Accelerated Biodegradation of Chlorinated Contaminants Using an In-Situ Liquid Activated Carbon
A Case Study in South Carolina

Presenter: Gordon G. Araujo Jr. [REGENESIS]
Project Team: Matthew J. Valentine, P.G., LRS [Woodard & Curran]
Jill D. Tribley, P.G. [Woodard & Curran]
Barry A. Poling [REGENESIS]
Conceptual Site Model

Former Manufacturing Facility (began operations in 1950's)

Source Area (degreaser)

cVOC Plume extends approximately 1,700 feet from source area

Residential Area

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

- Several rounds of source area treatment have been completed:
  - 2010: Nanoscale ZVI pilot tests and injections
  - 2014: 3DMe / HRC / BDI injections
- 2014: Remedial alternatives evaluation completed (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 (downgradient remedy)
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 STUDY AREA

2017 Design and Construction Issues at Hazardous Waste Sites
Pilot Test Overview

**BL-55-II PILOT STUDY SUMMARY**
Injection Points = 10
PlumeStop Injected = 1,880 gal
Controlled Electron Donor (HRC) Injected = 300 lb
Biological DHC Culture (BDI+) Injected = 9 liters

**BL-59-II PILOT STUDY SUMMARY**
Injection Points = 12
PlumeStop Injected = 1,940 gal
Controlled Electron Donor (HRC) Injected = 300 lb
Biological DHC Culture (BDI+) Injected = 9 liters
What is PlumeStop?

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 binding to the aquifer matrix, rapidly removing contaminants from groundwater, and expediting permanent contaminant biodegradation.

- Rapidly reduces dissolved-phase plumes in days/weeks
- Distributes widely under low injection pressures
- Provides a colloidal biomatrix that completely biodegrades contaminants in-place
- Stops contaminant migration and protects sensitive receptors
- Provides a long-term means of addressing matrix back–diffusion
- Eliminates excessive time and end-point uncertainty associated with groundwater remediation
A Tale of Two Pilot Study Areas

BL-55-II Area

BL-59-II Area
## Pilot Test Results

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</thead>
<tbody>
<tr>
<td><strong>cVOCs (in µg/l)</strong></td>
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<tr>
<td>cis-1,2-Dichloroethene</td>
<td>--</td>
<td>14.9</td>
<td>136</td>
<td>737</td>
<td>375</td>
<td>1,160</td>
<td>9.04</td>
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</tr>
<tr>
<td>Trichloroethene</td>
<td>11,900</td>
<td>73.5</td>
<td>16.8</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>12.3</td>
<td>--</td>
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<tr>
<td>Vinyl Chloride</td>
<td>--</td>
<td>--</td>
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<td>--</td>
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<td>--</td>
</tr>
<tr>
<td><strong>Total cVOCs (µg/l)</strong></td>
<td>11,900</td>
<td>88.4</td>
<td>152.8</td>
<td>737.0</td>
<td>375.0</td>
<td>1,160</td>
<td>21.34</td>
<td>0.00</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<td><strong>Field Parameters</strong></td>
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<tr>
<td>pH (S.U.)</td>
<td>5.91</td>
<td>5.24</td>
<td>5.22</td>
<td>5.39</td>
<td>5.88</td>
<td>5.88</td>
<td>6.10</td>
<td>7.00</td>
<td>7.20</td>
<td>7.31</td>
<td>7.44</td>
<td>7.25</td>
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<tr>
<td>Specific conductance (µs/cm)</td>
<td>127</td>
<td>572.1</td>
<td>550.2</td>
<td>214</td>
<td>438.0</td>
<td>185.0</td>
<td>298</td>
<td>859</td>
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<td>425.0</td>
<td>417.0</td>
<td>381.0</td>
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<tr>
<td>Dissolved oxygen (ppm)</td>
<td>1.15</td>
<td>0.80</td>
<td>0.31</td>
<td>0.12</td>
<td>0.23</td>
<td>0.10</td>
<td>0.40</td>
<td>5.35</td>
<td>0.62</td>
<td>0.73</td>
<td>0.35</td>
<td>0.23</td>
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<tr>
<td>Redox potential (mV)</td>
<td>90</td>
<td>76</td>
<td>46.1</td>
<td>-167</td>
<td>-166</td>
<td>-199</td>
<td>-148</td>
<td>7.4</td>
<td>-22.8</td>
<td>-176.0</td>
<td>-205</td>
<td>-202</td>
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</table>
Barrier Line #1 (275 ft long)
Injection Points = 59
PlumeStop Injected = 31,860 gal
Controlled Electron Donor (HRC) Injected = 2,930 lb
Biological DHC Culture (BDI+) Injected = 48 liters

Barrier Line #2 (280 ft long)
Injection Points = 50
PlumeStop Injected = 22,785 gal
Controlled Electron Donor (HRC) Injected = 1,920 lb
Biological DHC Culture (BDI+) Injected = 39 liters

Barrier Line #3 (400 ft long)
Injection Points = 50
PlumeStop Injected = 10,190 gal
Controlled Electron Donor (HRC) Injected = 1,080 lb
Biological DHC Culture (BDI+) Injected = 0 liters
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
## Performance Monitoring Results

### Chlorinated Volatile Organic Compounds (cVOCs) (µg/l)\(^{(a)}\)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>BL-22</th>
<th>BL-62-II</th>
<th>BL-59-II</th>
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<tbody>
<tr>
<td>1,1-Dichloroethene</td>
<td>1,650</td>
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<td>17.5</td>
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<tr>
<td>cis-1,2-Dichloroethene</td>
<td>1,570</td>
<td>282</td>
<td>1.54</td>
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<tr>
<td>Trichloroethene</td>
<td>13,500</td>
<td>448</td>
<td>14.1</td>
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<tr>
<td>Vinyl chloride</td>
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<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>Total cVOCs</strong></td>
<td>16,720</td>
<td>448</td>
<td>280</td>
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</table>

### Indicator Parameters (mg/l)

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<tr>
<th>Parameter</th>
<th>9/23/15</th>
<th>4/20/16</th>
<th>7/19/16</th>
<th>11/19/15</th>
<th>4/20/16</th>
<th>7/19/16</th>
<th>9/22/15</th>
<th>4/19/16</th>
<th>7/20/16</th>
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<tbody>
<tr>
<td>Ethene</td>
<td>0.0253</td>
<td>--</td>
<td>0.00563</td>
<td>0.00901</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Methane</td>
<td>0.0363</td>
<td>1.23</td>
<td>3.19</td>
<td>0.00632</td>
<td>NA</td>
<td>NA</td>
<td>1.67</td>
<td>4.64</td>
<td>9.08</td>
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<td>Iron, Total</td>
<td>0.925</td>
<td>3.44</td>
<td>5.17</td>
<td>10.3</td>
<td>NA</td>
<td>NA</td>
<td>1.43</td>
<td>1.71</td>
<td>1.76</td>
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<tr>
<td>Sulfate</td>
<td>1.04</td>
<td>4.88</td>
<td>14.7</td>
<td>9.85</td>
<td>NA</td>
<td>NA</td>
<td>1.43</td>
<td>1.71</td>
<td>1.76</td>
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<tr>
<td><strong>Total Organic Carbon (TOC)</strong></td>
<td>1.21</td>
<td>418</td>
<td>343</td>
<td>2.39</td>
<td>NA</td>
<td>NA</td>
<td>4.73</td>
<td>5.02</td>
<td>3.5</td>
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### Field Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>9/23/15</th>
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<th>7/19/16</th>
<th>11/19/15</th>
<th>4/20/16</th>
<th>7/19/16</th>
<th>9/22/15</th>
<th>4/19/16</th>
<th>7/20/16</th>
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</thead>
<tbody>
<tr>
<td>pH (S.U.)</td>
<td>7.40</td>
<td>6.65</td>
<td>5.34</td>
<td>7.46</td>
<td>6.80</td>
<td>6.70</td>
<td>7.25</td>
<td>7.14</td>
<td>7.14</td>
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<td>Specific conductance (µs/cm)</td>
<td>362</td>
<td>1087</td>
<td>1,245.1</td>
<td>322</td>
<td>484</td>
<td>386.1</td>
<td>381</td>
<td>386</td>
<td>377.6</td>
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<tr>
<td>Dissolved oxygen (ppm)</td>
<td>0.27</td>
<td>8.21</td>
<td>0.02</td>
<td>22</td>
<td>0.08</td>
<td>0.17</td>
<td>0.23</td>
<td>2.28</td>
<td>0.42</td>
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<td>Redox Potential (mV)</td>
<td>-214</td>
<td>-42.6</td>
<td>-63.2</td>
<td>94</td>
<td>-65.1</td>
<td>-103.3</td>
<td>-202</td>
<td>-81.1</td>
<td>-134.7</td>
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</tbody>
</table>

### SUMMARY OF RESULTS

- **97% Reduction in 3mo**
- **98% Reduction in 6mo**
- **100% Reduction after 3mo; Reducing conditions persist**
- **Sustained 100% Reduction after 21mo (Pilot Well)**
Summary and Conclusions (Pilot Test)

• 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
Summary and Conclusions (Full-Scale)

• 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.