DPT Jet Injection for Remediation in Clay Till: Full-Scale Case Study Results from 4 Years of Treatment

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Partners in Developing DPT Jet Injection
Two Key Take Home Points

DPT Jet Injection Provides:

• Better Control: Flat Fractures and Limited Surfacing

• Competitive Cost: $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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Method development partially funded by Danish government.

Why?
• 40% Denmark covered in highly fractured clay till.
• Hundreds of chlorinated solvent sites.

Clay till + solvents = long-term source zones
Remediating low-permeability sites is a major challenge for US and Canadian Sites.

Source:
Injecting remediation amendment slurries using traditional direct push methods often results in uncontrolled fracturing of the subsurface. DPT Jet Injection overcomes this limitation.
DPT Jet Injection – How does it work?
DPT Jet Injection – How Does it Work?

Direct push tooling advancement
DPT Jet Injection – How Does it Work?

10,000 psi water jetting
DPT Jet Injection – How Does it Work?

10,000 psi water jetting

Path of jet cutting across saprolite
DPT Jet Injection – How Does it Work?

100 to 400+ psi slurry injection
Slurry contains solid proppant which is emplaced to create a reactive and more permeable zone.
DPT Jet Injection – Applications

- Demonstrated in clay till (Maine, Ohio, Denmark), silt and clay (Louisiana, New Jersey, North Carolina) 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
  - Apatite II (metals stabilization)
Conceptual Model – Treatment with DPT Jet Injection

- Redox Boundary
- Silty Sand
- Dense Gray Till
- Sand Aquifer
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Diagram showing the treatment process with DPT Jet Injection.
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Objective
CASE STUDY: Full-scale Source Treatment in Denmark
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

5 to 80 mg/kg VOCs (mostly TCE)
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: Denmark – ZVI Distribution
• Advanced 80 borings in TTA
• Confirmed that we met our 4 m design ROI
Case Study: Tracing Single Fractures

Depth below ground surface (meters)

Distance from the injection point (meters)

Injection Characterization Soil Borings

North

Ground Surface

Injection Location I-10

South

Distance 3 m Thickness 3 mm
Distance 2.5 m Thickness 5 mm
Distance 1.25 m Thickness 11 mm
Distance 0.25 m Thickness 8 mm
Distance 2 m Thickness 6 mm
Distance 4.7 m Thickness 1 mm

Distance 2 m
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Distance 2 m
Thickness 6 mm
Distance 4.7 m
Thickness 1 mm
Documented multiple overlapping ZVI-filled zones between injection locations.
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 co-located with visual identification of ZVI-filled fractures.
Lateral Distribution of Horizontal Fractures – Cross Sections

Black tick marks are visual ZVI observations in soil borings (3D model verification)
Case Study – 3-D Print of Distribution

Virtual 3-D Model (EVS)

3-D Printed Model
CASE STUDY: Denmark – Treatment Results
TCE in Soil – Baseline

![Graph showing TCE (mg/kg) versus Depth (m) with data points and a blue ellipse highlighting a specific area.]

- Depth (m)
- TCE (mg/kg)

PRE mZVI (n = 315)
TCE in Soil – 18 month Post-Treatment

POST mZVI Y2 (n = 435)
TCE in Soil – 4 years Post-Treatment

- Depth (m)
- TCE (mg/kg)

Post mZVI Y4 (n = 414)
Distribution of Total VOCs in Soil – Baseline to 4 years Post-Treatment

3-D model shows decrease in magnitude and extent of Total VOCs in soil.
Distribution of Total VOCs in Soil – 4 years Post-Treatment
Distribution of Total VOCs in Soil – Baseline, 6 months Post-Treatment

Nov 2014 (Baseline)  June 2015

Legend:
Total CVOC Concentration (mg/kg)
- ≤1
- >1 and ≤5
- >5 and ≤10
- >10 and ≤20
- >20 and ≤40
- >40

Sum total CVOC Mass/Grid Column (kg)
- 0.000000 - 0.001000
- 0.001001 - 0.002000
- 0.002001 - 0.004000
- 0.004001 - 0.008000
- 0.008001 - 0.010000
- 0.010001 - 0.020000

68% Reduction 6 months
Distribution of Total VOCs in Soil – Baseline to 4 years Post-Treatment

Nov 2014 (Baseline) | June 2015 | May 2016 | May 2018

64% in 18 months

68% Reduction 6 months

83% Reduction in 4 years
Mass Discharge VOCs in Groundwater from TTA

92% Reduction in Total VOCs over 4 years

Downgradient Fenceline (S1/S2)

- TCE
- cis-DCE
- VC
- Ethene & Ethane

Geosyntec consultants
Mass Discharge VOCs in Groundwater from TTA

Downgradient Fenceline (S1/S2)

- TCE
- cis-DCE
- VC
- Ethane + Ethene

Baseline 92% Reduction in Total VOCs over 4 years
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 92% after 4 years.
- Total VOC mass in soil decreased by 83% after 4 years.
- Total VOC mass discharge in groundwater decreased by 92% after 4 years.
- Increasing ethane/ethene concentrations demonstrate complete degradation (max. ethane conc. in 2018 = ~7 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
- **Reduced Injection Time**: 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 semi-passive treatment of long-term source zones**
- **Competitive Cost**: 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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