

Combined Remedies - Overview

Jim Cummings – OSRTI/TAB/USEPA

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Disclaimer

- Mention of vendors and/or products are for illustrative purposes only and do not constitute an endorsement by EPA

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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

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Sea Changes (cont.)

- **(Near) Real-Time Process Control (Looming?)**
 - Cheap Sensors
 - Telemetry
 - Cheap/Powerful Computation Capability
 - Drones ?

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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

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Compartments

- **‘New, Improved’ 3-Domain Model**
 - Transmissive
 - Slightly Transmissive
 - Storage
- **(Dreaded) ‘Back Diffusion’**
 - An engineering speed bump, not a road block to site remediation

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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

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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

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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'...)

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Package Deals

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

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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**

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Terra Systems


- **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

Credit...



ENGINEERING SERVICE CENTER
Fort Huachuca, California 92029-4279

TECHNICAL REPORT
TR-2279-ENV

FINAL REPORT - COST AND PERFORMANCE REVIEW OF
ELECTRICAL RESISTANCE HEATING (ERH) FOR
SOURCE TREATMENT


Prepared by:
Amit Deshpande, SanDiego
Mukul Bhargava, SanDiego
Wesley Coakley, SanDiego

Prepared for:
Naval Facilities Engineering Service Center

March 2007

Approved for public release; distribution is unlimited.

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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

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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

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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*

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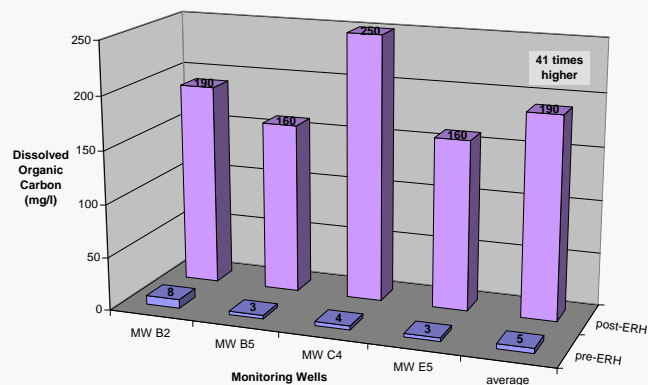
'Synergies' – A/The Holy Grail of Combining Remedies

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

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Effect of ERH on Groundwater Dissolved Organic Carbon



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Courtesy Thermal RS



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

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Approaches (cont.)

- Phased/Progressive/Contingent
 - *‘If, then...’*
- See Grants NM Drycleaner ‘ERH +’ ROD
 - ISCO or ERD (went w/ ERD)

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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...*

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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

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Attentive... (Especially Bio)

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

- *Jack Sheldon*
Antea Group

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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...’

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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)

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Some New(er) Tools We are Tracking



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• Injection of Activated Carbon

- After decades of pumping gazillions of gallons to the surface for carbon treatment...
- Sequester and Treat contaminants

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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

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Horizontal Wells at a Gas Station



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Horizontal Electrodes



Courtesy ThermalRS



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**

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BioTraps





BioTrap Sam



Biotraps

- 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



Contact Information

- cummings.james@epa.gov
- 703-603-7197
- www.cluin.org