Coupling Oxidative and Reductive Treatment Technologies for Integrated Site Remediation

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Source Area
TCE 200,000 μg/L

Plume Area extends 287 m from source
Site-Specific Challenges

• Very concentrated source area
  – \( TCE > 200,000 \ \mu g/L \)

• Low permeability saprolite over fractured rock
  – \textit{Strong contrast in mass flux/discharge rates}

• Large offsite plume area with limited access
  – \textit{Steep hill, forested area}

• Very little natural attenuation

• Remedy complete (MCLs) in 20-yr timeframe
Couple ISCO and ISCR

Source Area
Permanganate ISCO

Plume Area
3 ZVI Barriers
Source: In-Situ Chemical Oxidation

- Direct, rapid attack of source
- Potassium permanganate solid slurry injection
  - Low permeability & deep depth
  - Wide horizontal distribution of solid
  - Dissolves slowly (>2 years)
  - Vertical diffusion between injection intervals
Plume: In-Situ Chemical Reduction

- Barrier design due to limited access
- Deflection of flow into horizontal treatment zones
- Granular ZVI – long lifetime (>10 years)
- Solid slurry injection
  - Low permeability & deep depth
  - Does not migrate
Quantitative Design Considerations

• Source Area
  – Permanganate degradation downgradient
  – Vertical diffusion between injection intervals
  – Radial distribution and injection point spacing

• Plume Area
  – Vertical distribution of injection intervals
  – Spacing between points within a barrier
  – Spacing between barriers (advection/desorption)
Permanganate Pilot Test

• Two injection locations
  – 1 bedrock and 4 saprolite intervals
  – 5 saprolite intervals
• 12,700 kg KMnO₄ / sand blend
• 7 field days
• 18 months monitoring to date
Wells <8 m from Injection Points

Permanganate detected

TCE Concentration (μg/L)

7/1/2011 12/31/2011 7/1/2012 12/31/2012
ZVI Pilot Test

- 14 Field days
  - 5 borings / 46-m barrier
  - 5-7 fractures per boring
  - 66 metric tonnes ZVI
- 3 Post-injection borings
- 22 months monitoring to date
ZVI Pilot Test Layout

Zero-valent Iron Barrier

Two Monitoring Well Clusters

9 m
3 Post-Injection Test Borings

Depth (ft below grade) | Lithology | Magnetic Susceptibility Meter Readings (dimensionless)

0 |  | 0
10 |  | 10
20 |  | 20
30 |  | 30
40 |  | 40
50 |  | 50

End of Borring 50 ft

Geo-Cleanse® INTERNATIONAL, INC.
Saprolite Well Results

MW-32 (West)

MW-5 (East)

VOC Concentration (μg/L)


VOC Concentration (μg/L)


TCE

cis-DCE
Bedrock Well Results

MW-33 (West)

MW-34 (East)

VOC Concentration (μg/L)

TCE

cis-DCE


Pilot Test Conclusions

• Source area permanganate pilot
  – Approximately 8 m radius of influence
  – Permanganate still present (18 months)
  – 2-3 orders of magnitude reductions
  – Source dispersal pattern
    • Not towards ZVI barriers in pilot test area
Pilot Test Conclusions

• Plume area ZVI pilot
  – Approximately 4.5 m radius of iron distribution
  – Distribution confirmed by test borings
  – 1-2 orders of magnitude reductions
  – Forming cis-DCE
  – Need to increase iron loading, decreasing spacing
Full-Scale (July 2013)

Source Area
Permanganate ISCO
8 Borings
38 metric tonnes perm / sand blend

Plume Area - 3 ZVI Barriers
65 Borings / 227 intervals
392 metric tonnes ZVI