Combined Remedies - Overview

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NEWMOA Workshops – Nov 2017

Disclaimer

- Mention of vendors and/or products are for illustrative purposes only and do not constitute an endorsement by EPA
Sea Changes (Whether one tool or several)

- Larger tool box of remedial alternatives (especially *In Situ*)
  - (Much) Better Process Control

- Better understanding of subsurface compartments and contaminant phases
  - Heterogeneity is the Norm
  - Investment in developing ‘better’ CSMs can pay dividends
    - ‘Return on Investigation (ROI)’ – Joe Quinnan, Arcadis
  - The Subsurface is NOT static before or during remediation

- Flexible, Adaptive, Attentive Deployment

- High(er) Resolution Site Characterization
  - But, still making too many simplifying assumptions

Sea Changes (cont.)

- (Near) Real-Time Process Control (Looming?)
  - Cheap Sensors
  - Telemetry
  - Cheap/Powerful Computation Capability
  - Drones?
Combined Remedies – The ‘New Normal’

• Growing awareness that different tools may be most suitable to address:
  – Different contaminant phases/concentrations
  – In different site ‘compartments’

• Not just for larger or more complex sites

Compartments

• ‘New, Improved’ 3-Domain Model
  – Transmissive
  – Slightly Transmissive
  – Storage

• (Dreaded) ‘Back Diffusion’
  – An engineering speed bump, not a road block to site remediation
Examples (Not Exhaustive)

- Thermal + Thermal
- Thermal + Bio
- Thermal + ISCO + Bio
- ISCO + ISCO
- ISCO + Bio
- ISCO + ISCR... *(Say What??)*
- Surfactant + ISCO
- ISS + ISCO//ISS + Ex Situ Thermal Desorption
- Ex Situ + In Situ

Pioneers - Giving Credit Where Credit is Due...

- Biodegradation of PCP enhanced by chemical oxidation pretreatment,
  - Lee and Carberry, *Water Env Research*, vol. 64, no. 5 pp 682-690, 1992
- *Sequential Biological/ Chemical/Biological Treatment of Organic Chemicals - Patent No. 5,955,305*
  - Soni, Kayser, Kelley, Srivastava, Institute of Gas Technology, 1997
- ‘Chemical Oxidation Priming for Enhancing Pollutant Removal in Soils by Biological Treatment’
  - Mark Zappi (now at U of Louisiana Lafayette) *ACS Nat'l Meeting*, 2002
Approaches

- **Temporal** – Adjust/change technologies at appropriate changeover points

- **Spatial** – Treat different zones with different technologies

- ‘Package Deals’ – Some tools have more than one mechanism of action (‘two-fers’ and ‘three-fers’...)

Package Deals
In Situ Chemical Oxidation Vendors Are Morphing Into Chem+Bio Firms

FMC Corp**. - 11 Apr 2008 Press Release

• FMC Launches Klozur® CR, A Combined Remedy Product That Couples Chemical Oxidation Plus Enhanced Aerobic Bioremediation

• ** - Now Peroxychem
• SRS®-EZVI Emulsified Zero Valent Iron Substrate
  – Combination of Biotic and Abiotic Reductive Dechlorination Mechanisms
  – Licensed from NASA
  – for DNAPL, Freon 113, and Biobarrier Applications

Redox-Tech Anaerobic BioChem Plus (ABC®+) and Peroxychem EHC

– Promote both reductive dechlorination and anaerobic biodegradation of halogenated solvents in groundwater
Excerpt from NAVFAC Report
Executive Summary

• “In addition to volatilization and steam stripping, enhanced biodegradation and other abiotic reactions at elevated temperatures were an active mechanism at all five sites.”

• SIDE NOTE: See Hydrolysis
Monitored Natural Attenuation (MNA)

- Frequently used ‘polishing’ component of remedies
  - Concerns regarding DCE/VC ‘stall’

- EPA MNA Guidance: *MNA is most suitable when used in conjunction with source treatment*

- Increasing use of quantitative ‘lines of evidence’
  - Traditional – Stable or shrinking plume/declining concentrations
  - Newer – QPCR, PLFA, Qantarray to determine micro-organisms and activity

MNA – A ‘Natural’ Combo (?)

- **Biotic AND Abiotic** Mechanisms
  - Investigation of Magnetic Susceptibility (magnetite) at the Hopewell Precision NPL site in NY – John Wilson, EPA, Ada/ORD(ret.)

- See also ‘Biogeochemical Transformation’
  - Micro-organisms potentiate metallic species
‘Synergies’ – A/The Holy Grail of Combining Remedies

- Thermal and ISCO Source Zone remedies can release bioavailable dissolved phase carbon
- Dechlorinating micro-organisms thrive at 30 C
Approaches (cont.)

• ‘Type 1’ - Anticipatory/Intentional (Newer sites)
  – Inclusion in original decision documents
  – ‘Mid-course corrections’ the norm
    • Both for original remedy and follow-on
    • Even then, ‘No plan survives the first encounter with the enemy’

• ‘Type 2’ - Ad Hoc/Post Hoc (esp. Older/Legacy sites)
  – (Scrambling) to try something else when ‘Plan A’ falters

Approaches (cont.)

• Phased/Progressive/Contingent
  – ‘If, then...’

• See Grants NM Drycleaner ‘ERH +’ ROD
  – ISCO or ERD (went w/ ERD)
IMPORTANT NOTE: How You Do It Is As Important as What You Do

• “Remedy implementation is just the next phase of site characterization”

• “Sources begin to reveal themselves as the remedy progresses’”
  – Many/Most ISCO remedies have a smaller footprint for subsequent injections

• Therefore: Flexible, Adaptive, Attentive...

Attentive…

• Even system installation can be informative
  – AECOM webinar discussed ERH installation found top of confining unit topology which resulted in completely different GW flow regime

• Process Control!!!!
  – Initially an advantage for In Situ Thermal
  – ISCO vendors now monitoring reagent presence, DO, ORP, conductivity, color, etc on a frequent basis
  • At least one vendor reports doing MIP probes between ISCO injections
Attentive… (Especially Bio)

• ‘It has become standard practice on our projects to do microbial evaluation throughout the remedial process.’

  - Jack Sheldon
  Antea Group

Remaining Challenges

• Tools to Predict Resource Restoration Timeframes
  – And tools to QA/QC calculations

• Decision Rules to delineate boundaries/temporal transition points among remedial components
  – ‘How much to heat/how much to eat…’
Desired End State/Least Cost Solutions

- Adequate Use of Robust Source Term Removal Technologies
- Timely transition to cost-effective ‘polishing’ step(s)
- Reduce/Eliminate Need for ‘Pump and Treat’
- Appropriate Reliance on Monitored Natural Attenuation (MNA)

Some New(er) Tools We are Tracking
• Injection of Activated Carbon
  – After decades of pumping gazillions of gallons to the surface for carbon treatment…
  – Sequester and Treat contaminants

Carbon Injection - State of Practice

• >1000 full-scale UST applications
• Dozen(s) of CVOC applications (including Fractured Rock)
• Several NPL applications
Horizontal Wells

- Improved emplacement accuracy
- Helpful where accessibility is an issue
- Can be used to inject reagents or extract contaminants

Horizontal Wells at a Gas Station
Horizontal Electrodes

Dynamic GW Recirculation (DGR)

- Vary injection/extraction patterns
- Maximize contaminant mass extraction for traditional Pump and Treat
Electro-Kinetics

- Promising DC-current technology for low permeability/back diffusion situations

- E-K Version 2.0
  - Original - E-K tried to move/recover contaminants
  - ‘New, Improved’ – Move reagents, nutrients, bugs

- Bio and ISCO variants

BioTraps
BioTrap Samplers

- 2-4 mm diameter beads - engineered composite of Nomex® and powdered activated carbon (PAC)
  - Provides a large surface area for the microbes to colonize and form biofilms

- Bio-Trap® sampler is deployed in a monitoring well - Bio-Sep® beads absorb contaminants and nutrients present in the aquifer essentially becoming an in situ microcosm

- Provide microbial, chemical, and geochemical evidence to screen remedial alternatives and evaluate biodegradation
BioTrap (cont.)

- Quantify specific microbes or contaminant degrading bacteria (e.g. *Dehalococcoides*)
- Evaluate monitored natural attenuation (MNA),
- Compare microbial populations at different sampling points across a site, and
- Monitor shifts in microbial communities following enhanced bioremediation (i.e. amendment additions).

Courtesy Microbial Insights

Hot Off the Press...

- Bio-Trap Sampler Concept employed in an “In Situ Bioreactor” configuration to treat contamination in fractured rock
- Subject of presentation at 2017 AEHS Soils Conference
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