Sustainable Combination Heating: An Innovative Approach for In Situ Thermal Remediation in Challenging Lithology

RemTech 2018
Fairmont Banff Springs Hotel
Banff, Alberta

Presented by: Jay Dablow
ERM, Irvine, California

Date: 11 October, 2018
Switzerland Site Setting

- 70,000 m³ waste, 50,000 m³ soil
- Complex Inventory of Contaminants (chlorobenzene, anilines, chlorinated solvents, pesticides and heavy metals)
- Wide Range of Contaminant Concentration
- Swiss law enforced remediation by:
  - Complete excavation of waste
  - Soil & groundwater remediation
- Rigorous remediation targets
- Stringent Schedule
Underground Constraints

Forecast: ca. 5,000 kg of contaminant mass

Remediation Target Area

**ca. 70 m**

Belastungsschwerpunkt

- 40 kg
- 910 kg
- 1,700 kg
- 1,700 kg
- 390 kg
- 200 kg
- 20 kg
- 18 kg
- 2 kg
- <1 kg
- <1 kg

Silt

Sand
Implementation-Design elements

provided by Krüger/TerraTherm
Boundary Conditions – sensitive infrastructure

- **Sand Ton**
- **6 m**
- **5 m**
- **Rail Line**
- **Drilled piles**
- **Roadway**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>70</td>
<td>m</td>
</tr>
<tr>
<td>Width</td>
<td>25</td>
<td>m</td>
</tr>
<tr>
<td>Unsaturated Zone</td>
<td>0 – 6</td>
<td>m</td>
</tr>
<tr>
<td>Saturated Zone</td>
<td>6 – 11</td>
<td>m</td>
</tr>
<tr>
<td>Volume (unsaturated)</td>
<td>10,500</td>
<td>m³</td>
</tr>
<tr>
<td>Volume (Saturated)</td>
<td>8,750</td>
<td>m³</td>
</tr>
</tbody>
</table>

Target Treatment Zone
Phase II – Soil & Groundwater Remediation

In-Situ Thermal Desorption @>100°C
Treatment volume: appr.11,000 m³

Steam Enhanced Extraction ~100 °C
Treatment volume: appr.9,000 m³
ISTR Installation

- Inclined Bores railway embankment
- Completed heaters and wells
- Install Vapor Capture Zone
- Apply HDPE liner & Vapor Cap
Performance & Achievements of Soil Remediation

extracted air before treatment

Total organic contaminant mass extracted
5'350 kg

steam/air extraction

liquid phase extraction
Rebound??

Post Remediation Monitoring (20 m downgradient from TTZ)

[Graph showing concentrations of various substances over time, with a shaded area indicating Thermal Treatment.]
## Performance & Achievements of Soil Remediation

<table>
<thead>
<tr>
<th>11 Target Compounds with remedial objectives</th>
<th>Soil</th>
<th>Groundwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Soil Conc. before ISTD [mg/kg]</td>
<td>Remediial Success [%-Reduction]</td>
<td>Average Conc. before ISTD [µg/L]</td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>834</td>
<td>99.9 %</td>
</tr>
<tr>
<td>1,2-cis-Dichloroethene</td>
<td>109</td>
<td>99.9 %</td>
</tr>
<tr>
<td>1,2-Dichlorethane</td>
<td>19.8</td>
<td>~100 %</td>
</tr>
<tr>
<td>Vinyl chloride</td>
<td>2.8</td>
<td>99.6 %</td>
</tr>
<tr>
<td>1,2-Dichlorobenzene</td>
<td>2,855</td>
<td>99.8 %</td>
</tr>
<tr>
<td>1,4-Dichlorobenzene</td>
<td>34.6</td>
<td>99.8 %</td>
</tr>
<tr>
<td>Chlorobenzene</td>
<td>719</td>
<td>99.6 %</td>
</tr>
<tr>
<td>Anilines</td>
<td>111</td>
<td>95.0 %</td>
</tr>
<tr>
<td>Metobromuron</td>
<td>1.13</td>
<td>99.1 %</td>
</tr>
<tr>
<td>Fluometuron</td>
<td>2.10</td>
<td>99.5 %</td>
</tr>
<tr>
<td>Bisphenol A</td>
<td>417</td>
<td>56.4 %</td>
</tr>
</tbody>
</table>
California Site Background

- Former aerospace manufacturing facility
- TCE and PCE impacts from degreasing operations
- Site planned for sale and redevelopment for industrial/commercial reuse.

Lithology

- Shallow unit - relatively low permeability clays and silts to approximately 25 to 30 feet bgs.
- Intermediate unit
  - Sand A - Sand and gravelly sand from 30 to 40 feet bgs.
  - Sand B - Sand and gravelly sand. Slightly more permeable than Sand A. 40 to 70 feet bgs
Summary of Remediation

- Remedial Strategy
  - Implement Electric Resistance Heating (ERH) to heat fine-grained Shallow Unit soils.
  - Implement Steam Enhanced Extraction (SEE) to heat A and B Sands.
  - Raise soil and groundwater temperatures to above VOC co-boiling and boiling points:
    - PCE = 88°C (co-boiling)
    - TCE = 73°C (co-boiling)
    - 1,4-Dioxane = 78°C (co-boiling)
    - cis-1,2-DCE = 60.1°C (boiling)
    - VC = -13.8°C (boiling)
  - Achieve asymptotic mass removal.
  - Reduce soil concentrations to below risk based Environmental Screening Levels
    - PCE 0.6 mg/kg
    - TCE 1.2 mg/kg
  - Reduce groundwater concentrations
Extent of Impacts

ERH Zone

Steam Zone

B-10 Area

PCE North Area

PCE South Area

TCE Area

Downgradient Area
Implementation Sequence

- Building Demolition
- Well electrode installation
- Electrode installation
- Vapor Cap Construction
- Piping and electrical construction
- Boiler and Treatment Compound
Subsurface Temperatures (Temperature Graphs)

ERH Zone – 3 to 30 feet bgs

Co-boiling point
Steam Impacts in ERH zone (24 to 30 feet bgs) (Rapid Rise from Steam Contact)
ERH Effects (Steady Temperature Increase)
Subsurface Temperatures (Temperature Graphs)

Steam Zone A Sand – 30 to 40 feet bgs

Steam Zone B Sand – 40 to 60 feet bgs

Co-boiling point
Steam Impacts (Rapid Rise from Steam Contact)
Asymptotic Mass Removal

Asymptote determined by Sigmoidal model
Performance Monitoring - Soil

Pre/Post Remediation PCE and TCE Concentrations – B10 Area

Pre/Post Remediation PCE and TCE Concentrations – TCE Area

Pre/Post Remediation PCE and TCE Concentrations – PCE South

Pre/Post Remediation PCE and TCE Concentrations – PCE North
Performance Monitoring - Groundwater
Conclusions

- Combined ERH and SEE achieved asymptotic mass removal.
- System removed more than 3,300 lbs. of VOC mass from soil and groundwater.

- 175 of 178 soil samples collected were below ESLs.
- Remedial system in areas around 3 elevated samples was optimized by installing targeted steam injection wells and increasing steam injection mass flow rate.

- VOC concentrations in groundwater were reduced up to 4 orders of magnitude.
- VOCs in 6 of the 10 performance monitoring wells were reduced below MCLs (or non-detect).
Thank you

Jay Dablow
Technical Fellow:
Irvine, California
jay.dablow@erm.com
714-606-9110