Rapid Remediation of Subsurface Organic Contaminants - a Contact Sport!

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Investigation - Remediation - Risk Assessment
Example 1 - Natural Contact

How do you transform a contaminated commercial site into a marketable property?
Mechanism for Natural Contact

The groundwater gradient both created the plume and provided a natural mechanism for achieving contact with the contamination.
HRC® (Hydrogen Release Compound) is an electron donor material. It produces a controlled release of lactic acid upon contact with water. Microbes metabolize the lactic acid and generate hydrogen. Hydrogen is then used for anaerobic reductive de-chlorination.
Injection Points

Injection locations were limited, forcing reliance on natural groundwater movement to make contact between HRC and the contamination.
Concentrations

Remediation cost was $150,000.

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Aquatic Life Standards</th>
<th>Pre-Remediation Concentrations</th>
<th>Post-Remediation Concentrations</th>
<th>Time to Remediation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCE (Perchloroethylene)</td>
<td>1,100 ppb</td>
<td>4,000 ppb</td>
<td>&lt;100 ppb</td>
<td>7 months</td>
</tr>
<tr>
<td>TCE (Trichloroethylene)</td>
<td>200 ppb</td>
<td>1,500 ppb</td>
<td>&lt;200 ppb</td>
<td>7 months</td>
</tr>
<tr>
<td>VC (Vinyl Chloride)</td>
<td>200 ppb</td>
<td>(700 ppb)</td>
<td>&lt;200 ppb</td>
<td>26 months</td>
</tr>
</tbody>
</table>
Example 2 – Forced Contact

How do you transform a Brownfield into a profitable new development?
The Site

Strip mall with Dry Cleaner.
The Source

Former Dry Cleaner

Leaking Seals

Sanitary

PCE above 1500ppb

SILT

SAND

0m
1.5m
3.0m
4.5m
16.0m
## Regulatory Issues

Introduction of Drinking Water standards in three (3) months will dramatically increase the size of the contaminant plume.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PCE</td>
<td>Soil: 50 ppm</td>
<td>Soil: 50 ppm</td>
</tr>
<tr>
<td></td>
<td>G’water: 1,500 ppb</td>
<td>G’water: 30 ppb</td>
</tr>
<tr>
<td>TCE</td>
<td>Soil: 50 ppm</td>
<td>Soil: 0.015 ppm</td>
</tr>
<tr>
<td></td>
<td>G’water: 11,000 ppb</td>
<td>G’water: 5 ppb</td>
</tr>
</tbody>
</table>
Technical Issues

Obstacles to numerical remediation in only three months

- Excavation is extremely limited due to high groundwater table and floodplain soils which can easily collapse as a sinkhole when de-watering.
- Flat groundwater gradient resulting in a flow rate of 1.5m/yr, means unsuitable natural delivery system for the injectant.
- Need fast-acting injectant
Potassium permanganate ($\text{KMnO}_4$) is a powerful oxidant.

\[
PCE + \text{Permanganate} \\ \\
\begin{array}{c}
\text{Cl} \\
\text{Cl} \\
\text{Cl} \\
\text{Cl}
\end{array} \\
\text{C} \equiv \text{C} \\
\text{Cl} \\
\text{Cl} \\
\text{Cl} + \text{MnO}_4^-
\]

- Oxygen donation to form cyclic hypopermanganate ester intermediate
- pH dependent steps
- $2\text{CO}_2 + 4\text{HCl} + \text{Mn(IV)O}_2$
Fast Contact Mechanism

Accelerate groundwater flow by combining extraction and injection.
Forced Delivery System

The concept is simple. Execution requires precision.
Injection Series

LEGEND
- Plume
- Extraction Points
- Injection Round 1
- Injection Round 2
- Injection Round 3

Drycleaner
Remediation cost was $850,000.

<table>
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<tr>
<th>Contaminant</th>
<th>DNAPL Standards</th>
<th>Pre-Remediation Concentrations</th>
<th>Post-Remediation Concentrations</th>
<th>Time to Remediation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PCE</strong>&lt;br&gt;(Perchloroethylene)</td>
<td>1,500 ppb</td>
<td>41,000 ppb</td>
<td>&lt;600 ppb</td>
<td>3 months</td>
</tr>
<tr>
<td><strong>TCE</strong>&lt;br&gt;(Trichloroethylene)</td>
<td>11,000 ppb</td>
<td>78,000 ppb</td>
<td>&lt;940 ppb</td>
<td>3 months</td>
</tr>
</tbody>
</table>
Landfill, Burnaby

Bulk Fuel Storage, North Vancouver

Works Yard, Nelson

Service Station, Vancouver

Commercial/Industrial, North Vancouver

Drycleaner, Richmond

Tungsten Carbide Facility, Port Coquitlam

Shipyard, North Vancouver
Degradation Sequence of PCE

BH406 VOC Concentration vs. Time

- **PCE**
- **TCE**
- cis-1,2-DCE
- Vinyl chloride

Date:
- 10/19/2005
- 6/15/2007
- 2/19/2008
- 5/28/2008
- 8/21/2008
- 11/28/2008
- 2/27/2009

Concentration (ug/L)