• Technology Functionality Basics
• Field Performance
• Case Studies
• Q&A
REGENESIS

• Since 1994 - 20 years of leadership in remediation technology development, design and application
  – First product was ORC, first remediation implementation in 1995

• Currently, multiple products covering in situ aerobic/anaerobic bioremediation, oxidation, hexavalent chrome treatment, and vapor barrier systems

• Our products applied on >17,000 sites worldwide
  – Global Presence in over 22 Countries

• Headquarters in San Clemente, CA
• Regenesis Remediation Products Division

• Land Science Technology
Heterogeneous Aquifer Model

Upon Flushing and Removal of Adsorbed Mass “Back Diffusion” Continues

Challenges
- Meet Low Targets
- Rebound
- Remediation Time
Anatomy of a Groundwater Plume

Source Area:
- Dig & Dump
- Thermal
- AS/SVE
- ISCO
- Stabilization

Core Plume Area:
- ISCO
- Bioremediation
- Pump & Treat
- PlumeStop

Dissolved Plume Area:
- Bioremediation
- Natural Attenuation
- ISCO
- PlumeStop

Contaminant Concentration
The Reagent – what it is

• A highly dispersive, injectable sorbent and microbial growth matrix

• Colloidal activated carbon (1 – 2 µm)
  • Size of a bacterium – suspends as ‘liquid’
  • Huge surface area – extremely fast sorption

• Proprietary anti-clumping / distribution supporting surface treatment (patent applied for)
  • Core innovation
  • Enables wide-area, low-pressure distribution through the soil matrix without clogging
PlumeStop

Powdered Activated Carbon
WHAT IS PLUMESTOP®?

PlumeStop® Liquid Activated Carbon™ is an innovative Groundwater Remediation Technology which Rapidly Reduces Contaminant Concentrations and Promotes Biodegradation.

**Colloidal Activated Carbon (1-2 μm)**
- Size of a bacterium suspended as “liquid”
- Huge surface area for extremely fast sorption

**Proprietary Anti-Clumping Formulation Designed to Enhance Distribution**
- Enables wide-area, low-pressure distribution through the soil matrix without clogging

PlumeStop® is Effective On:
- Dry Cleaners
- Industrial (Miltary)
- Gas Stations
- Energetics
- Farming and Agriculture
- Emerging Contaminants

**The PlumeStop® Timeline**

R&D Stages: Ongoing ancillary research

- Field Beta Test: Early test still running for long term data
- Commercial Launch: Satellite 2014
- Commercial Applications: 2015


Site Types:
- 47% AEROSOLS
- 47% ANAERONICS
- 6% OTHERS*

7 COUNTRIES 27 STATES 83 SITES +337 PROJECTS FENCING APPLICATION

*No detectable class
Other contaminants of interest: PAHs, MTBE, chloroform
Regulatory Acceptance

• Plume Stop applied in 27+ states, and six countries
• EPA Region 9 initiated consideration for Plume Stop Pilot at Motorola 52nd Street Superfund Site. (Rachael Loftin)
• NYDEC has recommended Plume stop on sites they are managing
• Many state lead or funded sites, several Superfund under consideration
Distribution: Frequently Asked Questions

• What about distribution in low permeability zones?

• What about contamination in clays?

• What’s your injection radius of influence?
PlumeStop® flows into the subsurface at low pressure - coating the principle flux channels

Contaminant mass back-diffusing from the low-perm zones is captured.

专科 & high perm zones are addressed
Distance / radius progressed depends on volume injected
PlumeStop Injection – Field

Post Application
Tank set up with alternating high and low k zones. 
Low k = $1 \times 10^{-4}$ cm/sec
Post PlumeStop injection
POTASSIUM PERMANGANATE

• During treatment:
Contaminants Sorbed, Now What?

3 Primary Methods of Contaminant Destruction

- **Aerobic Treatment**
  - Electron Acceptor Addition, Sparging…

- **Anaerobic Treatment**
  - Slow release electron donors
  - Lactate, recirculation systems

- **Monitored Natural Attenuation/Intrinsic Remediation**
PlumeStop Mode of Action

Contaminants sorb to sites available on PlumeStop particle. Microbes biodegrade sorbed contaminants. Sorption sites become available for additional contaminant.
Contaminants Treated

- CVOCs, including ethenes, ethanes
- Petroleum hydrocarbons (TPH, BTEX)
- Pesticides
- PFAS
When/Where to Use

1. When time is critical
2. As a long-term barrier
3. To achieve stringent cleanup standards
4. To address matrix back diffusion
5. When remediation is “flat lining”
Combined Remedy

- Heating Oil Property
- Soil and groundwater contamination
- Concern about private well in proximity to spill

- Technologies Used:
  - Excavation
  - ISCO
  - Carbon Sorption/Bioremediation
Heating Oil Spill

Private Well

MW1 >3mg/L
EPH
GW1 Target

Plume Stop Barrier
### Results

All results reported in mg/L

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<th>Volatile Petroleum Hydrocarbons:</th>
<th>VPH Fractions:</th>
<th>VPH Target Analytes:</th>
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</tr>
<tr>
<td></td>
<td>7/13/2016</td>
<td>93.12</td>
</tr>
</tbody>
</table>

| Method 1 GW1 Standard | 0.3 | 0.7 | 0.2 | 0.005 | 1 | 0.7 | 10 | 0.07 | 0.14 |
| Method 1 GW2 Standard | 3 | 5 | 4 | 1 | 50 | 20 | 3 | 50 | 0.7 |
| Method 1 GW3 Standard | 50 | 50 | 50 | 10 | 40 | 5 | 50 | 20 |
Stratigraphy consists of Coastal Plain sediments that are primarily composed of clay, silt, and sand units. Target unit consists of a sandy clay with sand stringers.

Conducted a Remedial Alternatives Evaluation for the downgradient portion of the plume and recommended accelerated biodegradation using PlumeStop® Liquid Activated Carbon™ (LAC).

A pilot test was conducted, including injection of the LAC with a controlled-release electron donor (HRC) / bioaugmentation culture (BDI+) to enhance reductive dechlorination.

Pilot study results demonstrated total cVOCs decreased between 98.7 and 100 percent in the two pilot test areas.

Based on pilot test results, full-scale remedial design and implementation using injection barriers was completed. Performance monitoring is ongoing.
Several rounds of source area treatment have been completed including:

- 2010 - Nanoscale ZVI pilot tests and injections
- 2014 - 3DMe / HRC / BDI injections

- 2014 - Remedial alternatives evaluation completed for downgradient area
- Late 2014 – Conducted downgradient pilot tests
- 2015 – Remedial Design completed
- **Remedial Objective:** to reduce contaminant concentrations within the downgradient plume and limit further migration
- Late 2015-2016 - Full-scale implementation of the downgradient remedy
CONCEPTUAL SITE MODEL

Former Manufacturing Facility (began operations in 1950’s)

Source Area (degreaser)

cVOC Plume extends approximately 1,700 feet from source area

Groundwater flow and contaminant transport is relatively slow (approximately 60 and 30 feet per year, respectively).

Residential Area
**UNIT I**
- Primarily silts and sands
- Present from 5 to about 20 feet, bgs
- Average horizontal hydraulic conductivity is ~5-6 feet/day
- Strong downward vertical gradient

**UNIT II**
- Primarily sandy clay with sand stringers
- Present from 25 to about 45 feet, bgs
- Average horizontal hydraulic conductivity is ~2-3 feet/day
- Slight downward vertical gradient
- Target Unit for Remedial Action (Contains ~90% of Contaminant Mass)

**UNIT IV**
- Primarily fine sands, partially cemented
- Present from 60 to about 80 feet, bgs
- Average horizontal hydraulic conductivity is ~3-4 feet/day
**PILOT TEST OVERVIEW**

**BL-55-II PILOT STUDY SUMMARY**
Injection Points = 10  
PlumeStop Injected = 1880 gallons  
Controlled Electron Donor (HRC) Injected = 300 pounds  
Biological Amendment (BDI+) Injected = 9 liters

**BL-59-II PILOT STUDY SUMMARY**
Injection Points = 12  
PlumeStop Injected = 1940 gallons  
Controlled Electron Donor (HRC) Injected = 300 pounds  
Biological Amendment (BDI+) Injected = 9 liters
PILOT MONITORING WELL BL-55-II

- Baseline concentrations
  - TCE: 11,900 µg/l
- Performance monitoring results:
  - 6-month cis-1,2-DCE: 375 µg/l
  - 12-month cis-1,2-DCE: 1,160 µg/l
  - 96.8 and 90.5 percent reduction in total cVOCs in 6 and 12 months, respectively
- Indicator parameters TOC, volatile fatty acids, and biodegradation byproducts methane and CO2 increased during performance monitoring periods, indicating the degradation process was ongoing.
BL-55-II TIME TREND GRAPH

![Graph showing concentration trends over time for Trichloroethene, Total CVCCs, and Pilot Injection. The graph illustrates a significant drop in concentration following a specific date.]
PILOT MONITORING WELL BL-59-II

- Baseline concentrations
  - cis-1,2-DCE: 9.04 µg/l
  - TCE: 12.3 µg/l
- Performance monitoring results
  - Non-detect results achieved in one month and sustained through 12 months
  - 100 percent cVOC reduction
- Indicator parameters remain close to baseline concentrations, likely due to low initial cVOC concentrations at this location
REMEDIAL DESIGN

- Design included 3 injection barriers (each ~400 feet long) that transect the plume at varying distances from the source area
- Worked with REGENESIS to determine injection point spacing, dosage, and product volumes
- Worked with off-site landowners regarding access issues
  - Required road building activities at furthest downgradient transect (through swamp)
- Discussed approach with regulatory agencies and submitted Remedial Action Work Plan (RAWP)
- Proceeded implementing RAWP in November 2015 through January 2016
Support from REGENESIS in developing details of the Proposed Remedial Action:

1) Dosage
2) Product Volume
3) Injection Point Spacing
**BARRIER #1 DESIGN**

<table>
<thead>
<tr>
<th>PS - Injection Point</th>
<th>HRC - Injection Point</th>
<th>Core Barrier</th>
<th>Outer Barrier</th>
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</table>

**Legend**
- ▲: PS - Injection Point
- ●: HRC - Injection Point

**Map Details**
- **MW-IRM-2-II**
- **MW-IRM-7**
- **BL-22**
- **BL-40-I**
- **MARGARET SHORTER**
- **BRANCHVILLE PROPERTY**
- **JOHN EDDIE**

**Barrier 1 - Core**
- **Barrier Length (ft):** 125
- **Spacing Within Barrier (ft):** 8
- **Number of Lines:** 2
- **Number of Points:** 31
- **Application Method:** Direct Push
- **Top Application Depth (ft lbs):** 25
- **Bottom Application Depth (ft lbs):** 45
- **PlumeStop to be Applied (lbs):** 12,000
- **PlumeStop per point (lbs):** 367
- **PlumeStop per point (gals):** 46
- **Mixing Water (gals):** 11,987
- **Mixing Water per point (gals):** 107
- **Total Application Volume (gals):** 13,319
- **Injection Volume per Point (gals):** 430

**Barrier 1 - Ext**
- **Barrier Length (ft):** 275
- **Spacing Within Barrier (ft):** 10
- **Number of Lines:** 1
- **Number of Points:** 28
- **Application Method:** Direct Push
- **Top Application Depth (ft lbs):** 25
- **Bottom Application Depth (ft lbs):** 45
- **PlumeStop to be Applied (lbs):** 23,200
- **PlumeStop per point (lbs):** 829
- **PlumeStop per point (gals):** 99
- **Mixing Water (gals):** 15,760
- **Mixing Water per point (gals):** 563
- **Total Application Volume (gals):** 16,540
- **Injection Volume per Point (gals):** 662

**Anoxic Bioremediation - HRC**
- **HRC Application Points:** 16
- **PlumeStop to be Applied (lbs):** 1,200
- **HRC per point (lbs):** 80
- **Total Application Volume (gals):** 118
- **Injection Volume per Point (gals):** 7.4

**Biogaugmentation - BOI Plus**
- **BOI Plus Application Points:** 16
- **BOI Plus to be Applied (lbs):** 16
- **BOI Plus per point (gals):** 1.0

**Biogaugmentation - BOI Plus**
- **BOI Plus Application Points:** 28
- **BOI Plus to be Applied (lbs):** 32
- **BOI Plus per point (gals):** 1.1
FINAL COMPLETED REMEDIAL ACTION

CHALLENGE #1: Access was difficult in timbered, swampy area

CHALLENGE #2: Difficult product delivery at Barrier #1 even though no issues at Barriers #2 and #3
### PRELIMINARY PERFORMANCE MONITORING RESULTS

**SUMMARY OF RESULTS**

- **97% Reduction in 3 months;**
- **98% Reduction in 6 months;**
- **100% Reduction after 3 months; Reducing conditions persist;**
- **Pilot Test Well; Sustained 100% Reduction after 21 months.**

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<tr>
<td>1,1-Dichloroethene</td>
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<td>17.5</td>
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<td>cis-1,2-Dichloroethene</td>
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<td>Trichloroethene</td>
<td>13,500</td>
<td>448</td>
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<tr>
<td>Vinyl chloride</td>
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<td>Dissolved oxygen (ppm)</td>
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<td>8.21</td>
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<tr>
<td>Redox Potential (mV)</td>
<td>-214</td>
<td>-42.6</td>
<td>-63.2</td>
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SUMMARY AND CONCLUSIONS

- PlumeStop was used in both a pilot test and full-scale application to treat the downgradient portion of a long, narrow cVOC plume.
- Pilot test results indicated a rapid and sustained degradation of cVOCs in groundwater.
- Post-Injection performance monitoring of the pilot test resulted in 90 to 100 percent reduction in cVOC concentrations.
- Based on the success of the pilot tests, PlumeStop was also used in full-scale implementation utilizing an injection barrier design with three, 400-foot long barriers.
Preliminary performance monitoring results of the full-scale implementation indicate contaminant concentration reductions of 98 to 100 percent for wells located within the zone of influence.

Indicator parameters are showing positive results indicating the degradation process is ongoing.

A one-year performance monitoring event will take place in January 2017 and will allow for evaluation of remedial progress at additional monitoring wells located further downgradient of the injection barriers.
- Perfluorinated Compounds -

![Chemical structures of perfluorinated compounds](image-url)
Sorption only
(currently no validated destruction methods are available)
PlumeStop + PFOA/PFOS: Capture Capacity Example

- Plume Concentration 100 µg/L
- Target Concentration 0.5 µg/L
- Seepage velocity 150 ft/year

- PlumeStop barrier width 15’ (single application at average dose)

- PFOA = 12 years capture*
- PFOS = 11 years capture*
- PCE = 3 years capture*

More years’ capture? Add another barrier

*based on single component
Case Study

Location: Canada
Soil: Silty sand
DTW: 4 ft
GW velocity: 2 ft/day
History:
• Hydrocarbon spill
• Former fire training area

Baseline Contamination:
PFOS: 0.3 – 1.5 µg/L
PFOA: 0.5 – 3.3 µg/L
BTEX: <0.5 – 264 µg/L
TPH: <25 – 6,000 µg/L
Case Study

PFOA, PFOS concentrations in ng/L.

Results

- PFOS: ND (<20 ng/L)
- PFOA: ND (<20 ng/L)
- BTEX: ND (<0.5 µg/L)
- TPH: ND (<25 µg/L)

Through 3, 6, and 15-month (May ‘17) monitoring events

Remedial Technology Used:

- PLUME STOP
- Liquid Activated Carbon

Remedial Technology Used: