Electrically Induced Redox Barriers (e-barriers)

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e-barrier concept

In-Situ Electrodes → D.C. Power Supply

Groundwater Flow

Dissolved Chlorinated Solvent Plume

Nonaqueous Phase Chlorinated Solvent Source Zone

Electrically Induced Reduction Zone

Electrically Induced Oxidation Zone
Presentation

• Laboratory Studies
  – Chlorinated Solvents
  – Energetics

• Field Studies
  – CFB Borden, Ontario
  – F. E. Warren AFB, Cheyenne, Wyoming
Beaker Test

Current (mA) vs. Days

- IPCE
- ITCA
- IMTBE
- IH2O
Borden Column
and Tank Experiments
Removal in Borden 2-D
March 19

Concentration (ug/l)

linear position (cm)

+ electrode

- electrode

TCE

PCE
Sequential Electrolytic Degradation of Energetic Compounds in Groundwater
Flow through reactors

- TNT Columns
- Control Columns
- RDX Columns
Electrode detail

Active Electrode Set
RDX Results

-41.5 -22.3 -3.1 16.1 35.3 54.5

position in reactor (cm)

RDX (C/C₀)

positive - negative sequence
negative - positive sequence
control (no voltage)
RDX Results

- minor peaks present also in control
- oxidation products transient
TNT Results

TNT (C/C₀) vs. position in reactor (cm)

-41.5 -22.3 -3.1 16.1 35.3 54.5

- Positive - negative sequence
- Negative - positive sequence
- Control (no voltage)
TNT Results

- common intermediate compounds absent
- minor peaks present also in control
CFB Borden Field Experiment
Field Prototype Objectives

• Evaluate Scaling Lab to Field
  – Panel Fabrication/Construction
  – Installation
  – Performance
    • Electrical
    • pH and pe shifts
    • PCE-TCE depletion
Construction Materials

- HDPE Geonet Spacer
- Titanium Electrode
- Geotextile Filter

Dimensions:
- 4.2 cm
- 254 cm
- 0.7 cm
- 1.4 cm
Expanded titanium
Borden Field Prototype
Multilevel Sampling Ports
Amperage vs. Time

System Amperage (ADC)

- 5.3 V
- 7.8 V

Dates:
- 12/25/01
- 02/13/02
- 04/04/02
- 05/24/02
- 07/13/02
- 09/01/02
- 10/21/02
Reference Electrodes

-3.00  -2.00  -1.00  0.00  1.00  2.00  3.00

5.3 V  7.8V  10.8V

electrode potential (V; SHE)

date

12/25/01  02/13/02  04/04/02  05/24/02  07/13/02  09/01/02  10/21/02  12/10/02
pH and pe

10 ft Transect 3/18

Position (m)

pe, pH, pe+pH

pH
pe
pe+pH
Results - PCE

Background PCE (ug/L) January 14, 2002 -0.0V

B-Transect PCE (ug/L) July 9, 2002 -5.4V (Week 24)

B-Transect PCE (ug/L) August 22, 2002 -7.8V (Week 30)
Results - TCE

Background TCE (ug/L) January 14, 2002 -0.0V

B-Transect TCE (ug/L) July 9, 2002 -5.4V (Week 24)

B-Transect TCE (ug/L) August 22, 2002 -7.8V (Week 30)
Results - c-DCE

B-Transect cis-DCE (µg/L) July 9, 2002 -5.4V (Week 24)

B-Transect cis-DCE (µg/L) August 22, 2002 -7.1 (Week 30)
CFB Borden
Preliminary Conclusions

• Panel Construction – Worked, room for improvement
• Installations – Feasible, challenging
• Performance
  – Sustained amperage
  – Cost ~ $0.01/day/m²
  – pH, pe, Ref Potentials shifted
  – High level of PCE depletion sustained, generation of cis-DCE
Electrically Induced Redox Barrier for Treatment of a Trichloroethylene Plume
Panel Design

(Dimensions in m)
Initial Cut with Dozer

Baseline monitoring wells along barrier alignment
Initial Cut
With Excavator
Set \( \frac{1}{2} \) Barrier in the Trench
½ of the Barrier Set

Well Sorted Medium Sand Backfill
Finish Assembly at Grade
Acknowledgements - Funding

• University Solvents-in- Groundwater Research Consortium
• ESTCP
• SERDP
• United Technologies Corp.
• National Science Foundation
Acknowledgements

• University of Waterloo - Bob Gillham, Beth Parker, John Cherry, Cory Repta, Matthew Ballaban, Greg Friday, Bob Ingleton, Paul Johnson

• CSU - Willard Lindsay, David McWhorter, Junior Garza, Bart Rust, Pete Romack, Jay Bryner, Ted VanHolland, Dawn Fairchild, Brian Cranmer, Don Dick