Site-Specific Reductive Dechlorination Designs Bundling Multiple Abiotic with Biotic Reagents: Lessons Learned

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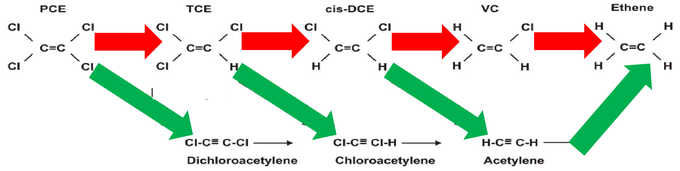
Biotic and Abiotic Dechlorination



- Carbon substrate electron donors for **enhancing anaerobic bioremediation** (biotic) and zero valent iron (ZVI) for **chemical remediation (abiotic)** are important tools for remediation practitioners.
- Enhanced in-situ dechlorination (EISD) through injection of both carbon substrate and reactive iron has become a more common approach for treatment of chlorinated volatile organic compounds (CVOCs).
- There are many advantage of combined biotic and abiotic dechlorination: multiple reaction processes, lower reducing conditions, reduced accumulation of lesser chlorinated CVOCs, extended reactivity, and pH buffering (OH- as a product of ZVI hydrolysis)

EISD Reagents

- Many carbon substrates and reactive iron remediation amendments can be used for enhanced in-situ dechlorination. Each of these EISD reagents have different properties and consistencies.

Liquid carbon substrates
- quick release (lactates, molasses, corn syrup)
- slow release (vegetable oil)
  - different droplet sizes available

Solid carbon substrates
- mulch, wood chips, other compost

Reactive iron
- zero valent iron (Fe^0)
  - range of particle sizes
  - reaction rate vs. longevity
  - sulfidated
- ferrous sulfide (FeS)
- Emulsified ZVI (Fe in EVO) zero valent iron (Fe^0)

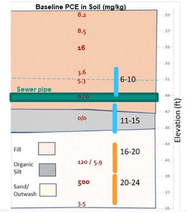
Combined Products
- Carbon substrate with ZVI
- Activated carbon, reactive iron, carbon substrate (CAT 100™)

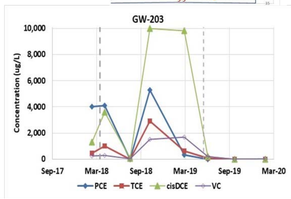
Remediation effectiveness can be improved by developing site-specific remedial designs developed around the site's conceptual site model, geology, contaminant concentration range, plume size, geology, and sensitive receptors.

Case Study 1 – Redevelopment at Former Mill

- Soil impacted by PCE & TCE
- Site adjacent to pond with numerous utilities
- Water soluble electron donors for injection near pond
  - Glycerol with ZVI (2-3 μm) near hot spot
  - Sodium lactate in downgradient area
- Dechlorination successful, but ERD conditions faded after 10-12 months
- Additional treatment required at hot spot (~600 sq ft)
  - Longer remediation persistence desired
  - **Shallow Interval: ELS (lecithin)**
  - **Deep Interval: SRS®-NR (15% ZVI by mass)**
    - **SRS®-NR: EVO designed to be stickier for high K soils**
    - **First ever application of SRS®-NR with ZVI**
- 4 EISD reagents used

Site was closed

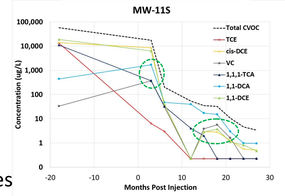


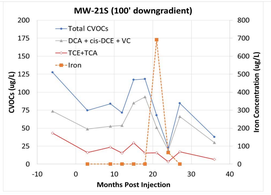


Case Study 2 – Bedrock Site 1

- Sedimentary bedrock impacted by CVOCs
- Objectives
  - Reduce source area CVOC concentrations
  - Establish natural attenuation conditions in injection area & downgradient (wells 50-200 feet away)
- Sequential injection of multiple EISD reagents
  1. Sodium Lactate to accelerate reducing conditions
  2. Small droplet EVO to allow migration of organic carbon in fractures
  3. Large Droplet EVO with ZVI to keep EVO with ZVI in source area
  4. Blended Bioaugmentation culture with DHC & DHB - for TCA
  5. Diaphragm pumps (0-75 psi) with straddle packers
- >99% reduction of CVOCs in all injection area MWs
- EISD lines of evidence observed 90-200 feet downgradient ~2 years after injection

	MW-1	MW-8
1,1,1-TCA	17,000	6,000
1,1-DCE	21,000	25,000
TCE	23,000	17,000
cis-DCE	14,000	39,000





Case Study 3 – Redevelopment Site

- 10+ acre site being redeveloped
- 4+ acres of groundwater contaminated with TCE and/or 1,4-dioxane in overburden and bedrock
- Objectives
  - Enhanced in-situ dechlorination for TCE only plumes
  - Reduce COC concentrations as much as possible with 1 injection before construction
  - Transfer the site to MNA program
- Deep Overburden Plume (3+ acres)
  - Fine sand and silt
  - ~1,200 linear feet of PRBs with 2 rows of injection points in each barrier
  - Small droplet EVO for fine grain soils and longevity in barrier
  - 4-micron ZVI for rapid reduction in CVOCs
  - FeS Solution for sulfidation and additional abiotic dechlorination
- Bedrock (1+ acre)
  - Sedimentary bedrock
  - Large droplet EVO (SRS-FRL®)
  - 4-micron ZVI (11% of ZVI)
  - 44-micron ZVI (89% of ZVI)
  - FeS Solution for sulfidation and additional abiotic dechlorination
  - Mix of iron to achieve rapid dechlorination (4 μm) and achieve longevity with more mass of less expensive iron (44 μm)
- Negative ORP and 90% TCE reduction TCE observed 2 months post-injection