Leachate-Focused Remediation Strategy for Bunker-C Contaminated Site Using Chemical Oxidation

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In general remediation strategies try to achieve 3 goals:

- Reduce risk of toxic impacts to human (or other) receptors
- Restore usability of site according to natural vocation or urban planning
- Reduce risk of unpleasant odors/flavors in groundwater

Assumption 1): higher HC conc. leads to higher toxicity/leachates or other impacts (for example fertility)
Assumption 2): reducing HC conc. to sufficiently low level will reduce or eliminate those impacts (to acceptable levels)

What if the impacts could be reduced without concentrating on HC conc., but the impacts themselves? (save $$$)
Treatment focused on reducing the impact (easier) than the HC conc.
Site: Bunker-C Contaminated Soil In a Thermal-Electric Plant

- Bunker-C fired thermal-electric plant (1963) converted to gas in 1990s
- Demolition of old fuel tanks, boilers, fuel distribution area to build new plant and double capacity
- Underlying soil contaminated with weathered fuel oil in sandy loam soil ~2.5 - 3% TPH (heavy oil range)

- Very low toxicity, almost null volatility, but potential to leach and contaminate ground water → aesthetic characteristics priority
- Site was actually remediated to 9,600 mg/Kg with chem-ox, but....

- Could it have been remediated more efficiently with less cost by concentrating the remediation strategy directly at reducing soil leachate potential???
  - → objective of this study
• Soil was collected from the site and water added to 30% moisture
• H$_2$O$_2$ was added (30% w/v solution) until final concentrations of: 0.1, 0.2, 0.3, 0.6 and 1.2% w/w of the reagent in soil (3 pseudo-replicates)
• Well mixed and later, air dried
• Water repellency measured by MED and WDPT as per Adams et al. 2008
• TPH measured by EPA 418.1 using PCE for solvent with calibration curve made with oil from site
• TPH measured also measured TCLP extracts
Initial Soil Conditions

Table 1. Untreated soil characteristics

<table>
<thead>
<tr>
<th>Sample</th>
<th>pH</th>
<th>SOM (%)</th>
<th>EC (dS/m)</th>
<th>Sand (%)</th>
<th>Clay (%)</th>
<th>Silt (%)</th>
<th>FC (%)</th>
<th>BD (kg/m³)</th>
<th>TPH (mg/kg)</th>
<th>LP (mg/l)</th>
<th>MED10 (M)</th>
<th>WDPT (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>8.2</td>
<td>13.2</td>
<td>0.6</td>
<td>32.0</td>
<td>16.0</td>
<td>52.0</td>
<td>19.3</td>
<td>976.4</td>
<td>31,785</td>
<td>4.3</td>
<td>4.6</td>
<td>3,270</td>
</tr>
<tr>
<td>SD</td>
<td>0.2</td>
<td>0.01</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>423.15</td>
<td>0.59</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Water Repellency

- Water repellency reduces effectiveness of water based reagents.
- Reducing water repellency may increase effectiveness.
- Measured as the Molarity of Ethanol in a drop that can penetrate soil in less than 10 seconds (MED).
- Or time for pure water to infiltrate (Water Drop Penetration Time – WDPT).

Graph:
- The graph shows the relationship between hydrogen peroxide concentration and water drop penetration time (WDPT).
- The equation is $y = 388.759x^{-0.456}$ with $R^2 = 0.995$.
- The x-axis represents hydrogen peroxide concentration (%), and the y-axis represents WDPT (s).
- The graph delineates the severity of repellency, with points indicating samples in strongly and severely repellent categories.
Hydrocarbon Concentrations in Soil

- 35% reduction in TPH in soil
- Rate decreases - less available?
- Oxidized crusts?
Hydrocarbon Concentrations in Leachates

- 82% reduction in TPH in leachates!
- does not level off as much

\[
y = 4.452e^{-1.436x} \\
R^2 = 0.982
\]
Comparison of Soil TPH and Leachates

- **1st phase:**
  - 27% reduction in TPH
  - 24% reduction in HC in leachates

- **2nd phase:**
  - 15% reduction in TPH
  - 76% reduction in HC in leachates!
  - Acceptable leachates at ~2.1% TPH vs. 1% (10,000 ppm)
Conclusions

1) At only 1.0% w/w H₂O₂ a concentration of petroleum hydrocarbons in leachate safe for human consumption (< 1mg/l) could be obtained even with a final hydrocarbon concentration in soil >2%.

2) Alternative strategy focused on direct impacts (leachates) vs. TPH in soil allows for site remediation at higher TPH levels → much less cost
Conclusions

- Actual on-site processing times approx. 2 – 4 weeks → could have been reduced by about 1/2
- Could have used about 1/3 – 1/5 less reagent → save money, time
- Actual TPH reduction of 65 – 85% → could have been reduced to only 35%

Optimization using:
1) lab/field test for reactant ratios
2) Specialized equipment designed for mixing (ALLU)
Conclusions

• Probably longer but possible up to 70,000 ppm initial TPH

• Complications with higher concentrations, especially in asphaltenes contaminated soil

→ formation of oily crust?

Importance of really focusing on what is the problem
(rather than on some TPH number)
Thank you for your attention