MGP Site Remediation Completed by In Situ Gas Thermal Remediation

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Outline of Presentation

(1) Introduction via Examples
   - Case 1: MGP site remediation (In-Situ)
   - Case 2: TPH-d/highly chlorinated contamination site remediation (Ex-Situ)

(2) Further Discussion
   - Advantages of GTR
   - Challenges of GTR
Example 1: Site Information

- Looking East at Basque Hotel Restaurant (Urroz Property)
- Looking East at Basque Hotel Restaurant Parking Lot
- Looking East at Office Building (Ford Property)
- Looking Southeast A&R Auto Sales Lot (Ford Property)
Example 1: Pilot Test Site

- **Area**: 400 ft\(^2\) * 20 ft bgs
  - Constituents and magnitude of impacts consistent with remaining portions of the site
- **COCs**: MGP waste, Benzo(a)Pyrene or equivalent, Naphthalene, Chrysene, TPH, and other VOCs
- **Lithology**: Silty sand and clay, highly heterogeneous
- **Setting**: Dirt/Gravel Parking Lot
- **Utilities Used**: Natural Gas and temporary electrical connection
Screening of Remediation Technologies
Screening of Remediation Technologies

- Thermal
- No Action
- Natural Attenuation
- Excavation
- Pump-Treat
- SVE
- Chemical Injection
- Chemical Flushing
- Bioenhancement

Land Development Tight Schedule
Screening of Remediation Technologies

- Thermal
- Bioenhancement
- Chemical Flushing
- Chemical Injection
- SVE
- Pump-Treat
- No Action
- Natural Attenuation
- Excavation

Land Development
Tight Schedule
Transportation / Disposal fee
Screening of Remediation Technologies

- Thermal
- No Action
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- SVE
- Bioenhancement
- Chemical Flushing
- Chemical Injection

Factors:
- Transportation / Disposal fee
- Land Development
- Tight Schedule
- Low Solubility
Screening of Remediation Technologies

- Low Permeability
- Highly Heterogeneous lithology
- Low Vapor Pressure
- Low Solubility
- Transportation / Disposal fee
- Land Development
- Tight Schedule

Thermal
- No Action
- Natural Attenuation
- Excavation
- Pump-Treat
- SVE
- Chemical Injection
- Chemical Flushing
- Bioenhancement

GEO Environmental Remediation Company
GTR = Gas Thermal Remediation

- Propane/Natural gas/Diesel as fuel to heat the thermal conduction heater wells.
- Soil and groundwater are heated indirectly through conduction. Treatment temperatures from \( \sim 100^\circ\text{C} \) to \( >400^\circ\text{C} \).
- Vaporized contaminants collected from extraction wells are routed to the appropriate vapor treatment module.
- Closed-loop in-situ thermal conduction heating system. No pollution emission into atmosphere.
Health and Safety

- Combustion air and contaminant vapor are in different close loops.
- No hot air or any injection to the ground. Only energy to ground.
- No contaminant release into atmosphere.

All vaporized contaminants are collected in vapor treatment system from extraction wells.

The combustion air into the atmosphere only include CO\textsubscript{2}/H\textsubscript{2}O (like home BBQ)

Only energy to the ground
In Situ Heating + Vapor Extraction = In Situ GTR
Heating Equipment
Heater Wells (co-axial)

TCU Inside

How GTR Works:
- Propane or natural gas is used to heat the air circulating within the pipes.
- Soil is heated indirectly through conduction.
- Vaporized contaminants are collected from extraction wells and routed to the appropriate vapor treatment system.

Temperature after the flame: 600-900°C

O₂% = 15-16.5%
CO < 50ppm

Outer tube
Inner tube
Vapor Treatment System
Remote Monitoring System

Remote site monitoring data are available on GEO’s website for both GEO and Client’s engineers and managers. Operation adjustment is conducted in time based on the monitoring results.

- Insufficient ground insulation
- Electricity interruption

![Graphs showing temperature changes with depth and dates]
Performance Evaluation Criteria: Temperature Evolution

1 Day of Heating
5 to 15 ft bgs, MGP Site, Fresno, CA
Well Distance = 6ft

GEO Environmental Remediation Company
What happens when Temperature increase

Vapor pressure
Viscosity
Desorption
Diffusion
Solubility

Biodegradation
Hydrolysis
Thermal Oxidation

Source: Modified from Huling, S.G., and J.W. Weaver 1991
Final Results

- Pre-treatment samples collected during infrastructure installation (9/2013)
- Post-treatment samples collected prior to system shutdown (3/2014)*

*VOC samples collected with Terracores and cooled immediately to eliminate the potential for VOC loss during sampling
System Usage and Mass Reduction

**Input:**
- Natural Gas: $1.78 \times 10^4$ therms
- Electricity: $6.39 \times 10^4$ KWh

**Output:**
- Contaminant Reduction:
  - TPH-d and TPH-mo: 100%
  - BaP equivalents: 99.7%
- Off-Gas Treated: $6.81 \times 10^6$ cubic feet
- Water Treated: 16,400 gallons
- VGAC Utilized: 1,500 pounds
Conclusions

1. Meets DTSC’s goals for more sustainable MGP remediation
2. GTR contained and captured all vapors
3. Schedule extended due to electrical interruption and higher soil moisture content
4. Cost-effective vs. excavation for deep impacts
5. Provided specific kinetic information for full scale design
6. Limited risk to Client (guaranteed scope of work from GEO). Client costs would only be for mob/demob, energy, oversight and sampling/analysis, if unsuccessful
7. GTR is a sustainable and risk mitigating remedial approach
1. Higher water content of soil than expected impacted heating schedule – recommend provide greater density of sampling for moisture content

2. Electrical interruption caused down time, and thereby impacted system heating capabilities (downed power line away from the site) – recommend providing backup generators

3. Longer heating duration increased heat lost to surface – installed thermal blankets. Recommend higher R value ‘air entrained’ material to improve overall thermal efficiencies
Example 2: Ex-Situ GTR

Central Valley California

- Target Temperature: 200°C
- Thermal Treatment Duration: 39 days
- Treatment Goal: Reduction of more than 30,000 mg/kg to less than 100 mg/kg Diesel
Ex-situ: PAHs site in France

- Contaminants: PAHs and Heavy Hydrocarbons > 50,000 mg/kg
- Geology: Clay, sand  
  Volume: 620 m³
- Treatment Time: 37 days  
  Target Temperature: 200°C
- Challenges: Treatment area surrounded by residences on three sides
- Heating Tubes: 15
- Return Tubes: 5
- Remedial Goal: < 50 mg/kg
- Remedial Result: Avg. Concentrations < 25 mg/kg
- Both Performance and Time Guarantees Achieved
No onsite electricity required

Small Generator

- 25 – 60 kVA
- Gas or Diesel

Project Site in Netherlands
February 2012
Advantage 1: Versatility

Heat Transport Equation:

\[ q^\alpha_x = -k \left( \frac{dT}{dx} \right) \]

Where:
- \( q^\alpha_x \) = heat energy flux in the \( x \) direction (W/m²)
- \( k \) = thermal conductivity (W/m·K)
- \( \frac{dT}{dx} \) = temperature gradient in the \( x \) direction (K/m)

<table>
<thead>
<tr>
<th>Soil</th>
<th>Thermal Conductivity (( \lambda )) [W/m/K]</th>
<th>Hydraulic Conductivity (( K )) [cm/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay (dry)</td>
<td>0.15-1.8</td>
<td>( 10^{-5}-10^1 )</td>
</tr>
<tr>
<td>Water saturated clay</td>
<td>0.6-2.5</td>
<td>( 10^2-10^5 )</td>
</tr>
<tr>
<td>Sand</td>
<td>0.15-0.77</td>
<td>( 10^4-10^7 )</td>
</tr>
<tr>
<td>Water saturated sand</td>
<td>2-4</td>
<td>( 10^4-10^7 )</td>
</tr>
<tr>
<td>Gravel (dry)</td>
<td>0.7</td>
<td>( 10^{10} )</td>
</tr>
<tr>
<td>Water saturated gravel</td>
<td>1.7-4</td>
<td>( 10^{-7}-10^7 )</td>
</tr>
<tr>
<td>Fractured Bedrock</td>
<td>1.4-4.0</td>
<td>( 10^{-7}-10^7 )</td>
</tr>
</tbody>
</table>

\[ \frac{Clay}{Sand} = \frac{1.3}{0.52} = 2.5 \]

\[ \frac{Sand}{Clay} = \frac{10^4}{10^{-4}} = 100,000,000 \]
## Advantage 1: Versatility

<table>
<thead>
<tr>
<th>Level of Heating &amp; Contaminant</th>
<th>TTT (Target Treatment Temperature, °C)</th>
<th>Heating Well Spacing (m)</th>
<th>Heating days to TTT</th>
<th>Desiccation of Zone?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. VOCs:</strong> (Benzene, DCE, etc)</td>
<td>&lt;100</td>
<td>2.5-5.0</td>
<td>10-60</td>
<td>No</td>
</tr>
<tr>
<td><strong>2. VOCs</strong> (BTEX, TCE, PCE, gasoline, partial diesel, etc)</td>
<td>100</td>
<td>1.8-3.0</td>
<td>21-90</td>
<td>No</td>
</tr>
<tr>
<td><strong>3. SVOCs</strong> (motel oil, MPG, PAHs, PCBs, dioxins, etc)</td>
<td>&gt;100</td>
<td>1.5-2.2</td>
<td>80-150</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Advantage 2: Flexibility

- **Faster** (Rapid mobilization, smaller footprint, & no electrical installation)
- **Scalable** (Can be applied to very small and very large projects)

"No Job Too Big or Too Small"
Advantage 2: individual burners

- **Low energy consumption**
  - 100 -150 kWh per ton of soil treated
  - Energy efficiency: >85%

- **Safety**
  - Totally enclosed design
  - Low power (40 kW)

- **Easy to move (30 - 45 pounds)**
  - Modular grid and zone pre-heating approaches

- **Maximum control and flexibility**
  - Length, number, orientation, timing, temperature
  - Each burner is independent and controlled via PLC

- **Reliability**
  - Easy replacement in the field = no heating downtime
Advantage 3: Performance Guarantee

- Fast (2 – 6 months)
- Highly predictable results
- No vapor emission, No unwanted mobilization
- Minimal Neighborhood impact
Advantage 3: Performance Guarantee

Chemical injection or bioremediation may rebound post-remediation due to untreated contaminant mass in the less permeable soil bleeds back out and re-contaminates the more permeable zones.

No Rebound → Less long term cost
Challenge 1: Remediation Goal

Economically applicable to source zone: NAPLs, high concentration soil. Remediation goal is usually set as NAPLs removal and soil concentration reduction.
Challenge 1: Groundwater Goal

It needs to be very careful if **groundwater** is selected as remediation goal:

1. Sampling time selection
2. Invasion from outside treatment zone
Challenge 2: Site Condition

- Water is an important effect on thermal selection.

Humidity in Vadose zone

GW velocity at Saturated zone:

Dewatering needs to be designed if GW > 1 ft/day or 1E-3 cm/s
Challenge 2: Site Condition

Underground utility lines
Drench
Monitoring wells with PVC tube
# Challenge 3: Cost

## ISTD Project Estimates

<table>
<thead>
<tr>
<th>Surface (m²)</th>
<th>Avg. Depth (m)</th>
<th>Volume (m³)</th>
<th>Pollutant</th>
<th>Difficulty?</th>
<th>Total Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>62</td>
<td>4</td>
<td>248</td>
<td>TPH</td>
<td>normal</td>
<td>$43,500</td>
</tr>
<tr>
<td>23</td>
<td>14</td>
<td>322</td>
<td>CVOCs + TPH</td>
<td>normal</td>
<td>$90,350</td>
</tr>
<tr>
<td>3551</td>
<td>9</td>
<td>31959</td>
<td>TPH</td>
<td>normal</td>
<td>$3,770,000</td>
</tr>
<tr>
<td>1263</td>
<td>9</td>
<td>11367</td>
<td>CVOCs + TPH</td>
<td>ATEX zone</td>
<td>$2,262,325</td>
</tr>
<tr>
<td>80</td>
<td>12</td>
<td>960</td>
<td>Creosote + TPH</td>
<td>LNAPL present</td>
<td>$277,550</td>
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<tr>
<td>125</td>
<td>7</td>
<td>875</td>
<td>CVOCs + TPH</td>
<td>incl. saturated</td>
<td>$237,250</td>
</tr>
<tr>
<td>60</td>
<td>5</td>
<td>300</td>
<td>CVOCs</td>
<td>normal</td>
<td>$57,200</td>
</tr>
<tr>
<td>45</td>
<td>6</td>
<td>270</td>
<td>SVOCs + PAHs</td>
<td>under building</td>
<td>$55,250</td>
</tr>
<tr>
<td>73</td>
<td>4</td>
<td>292</td>
<td>Mercury; SVOCs</td>
<td>under building</td>
<td>$189,150</td>
</tr>
</tbody>
</table>

Prices are all inclusive (drilling, installation, energy/utilities, and operations).
Challenge 3: Cost

Both remediation goal and site condition affect the cost. Other important factors include:

**Factor 1: COCs**

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Challenge 3: Cost

- Factor 2: Design of heating wells spacing
Summary

GTR © ISTCH System:

1. **Applicability**: soil temperatures < 70°C to > 325°C
2. **Speed**: Mobilize and commence GTR operations in Weeks
3. **Scalability**: small pilots to acre size projects
4. **Economics**: No waiting/paying for electrical utilities, transformers, switchgear, third party inspections.
5. **Guarantees** available
Questions?

http://www.georemco.com/

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