TERRASTRYKE
bringing the ground to life

ERDenhanced Comparative Study Determining Efficacy of Biostimulation vs Abiotic Metal

RemTech 2022
Banff Alberta,

Kent Armstrong – October 12, 2022

Biostimulation

- Enhance nutritive capacity of treatment zone.
- Support indigenous populations
- Restores nutritive capacity of ecosystem.
- Allows microbes to collectively establish biofilms.
- Superior levels of sustainability, contaminant destruction with less impacts at lower costs.

Purpose

compare rates of degradation of chlorinated alkenes

- Biostimulation using ERDenhanced as sole electron donor.
- Abiotic oxidation using Zero Valent Iron (ZVi).
- Combined formulation ERDenhanced with ZVi .
- Perchloroethylene (PCE) contaminant electron source

1^0 & 2^0 Metrics

Evaluation metrics

- EPA Method 5021A (PCE/cVOCs)
- Heterotrophic Plate Counts (HPC)
- *Dehalococcoides spp*. (DHc) bulk water densities.
- Quorum Sensing & Signaling (QSS).
  - Autoinducer Signaling Molecule (AI2)
  - Proteins, Polysaccharides, Peptides (Biofilm)

Evaluation Amendments

ERDenhanced™

Supports reducing conditions for decades after single injection program

APPLICATIONS:
Dry cleaner, manufacturing, tool-dye

Evaluation Amendments

ZVi – SR-5

Oxidizer that also generates electrons and Hydrogen (H+)

APPLICATIONS:
Dry cleaner, manufacturing, tool-dye

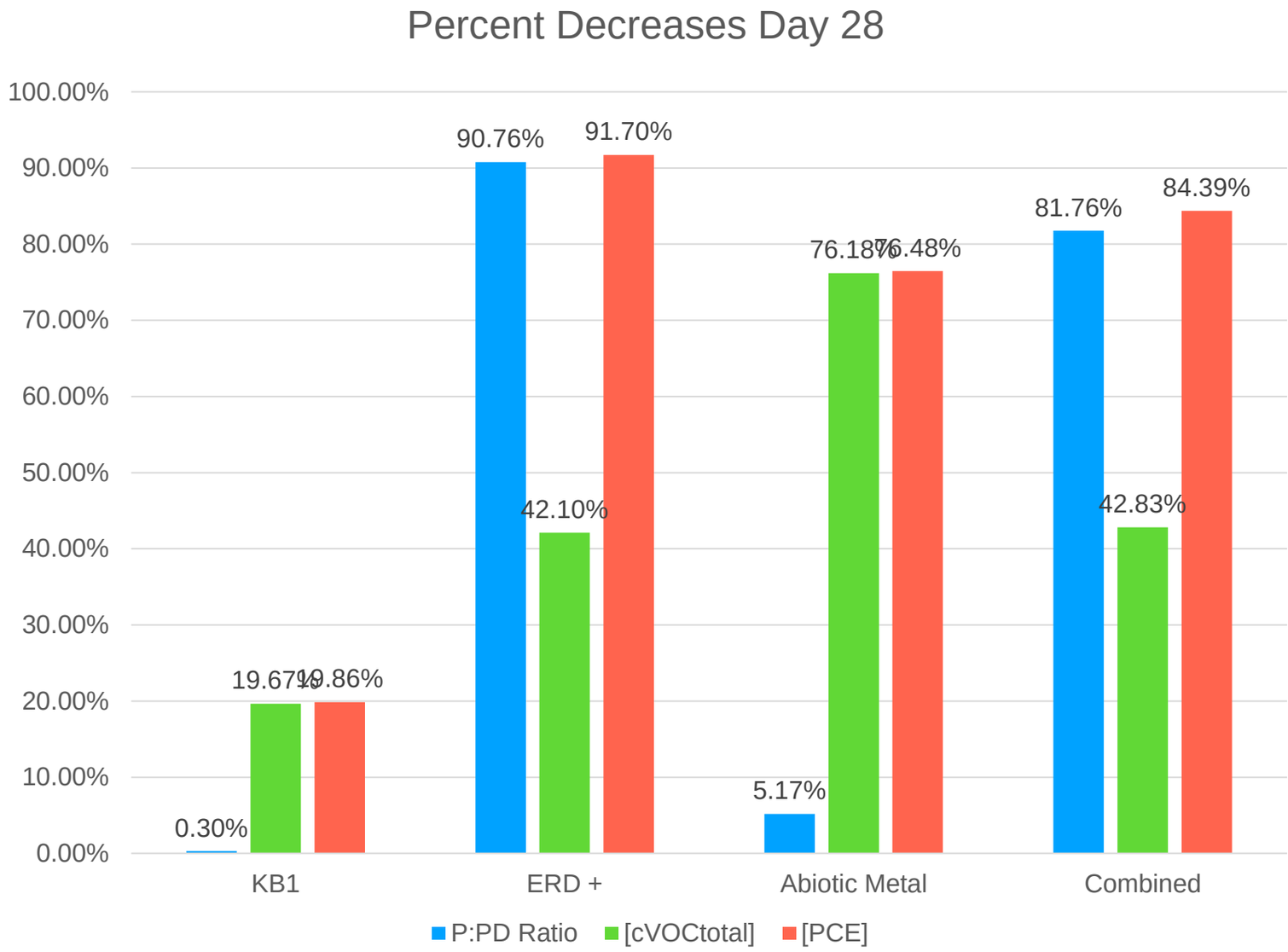
Microcosm Study

Independent Comparativ
Evaluatio

ERDENHANCED

28-day microcosm study

- Compared biostimulation vs. inorganic oxidation process.
- Baseline [PCE] 50,000 ug/L
- Established groundwater conditions to ongoing Ohio remediation project



Microcosm Study

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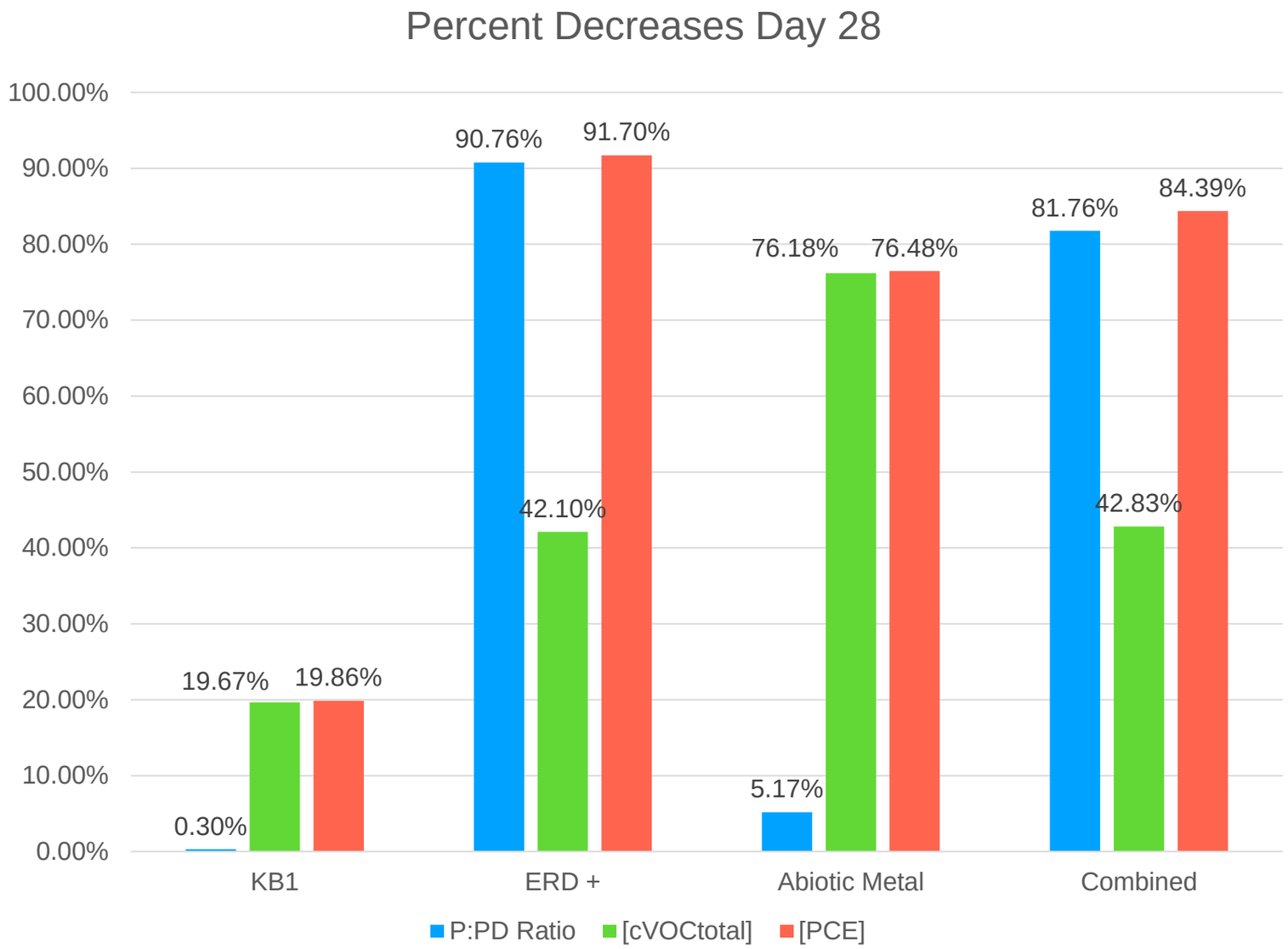
Demonstrated

- Oxidation realized greater diss.phased reductions in [cVOC]
- Biostimulation greater diss.phased reduction in parent [PCE]
- Greater % change in P:PD ratio = mass destruction
- Destroying parent cVOC contaminant faster achieving real mass elimination
- Battelle ‘ERDenhanced outperformed Zvi across the board’.



Microcosm Study

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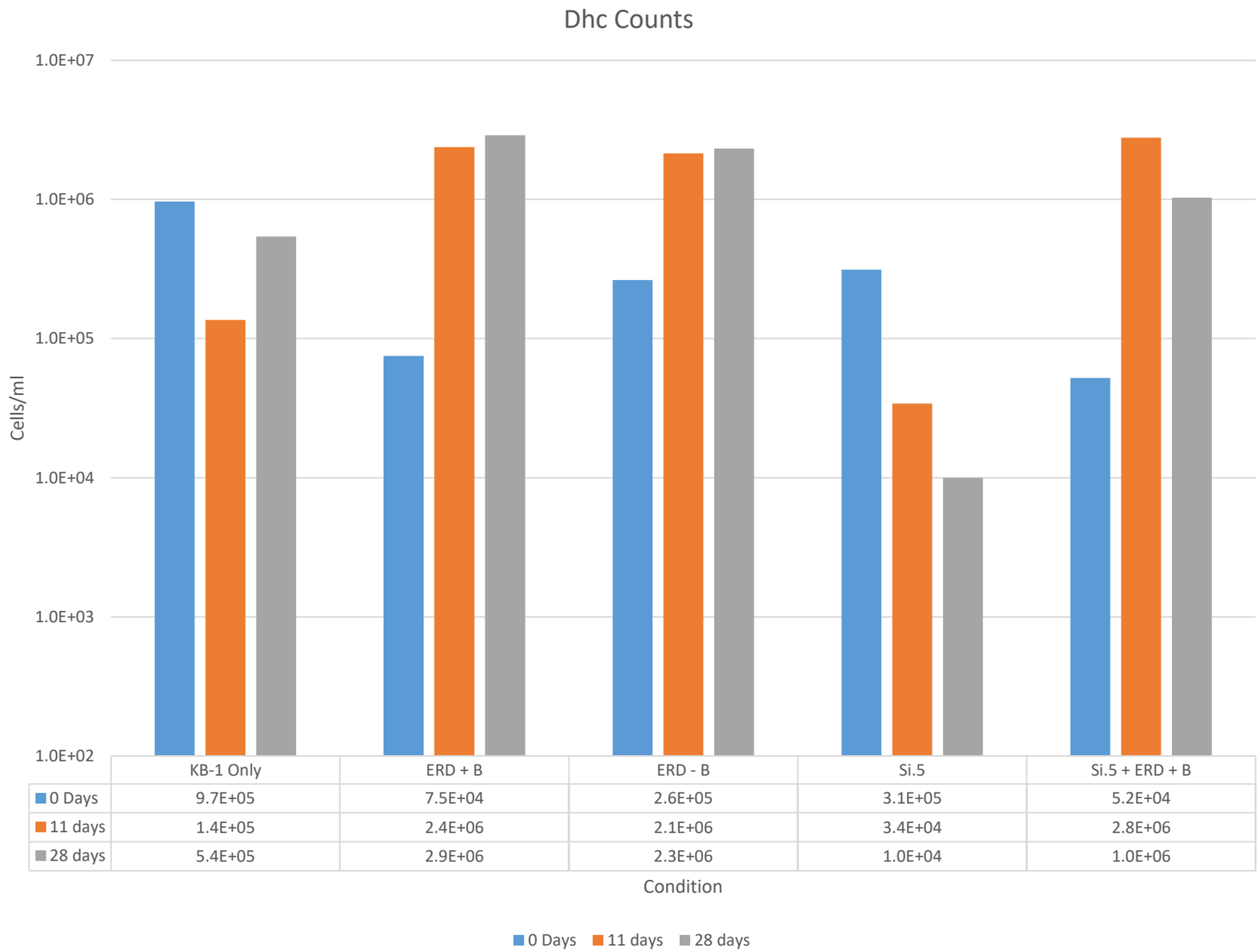
- Realized greater growth of Dehalococcoides (DHc).
- Oxidation resulted in decreasing populations



	KB-1 Only	ERD + B	ERD - B	Si.5	Si.5 + ERD + B
0 Days	9.7E+05	7.5E+04	2.6E+05	3.1E+05	5.2E+04
11 days	1.4E+05	2.4E+06	2.1E+06	3.4E+04	2.8E+06
28 days	5.4E+05	2.9E+06	2.3E+06	1.0E+04	1.0E+06

Microcosm Study

Independent Comparativ Evaluatio

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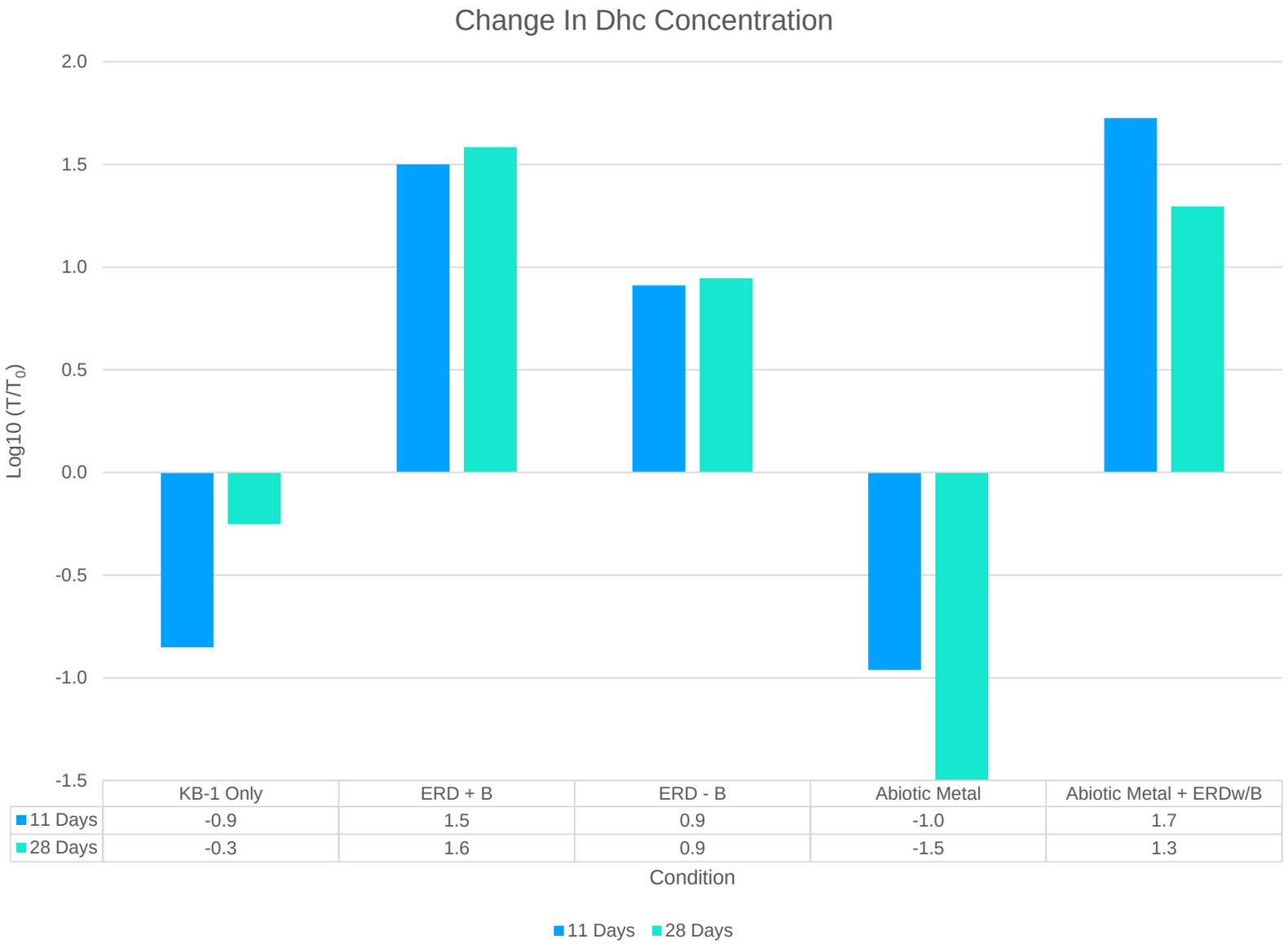
- Realized greater growth of Dehalococcoides (DHc).
- Oxidation resulted in decreasing populations
- Effects on signaling?
- ERD+ vs. ERD-



Case Study

Independent Comparativ
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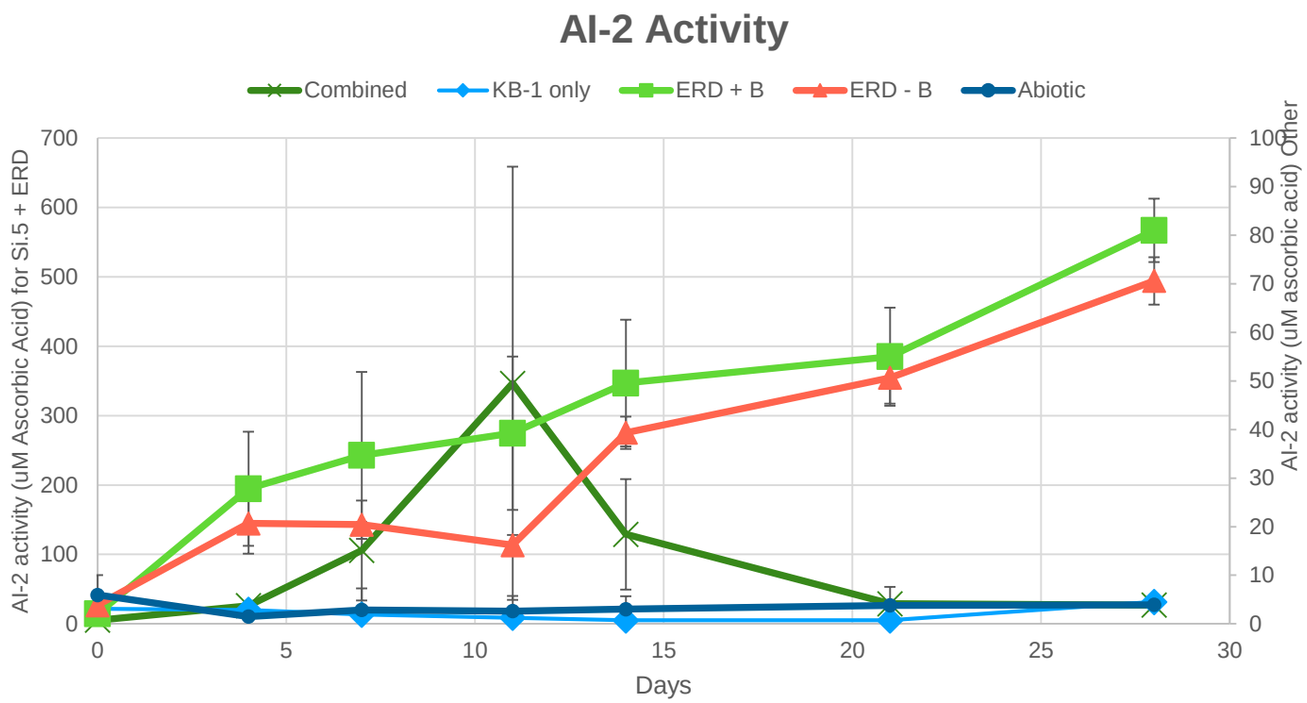
ERDENHANCED

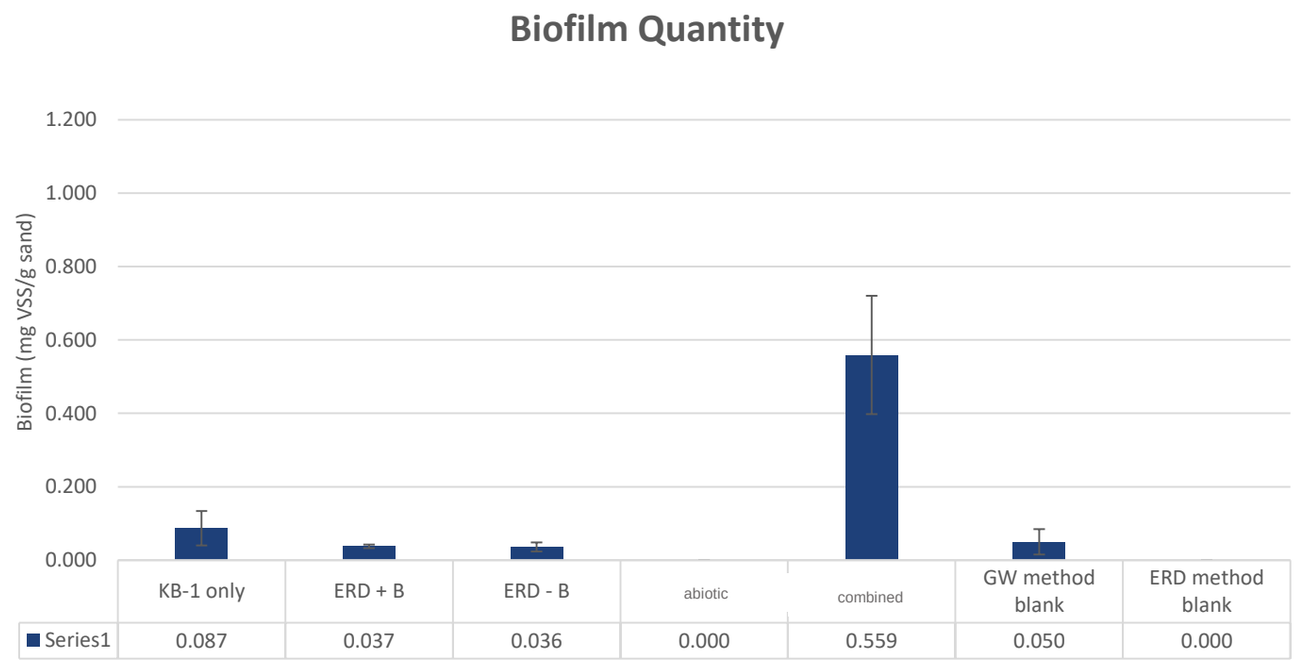
28-day microcosm study

Sharp decrease in Autoinducer-2 (AI-2) signal realized in combined formulation

See greatest biofilm growth in combined formulation

- Reached quorum densities
- Established a biofilm
- Bulk water concentrations AI-2 decrease as a result





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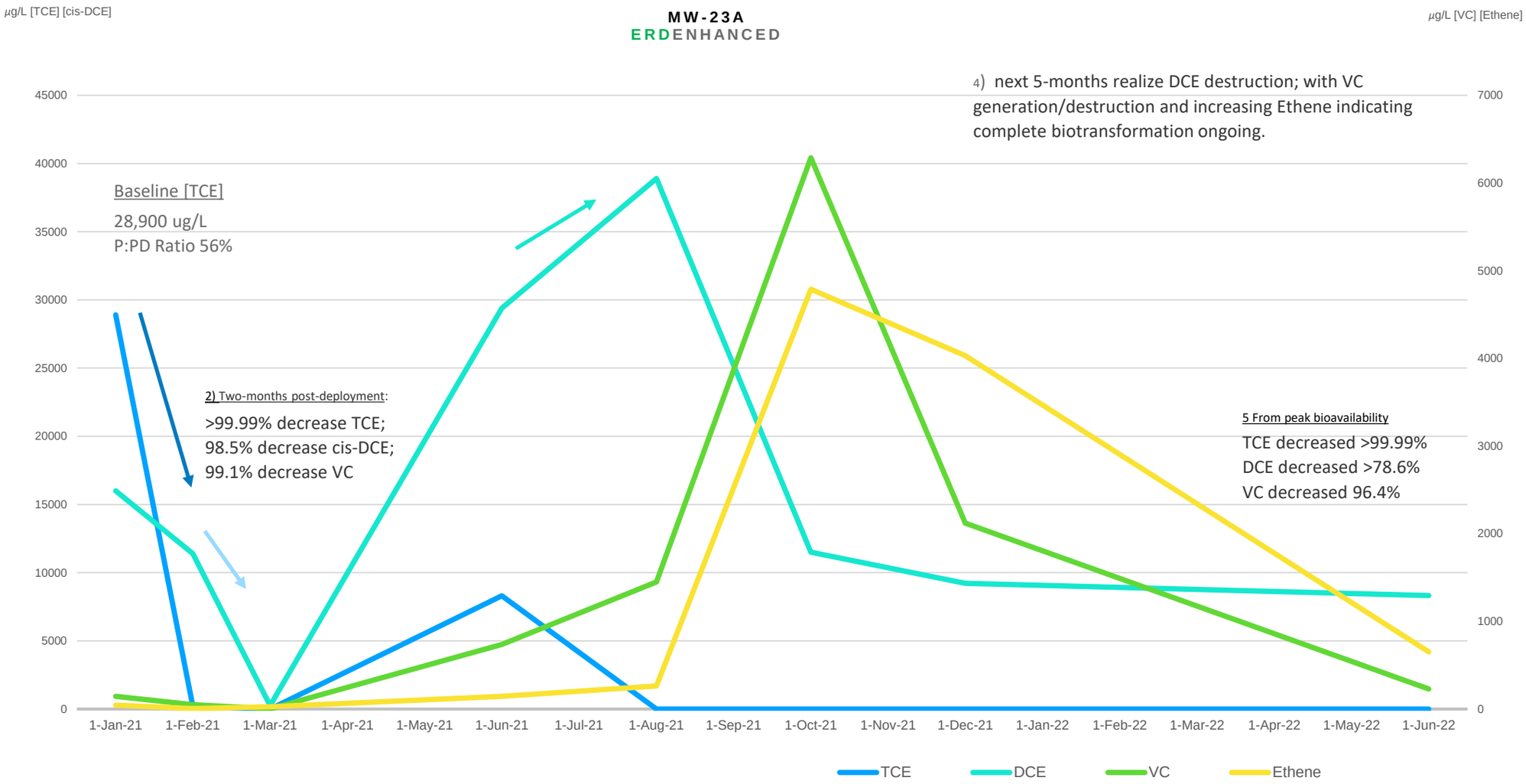
Field Study

On-Site Proof-of-Concep

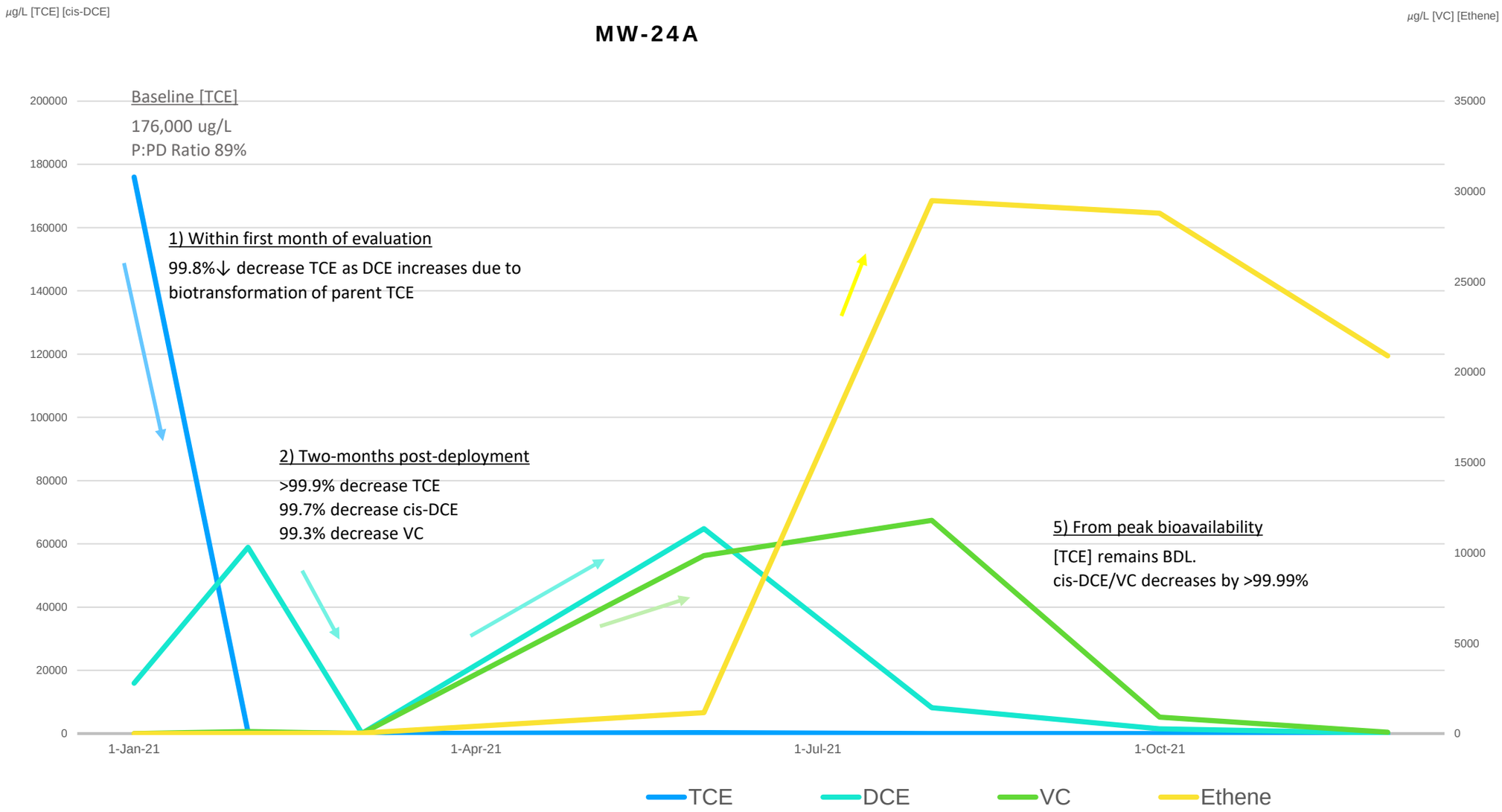
ERDENHANCED
18-month evaluation



Field Study

On-Site Proof-of-Concep

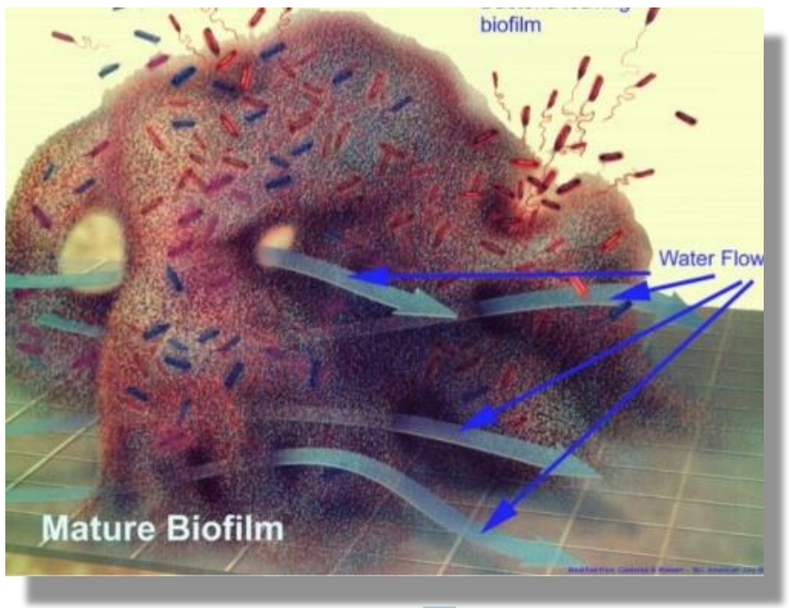
ERD ENHANCED W/ ABIOTIC METAL



The Power of the Unicellular

Historically believed

- Prokaryotes, single cell
- Solitary, capable of little.
- Planktonics rule.



We now have a completely different perspective

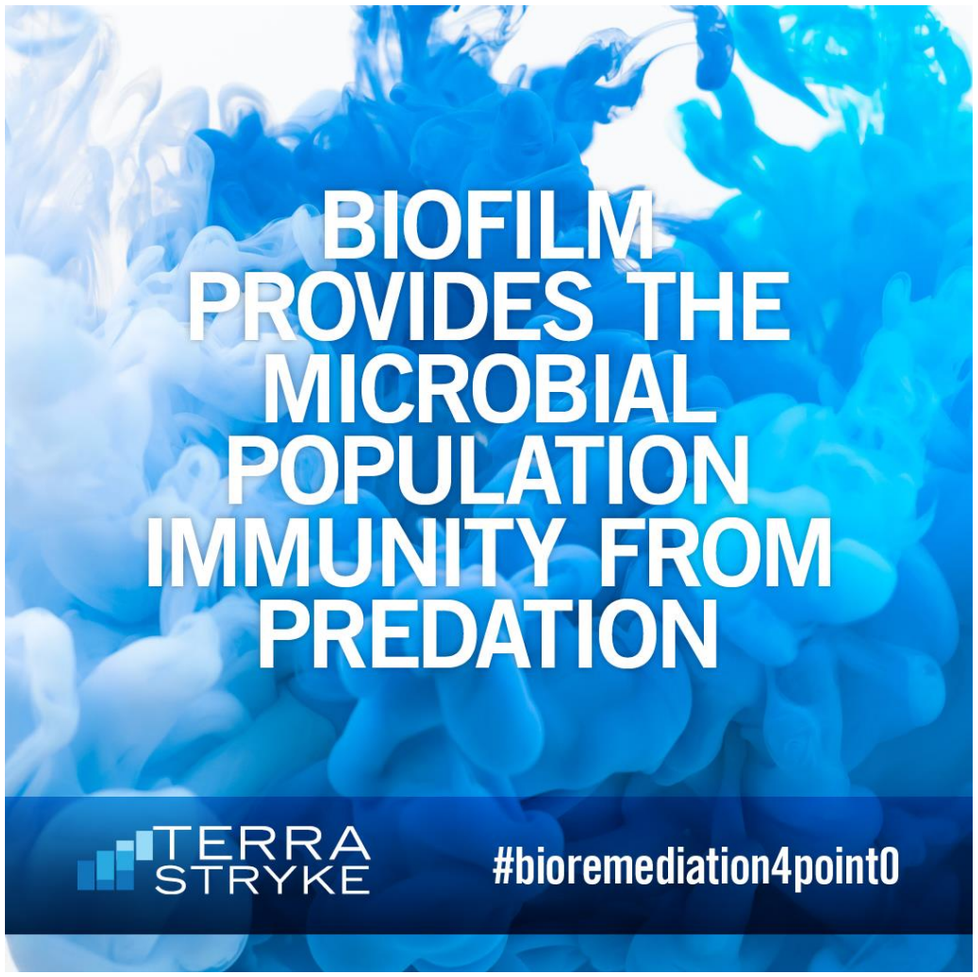
- < 1% of bacteria exist in planktonic form
- >99% of microbial populations live in biofilm
- Communicate (‘talk’), share information, and recruit.
- Determine what benefits the population.
- Abandon individual roles for specific roles.
- Establish structures, act as eukaryote.

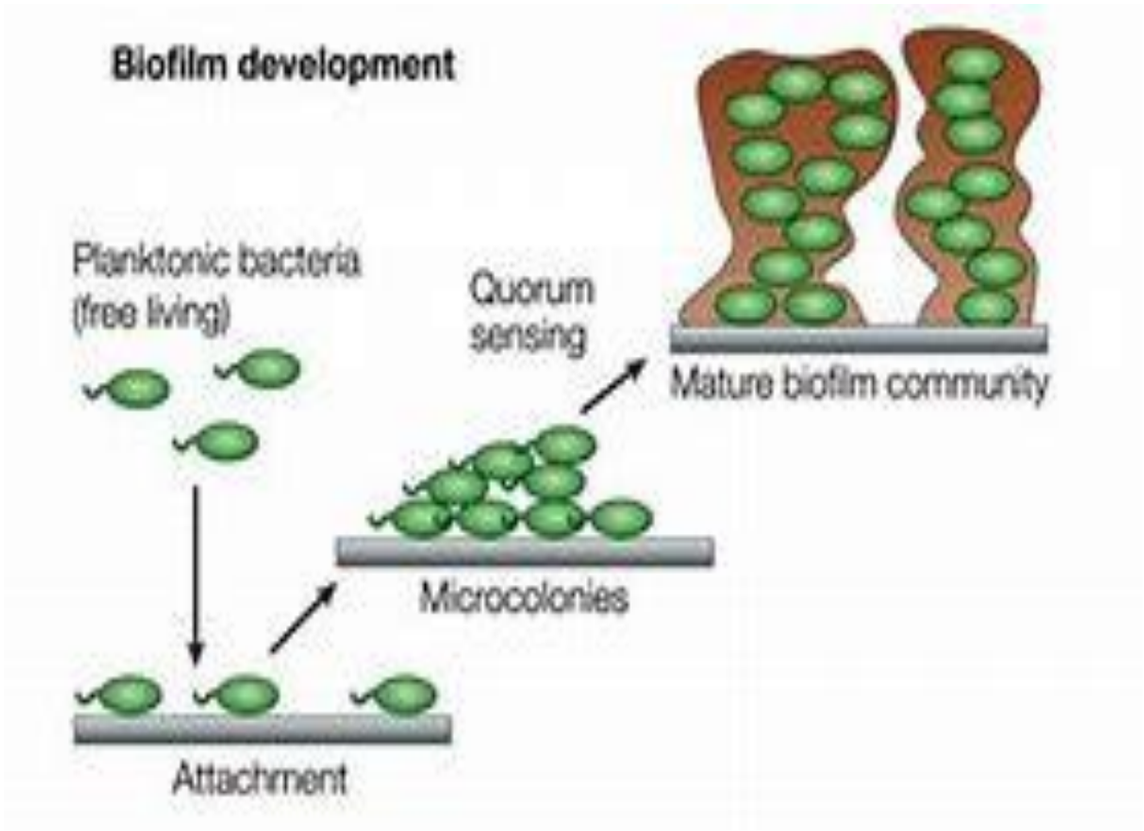
Quorum Sensing & Signaling (QSS)

- Initiated with adequate nutritive capacity of microbial ecosystem
- Requires bulk water planktonic densities to achieve ‘quorum levels’
- Allows signaling molecule (AI-2) to reach ‘quorum’ concentrations.
- ‘Instructs’ community of planktonic bacteria to phenotypically change.
- Collectively become sessile and begin to establish a multi-specie biofilm.

Biofilm

Biofilm development





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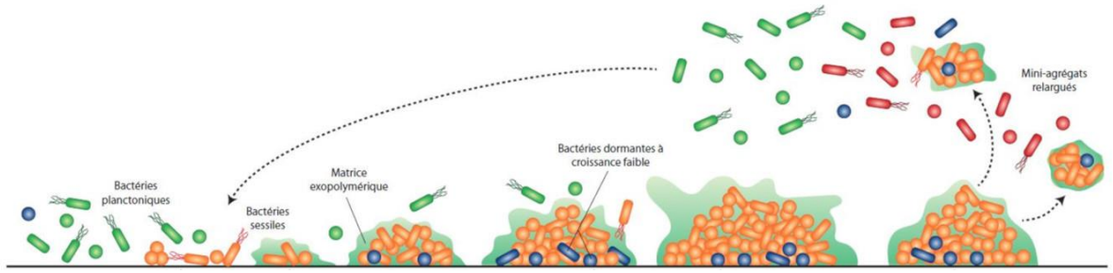
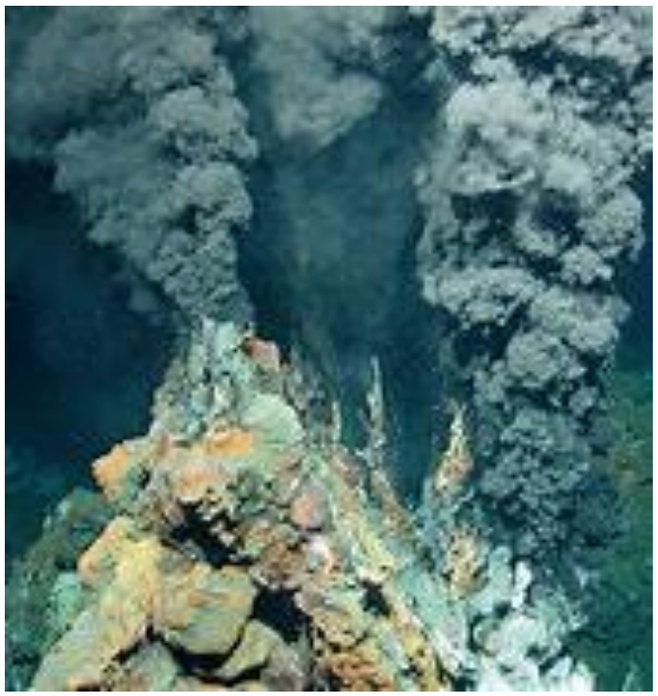
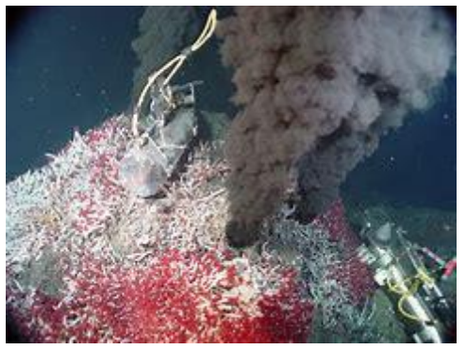
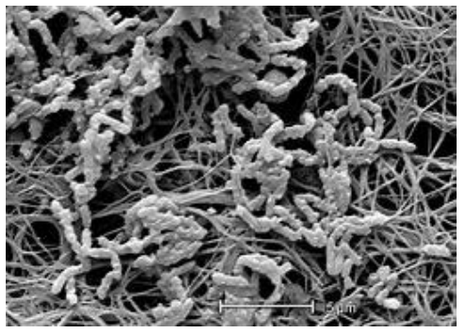






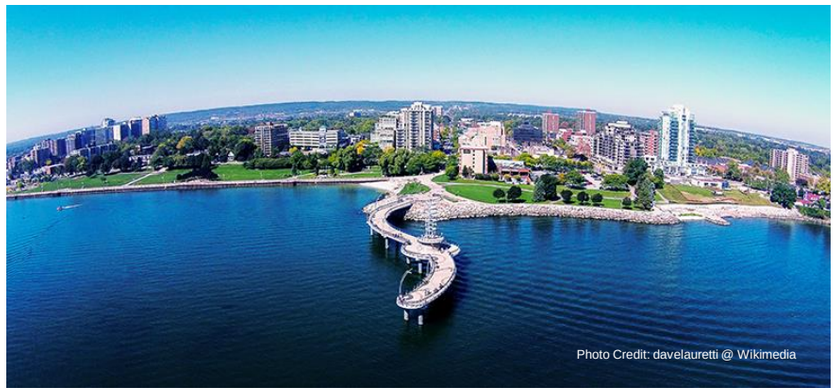


- enhanced cell-to-cell communication.
- nutrients, energy and metabolic substance sinks.
- Provides protection from predation and bulk water conditions
- Heterogeneous multi specie cultures.
- Most prevalent form of biology.

Case Study

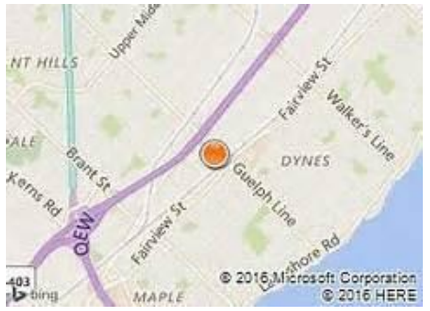
Burlington, Ontario Site

Former Dry Cleaner



Former Dry Cleaner

- [PCE] in saturated soil/groundwater above MOECC Table 3 SCS
- Residual source mass in saturated soils



Site Conditions

- Generally Coarse Textured Soils
- Highly weathered Shale with Silty-Sand
- Silt Generally moist
- 0.5m – 5m bgs elevated PID readings

Property Value

- Property attained by Owner thru bankruptcy
- 2011 Appraised Value $680,000

Case Study

Burlington, Ontario Site
Former Dry Cleaner

Excavation – Source Removal

- Removed 250m^3 contaminated soils
- Infiltration gallery installed w/in footprint
- Clear stone, 6-inch slotted PVC, 2-3m bgs

Additive Deployment

- Gravity fed 9% additive slurry
- 1,056 lbs to 1,100 gallons chase water March and again June 2014

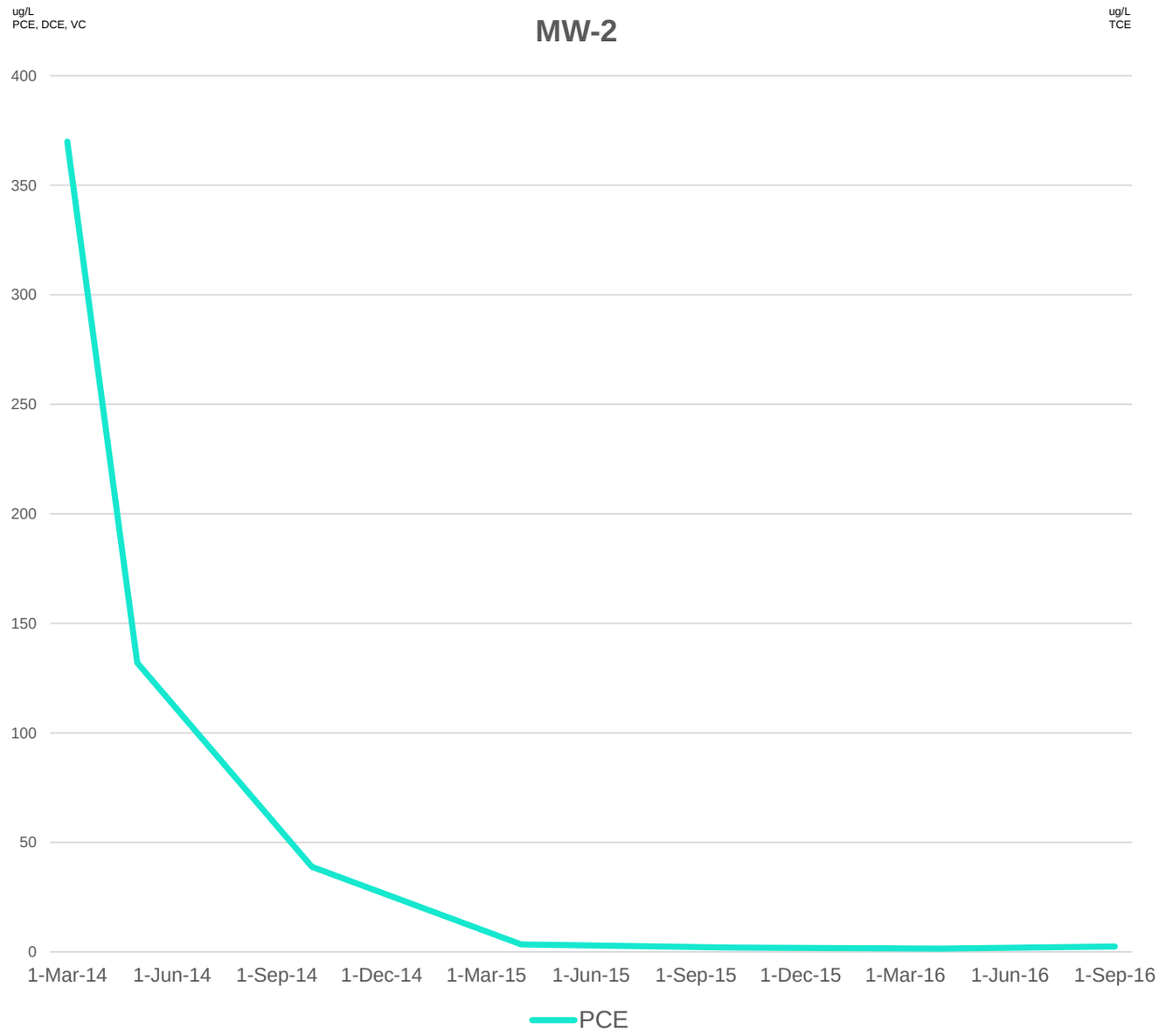
Case Study

Burlington, Ontario Site
Former Dry Cleaner

Results T=2 Years

MW-2 50-60ft downgradient

- 99.4% reduction [PCE]



Case Study

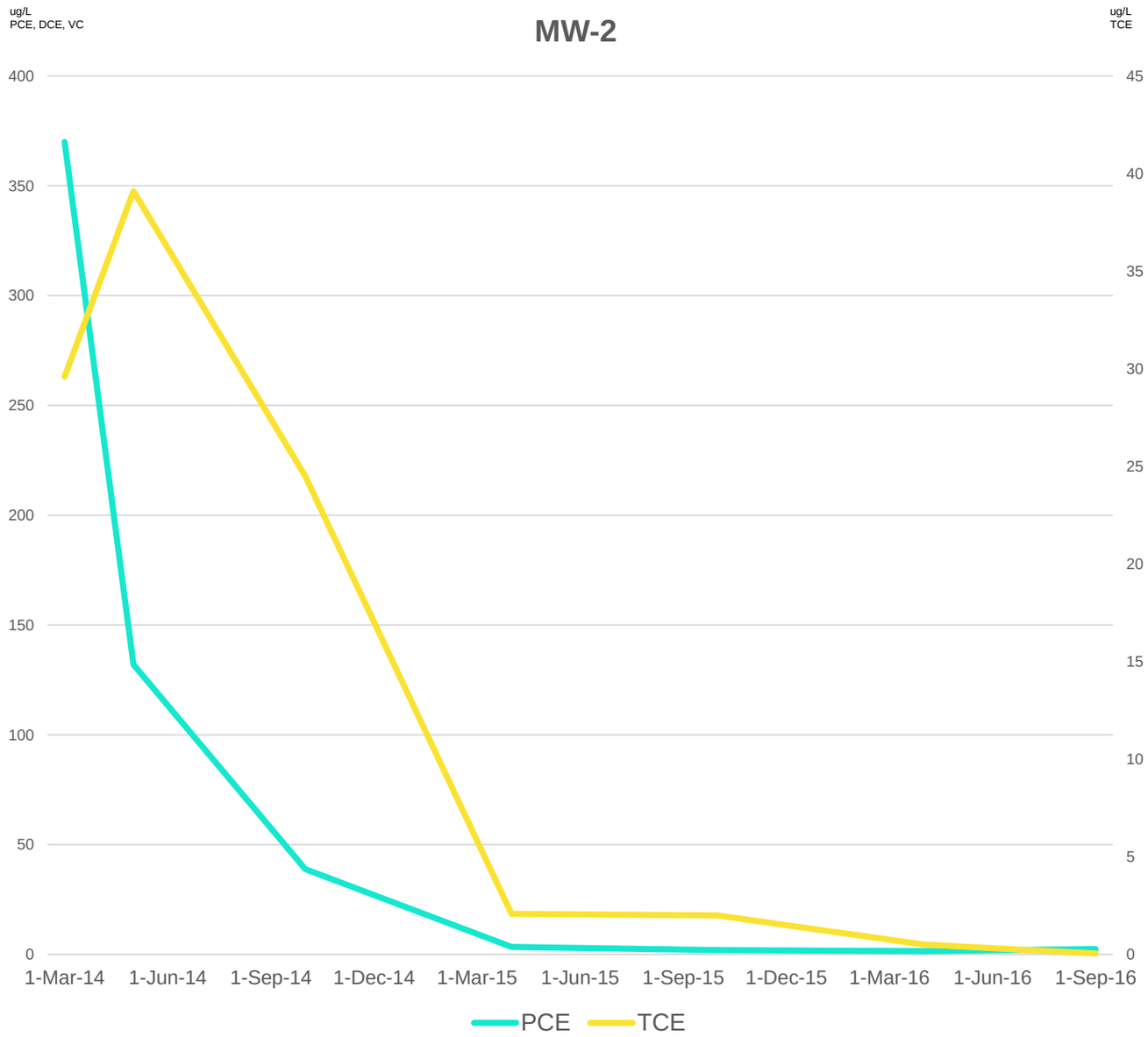
Burlington, Ontario Site
Former Dry Cleaner

Results T=2 Years

MW-2 50ft downgradient

- 99.4% reduction [PCE]

- After initial 32.1% increase
- 99.9% reduction [TCE] from peak.



Case Study

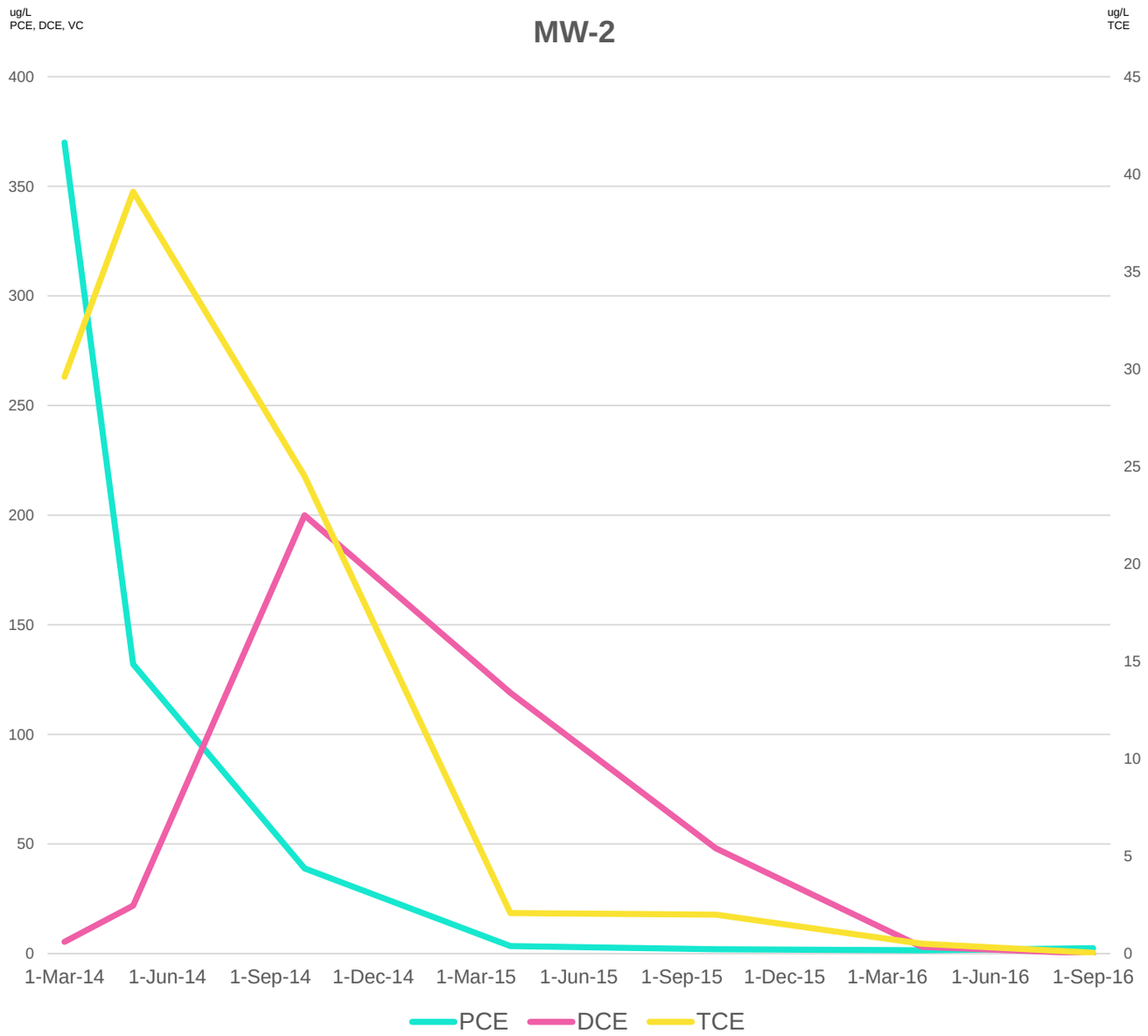
Burlington, Ontario Site
Former Dry Cleaner

Results T=2 Years

MW-2 50ft downgradient

- 99.4% reduction [PCE]
- 99.9% reduction [TCE]

- After 3,600% increase
- >99.99% reduction [cis-DCE] from peak



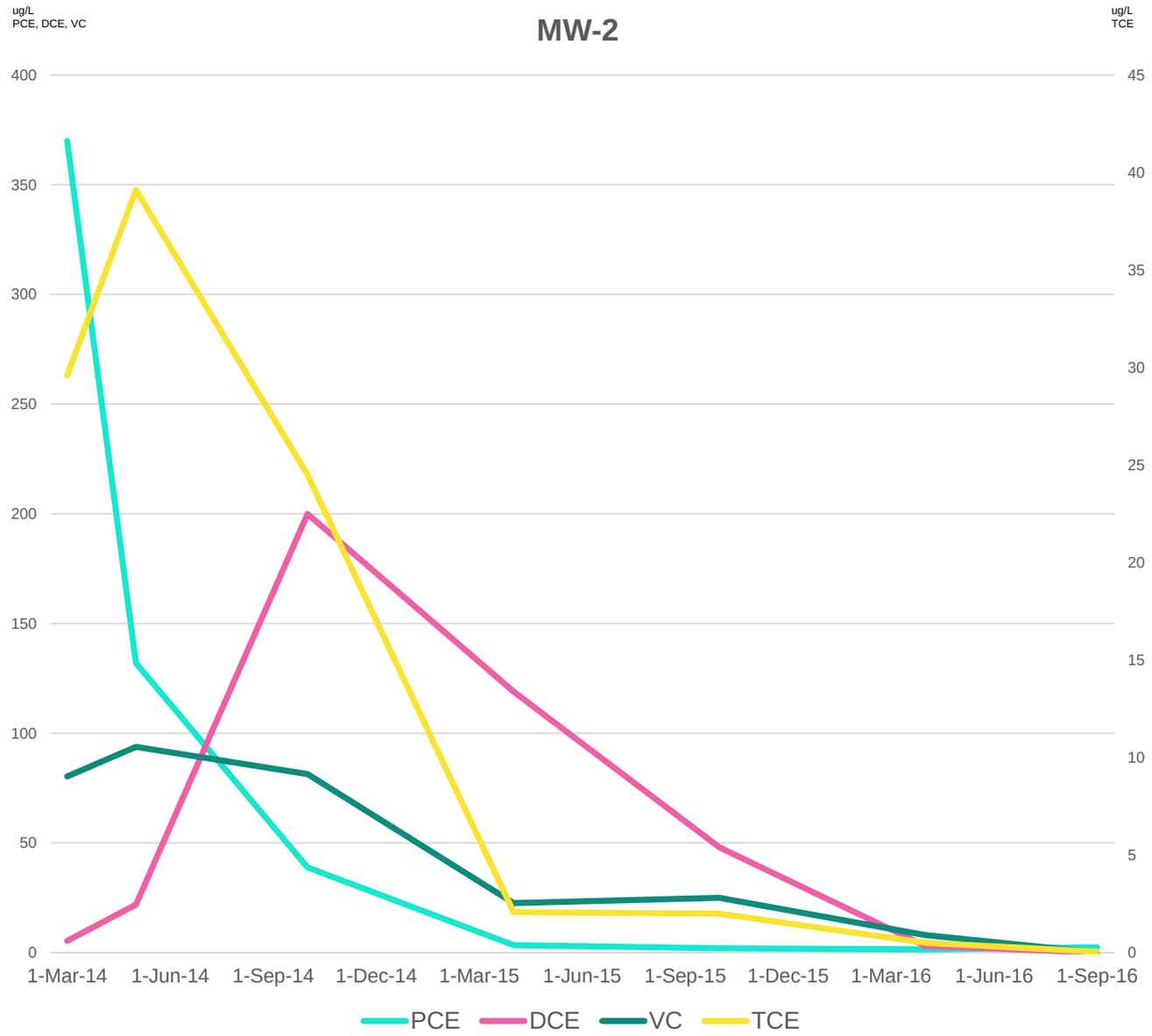
Case Study

Burlington, Ontario Site
Former Dry Cleaner

Results T=2 Years

MW-2 50ft downgradient

- 99.4% reduction [PCE]
- 99.9% reduction [TCE]
- ≈100% reduction [cis-DCE]
- 99.9% reduction [VC] after 16.8%↑
- 99.5% reduction in [cVOCtotal]
- [Ethene] generated throughout program = complete biotransformation



Case Study

Burlington, Ontario Site
Former Dry Cleaner

Contaminated, property value $680,000
P&T Estimated $750,000 over 12-15 years
Effective Property Value for 15-years $0.00

Biostimulation Strategy
Total project Costs

Soil removal/gallery install	$38,000
Pilot and Full-Scale Additive	$35,000
Consulting and Analytical	$150,000
	$223,000

During 4th year of remediation Site redeveloped

Property Manager attributes $1 million of property value increase to remediation strategy

2018 Property Value Assessed at MORE THAN $2.5 million

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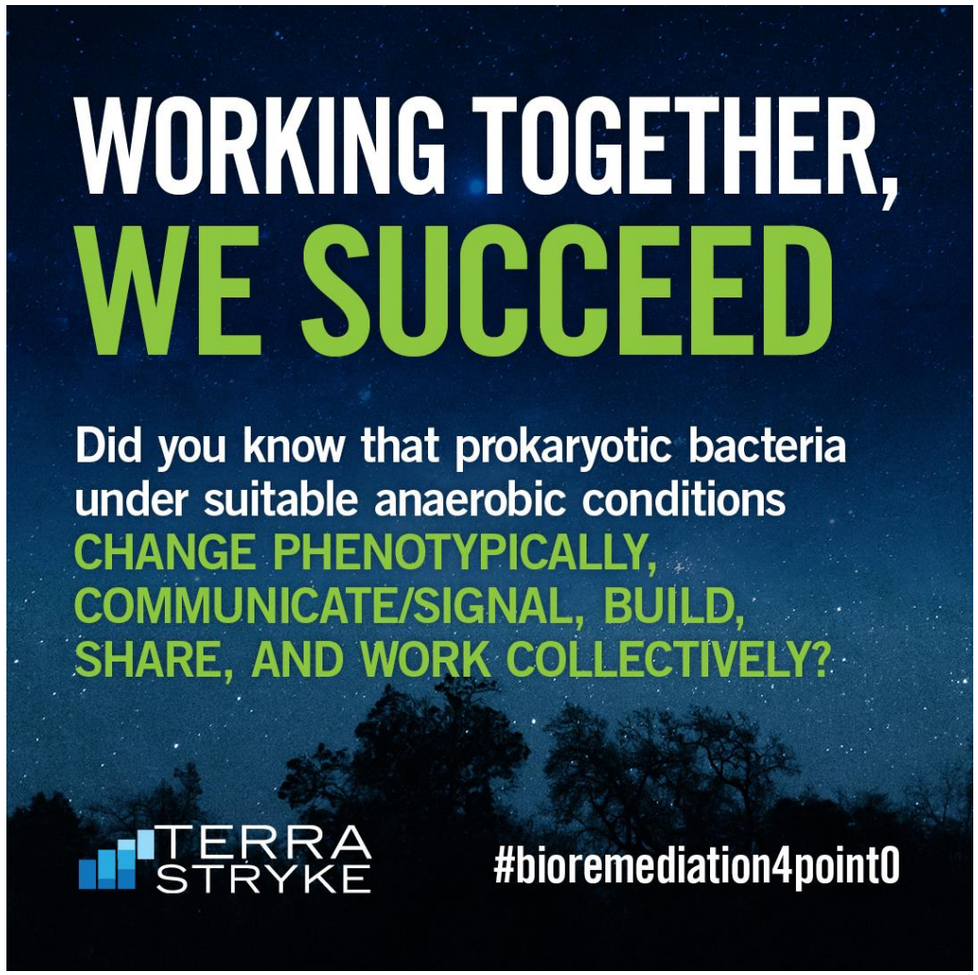
Conclusions

TerraStryke biostimulation additives support the subsurface ecosystem and microbes to expedite:

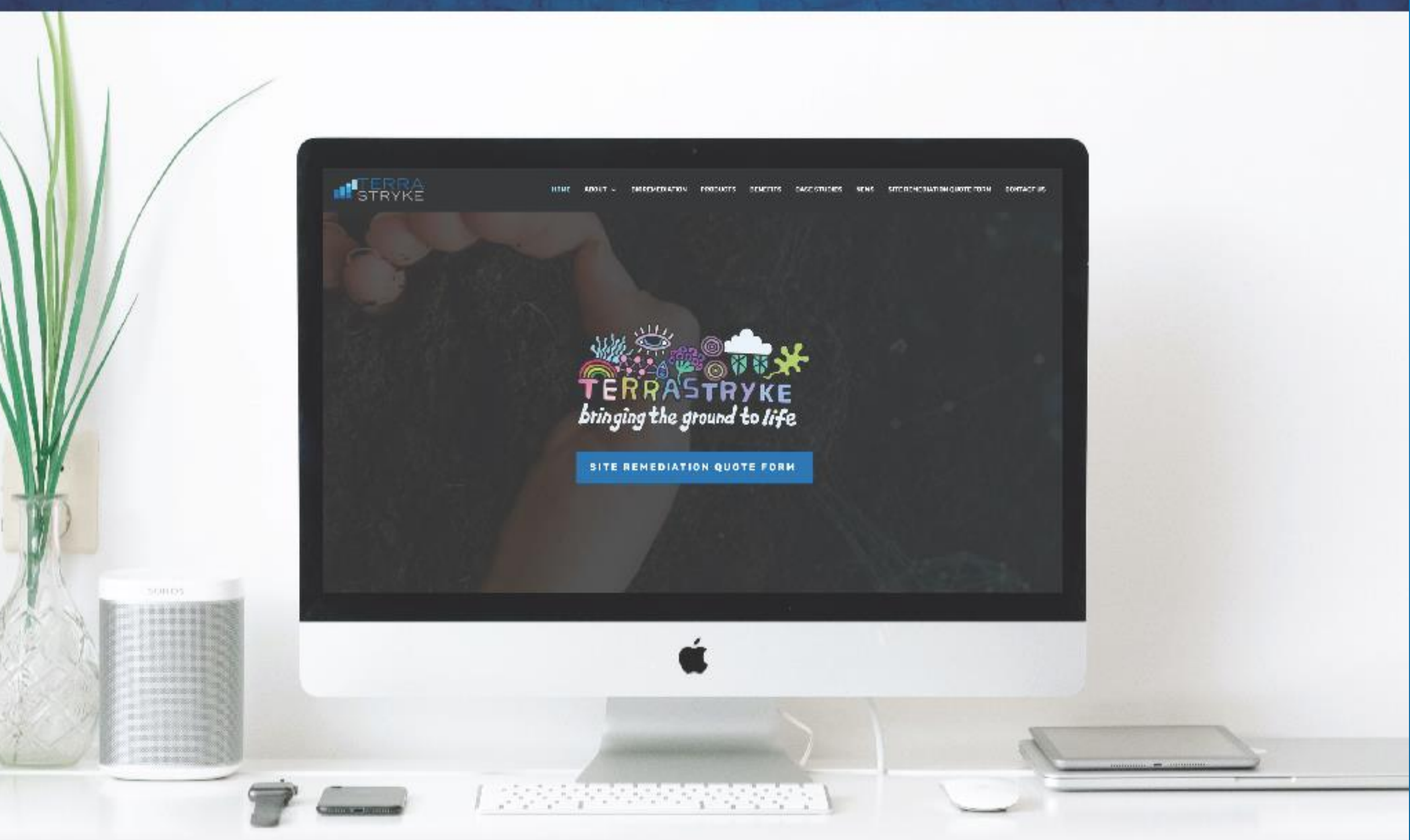
- LNAPL/DNAPL solubilization.
- Dissolved-phase contaminant utilization/destruction.
- The use of organic contaminants as electron donors/acceptors.
- Achieve sustainable remediation without above ground equipment costs/permitting.
- Sequester Greenhouse Gasses.
- Realize Site Compliance with less impacts, less costs simply by letting Nature have it.



Conclusions

There are lots of options out there

Site Remediation Quote Form



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Contact Information

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