Use of In-Situ Bioremediation of Trichloroethene to Reduce Long-Term Monitoring and Life Cycle Costs

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Chlorinated Solvents as Contaminants

- Trichloroethene (TCE), tetrachloroethene (PCE), and methylene chloride were commonly used as solvents, degreasers, and possibly as de-icing liquids.
- Many current and former DOD installations have chlorinated solvent plumes in the groundwater.
- Chlorinated solvents difficult to remediate.
- Remedial alternative evaluation:
  - High initial capital cost - short LTM period
  - Low initial capital cost - long LTM period
SS-32, Former Weapons Maintenance Area
Columbus AFB, MS

• Site History
  – Maintenance activities
  – Approximately 1959 to 1969

• Chemicals of Concern in Groundwater
  – TCE
  – Vinyl chloride

• Maximum Contaminant Levels (MCLs)
  – 5 µg/L for TCE
  – 2 µg/L for vinyl chloride

• Remedial Action for contaminated groundwater
## Evaluation of Remedial Alternatives

<table>
<thead>
<tr>
<th>Option</th>
<th>Time</th>
<th>Cost</th>
<th>Other Considerations</th>
<th>Conclusion</th>
</tr>
</thead>
</table>
| **Monitored Natural Attenuation**           | Time to reach MCL approx. 60 years | Lifecycle costs: $1.5-2.5 million | • Abiotic conditions prevalent  
• Biotic degradation limited  
• LUCs required for prolonged time  
• Threat to offsite receptors remains unmitigated  
• Regulatory acceptance?  | Not feasible by itself          |
| **Complete Remediation of Plume**           | Time to reach MCL approx. 5 years | High lifecycle cost: (approx. $30 million) | • Feasible but may be difficult to achieve due to the large size of the plume  
• In situ bioremediation or oxidation may be used  | Not cost effective              |
| **Source Reduction**                        | Reduces LTM period to 5-10 years | Lifecycles costs: $1.5 – 2.0 million | • Feasible and easily implemented  
• Highly likely to be accepted by the regulators because of source reduction and short LTM period | Best Value Approach             |
Selected Remedy: Source Reduction by In Situ Enhanced Bioremediation (ISEB)

Trichloroethene → Dichloroethene → Vinyl Chloride → Ethene

ISEB is implemented by creating a reducing environment in the contaminated groundwater with amendments (lactate, emulsified oil and microbes)
Project Status

- Remedial Action Construction - Completed July 5, 2008
- Remedial Action Operations (RA(O)) - Ongoing
  - Completed 1st Year Quarterly Monitoring in July 2009
  - ISEB GOAL ATTAINED July 2009
  - 2nd Year RA(O) Monitoring through July 2010
  - 3rd Year RA(O) Monitoring through July 2011
  - 5-10 years of LTM beyond 2011
Remedial Action

- Mobilized June 2, 2008
- Two Track Mounted DPT Rigs
- Injection Trailer
- Four Water Pillows
- Water Truck
- Fork Lift
- Connex Box
- Vehicles
Remedial Action for Target Areas
TCE > 100 µg/L

Groundwater Contamination
- Large Plume (TCE > 5 µg/L [MCL])
- Remedy Targets Two Areas (TCE >100 µg/L)
West Target Area Injection Points

94 Injection Points

Legend:
- Monitoring Well
- Hydropunch
- Injection Point
- TCE > 100 μg/L
- Groundwater Elevation Contour

Notes:
1. Number of injection points 94.
2. Injection locations are approximately 25 feet apart.
3. Groundwater elevation contours and flow direction are based on July 2007 data.
4. Northing and Easting are Mississippi State Plane coordinates, East Zone NAD27.
5. Aerial Photography Date: 06/15/2004

1 inch equals 200 feet
# W-118 Sample Results

## West Target Area

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Sep-07</th>
<th>July-08</th>
<th>Oct-08</th>
<th>Apr-09</th>
<th>Apr-10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Baseline</td>
<td></td>
<td>3 months</td>
<td>9 months</td>
<td>21 months</td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>µg/L</td>
<td>151</td>
<td></td>
<td>4.2</td>
<td>0.369</td>
<td>0.25</td>
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<tr>
<td>cis-1,2-Dichloroethene</td>
<td>µg/L</td>
<td>72.6</td>
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<td>178</td>
<td>0.668</td>
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<tr>
<td>Vinyl chloride</td>
<td>µg/L</td>
<td>5.4</td>
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<td>7.67</td>
<td>0.652</td>
<td>0.25</td>
</tr>
<tr>
<td>Ethene</td>
<td>µg/L</td>
<td>1</td>
<td>Injection</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>mg/L</td>
<td>1.40</td>
<td></td>
<td>0.79</td>
<td>0.78</td>
<td>0.56</td>
</tr>
<tr>
<td>ORP</td>
<td>mV</td>
<td>66.1</td>
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<td>-62.5</td>
<td>-228.5</td>
<td>-78.5</td>
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<tr>
<td>pH</td>
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<td>5.05</td>
<td></td>
<td>6.13</td>
<td>6.42</td>
<td>6.58</td>
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<tr>
<td>TOC</td>
<td>µg/L</td>
<td>-</td>
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<td>75,000</td>
<td>20,600</td>
<td>15,800</td>
</tr>
<tr>
<td>Dehalococcoides</td>
<td>cells/ml</td>
<td>-</td>
<td></td>
<td>120</td>
<td>19,000</td>
<td>770</td>
</tr>
</tbody>
</table>

**cells/mL** – cells per milliliter  
**Dehalococcoides** sp. (bacteria)  
**J** – The analyte was positively identified; the reported value is the estimated concentration of the constituent detected in the sample analyzed  
**mg/L** - milligrams per liter  
**ORP** - oxidation-reduction potential  
**U** - Not detected. The analyte was analyzed for, but not detected above the associated reporting limit.  
**µg/L** - micrograms per liter
W-118

Concentration (ug/L)

- TCE
- cis-1,2-DCE
- Vinyl chloride
- Ethene

Injection

Month:
- Sep-07
- Oct-07
- Nov-07
- Dec-07
- Jan-08
- Feb-08
- Mar-08
- Apr-08
- May-08
- Jun-08
- Jul-08
- Aug-08
- Sep-08
- Oct-08
- Nov-08
- Dec-08
- Jan-09
- Feb-09
- Mar-09
- Apr-09
- May-09
- Jun-09
- Jul-09
- Aug-09
- Sep-09
- Oct-09
- Nov-09
- Dec-09
- Jan-10
- Feb-10
- Mar-10
- Apr-10

Concentration (ug/L)
ISEB Goal

Individual TCE values are 25 µg/L or less for two most recent quarters AND average TCE for most recent quarter is 10 µg/L or less

Goal Attained for West Target Area
Remedial Action for Target Areas

TCE > 100 µg/L

Groundwater Contamination

- Large Plume (TCE > 5 µg/L [MCL])
- Remedy Targets Two Areas (TCE >100 µg/L)
East Target Area Injection Points

348 Injection Points

Legend:
- Monitoring Well
- Hydropunch
- Injection Point
- Injection Point 50 ft location adjustment per utility lines
- TCE > 100 µg/L
- Groundwater Elevation Contour

NOTES:
1. Number of injection points 348.
2. Injection locations are approximately 25 feet apart.
3. Groundwater elevation contours and flow direction are based on July 2007 data.
4. Northing and Easting are Mississippi State Plane coordinates, East Zone NAD27.
5. Aerial Photography Date: 08/15/2004

1 inch equals 200 feet
Injection Activities in East Area Near Runway
SS32-MW06 Sample Results
East Target Area

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Sep-07</th>
<th>July-08</th>
<th>Sep-07</th>
<th>Oct-08</th>
<th>Apr-09</th>
<th>Apr-10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Baseline</td>
<td></td>
<td>3 months</td>
<td>9 months</td>
<td>21 months</td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>µg/L</td>
<td>102</td>
<td></td>
<td></td>
<td>107</td>
<td>3.51</td>
<td>26.6</td>
</tr>
<tr>
<td>cis-1,2-Dichloroethene</td>
<td>µg/L</td>
<td>204</td>
<td></td>
<td></td>
<td>488</td>
<td>38.7</td>
<td>54</td>
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<tr>
<td>Vinyl chloride</td>
<td>µg/L</td>
<td>84.2</td>
<td></td>
<td></td>
<td>302</td>
<td>24.6</td>
<td>141</td>
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<tr>
<td>Ethene</td>
<td>µg/L</td>
<td>1</td>
<td>Injection</td>
<td></td>
<td>2</td>
<td>72</td>
<td>41</td>
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<tr>
<td>Dissolved Oxygen</td>
<td>mg/L</td>
<td>1.14</td>
<td></td>
<td></td>
<td>0.93</td>
<td>1.05</td>
<td>0.52</td>
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<td>ORP</td>
<td>mV</td>
<td>49.7</td>
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<td>-93.4</td>
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<td>pH</td>
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<td>6.02</td>
<td>6.13</td>
<td>6.21</td>
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<tr>
<td>TOC</td>
<td>µg/L</td>
<td>-</td>
<td></td>
<td></td>
<td>5,000</td>
<td>25,900</td>
<td>9,310</td>
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<tr>
<td>Dehalococcoides</td>
<td>cells/ml</td>
<td>4,200</td>
<td></td>
<td></td>
<td>8,400</td>
<td>2,700</td>
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</tr>
</tbody>
</table>

- cells/mL – cells per milliliter
- Dehalococcoides sp. (bacteria)
- J – The analyte was positively identified; the reported value is the estimated concentration of the constituent detected in the sample analyzed.
- mg/L - milligrams per liter
- ORP - oxidation-reduction potential
- U - Not detected. The analyte was analyzed for, but not detected above the associated reporting limit.
- µg/L - micrograms per liter
## SS32-MW07 Sample Results

### East Target Area

<table>
<thead>
<tr>
<th>Parameter</th>
<th>units</th>
<th>Sep-07</th>
<th>July-07</th>
<th>Oct-08</th>
<th>Apr-09</th>
<th>Apr-10</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Sept 07</strong></td>
<td><strong>July 08</strong></td>
<td><strong>Oct 08</strong></td>
<td><strong>Apr 09</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Baseline</td>
<td>3 months</td>
<td>9 months</td>
<td>21 months</td>
<td></td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>µg/L</td>
<td>183</td>
<td>0.625</td>
<td>0.339</td>
<td>0.25</td>
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</tr>
<tr>
<td>cis-1,2-Dichloroethene</td>
<td>µg/L</td>
<td>642</td>
<td>333</td>
<td>21.6</td>
<td>2.81</td>
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<tr>
<td>Vinyl chloride</td>
<td>µg/L</td>
<td>237</td>
<td>130</td>
<td>12.1</td>
<td>4.98</td>
<td></td>
</tr>
<tr>
<td>Ethene</td>
<td>µg/L</td>
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<td>3</td>
<td>45</td>
<td>17</td>
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<tr>
<td>Dissolved Oxygen</td>
<td>mg/L</td>
<td>0.39</td>
<td>3.07</td>
<td>0.86</td>
<td>47.1</td>
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<tr>
<td>ORP</td>
<td>mV</td>
<td>-369.2</td>
<td>-98.0</td>
<td>-168.0</td>
<td>-62.3</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>5.39</td>
<td>6.26</td>
<td>6.38</td>
<td>6.46</td>
<td></td>
</tr>
<tr>
<td>TOC</td>
<td>µg/L</td>
<td>-</td>
<td>52,900</td>
<td>59,300</td>
<td>25,200</td>
<td></td>
</tr>
<tr>
<td>DHE</td>
<td>cells/ml</td>
<td>-</td>
<td>11,000</td>
<td>180</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

- **cells/mL**: cells per milliliter
- **Dehalococcoides sp.** (bacteria)
- **J**: The analyte was positively identified; the reported value is the estimated concentration of the constituent detected in the sample analyzed.
- **mg/L**: milligrams per liter
- **ORP**: oxidation-reduction potential
- **U**: Not detected. The analyte was analyzed for, but not detected above the associated reporting limit.
- **µg/L**: micrograms per liter
SS32-MW07

Concentration (ug/L)

Injection

TCE  cis-1,2-DCE  Vinyl chloride  Ethene  GW

Feet Below Ground Surface

Concentration (ug/L)

Injection

TCE  cis-1,2-DCE  Vinyl chloride  Ethene  GW
### SS32-MW08 Sample Results

#### East Target Area

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Sep-07</th>
<th>July-08</th>
<th>Oct-08</th>
<th>Apr-09</th>
<th>Apr-10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Baseline</td>
<td>Injection</td>
<td>3 months</td>
<td>9 months</td>
<td>21 months</td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>µg/L</td>
<td>156</td>
<td>13.7</td>
<td>0.259</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>cis-1,2-Dichloroethene</td>
<td>µg/L</td>
<td>468</td>
<td>615</td>
<td>2.38</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Vinyl chloride</td>
<td>µg/L</td>
<td>186</td>
<td>222</td>
<td>2.81</td>
<td>0.749</td>
<td></td>
</tr>
<tr>
<td>Ethene</td>
<td>µg/L</td>
<td>1</td>
<td>2</td>
<td>57</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>mg/L</td>
<td>0.74</td>
<td>0.82</td>
<td>0.90</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>ORP</td>
<td>mV</td>
<td>49.1</td>
<td>-25.4</td>
<td>-165.7</td>
<td>-76.2</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>5.35</td>
<td>5.82</td>
<td>6.25</td>
<td>6.48</td>
<td></td>
</tr>
<tr>
<td>TOC</td>
<td>µg/L</td>
<td>-</td>
<td>59,200</td>
<td>72,000</td>
<td>49,800</td>
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<tr>
<td>DHE</td>
<td>cells/ml</td>
<td>-</td>
<td>360</td>
<td>16,000</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

- **cells/mL** – cells per milliliter
- **Dehalococcoides sp. (bacteria)**
- **J** – The analyte was positively identified; the reported value is the estimated concentration of the constituent detected in the sample analyzed
- **mg/L** - milligrams per liter
- **ORP** - oxidation-reduction potential
- **U** - Not detected. The analyte was analyzed for, but not detected above the associated reporting limit.
- **µg/L** - micrograms per liter
As of April 2010 SS32-MW06, SS32-MW07 and SS32-MW08 were near or below the 25 µg/L TCE goal AND
Average TCE for most recent quarter is less than 9.0 µg/L, below the 10 µg/L average goal.

Goal Attained for East Target Area
Path Forward

- ISEB goal has been met. Last RA(O) monitoring was conducted in April 2010
- RA(O) Monitoring: Currently quarterly as required by ROD
- Reduce RA(O) monitoring frequency to semi-annual.
- Future LTM frequency - annual
Questions?