Lessons Learned on the Design and Construction of Over 150 Thermal Remediation Systems

John LaChance, Technical Director
Design and Construction Aspects Important for Successful ISTR

1. Conceptual Site Model

2. Wellfield Design
   - Vapor Cover (Insulated?)
   - Heating Above, Below, and Surrounding Treatment Zone
   - Vapor and Liquid Extraction

3. Extraction Design and Treatment Technology
## Thermal Treatment Technologies

<table>
<thead>
<tr>
<th>DECADES OF EXPERIENCE</th>
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<tr>
<td><strong>THERMAL CONDUCTION HEATING</strong></td>
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<td>*In Situ</td>
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<td><strong>STEAM ENHANCED EXTRACTION</strong></td>
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<td><em>Steam Flushing</em></td>
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<td><em>Combined SEE and TCH/ERH</em></td>
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<td><strong>ELECTRICAL RESISTANCE HEATING</strong></td>
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<td><em>Three and Six-Phase Heating</em></td>
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Conceptual ISTR Setting

Courtesy of P. Hegele, Mc² Inc.
Conceptual ISTR Setting

Courtesy of P. Hegele, Mc² Inc.
Accurate Conceptual Model Very Important

- Geology
- Groundwater Flow
- Complete List of Chemicals
  - COCs
  - Other??
- Subsurface Utilities
- Source Area Definition
## Geologic Framework

- Stratigraphy
- Soil Type
- Organic Content
- Electrical Resistivity
- Rock Type
- Fracture Frequency and Orientation

<table>
<thead>
<tr>
<th>Geology</th>
<th>Low Temp Thermal</th>
<th>TCH Electric</th>
<th>TCH Gas</th>
<th>ERH</th>
<th>ET-DSP™</th>
<th>SEE</th>
<th>TCH/ERH with SEE</th>
<th>STAR</th>
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<tbody>
<tr>
<td>Sand and Gravels - Vadose Zone</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Maybe</td>
<td>Maybe</td>
<td>Maybe</td>
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<tr>
<td>Sand and Gravels - Saturated Zone</td>
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<td>Y</td>
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<td>Silt and Clay</td>
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<td>Heterogeneous Mixtures</td>
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<td>Interbedded/Layered Systems</td>
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<td>Saprolite</td>
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<td>Sedimentary Rock</td>
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<td>Maybe</td>
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<tr>
<td>Fractured Metamorphic/Igneous Rock</td>
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<td>Competent Rock</td>
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<td>Maybe</td>
<td>N</td>
</tr>
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Groundwater Flux

Important:
- Average K values may miss high flux zones
- >90% of flux occurs in less than 10% of the medium

• Account for range of flux in design
Complete List of Chemicals Present

- VOCs
- SVOCs
- PCBs
- PAHs
- TPH
- LNAPL
- DNAPL
- Metals too!

Known and Unknown Chemicals

Silresim Superfund Site, MA
Definition of Source Zone

- ISTR is a highly effective source zone treatment technology:
  - Treatment of high concentration DNAPL Zones
Definition of Source Zone

• ISTR is a highly effective source zone treatment technology:
  • Treatment of high concentration DNAPL Zones

• Proper implementation requires maintaining hydraulic and pneumatic control.
  • Note: there is almost always some mass flux in from outside the ISTR treatment zone.
Design of Heating, Extraction, and Treatment Strategies

Important to get it right the first time!

SRSNE Superfund Site, CT
Install an Insulated Vapor Cap

Johnson et al. (1990)
Install an Insulated Vapor Cap

• For this project, 336,500 kWh would have been lost without an R-6 vapor cap, representing $40,380 at $0.12 / kWh
Heating Outside Treatment Zone is Recommended

- 39 Heaters @ 15 ft spacing

Extent of Treatment Zone
Heating Outside Treatment Zone is Recommended

- 50 Heaters @ 15 ft spacing

Extent of Treatment Zone
Importance of Thorough Heating

- Co-boiling is the most significant mass removal mechanism at CVOC DNAPL sites
  - Vapor bubbles can contain high CVOC by mass (e.g., 90% for TCE)
  - Condensation will occur in cool zones

![Graph showing vapor concentration vs. temperature](image)

- Saturated Vapor
  - 700,000 ppmV – TCE
  - 300,000 ppmV – H2O
  - 90% TCE by Mass
  - 10% H2O
Importance of Thorough Heating – DNAPL Will Condense Out

Going from 80 to 20°C, the TCE saturated vapor concentration drops from 700,000 to 100,000 ppm.

Condensed DNAPL in Shallow Soils at a High Mass Site

Arnold AFB, TN
Designing a Robust Extraction and Treatment System

- VOCs
- SVOCs
- PCBs
- PAHs
- TPH
- LNAPL
- DNAPL
- Metals

Known and Unknown Chemicals!
Mass Recovery at a Pure TCE Release Site

153 kgs/day
Is
~3% of Total
Good “Rule-of-Thumb” to Estimate Peak Loading Rates

5,450 kgs of TCE

100°C
76°C
Co-Boiling

20°C
Estimated Starting Mass of 1M to 2M Pounds

Treat in phases to even out mass loading
Overlap phases to manage heating time

SRSNE Superfund site, Connecticut
Actual Mass Recovered 500,000 Pounds

Large Vapor Treatment System

SRSNE Superfund site, Connecticut

500,000 lbs removed
Conditioning of Vapor Stream For Phase Separation: *Vapor, Water, NAPL*
Conditioning Optimizes Performance of Granular Activated Carbon and Reduces Size of Treatment System
Vapor Treatment Options

Thermal Oxidizer

- Pass through w/ heat exchanger.
- Quench and scrubber required for CVOCs.
- Can handle high mass loading rates and wide range of chemicals.
- Good for moderate to high mass sites (>10,000 lbs).
- Requires natural gas, caustic, and discharge of scrubber blow-down.
Vapor Treatment Options

Steam Regen GAC

- 2 Bed design: one active, one in standby
- No quench or scrubber required for CVOCs.
- Can handle high mass loading rates and wide range of chemicals.
- Good for moderate to high mass sites (>10,000 lbs).
- Produces a NAPL that requires disposal

AMCO Superfund Site, CA: CVOCs and LNAPL
Vapor Treatment Options

Sacrificial GAC

- Multiple bed design: lead, lag, polish.
- Can handle wide range of chemicals.
- Good for low to moderate mass sites (<10,000 lbs).
- Requires conditioning front-end system.
- Stand-alone or as polishing / backup to primary system.

AMCO Superfund Site, CA: CVOCs and LNAPL
Pneumatic and Hydraulic Control Considerations
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Summary: A Good CSM is Critical To a Successful ISTR Project

- Geology
- Groundwater Flow
- Complete List of COCs and Other Chemicals
- Starting Mass
- Extent of COCs
- Subsurface Utilities
- Access Limitations

- Selection of optimal technology or combination
- Establishment of meaningful and achievable remedial goals
- Proper design of heating, extraction and treatment systems
- Accurate schedule and utility usage estimates