



REGENESIS[®]

**Solid Phase Colloidal Organic
Amendments Promote Sustained
Biodegradation in Permeable Reactive
Barriers**

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Overview

Enhanced
Reductive
Dechlorination

Coupling ERD
With CAC

New Donor
Introduction

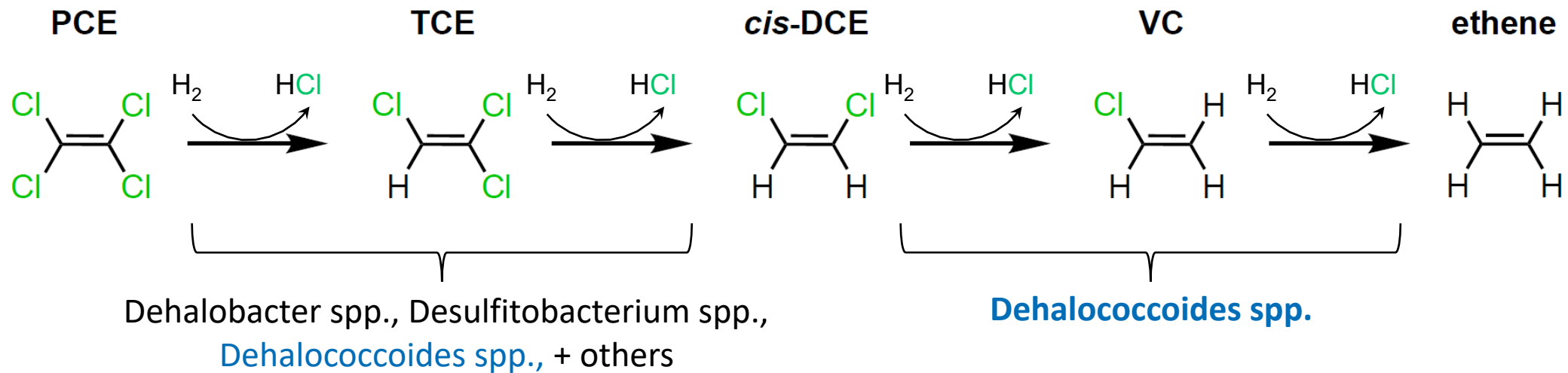
Field
Demonstration

Conclusions

Enhanced Reductive Dechlorination (ERD)

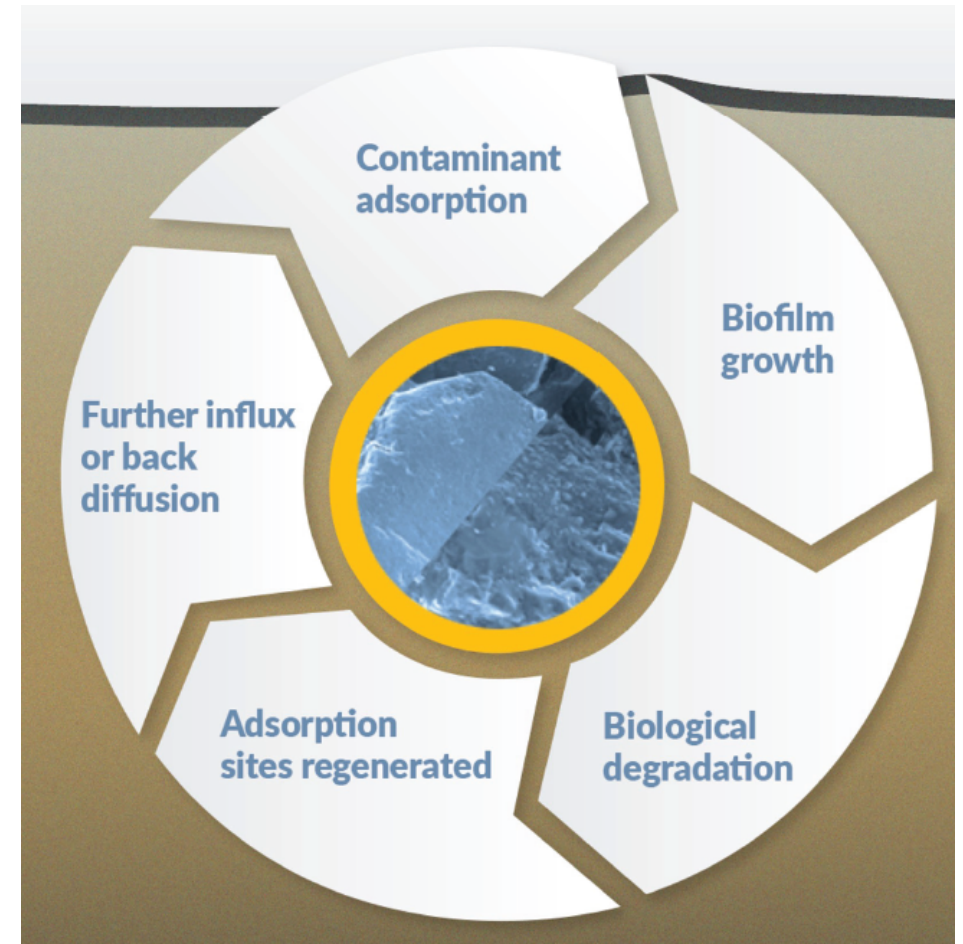
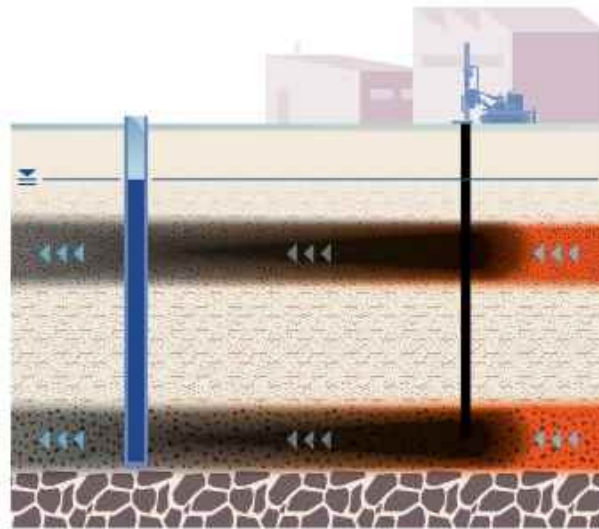
Bioremediation of halogenated contaminants

- Select microbes facilitate dechlorination
- Require H₂, produced by fermenters



ERD + Colloidal Activated Carbon (CAC)

- Rapid sorption, immediate reduction in concentrations, mass flux
- Minimal flux of CVOC daughters
- Allows for biodegradation within smaller footprint
- Long-term CVOC treatment through biotic and abiotic degradation pathways




Bioremediation Amendment Candidates

Comparing Hydrogen Sources

Donor Type	Examples	Application Method	Distribution	Persistence	Compatible with Activated Carbon
Soluble	Lactate, Molasses	Low Pressure	Excellent	Poor	Yes
Emulsion	EVO, 3DME	Low Pressure	Excellent	Moderate to Good	No
Solids	Cellulose, Chitin	High Pressure	Poor	Excellent	Yes

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Solids	Cellulose, Chitin	High Pressure	Poor	Excellent	Yes
Colloidal Solid	 Long-Lasting Colloidal Electron Donor	Low Pressure	Excellent	Excellent	Yes

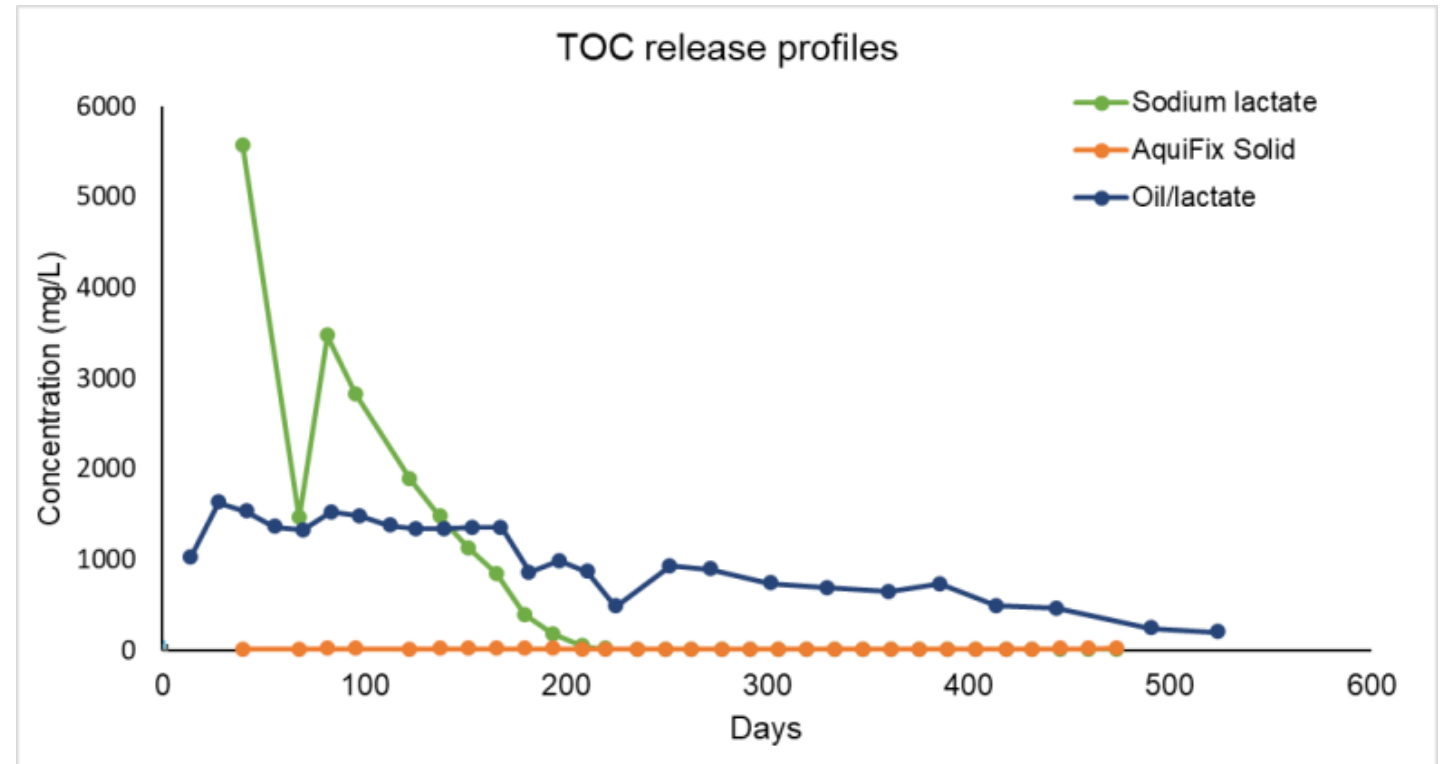
Colloidal Solid Donor Attributes

- Solid, colloidal (0.5 micron) organic substrate
- Blended with fast-release components
- Includes micronutrients (vit. B-12)
- Co-injectable with CAC under low pressure
- Slow release of TOC for 10+ years



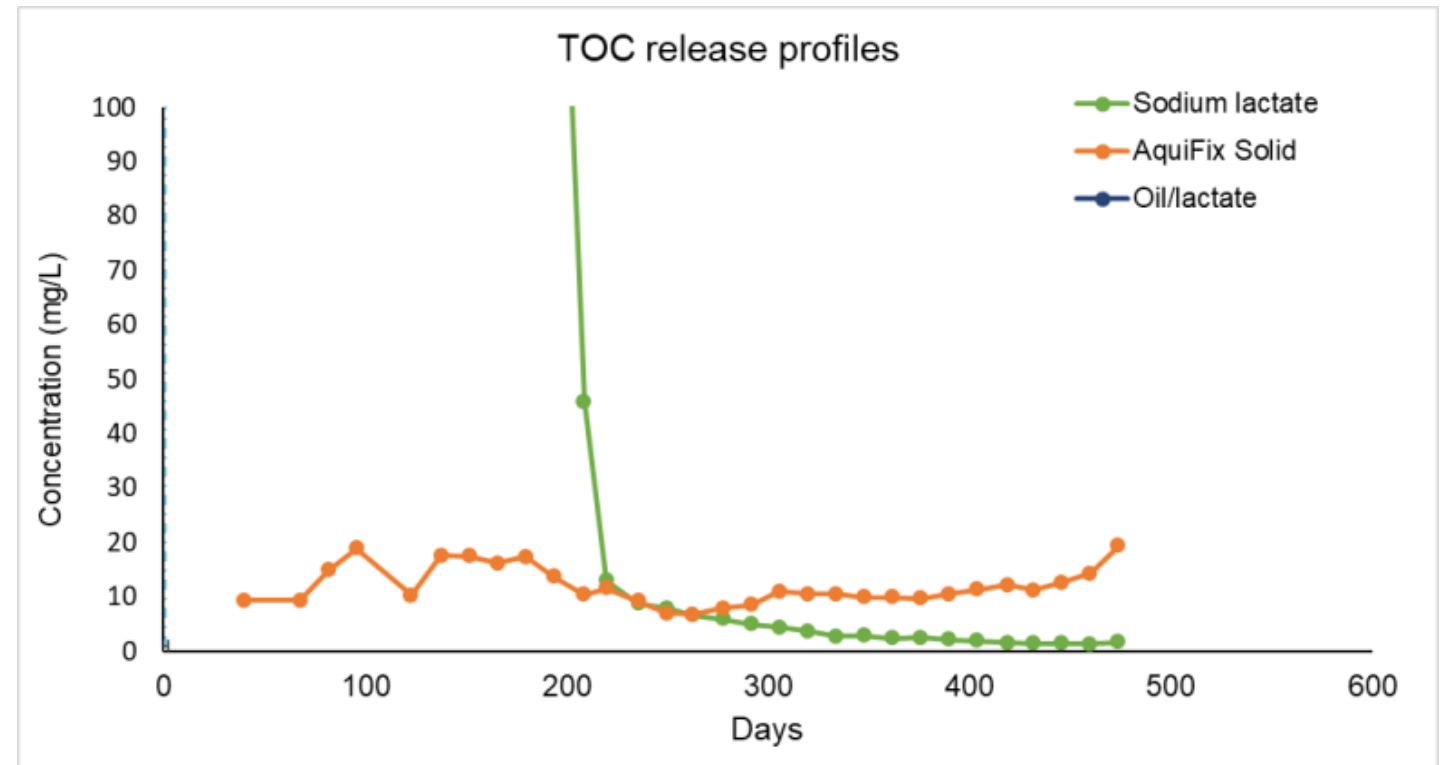
Demonstrating Donor Longevity

- 1000 mL Jars
- 20 g of organic substrates added
- Anoxic, spiked with BDI+
- 10% of volume replaced every 2 weeks
- Regular monitoring by TOC
- Early points also included volatile fatty acid analysis



Demonstrating Donor Longevity

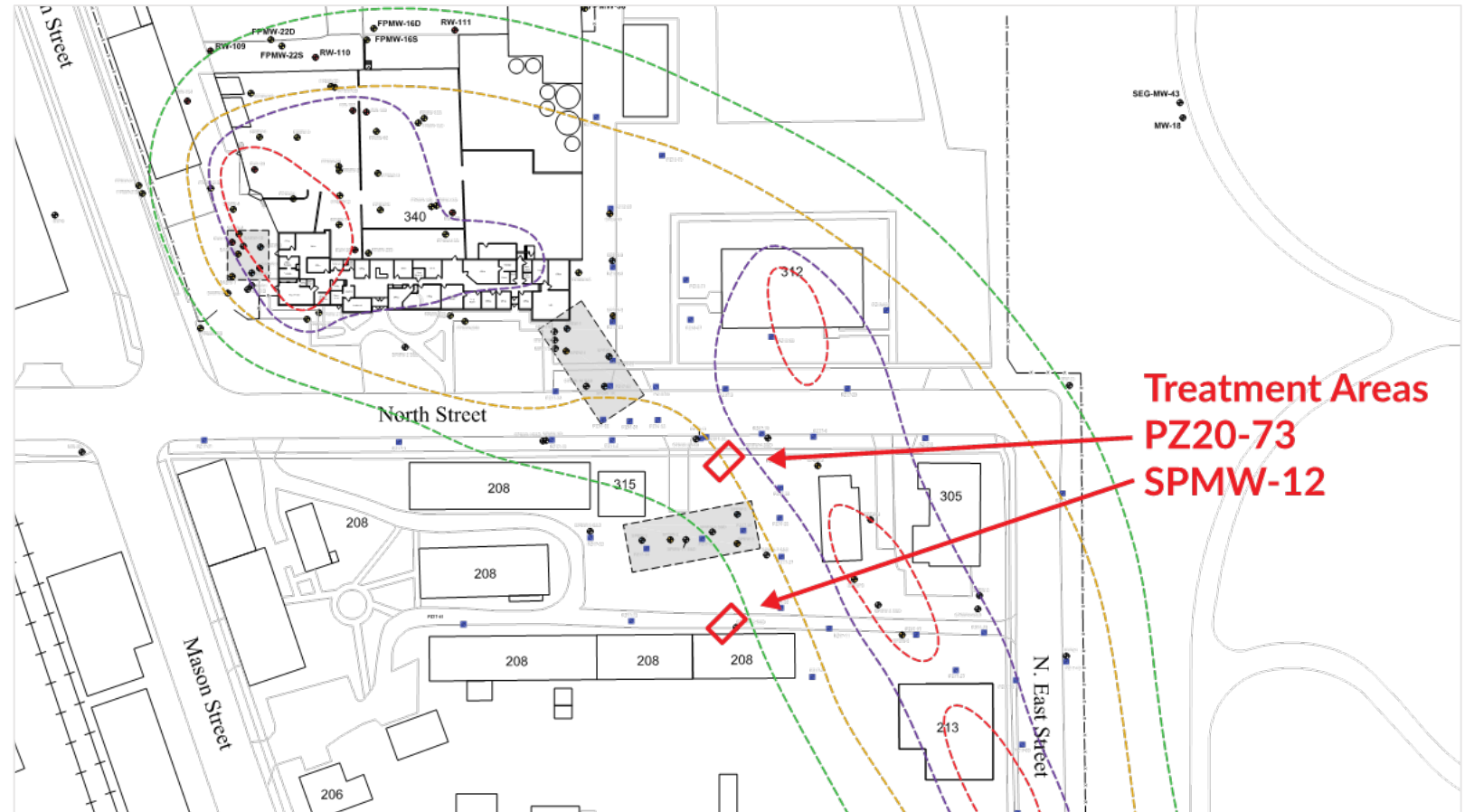
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Case Study

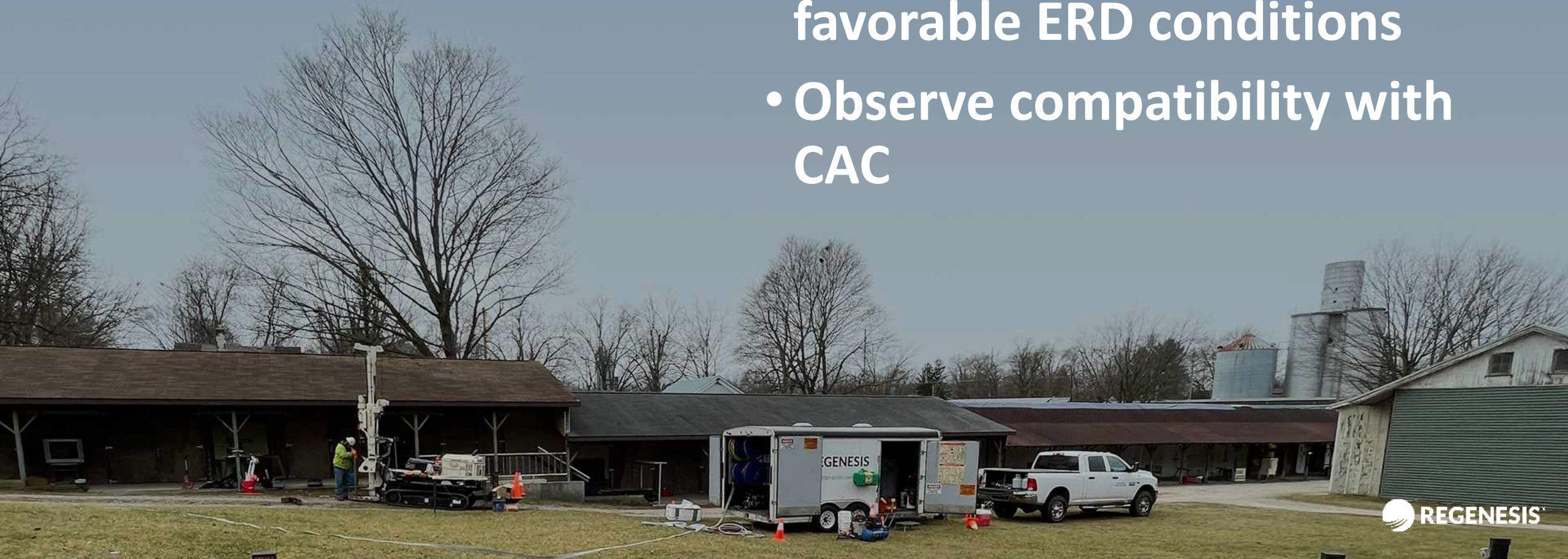
Site Overview

- Site in Michigan
- Manufacturing and Distribution Facility
- Large Plume
 - High mg/L CVOC, 1,1,1-TCA and 1,1-DCE
- Comingled plume with LNAPL, resulting in cis-DCE, VC
- Interesting geology (esker), high mass, GW flux



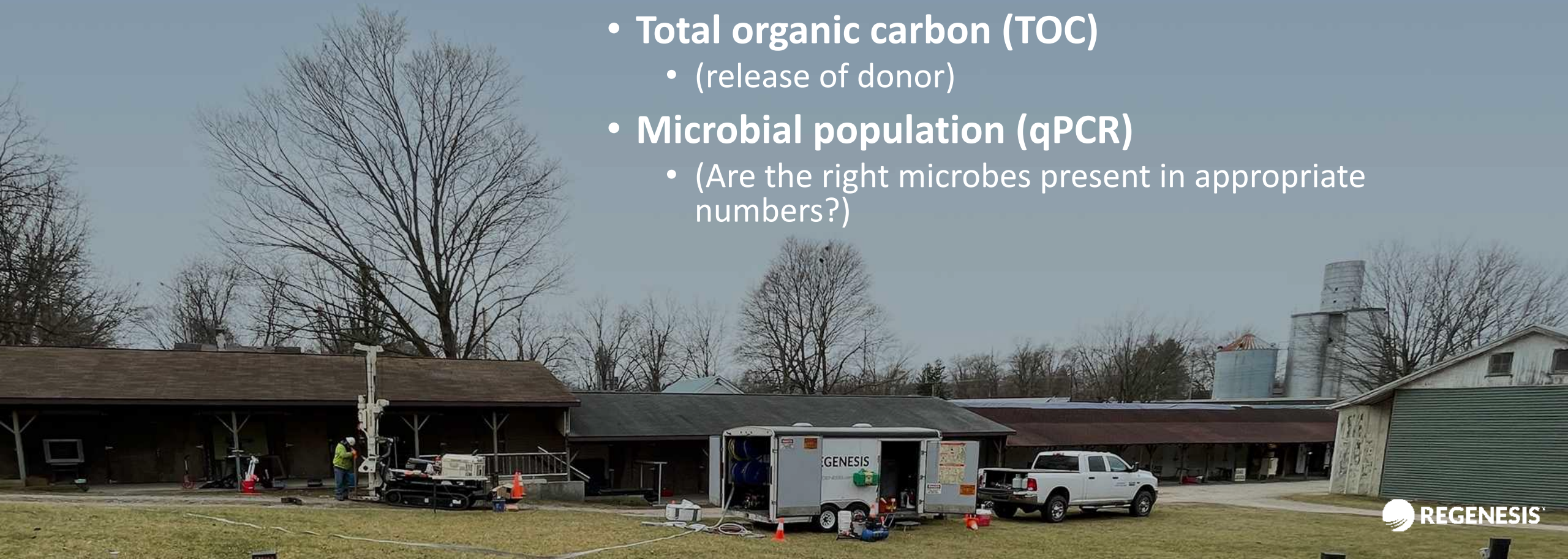
Study Objectives:

- Demonstrate Donor's ability to maintain favorable ERD conditions
- Observe compatibility with CAC



Evaluation:

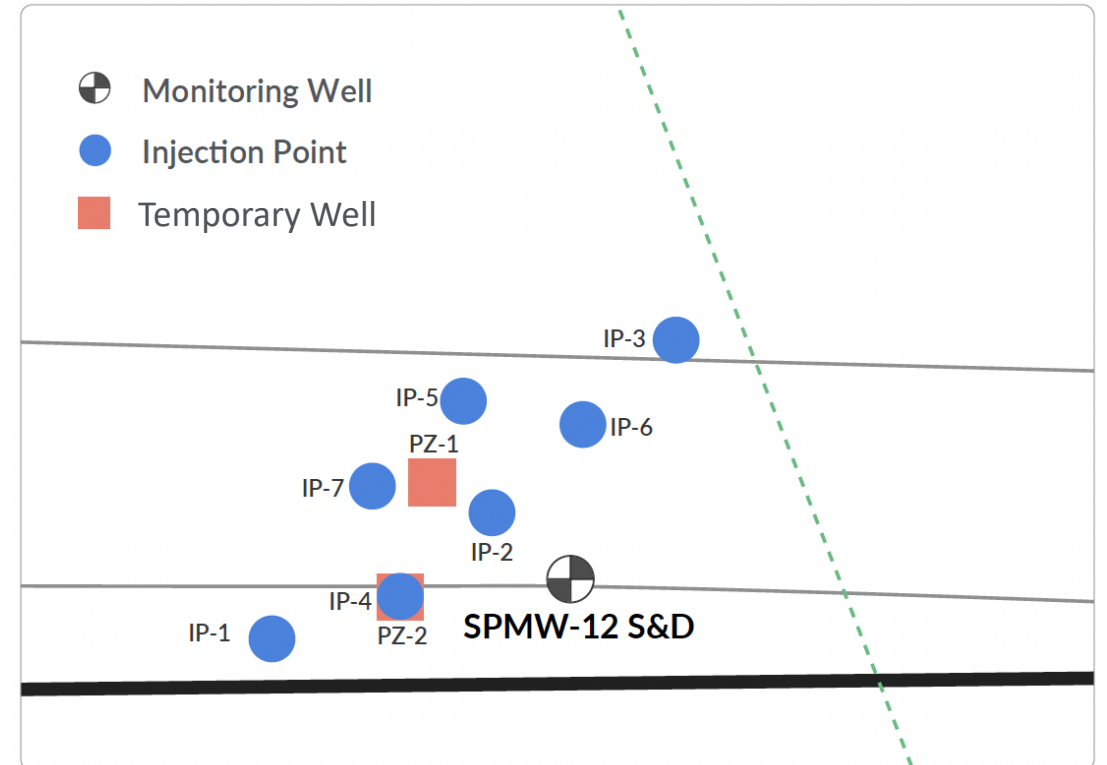
- **CVOCs (performance)**
- **Dissolved gases, including methane and ethene**
 - (complete mineralization, bio)
- **Total organic carbon (TOC)**
 - (release of donor)
- **Microbial population (qPCR)**
 - (Are the right microbes present in appropriate numbers?)



Application Details

SPMW-12

PRB Length	20 feet
Injection Interval	17.5 – 27.5 feet bgs
Amendments	
AquiFix	2,000 lbs
BDI	9 liters
Total Mix Volume Applied	1,475 Gallons



Application Details

SPMW-12

PRB Length

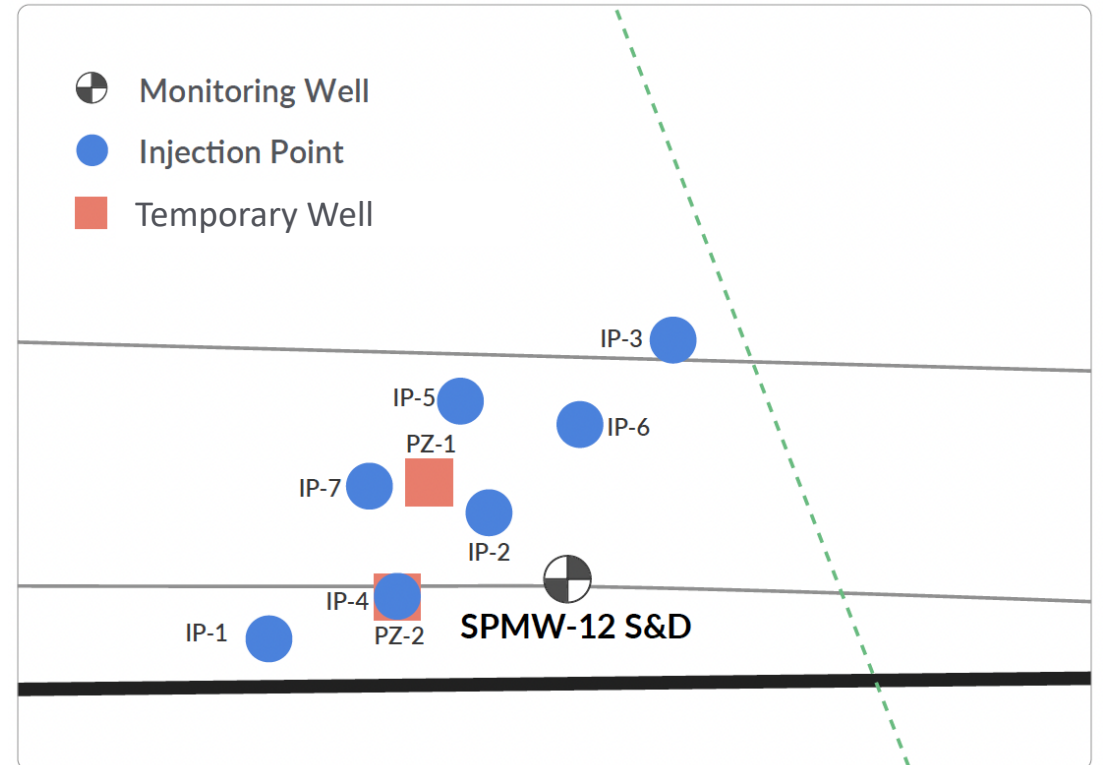
Injection Interval

Amendments

AquiFix

BDI

Total Mix Volume Applied



Application Details

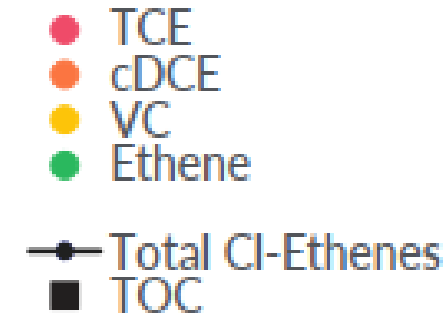
PZ20-73

PRB Length	20 feet
Injection Interval	17.5 – 27.5 feet bgs
Shallow, high-mass flux zone	17.5 – 22.5 feet bgs
Deep, extreme mass-flux zone	22.5 – 27.5 feet bgs
Amendments	
AquiFix	2,000 lbs
PlumeStop	1,434 lbs
BDI	9 liters
Total Mix Volume Applied	1,887 Gallons

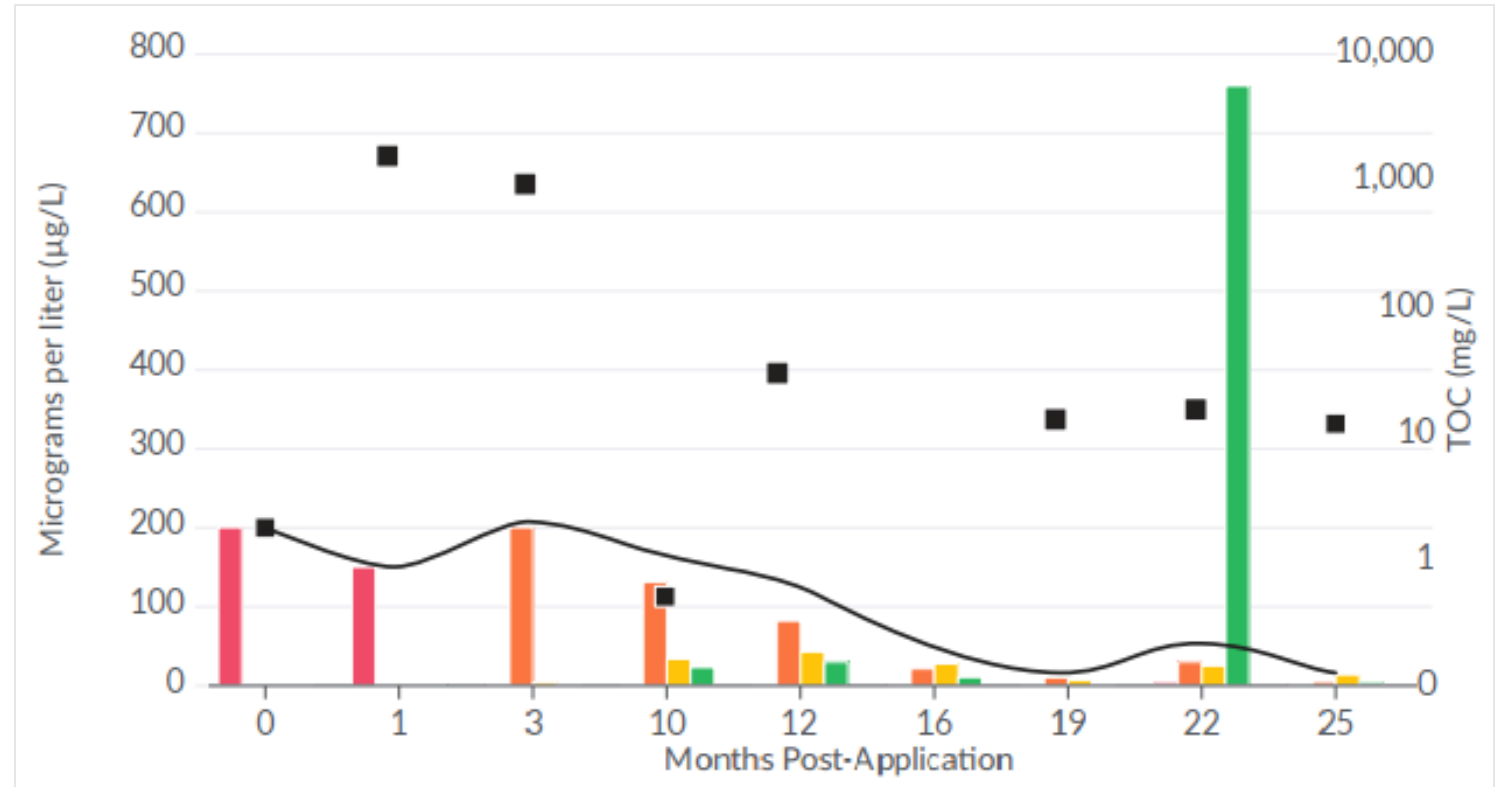


Results

SPMW-12 (Colloidal Donor)

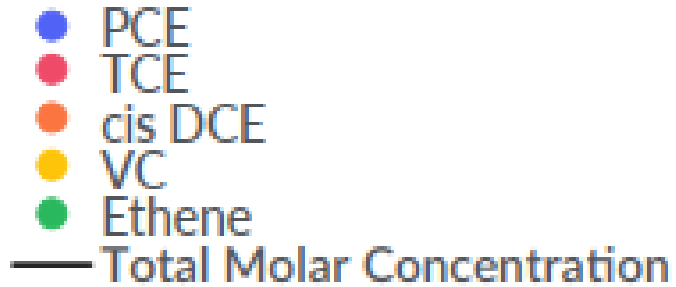


- TCE transformed after 3 months
- Over 90% cVOC removal after 2 years, steady TOC
- Vinyl chloride reductase (VCR), DHC look strong

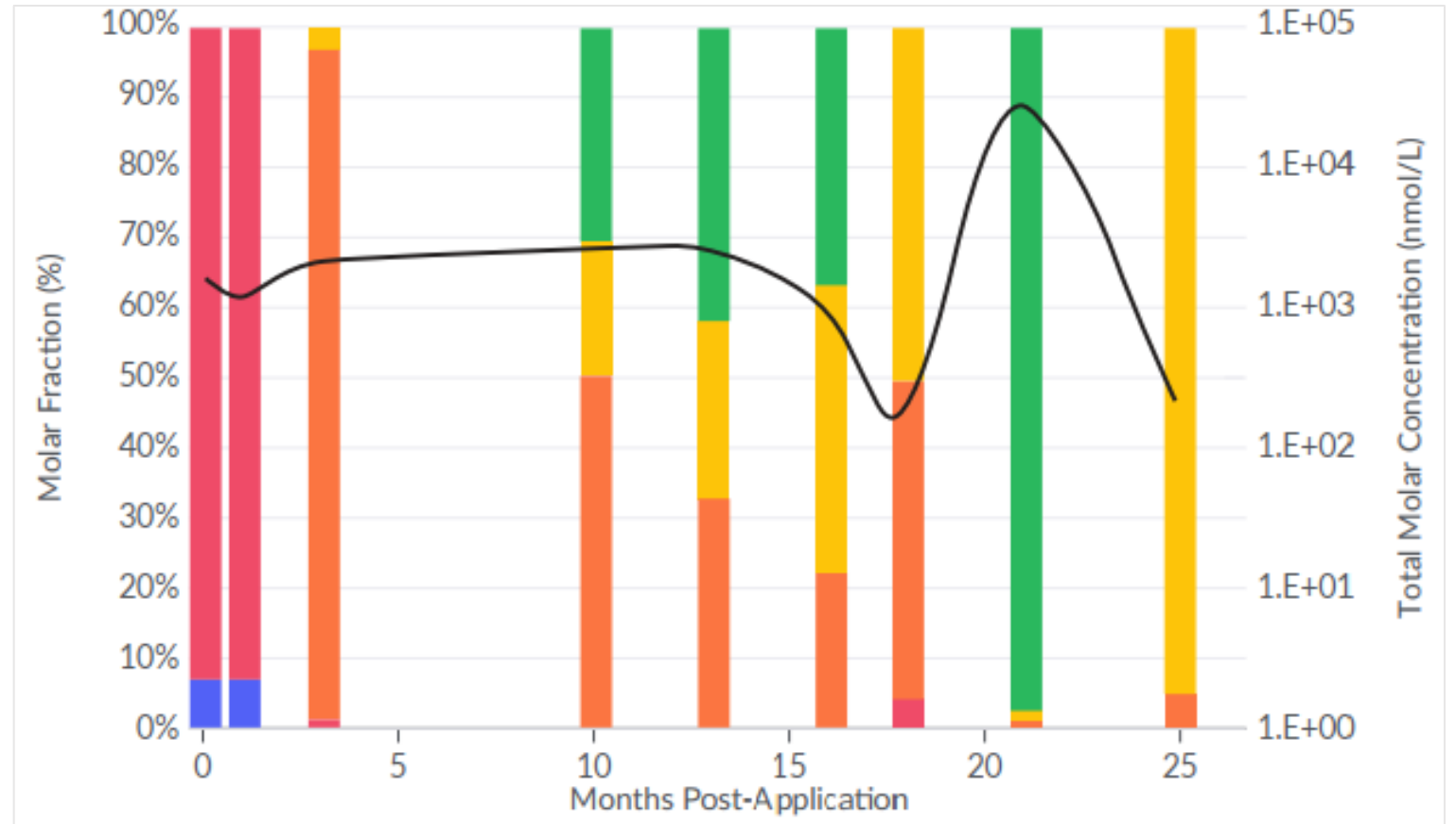


Results

SPMW-12 (Colloidal Donor)



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Results

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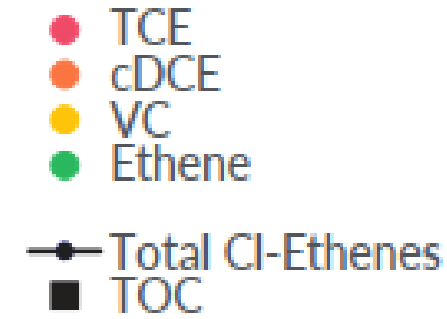
—●— VCR
—●— DHC

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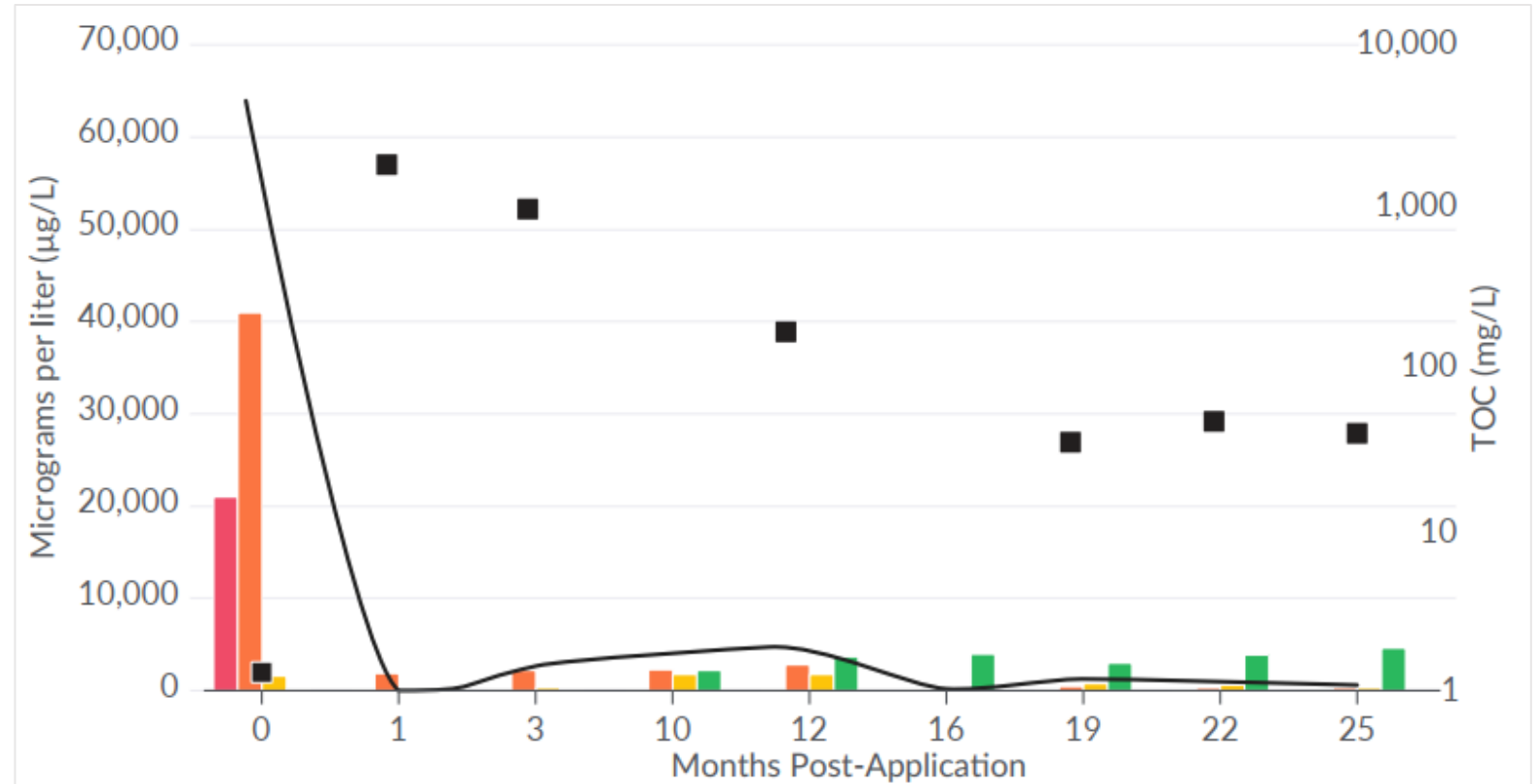


Results

PZ20-73D (Colloidal Donor, CAC)

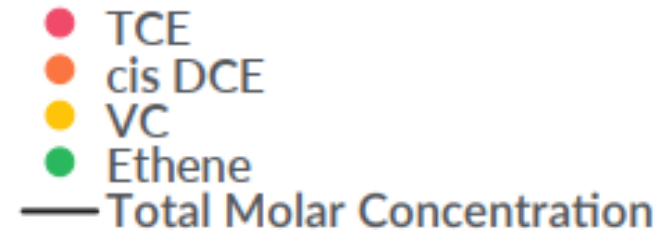


- Near immediate CVOC mass flux elimination
- Mineralization of CVOCs (ethene formation) observed
- Vinyl chloride reductase (VCR), DHC look strong

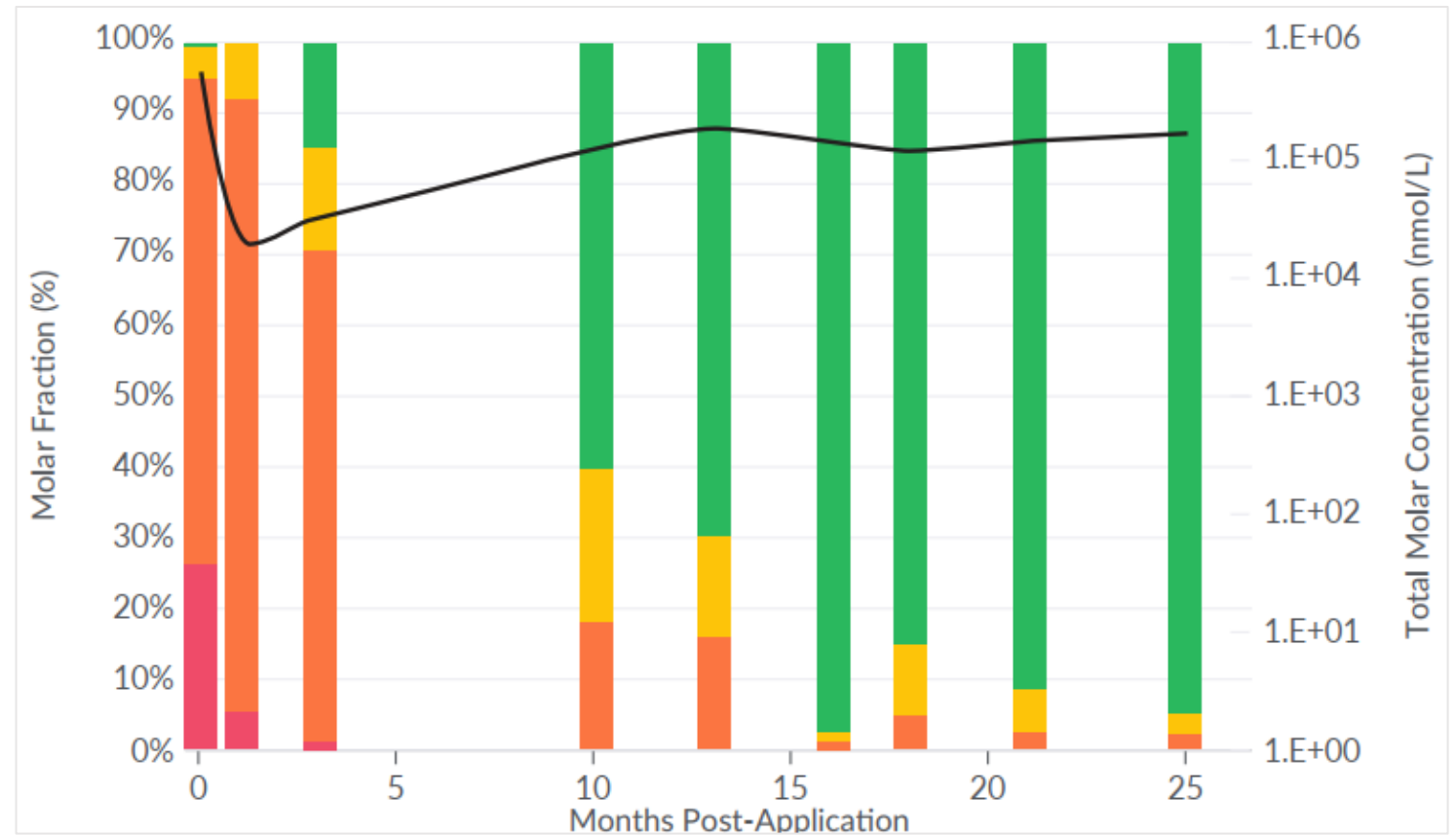


Results

PZ20-73D (Colloidal Donor, CAC)



- Near immediate CVOC mass flux elimination
- Mineralization of CVOCs (ethene formation) observed
- Vinyl chloride reductase (VCR), DHC look strong

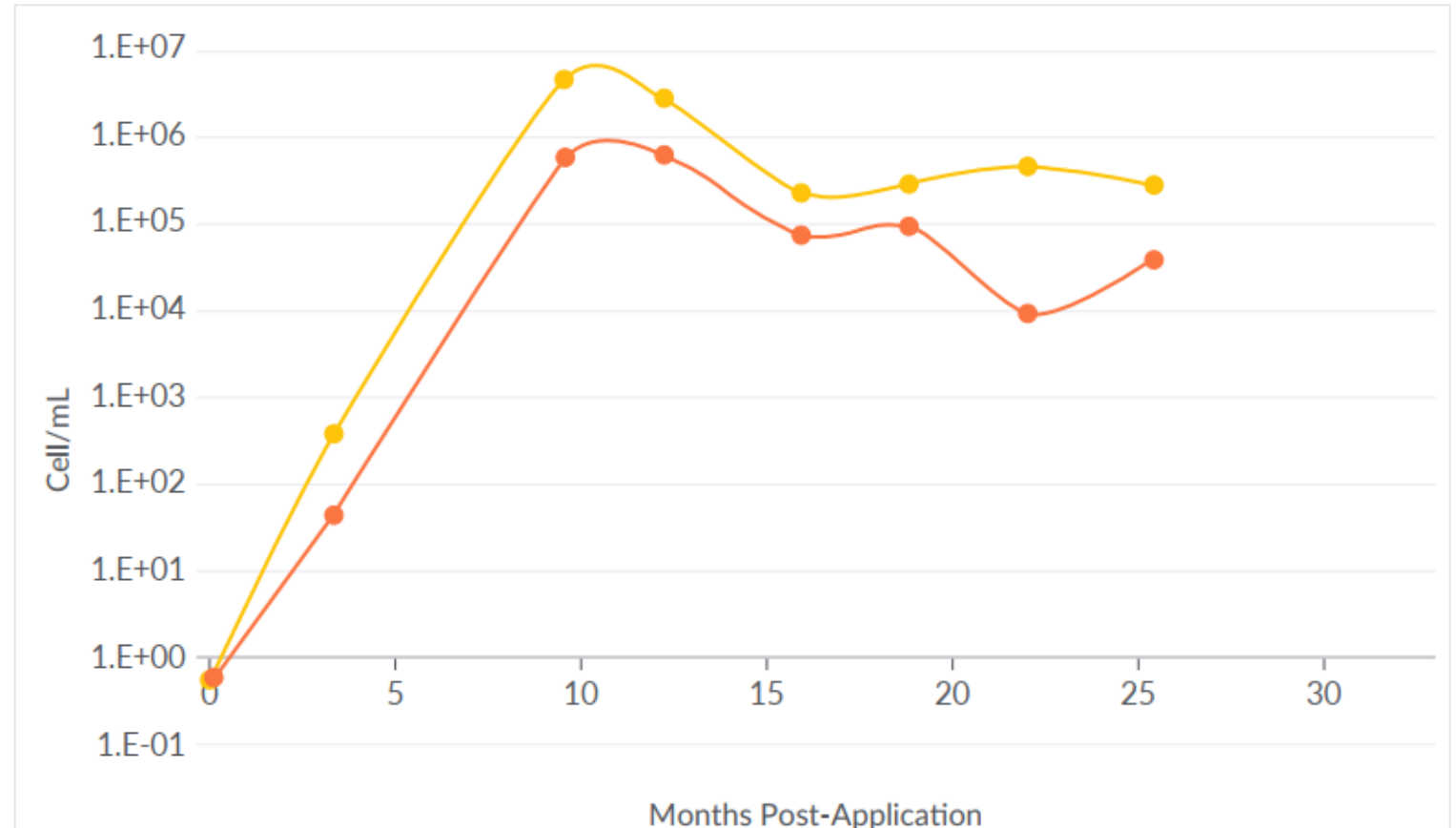


Results

PZ20-73D (Colloidal Donor, CAC)

—●— VCR
—●— DHC

- Near immediate CVOC mass flux elimination
- Mineralization of CVOCs (ethene formation) observed
- Vinyl chloride reductase (VCR), DHC look strong



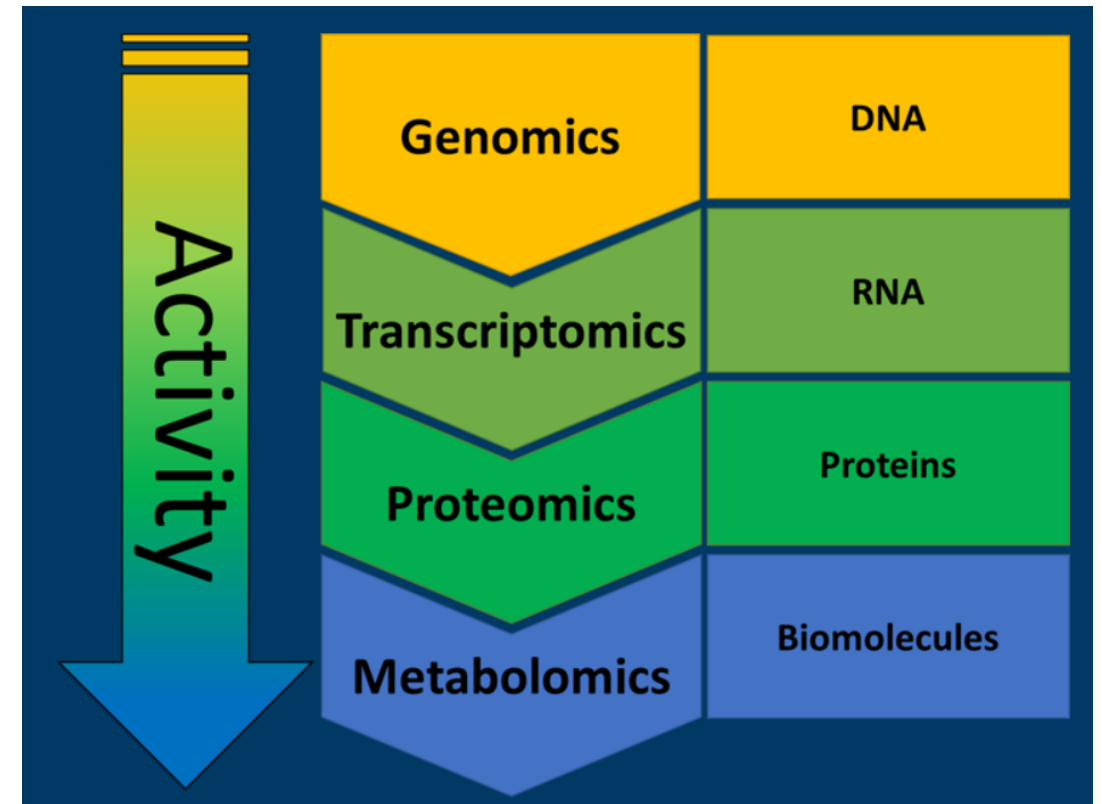
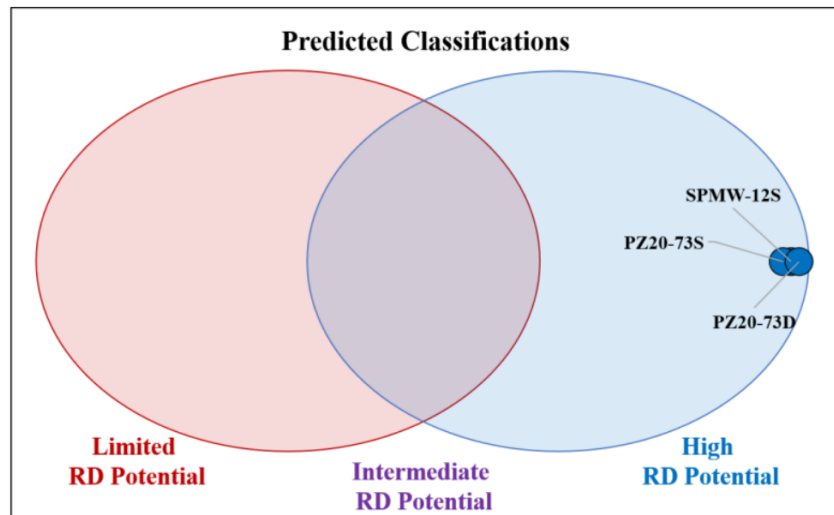
Results

MetaArray data for both treatment areas

Sample Overview Continued

Table 2: Support Vector Machine (SVM) Reductive Dechlorination Classifications

MI Identifier	Sample Name	Predicted Class	SVM Model Accuracy ¹
020UA-1	SPMW-12S	High Reductive Dechlorination Potential	93%
020UA-2	PZ20-73S	High Reductive Dechlorination Potential	93%
020UA-3	PZ20-73D	High Reductive Dechlorination Potential	93%



Metabolomic data also suggest strong ERD potential

Conclusions

- **Colloidal donor supports robust CVOC bioremediation**
- **Capable of long-term, sustained TOC release**
- **Action with or without CAC**
- **Can also be combined with ZVI**
- **TOC release profile consistent with lab results- expected activity for 10+ years**



Thank You!

Questions?



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