Performance Comparison of Aerobic and Anaerobic In-Situ Treatment Approaches
Former Materials Testing Laboratory (MTL)
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Site History and Conditions

- Materials testing laboratory for the Colorado Department of Transportation (CDOT) from 1957 to 2006
- 2 USTs stored 3 primary solvents (1,1,1-TCA, TCE, and methylene chloride) from 1972 to 1987
- CVOCs in groundwater above cleanup goals
- Denver Formation
- WBZs are highly fractured and highly weathered
- Groundwater flow direction is to the north/northeast
Site Plan View
Current Plume Conditions

Approximately 600 m or 2000 ft in length

<table>
<thead>
<tr>
<th>CVOC</th>
<th>Dissolved-Phase Plume Shallow WBZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,1-DCE</td>
<td>Max of 780 μg/L</td>
</tr>
<tr>
<td>1,1,1-TCA</td>
<td>Max of 40 μg/L</td>
</tr>
<tr>
<td>TCE</td>
<td>Max of 120 μg/L</td>
</tr>
<tr>
<td>Methylene Chloride</td>
<td>Not present in this area of the plume</td>
</tr>
</tbody>
</table>
Full-Scale Remedy Selection

• Both aerobic and anaerobic enhanced bioremediation strategies were evaluated in the CMS

• Recommendation was to install an aerobic system due to:
  – Concerns about vinyl chloride generation and its potential risk to indoor air; specifically uncertainty of vinyl chloride persistence
  – Indoor air systems were not completely in place at that time
What is Cometabolic Aerobic Biodegradation?

- Occurs when microbial growth is not supported by the target contaminant, but enzymes (i.e. methane monoxygenase [sMMO]) are produced that can destroy the contaminant
- Growth of the methanotrophs must be supported by other electron donors and carbon sources (i.e. methane)

![Diagram of Cometabolic Aerobic Biodegradation]

Source: Modified from EPA July 2000 (Modified from McCarty and others 1998)
AB System

- Start-up January 2001
- 76 injection wells
- 3 treatment buildings
- Added nutrients
- Methane sparge cabinet with micro-diffusers
- 0.1 - 0.5 gpm per well
**AB System Layout**

Full-Scale AB Treatment Area (shallow and deep WBZs) Began operation in January 2001

Source Area (Contained using Pump and Treat System)
Performance of the AB System

**Total Mass in Dissolved-Phase Plume**
Shallow WBZ

- **1,1-DCE**
- **TCE**
- **1,1-TCA**

AB system treatment begins January 2001

Elapsed Time (years) vs. Total Mass (kg)
Results of AB Treatment

• Successful treatment, however, biodegradation rates would not meet site goals despite several efforts to optimize the system

• Contributing challenges:
  – Injectability
  – Short half life of methane limits maximum distribution
  – Solubility of methane
  – Optimal observed performance only had modest treatment rates
Rationale

– Potential to meet remedial timeframes
  • Demonstrated performance in same geologic unit
– Reduced concern for vinyl chloride
  • Vinyl chloride is short-lived based on extensive experience since CMS
  • Indoor air systems are in place and proven to be protective

Questions/Objectives

1. Conversion within a reasonable timeframe?
2. Achieve remedial timeframes?
3. Are full-scale lifecycle costs less?
What is Anaerobic Biodegradation?

- Enhanced reductive dechlorination (ERD)
- Occurs under anaerobic conditions
- Chlorine atoms are sequentially replaced with hydrogen atoms
- Hydrogen is supplied through the fermentation of the carbon source (i.e. molasses)

1,1-DCE $\rightarrow$ Vinyl Chloride $\rightarrow$ Ethene

TCE $\rightarrow$ 1,2-DCE $\rightarrow$ Vinyl Chloride $\rightarrow$ Ethene

1,1,1-TCA $\rightarrow$ 1,1-DCA $\rightarrow$ Chloroethane $\rightarrow$ Ethane
Pilot Test Area (shall low WBZ only)

Full-Scale AB Treatment Area (shallow and deep WBZs)

Source Area (Contained using Pump and Treat System)
Geochemical Parameters of Key Pilot Wells

**TOC and Methane at MW-84S**

**Ferrous Iron and Sulfate at MW-114S**
Dechlorination Trends

1,1-DCE and Daughter Products at MW-115S

TCE and Daughter Products at MW-115S
Half Life Comparison

1,1-DCE

Average = 900 days

Average = 135 days

TCE

Average = 1,069 days

Average = 155 days
Pilot Test Results

• Achieved anaerobic conditions in 7-10 months in the test area
  – Only 3-4 month lag time compared to other sites in same geologic unit
• Full dechlorination at all wells
• Treatment goals achieved at 5 of 6 wells
• Half-lives are approximately 5 times faster
Projected Treatment Times and Costs

Current Average Concentration in Zone 1 is 208 ug/L

AB Half Life = 2.0 years

ERD Half Life = 0.5 years

MCL for 1,1-DCE = 7 ug/L

Projected AB System Costs

Projected ERD System Costs

Off-Site Plume Treatment Costs

Concentration (ug/L) vs. Time (years)

Average AB Decay Rate
Average ERD Decay Rate
AB System Costs
ERD System Costs
Path Forward

- Full-scale system converted in August 2008
  - Modifications and upgrades made to automate injection
- Anticipated operation is 3 to 5 years
Imagine the result

Questions?