Thermally Enhanced Biodegradation: Final Step to Rapid Site Closure

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The business of sustainability

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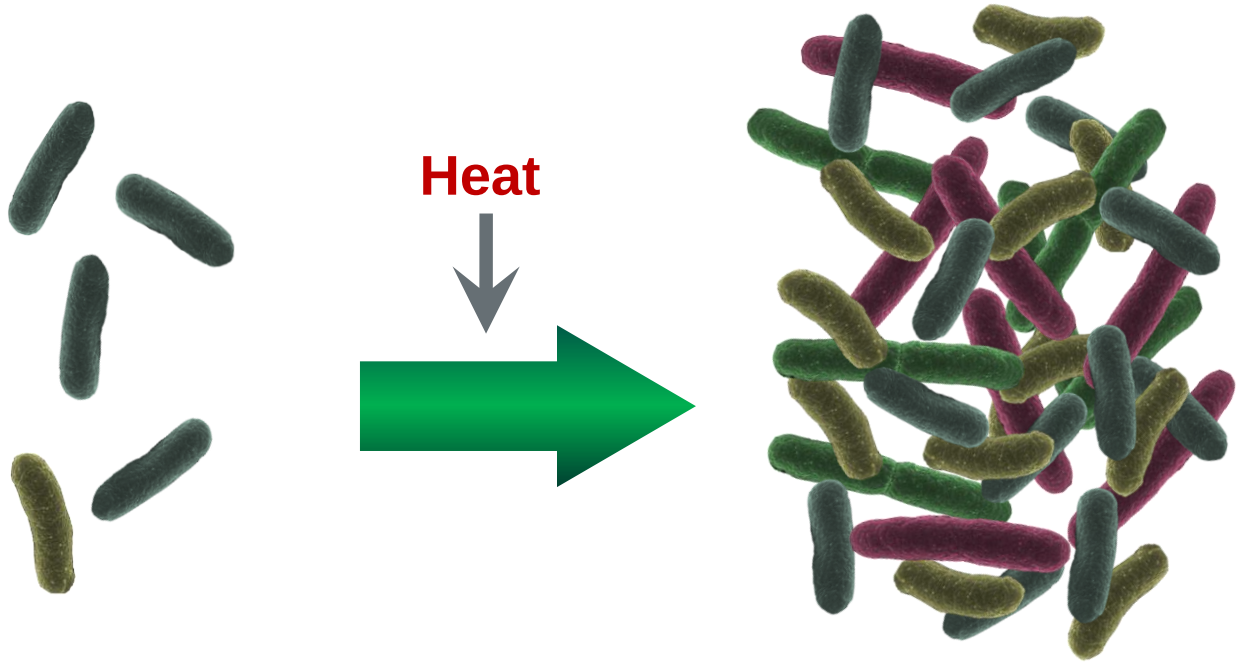
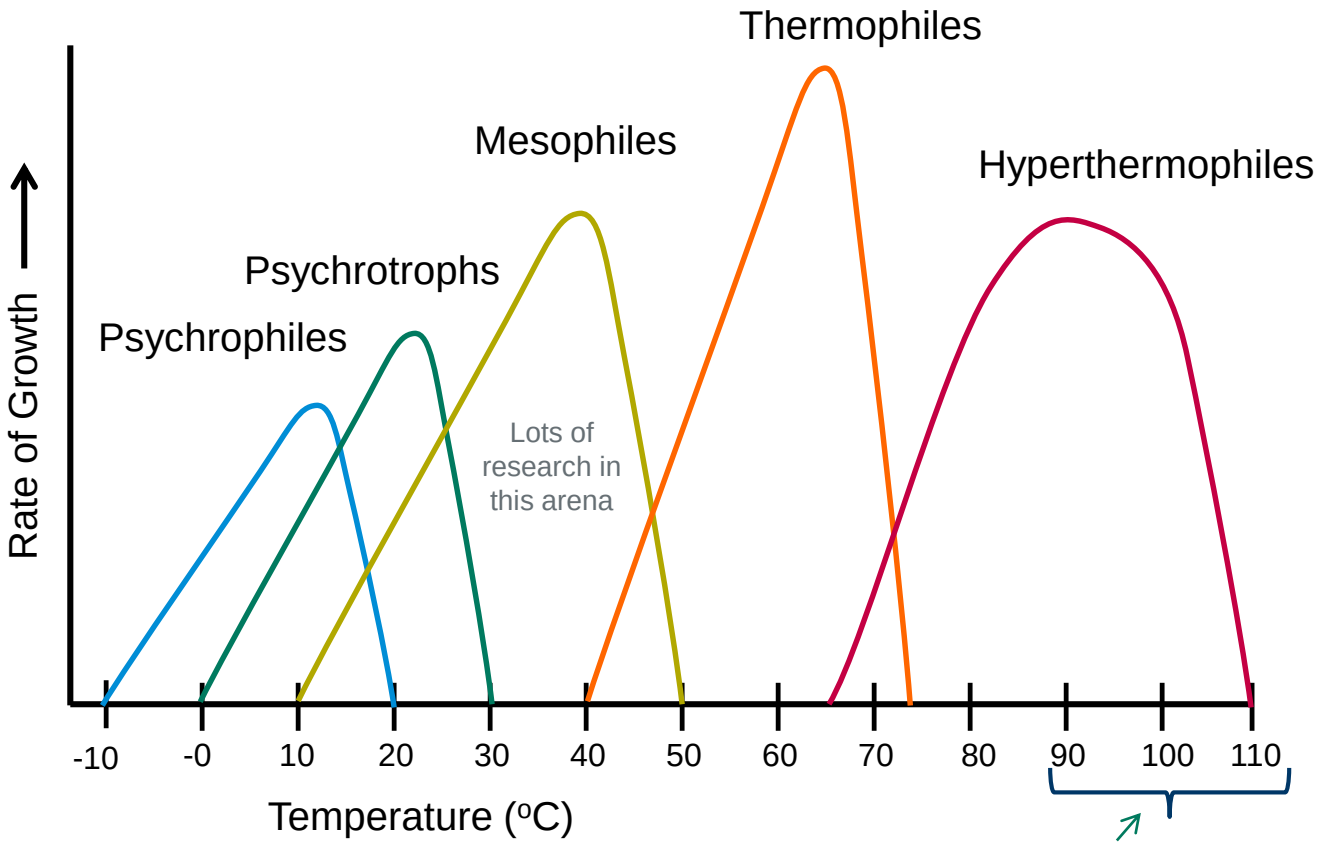
Agenda Slide

Introduction	Case Studies	What does this mean?
• Theory • Potential Benefits	• Microbial Activity • Abiotic Mechanisms	• Can we design more cost effective systems?

Microbial Stimulation using Heat



Effect of Temperature of Microbes



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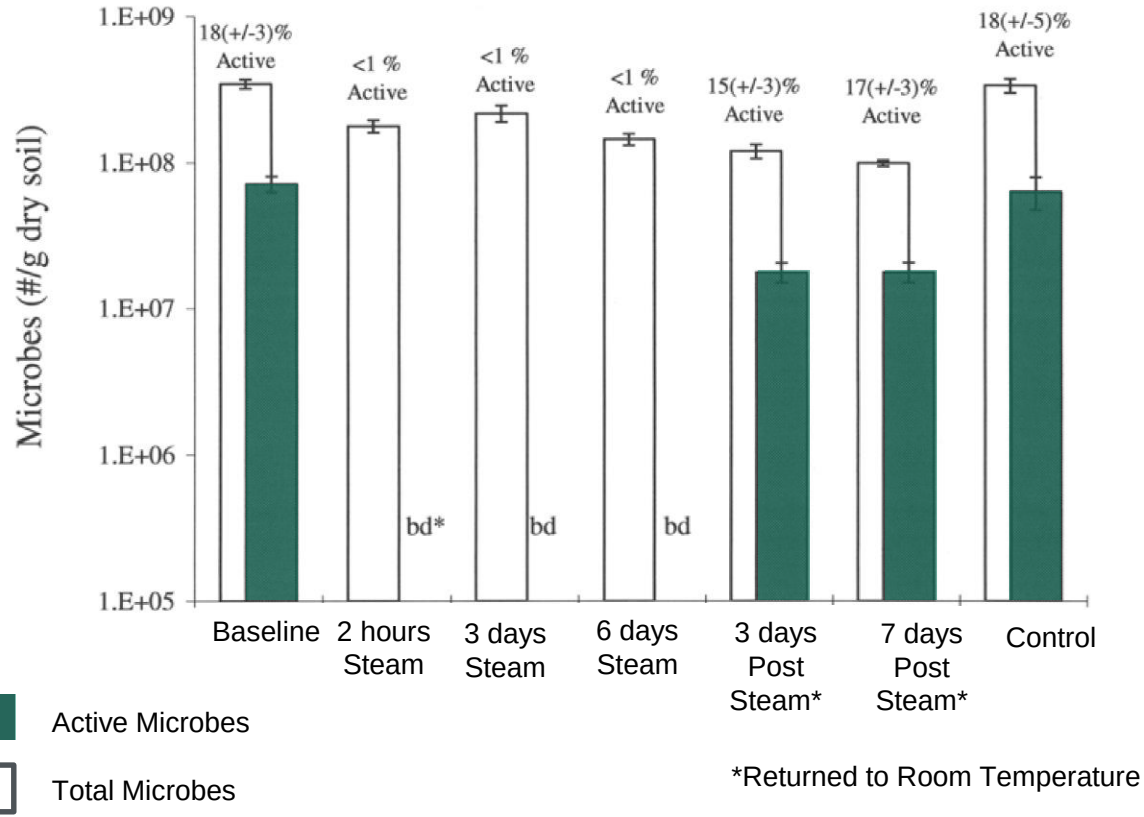
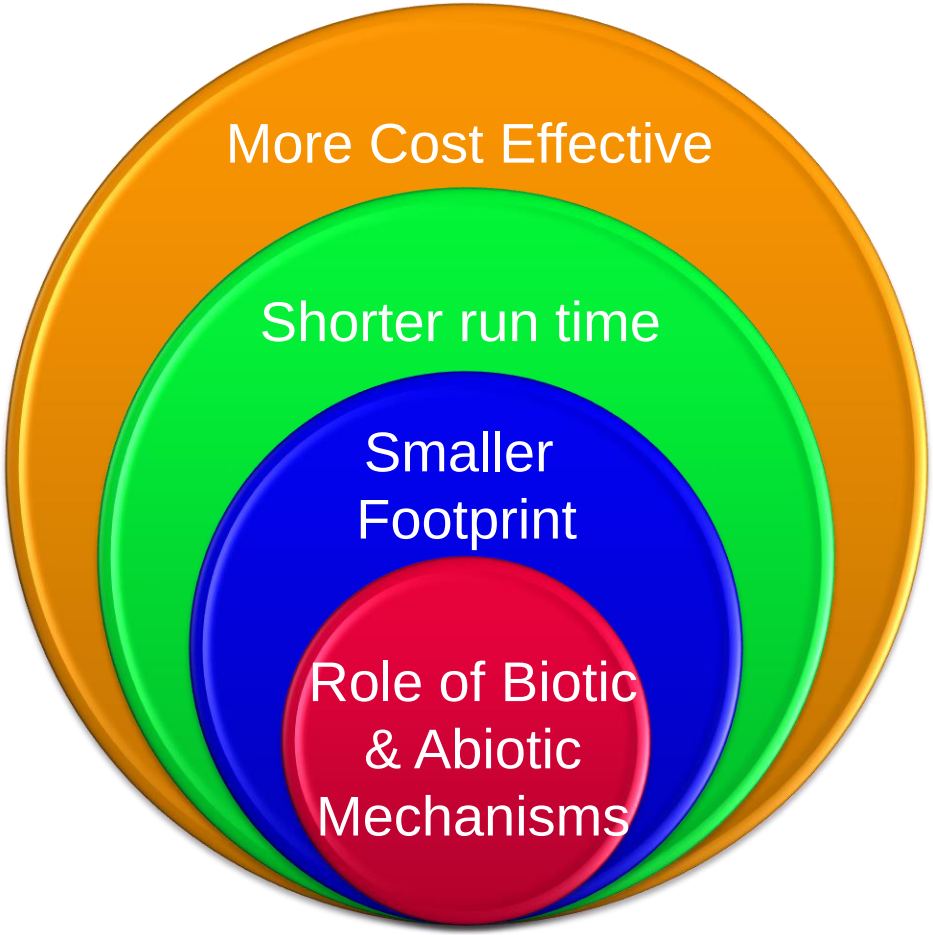
Effect of High Temperature Steam



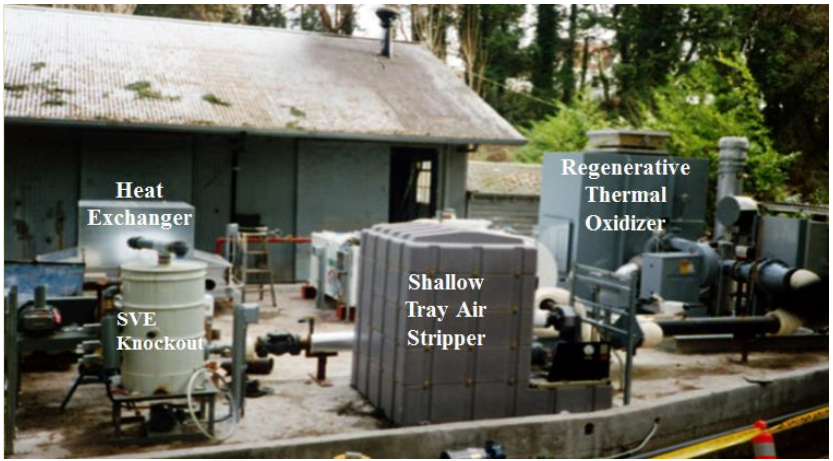
Source: Adapted from Richardson et al 2002

Potential Benefits: High Temp Thermal

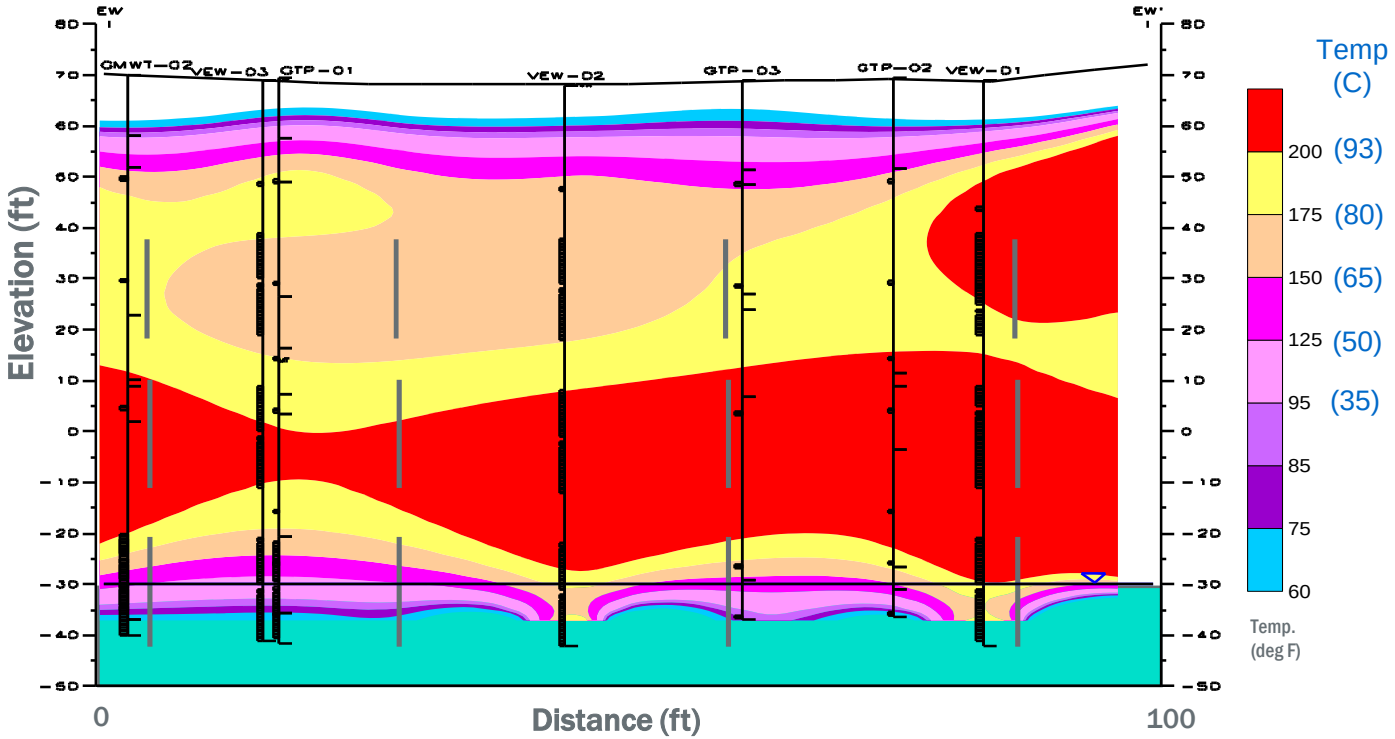


Case Study 1: 1990's Steam and Fuel Oil

- Site located in the Pacific Northwest
- Technology demonstration to recover No. 6 Fuel Oil
- Impacts to ~100 ft bgs



Soil temperature: 3 months heating



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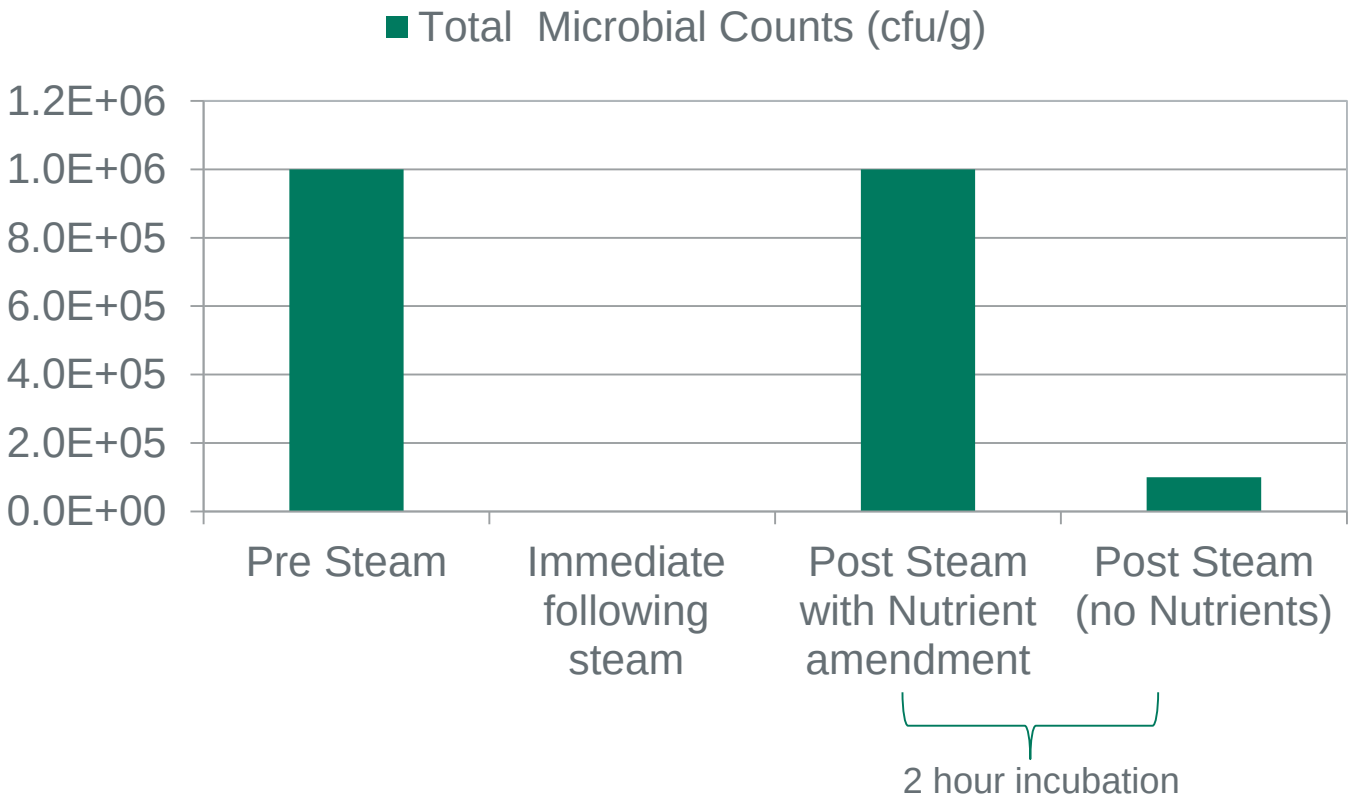
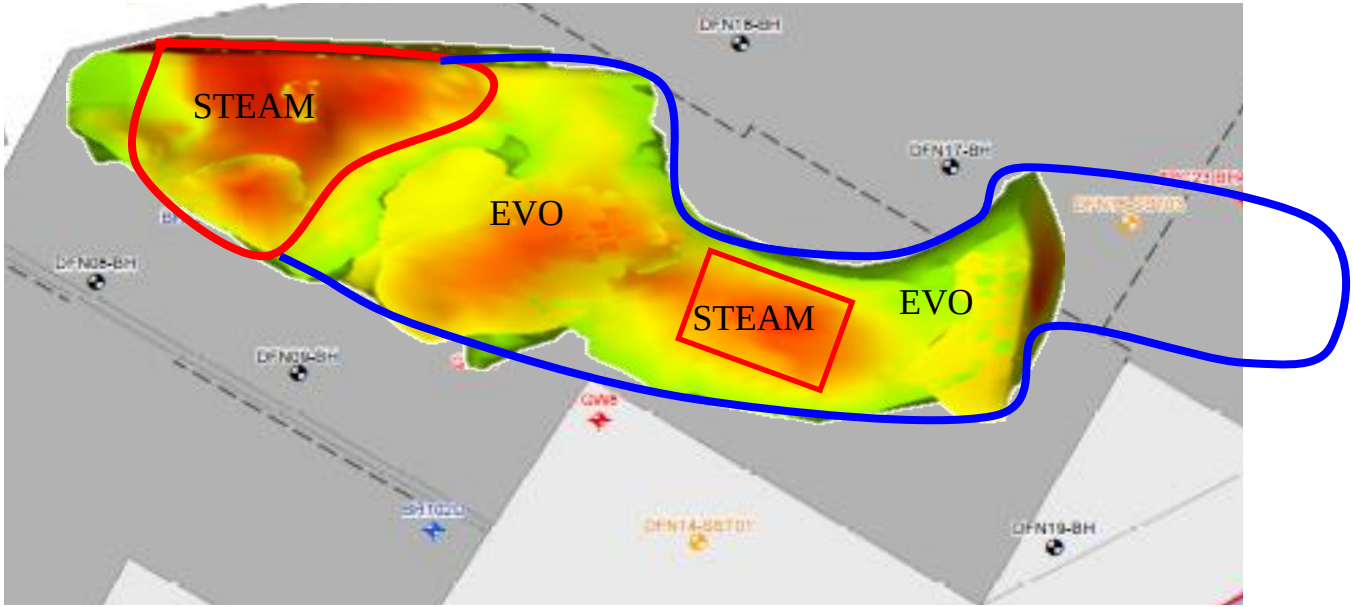
1990 Microbial Testing (Lab based)

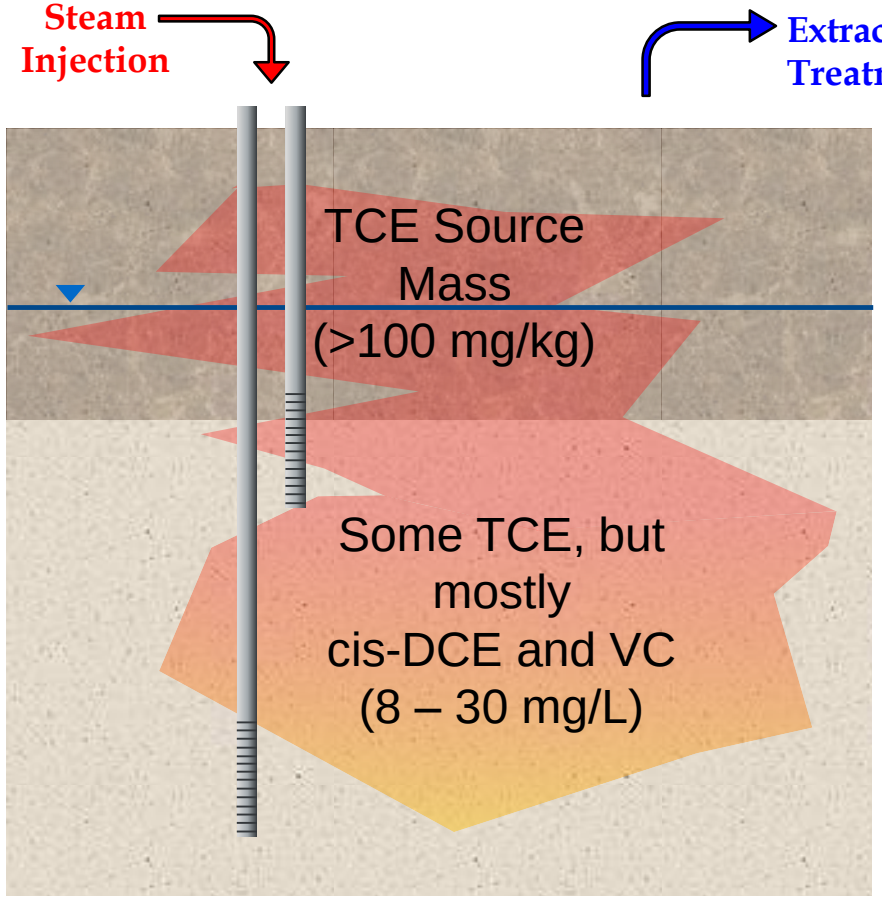


Case Study 2: Microbial Activity



- Combined bio/thermal remedial strategy at a site in the UK.
- Active heating in steam areas and downgradient EVO application
- Study included evaluation (2 years) microbiological activity within the thermal treatment source zone both pre- and post remediation

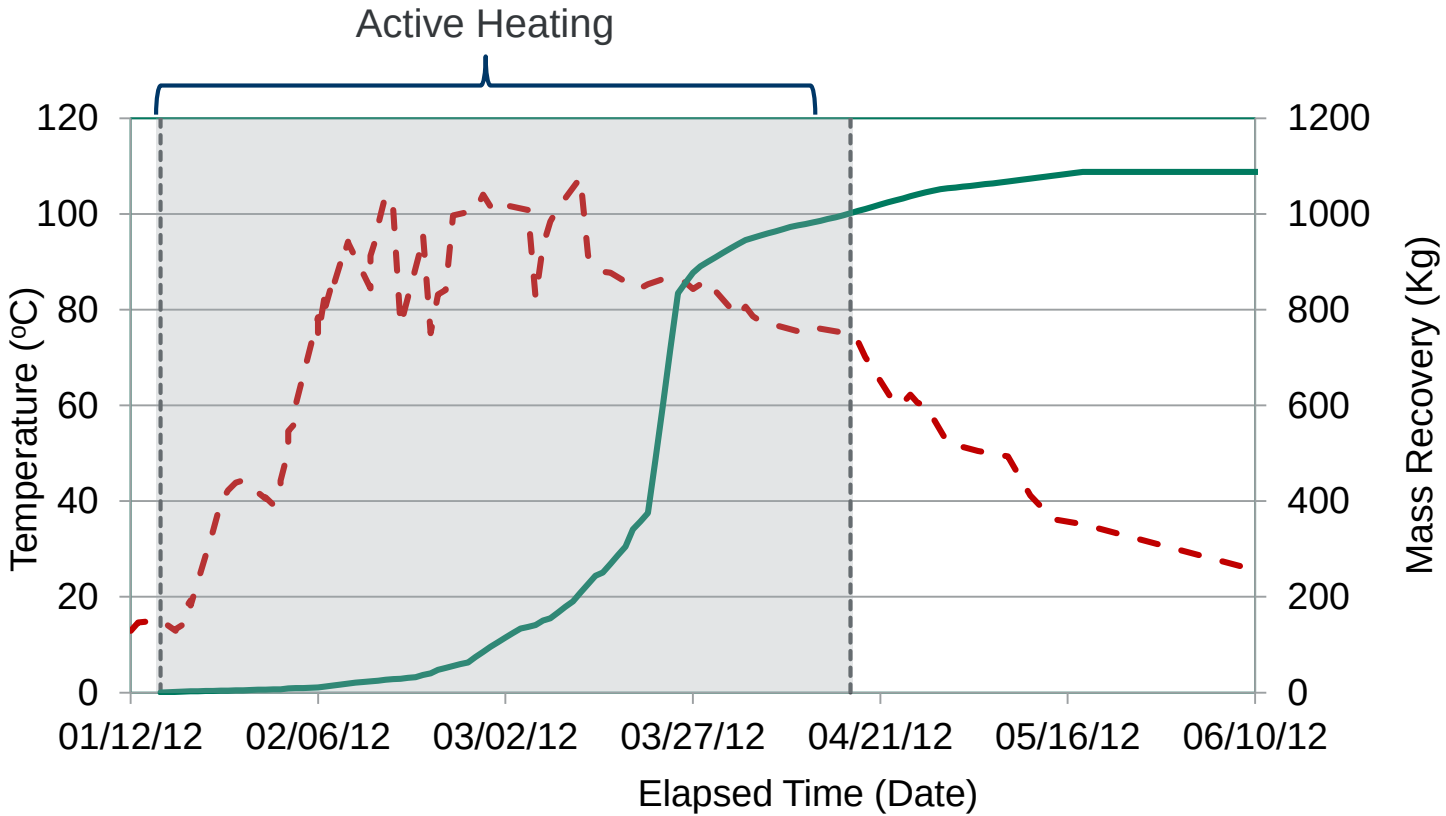
Conceptual Model (Source Zone)



Organic-rich material, BTEX

Highly weathered bedrock

Source Treatment



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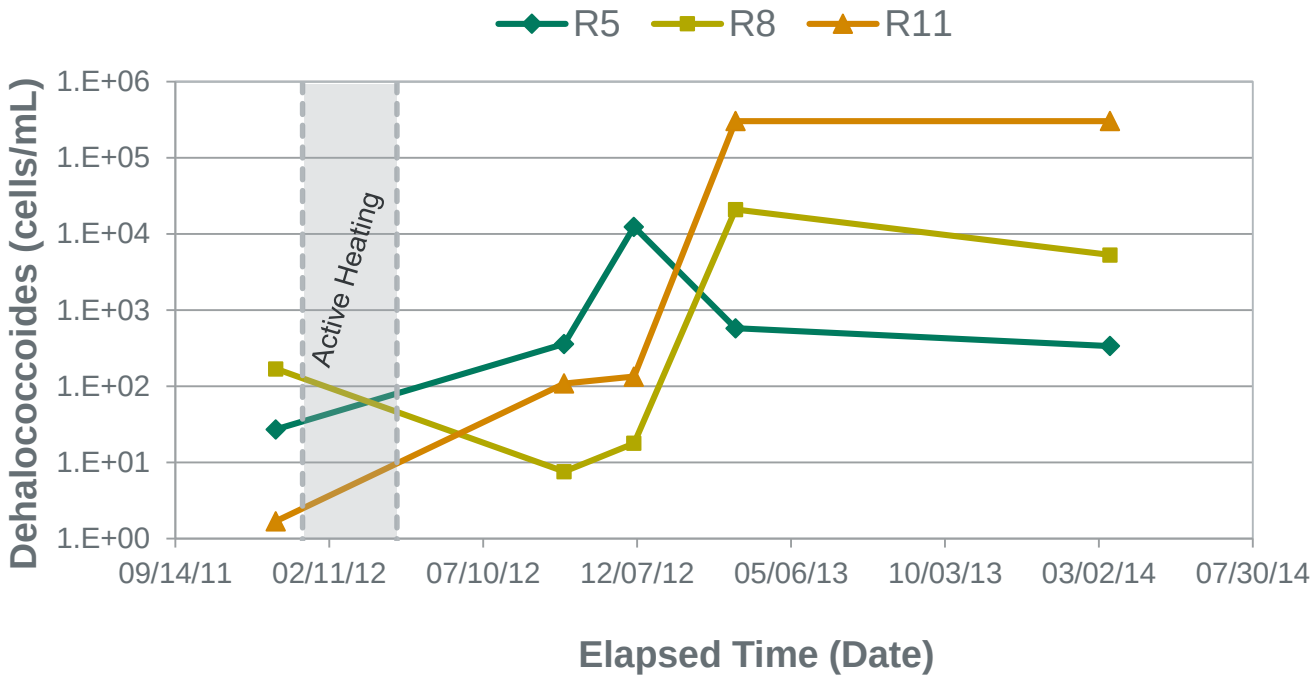
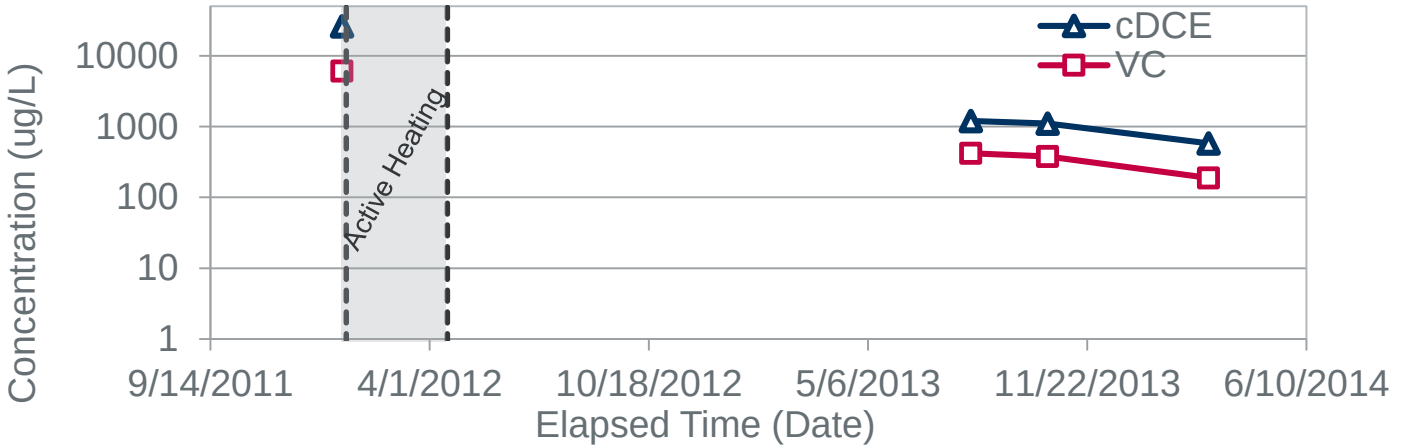
Microbial Characterization

- Baseline and post heating:
  - qPCR for *Dehalococcoides*
  - VOCs



Summary - 2 Years Post Thermal



- VOC concentrations continue to decrease 2 years post heating
- A viable dechlorinating population observed post high temperature thermal and can be used to polish residual concentrations
- Endpoints achieved for this project (sampling terminated), but if low concentration goal needed - carbon amendment could be used to enhance the rate of the polish

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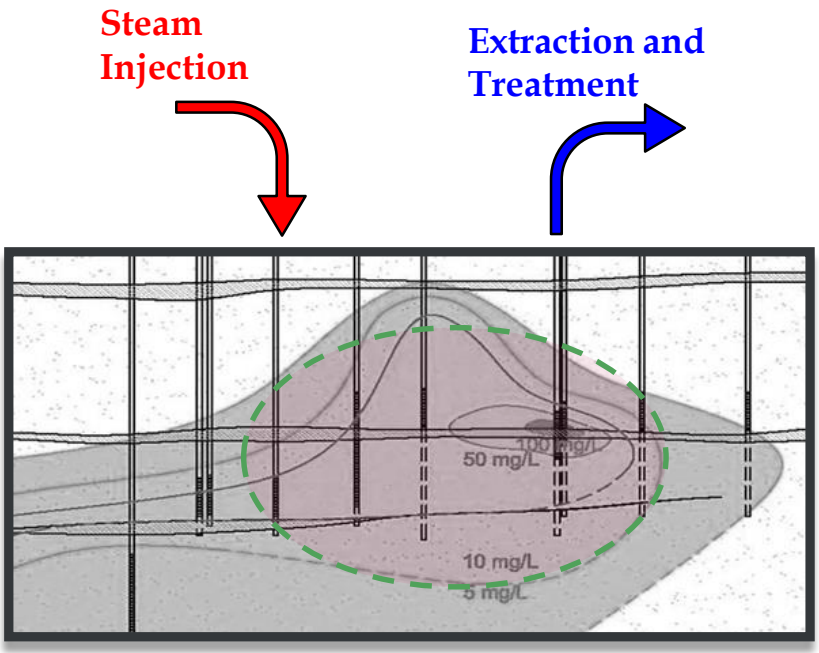
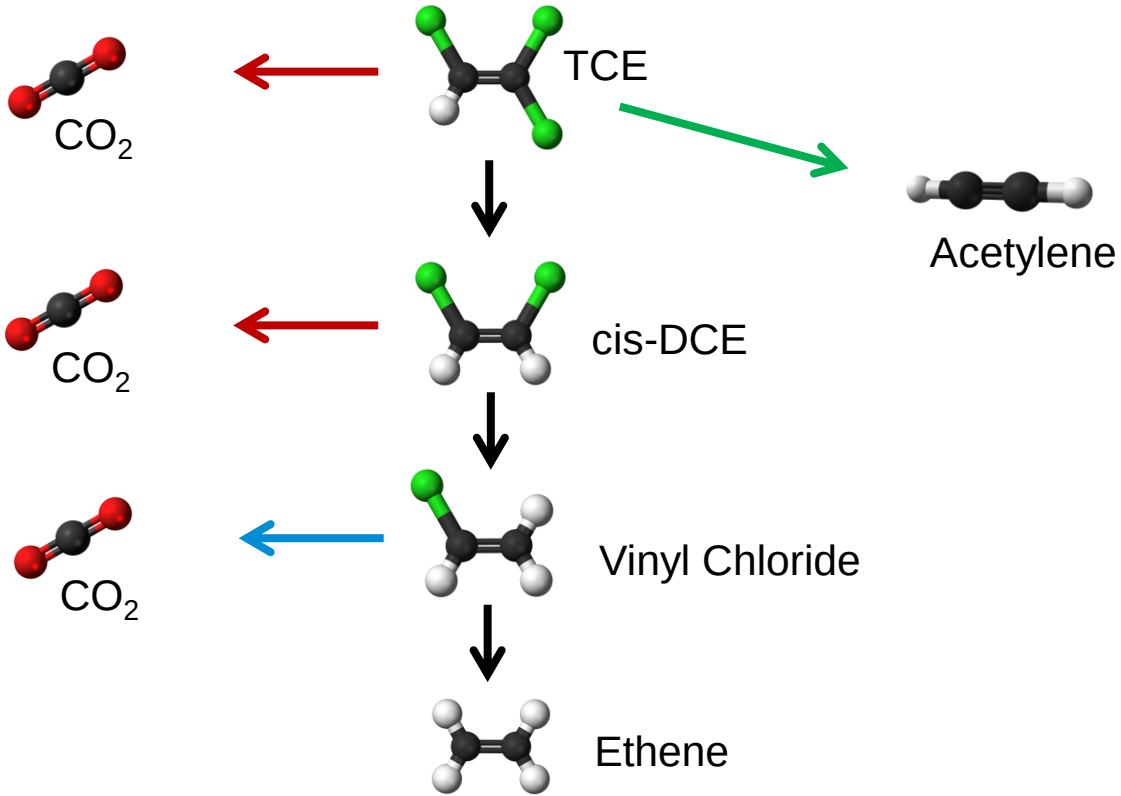
Case Study 3 : Compound Specific Isotope Analysis



Project Objectives:

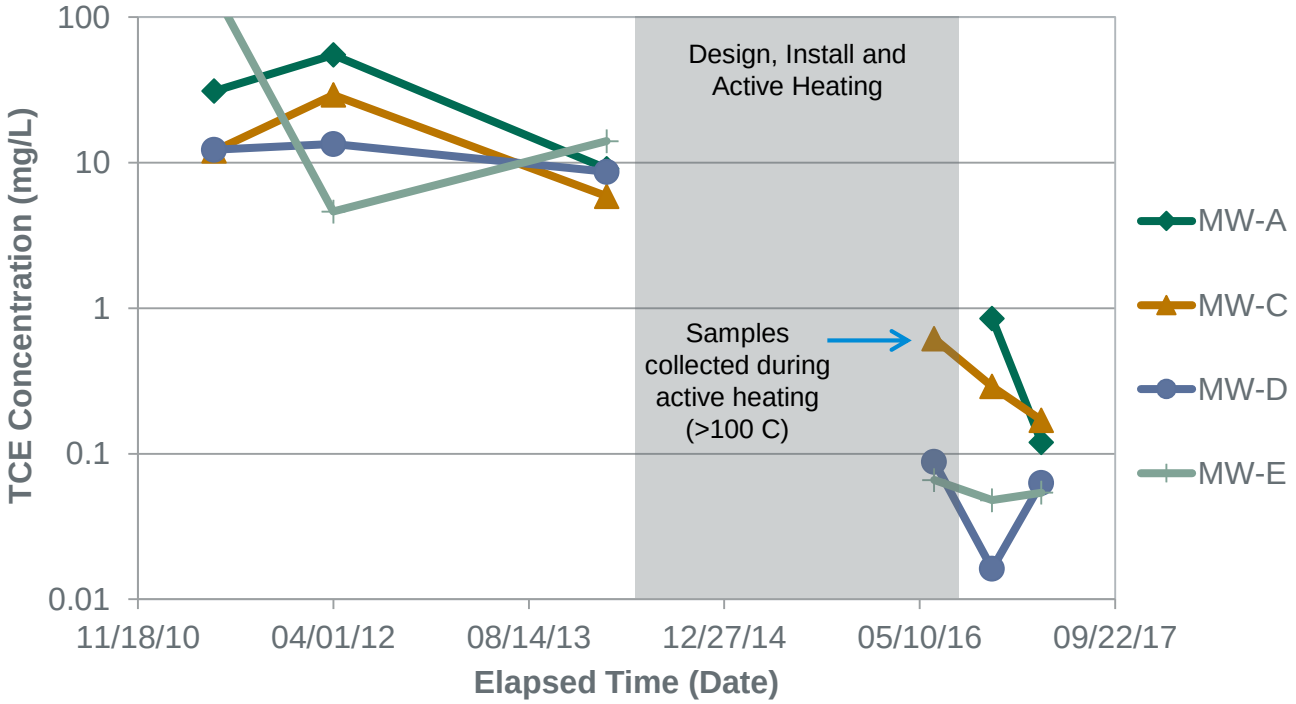
- Heat the groundwater to above the TCE co-boiling point to volatilize VOCs, extract the VOCs, and treat above ground
- Degrade the VOCs in-situ through biotic and abiotic processes

Potential Breakdown Pathways



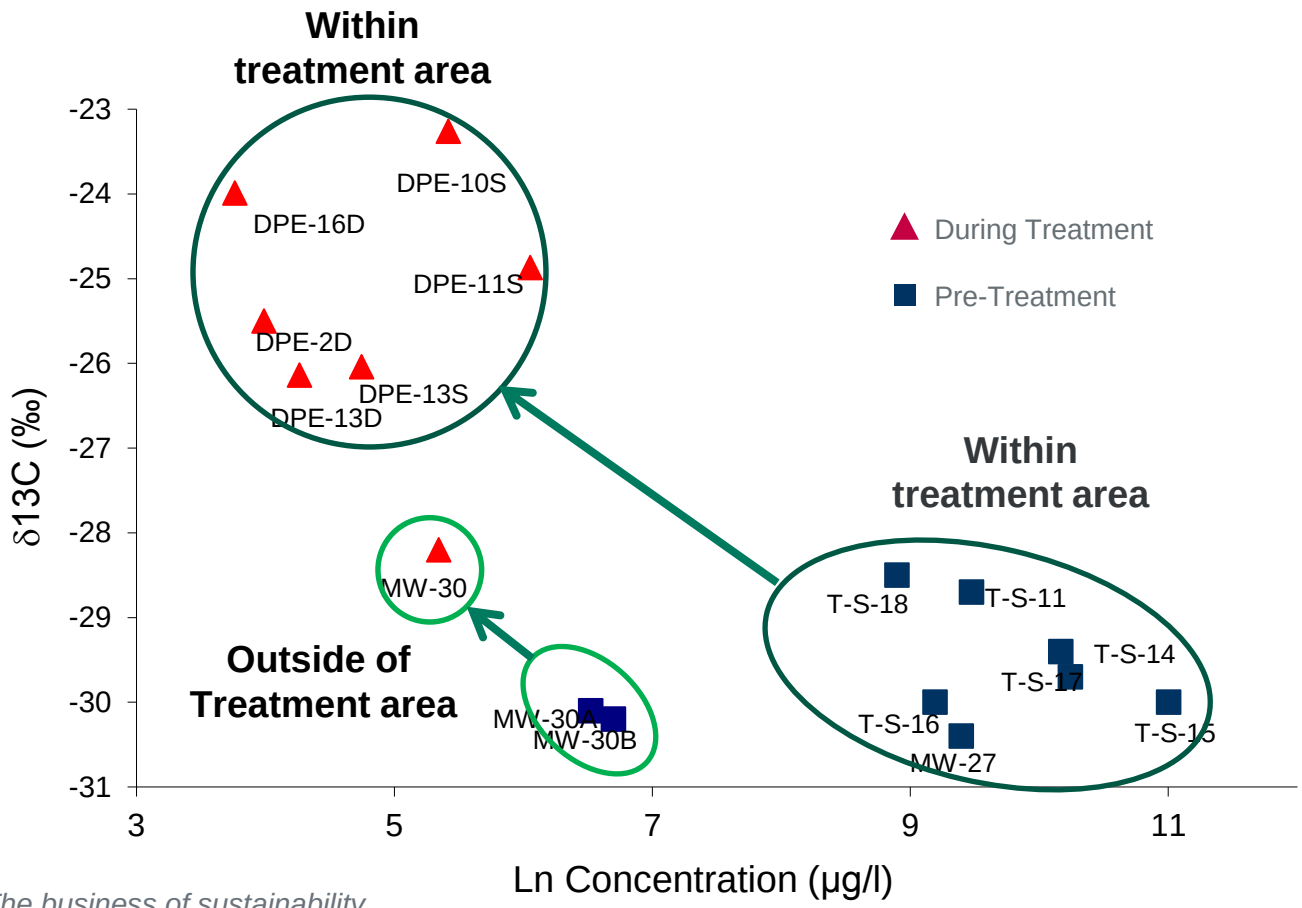
Reductive Dechlorination
Cometabolic (aerobic)
Metabolic (aerobic)
Abiotic

TCE Results



- Active heating: reached targeted temperatures (>100 ^{o}C)
- No observed daughter products during active heating period

Results: Compound Specific Isotope Analysis



- CSIA δ13C results show significant change in isotope ratios pre/during thermal treatment
- Higher δ13C confirm significant degradation of TCE has occurred

Case Study: Can we design smarter?

Field sample collection & baseline sampling

- Soil homogenized
- Sampled for microbes and key analytical parameters

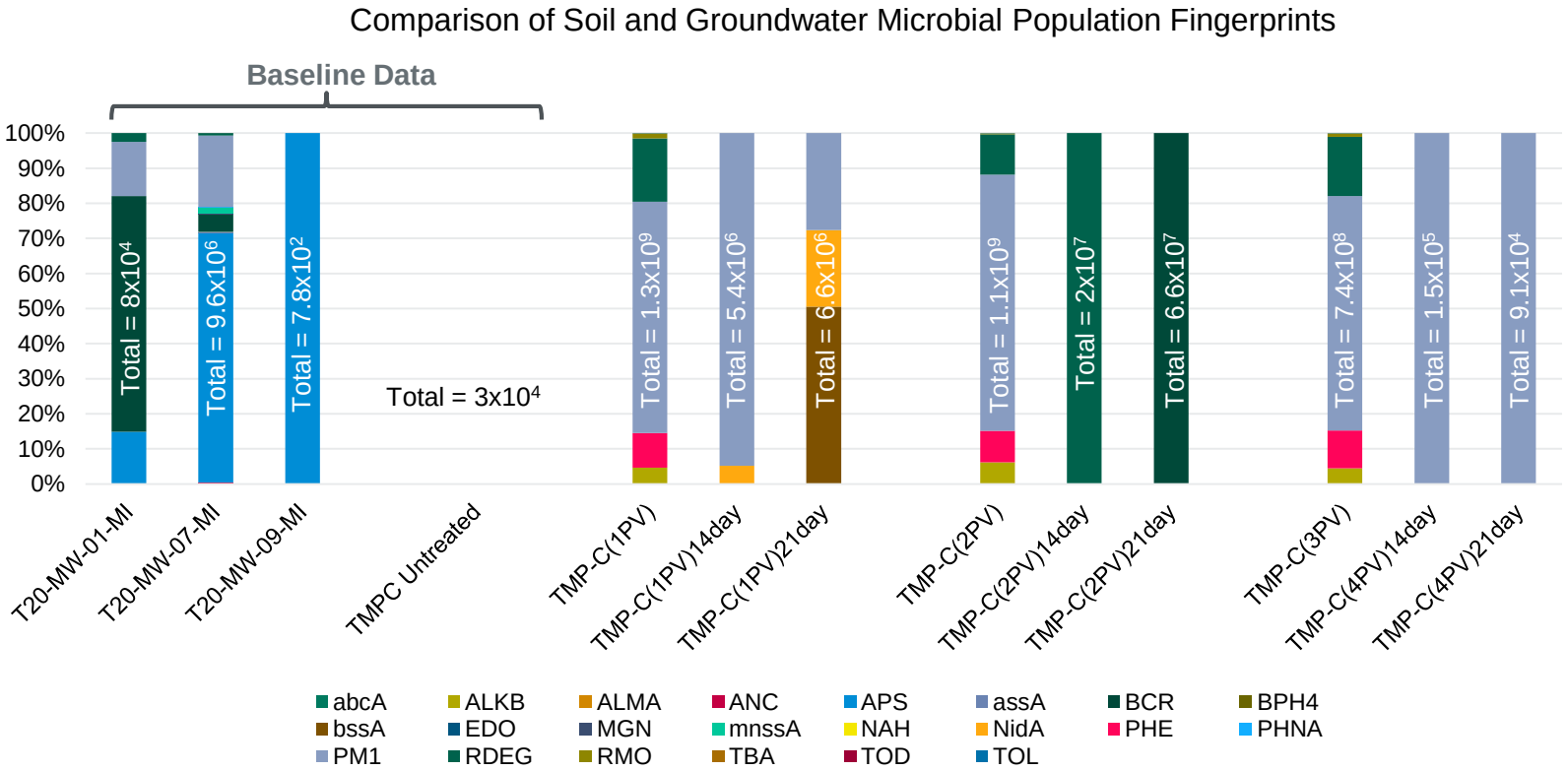
Lab-based steam flooding

- Flooded 1, 2 and 4 pore volumes (PVs)
- Note: typical field steam applications flood 100's of PVs

Post Flooding Laboratory Analysis

- Cooled to 40^{o}C
- Sampled at 14 and 21 days for microbes and key analytical parameters

Case Study: Can we design smarter?



Case Study: Can we design smarter?

Field sample collection & baseline sampling → Lab-based steam flooding → Post Flooding Laboratory Analysis

	1 Pore Volume			2 Pore Volumes			4 Pore Volumes		
Parameter	**Time 0 (µg/Kg)**	**1 PV (µg/Kg)**	**% Change**	**Time 0 (µg/Kg)**	**1 PV (µg/Kg)**	**% Change**	**Time 0 (µg/Kg)**	**1 PV (µg/Kg)**	**% Change**
Ethylbenzene	36.5	ND	**-100%**	55.7	ND	**-100%**	ND	ND	-
Total Xylenes	350	64.9	**-81%**	584	29.3 J	**-95%**	155	30.0	**-81%**
GRO	54,700	24,600	**-55%**	73,600	14,800	**-80%**	50,700	16,300	**-68%**
DRO	7,190	4,110	**-43%**	6,710	3,920	**-42%**	6,790	4,010	**-41%**
Soil Moisture	6%	12%	**+6%**	6%	13%	**+7%**	6%	7%	**+1%**

- Short-term steam flooding reduced concentrations of VOCs and TPH
- Short-term steam flooding (1 to 4 PV) does not appear to inhibit microbial growth
- Possible to rely on microbes to enhance natural attenuation rates during, and post steam flooding
- Microbial activity appears to be enhanced by the presence of steam (heat, enhanced moisture, and potentially greater oxygen content)

What does this all mean?

- Thermal remedies run off of mass recovery:
  - Biotic/abiotic inherently built in
  - Provide factor of safety

Intentional integration of low and high temperature thermal applications to provide lower cost, at lower risk

- Thermal remedies are costly to implement – price of failure is high
- Feasible to not run conservatively long
- Enhance pace to low-level groundwater standards with biological amendment

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