

DPT Jet Injection for Remediation of Low-Permeability Zones: Full-Scale Case Study Results from 3 Years of Treatment

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Partners in Developing DPT Jet Injection



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DPT Jet Injection Provides:

- <u>Better Control</u>: Flat Fractures and Limited Surfacing
- <u>Competitive Cost</u>: \$60-150/CY for ZVI treatment



Problem Statement: Develop Better Injection Technology to Treat Contaminants in Clay

Method development partially funded by Danish government. Why?

• 40% Denmark covered in highly fractured clay till.





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- 40% Denmark covered in highly fractured clay till.
- Hundreds of chlorinated solvent sites.



Clay till + solvents = long-term source zones

Applicability in US and Canada

Remediating low-permeability sites is a major challenge for US and Canadian Sites.





http://ftp.maps.canada.ca/pub/nrcan_rncan/publications/ess_sst/295/295462/gsccgm%5f195%5fb%5f2014%5fmn01p1.pdf http://pubs.usgs.gov/of/2003/of03-275/USGS_OFR03-275.pdf Surficial Geology of North America

Jet Injection Compared to Traditional DPT Injections



Injecting remediation amendment slurries using traditional direct push methods often results in uncontrolled fracturing of the subsurface. DPT Jet Injection overcomes this limitation.



CREATIVE THINKING EXCEPTIONAL SOLUTIONS



Direct push tooling advancement











Slurry contains solid proppant which is emplaced to create a reactive <u>and</u> more permeable zone.





DPT Jet Injection – Applications

- Demonstrated in clay till (Maine, Ohio, Denmark) and saprolite (Georgia and South Carolina)
- Effective in heterogeneous low-permeability formations
- Capable of emplacing wide range of powdered, granular, and liquid amendments:
 - nZVI, mZVI, Granular ZVI
 - Solid and Liquid-Phase Electron Donors
 - Persulfate, Permanganate
 - Carbon-based amendments





































































Objective







CASE STUDY: Full-scale Source Treatment in Denmark

CREATIVE THINKING EXCEPTIONAL SOLUTIONS

Case Study – Remedial Design

- 700 sq meter Target Treatment Area (TTA)
- 4 m design ROI
- 21 injection locations with 121 individual injections
- 5-7 discrete injection depths
- 50 tonnes mZVI (Hepure Ferox Flow)
- 25 tonnes sand





Case Study – Surfacing



Surfacing during injection was limited to 4 known historical borings and 2 other locations during 121 injections.

Surfacing during slurry injection can be controlled!!





CASE STUDY: ZVI Distribution

CREATIVE THINKING EXCEPTIONAL SOLUTIONS

Case Study – Lateral Fracture Distribution

- Advanced 80 borings in TTA
- Confirmed that we met our 4 m design ROI







Case Study: Tracing Single Fractures



Case Study: Mapping Overlap w/ Multiple Tracers



Case Study: Distribution of Fractures – 3D Modeling

METHODOLOGY

- 3D modeling (EVS software) was utilized to interpolate magnetic susceptibility (MS) readings.
- Interpolated MS readings >1x10⁻³ were generally colocated with visual identification of ZVI-filled fractures.



Lateral Distribution of Horizontal Fractures – Cross Sections





Case Study – 3-D Print of Distribution





CASE STUDY: Treatment Results

CREATIVE THINKING EXCEPTIONAL SOLUTIONS

VOCs in Soil – 6, 18, and 30 month Post-Treatment Profiles



TCE in Soil – Baseline and 30 month Post-Treatment



Distribution of Total VOCs in Soil – Baseline, 18 months, 30 months Post-Treatment



Distribution of Total VOCs in Soil – Baseline, 6 months Post-Treatment



Legend: Total CVOC Concentration Sum total CVOC Mass/Grid (mg/kg) Column (kg) ≤1 0.000000 - 0.001000 >1 and ≤5 0.001001 - 0.002000 >5 and ≤10 0.002001 - 0.004000 >10 and ≤20 0.004001 - 0.008000 >20 and ≤40 0.008001 - 0.010000 >40 0.010001 - 0.020000

Distribution of Total VOCs in Soil – Baseline, 6, 18, 30 months Post-Treatment



Mass Discharge VOCs in Groundwater from TTA



Case Study Conclusions

- DPT Jet Injection shown to be extremely effective for emplacing amendments in challenging low permeability formations.
- Total TCE mass in soil decreased by 93% after 30 months.
- Total VOC mass in <u>soil</u> decreased by 82% after 30 months.
- Total VOC mass discharge in groundwater decreased by 89% after 36 months.
- Increasing ethane/ethene concentrations demonstrate complete degradation (max. ethane conc. In 2017 = 7.8 mg/L).
- Lesson Learned: Bioaugmentation at beginning could have provided faster complete treatment in the first 2 years, limiting cis-DCE formation.



Advantages of DPT Jet Injection

- Better Control: Flat Fractures and Limited Surfacing
- <u>Reduced Injection Time</u>: Faster than standard DPT injection approaches
- Works reliably at shallow depths and in heterogeneous formations
- Injection of long-term amendments like ZVI can result in <u>semi-passive</u> <u>treatment</u> of long-term source zones
- <u>Competitive Cost</u>: When compared to other methods commonly used for treating low-permeability zones (e.g., thermal, excavation)

\$60-150/CY for ZVI treatment



Questions?

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