Surgical In-Situ Chemical Oxidation Remediation Utilizing a High Resolution Site Characterization-Driven Approach to Optimize Reagent Delivery and Remediation Strategy

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Some Reasons In-Situ Remediation Can Fail

- Lack of detailed characterization data (especially in source zones), relying on monitoring well data for site characterization and design
- Lack of information regarding mass vs. lithology and hydraulic conductivity of target intervals
- Inadequate subsurface reagent distribution
- High expectations not taking into consideration rebound from back diffusion
High Resolution Profiling

• Tools: Membrane Interface Probe (MIP), Hydraulic Profiling Tool (HPT), Electrical Conductivity (EC), Laser Induced Fluorescence (LIF)
  – Lack of vertical characterization data => MIP
  – Lack of information regarding mass vs. lithology/hydraulic conductivity => MIP/HPT
  – Lack of understanding regarding subsurface reagent distribution => EC
  – Poor expectations regarding rebound from back diffusion => MIP/HPT
Project Summaries

- **Site 1: VA Dry Cleaner**
  - Direct Sensing Technologies: Membrane Interface Probe (MIP), Electrical Conductivity (EC) radius of influence verification
  - Remediation Strategy: In Situ Chemical Oxidation (ISCO) injection with potassium permanganate (KPmag)

- **Site 2: NC Former Retail Gas Station**
  - Direct Sensing Technologies: MIP, EC radius of influence verification
  - Remediation Strategy: ISCO injection with high pH activated Klozur (sodium persulfate)

- **Site 3: ON Manufacturing Site**
  - Direct Sensing Technologies: MIP, EC radius of influence verification
  - Remediation Strategy: ISCO injection and in situ mixing with High pH activated Klozur (sodium persulfate)
Site #1 – Base Design

• VA (DC Metro) Dry Cleaner
  – Risk based goal of 100 ppb PCE at property boundary
• Preliminary design based on well data
  – Wells screened 3-6 m bgs, GWT @ 2.4 m bgs => Injection zone = 2.4-6 m bgs
  – Injection Footprint = 600 m²
  – 1,920 kg Potassium Permanganate specified based on COCs and estimated PNOD, @ 1% solution = 190,000 Liters
Site #1 – Optimized Design

- Optimized Approach
  - Pilot Phase (4 days)
    - MIP (1.5 days)
    - 3D imaging
    - Confirmation Sampling/PNOD Sample Collection (0.5 days)
    - Injection Testing (2 days)
      - Determine flow rate and pressure vs. depth
      - Determine ROI (EC + visual)
  - Full Scale Injection (9 days)
Site #1 – MIP Imaging

ECD Greater Than
1.03E+006 μV

Well Screen Zone
Site #1 – Optimized Design

• Revised Design
  – Design based on MIP data, discrete groundwater sampling, lab determined PNOD, and ROI from pilot test
  – Injection zone varied per MIP cross section
  – Permanganate concentration varied based on discrete sampling data
  – Injection Footprint = 460 m$^2$ (-140 m$^2$)
  – 2,169 kg (+13%) KPmag specified based on new COC concentrations and PNOD, @ 1-2% solution = 119,000 L (-38%)
Site #1 – Optimized Design

**Plume Area A**
Injection Zone = 5.5-6.7 m

**Source Area**
Injection Zone = 2.1-6.7 m

**ECD Greater Than**
1.00E+006 μV

- 1,300 ppb
- 200 ppb
- 150 ppb
- 300 ppb
- 300 ppb = [PCE]
### Site #1 – Data Summary

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Site #1 – Next Steps

- **Path Forward**
  - Additional MIP investigation in area of MW-3
  - Directional injection or angle borings to overcome access issues
Site #2 - Base Design

- NC, Confidential Location
  - Risk based goal of 5,000 ppb Benzene
  - Original design based on monitoring well data and TPH-GRO soil data
  - Wells screened 3-6 m bgs, GWT @ 3 m bgs => Injection zone = 3-6 m bgs
  - Injection Footprint = 230 m$^2$
  - 8,900 kg sodium persulfate (SP) specified based on COCs and estimated SOD, @ 12% solution = 70,000 L (100% mobile porosity injected)
Site #2 – Optimized Design

- Optimized Approach
  - Pilot Phase (4 days)
    - MIP (2 days)
    - 3D imaging
    - Confirmation Sampling/SOD/pH buffering Sample Collection (0.5 days)
  - Injection Testing (1.5 days)
    - Determine flow rate and pressure vs. depth
    - Determine ROI (EC)
  - Full Scale Injection (6 days)
Site #2 – MIP Imaging
Site #2 – Optimized Design

• Revised Design
  – Revised design based on MIP data and discrete soil samples
  – Injection zone = 3.7-5.2 ft bgs or 3.7-6.1 m bgs
  – Injection Footprint = 280 m² (increase from 230 m² to include additional mass identified with the MIP)
  – 4,700 kg (-47%) SP based on COCs and known SOD, @ 12% solution = 43,000 L (-39%)
Site #2 – Equipment Photos
ROI Verification Using EC

• EC can be used to track reagent distribution provided that the reagent or tracer provides a response over the baseline geological response

• Examples of reagents that can be tracked:
  – Sodium Persulfate, Sodium Percarbonate, Sodium and Potassium Pmag, Sodium Bicarbonate, Sodium Lactate
# Site #2 – Data Summary

## MW-5R

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<th>Benzene</th>
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<th>Xylene (total)</th>
<th>Methyl Tert Butyl Ether</th>
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## MW-8R

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<th>Methyl Tert Butyl Ether</th>
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Site #3 – Base Design

- COCs: BTEX, C6-C10
- MIP work performed by another contractor
- Initially scoped as injection project
Site #3 – MIP Imaging
Site #3 – Optimized Design

- Groundwater (Plume): Caustic Activated SP Injection
- Groundwater (Source): Caustic Activated SP In Situ Mixing
- Vadose Soil (Source): Excavation/Offsite Disposal
Site #3 – Optimized Design
Site #3 – Project Photographs
Conclusions

• High Resolution tools, when applicable, are critical to developing accurate and dynamic Conceptual Site Models and effective remedial designs.

• The tools allow you to understand how the geology/hydrogeology impacts contaminant distribution and the potential for rebound/back diffusion to set realistic expectations for remediation.

• ISCO application iterations are more precise and targeted.

• Lower life cycle cost savings over traditional sampling and design methods.
Questions?

Thank you!

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