1,4-Dioxane Treatment using Electrical Resistance Heating

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Stantec
Electricity is directed into the subsurface area.

TRS ERH PROCESS

TRS Power Control Unit
Electricity is directed into the subsurface area.
1,4 Dioxane – ERH Projects

Los Angeles, CA

Before ERH
140 ug/L

After ERH
5 ug/L

96.5% Removal

Before ERH
1,000 to 90,000 µg/L

After ERH
All <50 ug/L

>99.8% Removal

Confidential Client
1,4-Dioxane and Water Chemistry

Source: Scheider and Lynch, J. Am. Chem. Soc., 65(6), 1943
1,4-Dioxane and Water VLE

Source: Scheider and Lynch, J. Am. Chem. Soc. 65(6), 1943

Linearity at Low Concentrations
Allows for Modeling by Henry’s Law
Vapor-Liquid Mass Ratios

The V-L Mass Ratio Increases Substantially as 1,4-Dioxane Concentrations Decrease

Source: Scheider and Lynch, J. Am. Chem. Soc., 65(6), 1943
Henry’s Law Constant - Experimental Determination

Methodology

Henry’s Law – 1,4 Dioxane

Source: Stantec - Internal R&D Testing Report
1,000 scfm steam
1,500 scfm air

1,500 scfm air
1,600 ppb 1,4-Dioxane
= 0.12 lb/day

5 gpm condensate
94 ug/L 1,4-Dioxane
= 0.006 lb/day

95% of the 1,4-dioxane mass was conveyed into the vapor phase where it was effectively removed onto vapor phase granular activated carbon.

Only 5% of the 1,4-dioxane mass remained in the condensed steam.
Henry’s Law Data – Experimental vs. ERH Field Data

Henry’s Law

\[
\frac{5 \text{ gpm} \times 3.785 \frac{l}{\text{gal}}}{5 \text{ gpm} \times 3.785 \frac{l}{\text{gal}} + 0.009 \times 1500 \text{ scfm} \times 28.32 \frac{l}{\text{ft}^3}} \times 100\% = 4.7\%
\]

95.3\% mass transfers to vapor phase
4.7\% mass remains in condensate

To increase mass transfer to vapor phase.....
increase the extracted air flow
1,4-Dioxane Adsorption

Source: Stantec - Internal R&D Testing Report
1,4-Dioxane VLE Lab Study - Water

• Start with 1,000 mL of 26 mg/L 1,4-dioxane solution
• Boil solution down while collecting L and V samples
• Analyze samples using EPA Method 8260B (3 ug/L Detection Limit)
VLE Lab Study Results - Water

<table>
<thead>
<tr>
<th>Sample</th>
<th>1,4-dioxane (mg/L)</th>
<th>% Water Boiled</th>
<th>% Concentration Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting Concentration</td>
<td>26</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Liquid Sample 1</td>
<td>8.0</td>
<td>13.2%</td>
<td>69.23%</td>
</tr>
<tr>
<td>Liquid Sample 2</td>
<td>0.285</td>
<td>39.5%</td>
<td>98.9%</td>
</tr>
<tr>
<td>Liquid Sample 3</td>
<td>0.016</td>
<td>65.8%</td>
<td>99.94%</td>
</tr>
<tr>
<td>Liquid Sample 4</td>
<td>0.0063</td>
<td>98.7%</td>
<td>99.98%</td>
</tr>
<tr>
<td>Condensate 1</td>
<td>230</td>
<td>13.2%</td>
<td>N/A</td>
</tr>
<tr>
<td>Condensate 2</td>
<td>36</td>
<td>39.5%</td>
<td>N/A</td>
</tr>
<tr>
<td>Condensate 3</td>
<td>3.4</td>
<td>65.8%</td>
<td>N/A</td>
</tr>
<tr>
<td>Condensate 4</td>
<td>0.585</td>
<td>98.7%</td>
<td>N/A</td>
</tr>
</tbody>
</table>
# 1,4-Dioxane ERH Lab Study – Soil*

<table>
<thead>
<tr>
<th>Sample</th>
<th>Steaming Energy Density (kWh/yd³)</th>
<th>Results 1,4-dioxane (mg/Kg)</th>
<th>Percent Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting Concentration</td>
<td>0</td>
<td>5.4</td>
<td>0%</td>
</tr>
<tr>
<td>20% moisture boiled</td>
<td>75</td>
<td>0.67</td>
<td>87.6%</td>
</tr>
<tr>
<td>45% moisture boiled</td>
<td>169</td>
<td>&lt;0.58</td>
<td>&gt;89.3%</td>
</tr>
<tr>
<td>80% moisture boiled</td>
<td>300</td>
<td>&lt;0.51</td>
<td>&gt;90.6%</td>
</tr>
</tbody>
</table>

*Soil samples provided by NAVFAC SW*
Assumes 60 kWh/yd³ specific heat and 35% heat loss to surroundings during ERH. Cost for treatment likely to fall into the range of $150 to $300 per cubic yard.
Advantages over Pump and Treat

- 90% reduction achieved in 0.5 pore volume removal for ERH vs 20+ pore volume removals for P&T
- Condensate does not contain Fe, Mn or carbonates and it has lower 1,4-dioxane concentrations
- Most of the 1,4-dioxane is conveyed into vapor phase
- Cleanup occurs in several months vs several years
- ERH works great in low permeability soils
Conclusions

• 1,4-Dioxane can be remediated using ERH

• Design Targets:
  • ~ 220 kWh/yd³ for 90%
  • ~ 330 kWh/yd³ for 99%
  • ~ 440 kWh/yd³ for 99.9%

• Majority remains in vapor-phase

• Condensate residuals treated by POTW or easily treated with advanced oxidation processes

• Advantages over pump-and-treat include:
  • Significantly less water to treat
  • Lower aqueous concentrations of 1,4-dioxane
  • Less inorganic and organic interference for water treatment
  • Cleanup occurs in months rather than years