Implementation of a Nanoscale Zero Valent Iron Remediation Demonstration

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Overview of presentation

➤ Overview of Nanoscale Iron

➤ Full Scale Pilot Study, NAS Jacksonville

➤ Summary and Conclusions
Nanoscale Zero Valent Iron

Dehalogenation Schematic

Other Contaminants
- Chlorinated VOCs
- Nitrates
- Metals (e.g., Cr, As)
- Chlorinated Pesticides

Noble Metals
- forms galvanic cells
- catalyze hydrogenation

Source: modified after Lehigh University

Site Background

- Small area (1050 sq ft)
- Utility corridor
- Geology
  - Silty to fine sand from 0 to 24 feet bgs
  - Dense clay from 24 to 54 ft bgs
- Hydrogeology
  - Flow toward southeast
  - Water table at 7 feet bgs
  - Hyd. Conduct. ~2 ft/day
Site Contamination Summary
Hangar 1000, NAS Jacksonville

Maximum Total VOC
550 mg/kg in soil
80 mg/L in groundwater

Chemical oxidation conducted in 2001

Full Scale Pilot Study Design

- Remedial Goal as defined in the Work Plan
  - Reduce contaminant mass **40 to 50%**
  - Not expected to reach groundwater MCLs
  - MNA anticipated as next step

- How much iron is needed?
  - Reaction Capacity (VOCs : Nano Fe) = ~1:5-10 by wt.
  - CVOC mass estimated: 42 to 125 lbs
  - Need an estimated 210 to 1250 lbs
  - Injected 300 lbs

- Two injection methods:
  - Strategic DPT injections
  - Recirculation Process
Recirculation Setup

Nanoscale Iron
- Polymer Supported w/Palladium Catalyst
- No carbon substrate
Recirculation: Hydraulic Results

- Keep iron in source
- Good mixing
- Good iron distribution

Source Well H10MW37
Molar Concentrations

Chlorinated Ethene

Injections #1 and #2

CIS-1,2-DCE
TCE
PCE

ETHENE+ETHANE
VC

1,2-DCA
1,1-DCE
CA
1,1-DCA
1,1,1-TCA

Molar Concentration (uM/L)

Date

Date

Chlorinated Ethane

Months

0

3

6

9

12

0

30

25

20

15

10

5

0

0

3

6

9

12

Months
Source Well
H10MW34
Molar Concentrations

Beta-Elimination Pathway
Acetylene, Butane, & Isobutane
Round 1 (baseline)
TCE isoconcentrations

Round 3 (after inject)
TCE isoconcentrations
TCE isoconcentrations

Round 11 (after inject)

Geochemistry Results
Oxygen & ORP

Dissolved Oxygen

Oxidation-Reduction Potential

Injections #1 and #2

Concentrations (mg/L)

Injections #1 and #2

ORP (millivolts)

Months

Concentrations (mg/L)

Months
Geochemistry Results

Dissolved Iron & Sulfate

Dissolved Iron

Injections #1 and #2

Concentrations (ug/L)

0             3                 6  9               12

Months

H10MW10 (upgradient well)
H10MW32 (source well)
H10MW34 (source well)
H10MW37 (source well)
H10MW38 (down gradient well)
H10MW39 (down gradient well)

Sulfate

Injections #1 and #2

Concentrations (mg/L)

0             3                 6  9               12

Months

H10MW10 (upgradient well)
H10MW32 (source well)
H10MW34 (source well)
H10MW37 (source well)
H10MW38 (down gradient well)
H10MW39 (down gradient well)

Carbon Dioxide

Injections #1 and #2

Concentrations (mg/L)

0             3                 6  9               12

Months

H10MW10 (upgradient well)
H10MW32 (source well)
H10MW34 (source well)
H10MW37 (source well)
H10MW38 (down gradient well)
H10MW39 (down gradient well)

Geochemistry Results

Carbon Dioxide, Methane & pH (stable from 6-7)

Methane

Injections #1 and #2

Concentrations (ug/L)

0             3                 6  9               12

Months

H10MW10 (upgradient well)
H10MW32 (source well)
H10MW34 (source well)
H10MW37 (source well)
H10MW38 (down gradient well)
H10MW39 (down gradient well)
Is there evidence for biological activity?

- qPCR analysis for Dehalococcoides (GC/ML) conducted in 3 wells:

<table>
<thead>
<tr>
<th>Well</th>
<th>Baseline (GC/ML)</th>
<th>12 months after injection (GC/ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H10MW10</td>
<td>500 U</td>
<td>18</td>
</tr>
<tr>
<td>H10MW37</td>
<td>500 U</td>
<td>25 U</td>
</tr>
<tr>
<td>H10MW39</td>
<td>174 U</td>
<td>1.65</td>
</tr>
</tbody>
</table>

Soil Sampling Summary

Percent change: Soil data before & after study

<table>
<thead>
<tr>
<th>Soil Boring Depth (feet-bgs)</th>
<th>H1K-03 19'</th>
<th>H1K-31 8'</th>
<th>H1K-31 20'</th>
<th>H1K-34 20'</th>
<th>H1K-35 22'</th>
<th>H1K-36 20'</th>
<th>H1K-38 20'</th>
<th>H1K-39 16'</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,1,1-TCA</td>
<td>-50%</td>
<td>-83%</td>
<td>-100%</td>
<td>-92%</td>
<td>-77%</td>
<td>-97%</td>
<td>-99%</td>
<td>-99%</td>
</tr>
<tr>
<td>1,1-DCA</td>
<td>5%</td>
<td>-96%</td>
<td>-84%</td>
<td>-43%</td>
<td>-91%</td>
<td>46%</td>
<td>-97%</td>
<td>-97%</td>
</tr>
<tr>
<td>1,1-DCE</td>
<td>-36%</td>
<td>-100%</td>
<td>-77%</td>
<td>-97%</td>
<td>-97%</td>
<td>-97%</td>
<td>-97%</td>
<td>-97%</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>-28%</td>
<td>-100%</td>
<td>-99%</td>
<td>-99%</td>
<td>-99%</td>
<td>-99%</td>
<td>-99%</td>
<td>-99%</td>
</tr>
<tr>
<td>PCE</td>
<td>-100%</td>
<td>141%</td>
<td>-96%</td>
<td>-100%</td>
<td>-100%</td>
<td>-100%</td>
<td>-100%</td>
<td>-100%</td>
</tr>
<tr>
<td>TCE</td>
<td>-100%</td>
<td>141%</td>
<td>-96%</td>
<td>-100%</td>
<td>-100%</td>
<td>-100%</td>
<td>-100%</td>
<td>-100%</td>
</tr>
<tr>
<td>Vinyl chloride</td>
<td>-36%</td>
<td>-100%</td>
<td>-99%</td>
<td>-99%</td>
<td>-99%</td>
<td>-99%</td>
<td>-99%</td>
<td>-99%</td>
</tr>
<tr>
<td>cis-1,2-DCE</td>
<td>267%</td>
<td>1026%</td>
<td>174%</td>
<td>11%</td>
<td>11%</td>
<td>11%</td>
<td>11%</td>
<td>11%</td>
</tr>
<tr>
<td>Total % Change</td>
<td>11%</td>
<td>8%</td>
<td>92%</td>
<td>92%</td>
<td>75%</td>
<td>94%</td>
<td>88%</td>
<td>25%</td>
</tr>
</tbody>
</table>

RED/Yellow - indicates DECREASE in concentration
BLUE/Gray - indicated INCREASE in concentration
Mass Reduction Summary

- Total Mass Reduction before & after study
  - Soil mass
  - Dissolved mass
  - Sorbed mass

<table>
<thead>
<tr>
<th></th>
<th>Pre-Injection (Baseline)</th>
<th>Post-Injection (after Round 11)</th>
<th>Pounds destroyed</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>125 lbs</td>
<td>47 lbs</td>
<td>78</td>
<td>62%</td>
</tr>
<tr>
<td>Most Likely</td>
<td>61 lbs</td>
<td>47 lbs</td>
<td>14</td>
<td>23%</td>
</tr>
<tr>
<td>Minimum</td>
<td>42 lbs</td>
<td>35 lbs</td>
<td>7</td>
<td>16%</td>
</tr>
</tbody>
</table>

*RED/Yellow - indicates DECREASE in concentration
*BLUE/Gray - indicated INCREASE in concentration

How much was it?

  - Iron injection costs: $112K
  - Nanoscale iron: $37K (late 2003) *
    - Today this cost would have been $5 to 14K
  - Monitoring costs: $111K

- Comparable to other technologies today…
  - Chemical Oxidation: $145K
  - Bioremediation $150K - $175K
  - Excavation: $385K – $485K

* Pound per pound is not a good comparison
Summary

- Data suggests favorable results
  - Significant TCE & 1,1,1-TCA reductions across the site
  - Generation of daughter products
    - cis-1,2 DCE, 1,1-DCE, 1,1-DCA
    - very little VC
  - Mass destruction evident
    - Good mass balance in some wells
    - Ethene & ethene concentrations increased up to 2 order (770%)
    - Acetylene and light hydrocarbons increased up to 2 order
  - Longevity of iron: 6 to 9 months

Summary (cont.)

- Data suggests favorable results (cont.)
  - Plume extent was reduced (MW-33 & MW-36)
  - At or below GCTLS levels in MW-39 (downgradient well)
    - Reduced mass flux from source

- Concentrations in the ‘core’ returned (expected)
  - Elevated concentrations returned in source wells (MW-08, MW-32, MW-37)

- Mass reduced between 16 and 63 %
  - We met the 40-50% reduction goal (regulators)
  - To be included in the ROD for site

- Further reductions could have been achieved
  (not needed to meet project goals)
Is this the Silver Bullet?

- It works…but not in all cases.
  - Quick…Not much to do (no nutrients, no pH issues)
  - Good for small sources…not for very large ones
  - Bioremediation may work better in some environments
  - An emerging science that is making strides
  - Treatment trains and ‘combinations’

Tetra Tech NUS, Inc.

Thanks for attending

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