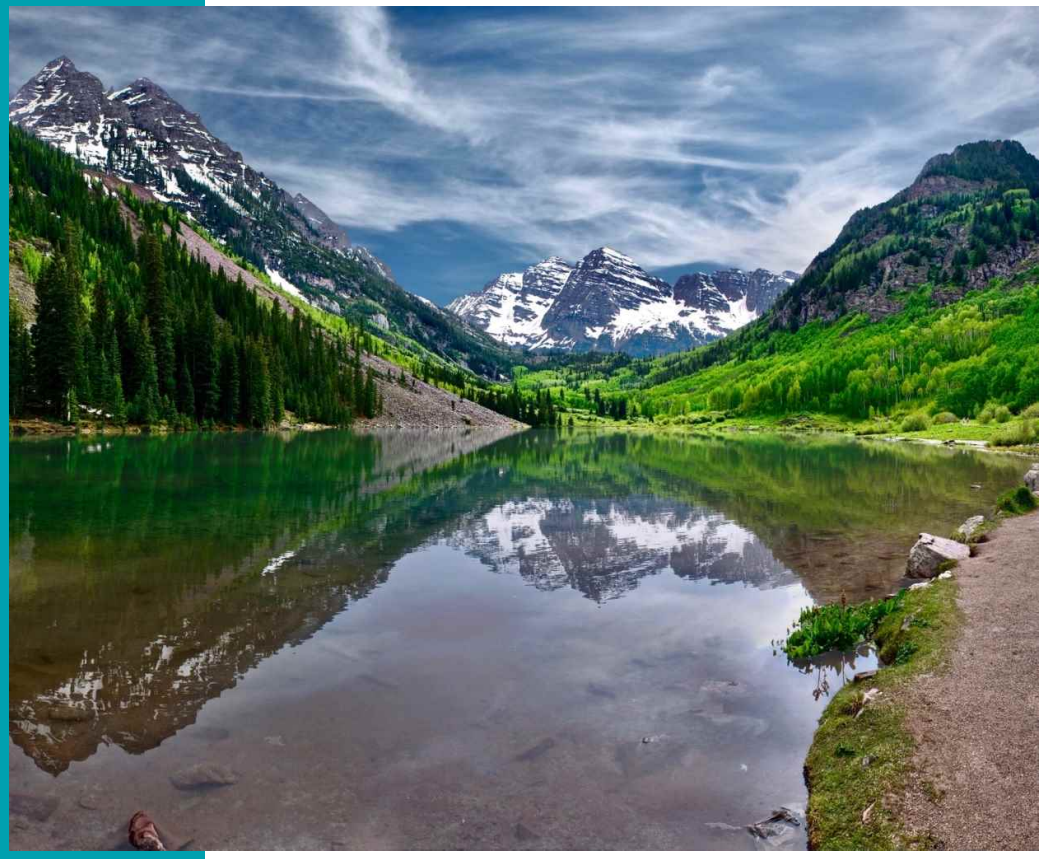
Geosyntec consultants

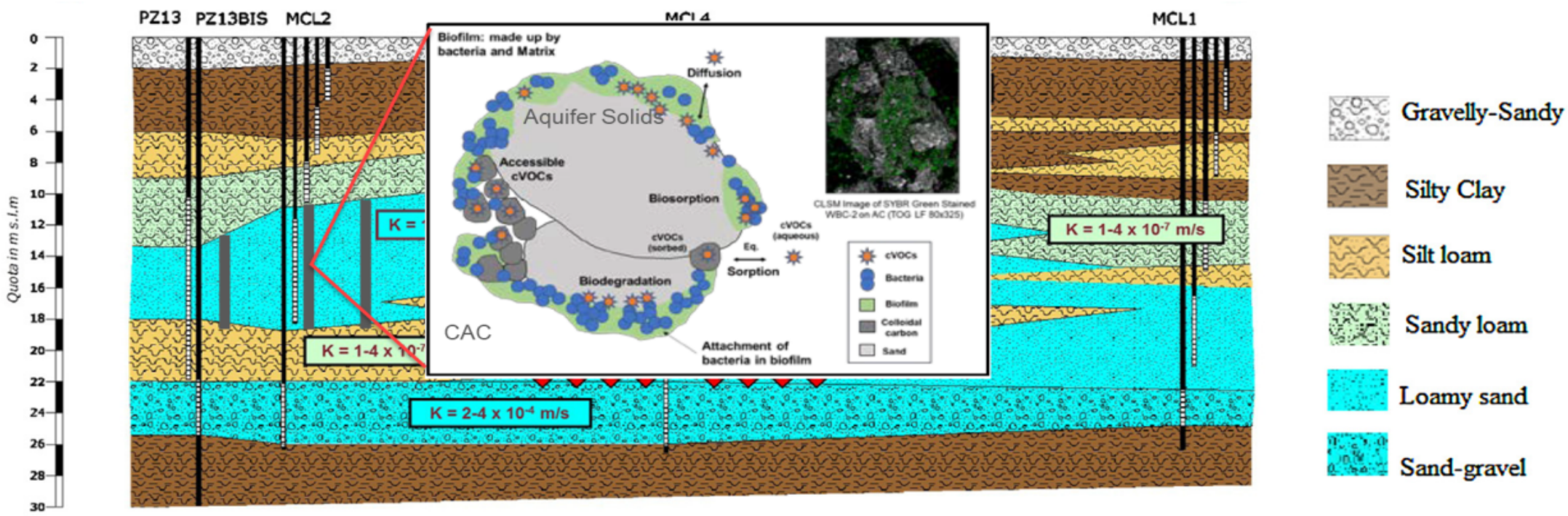
CREATIVE THINKING
EXCEPTIONAL SOLUTIONS



Laboratory Assessment of Injectable Activated Carbon on Biological Reductive Dechlorination of Chlorinated Ethenes

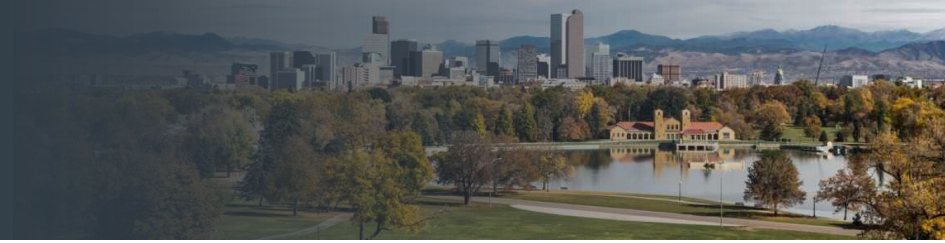
Dimin Fan, PhD, Staci Capozzi, PhD, James Wang, PhD, PE, **Geosyntec Consultants**
Larissa Smith, Sandra Dworatzek, **SiREM**
Birthe Kjellerup, PhD, Amir Riyahi, **University of Maryland, College Park**
Joe Pignatello, PhD, Zhengyang Wang, PhD, **Connecticut Agricultural Experiment Station**

Motivation



Fundamental – Pore scale ⟷ Practical – Plume scale

Outline

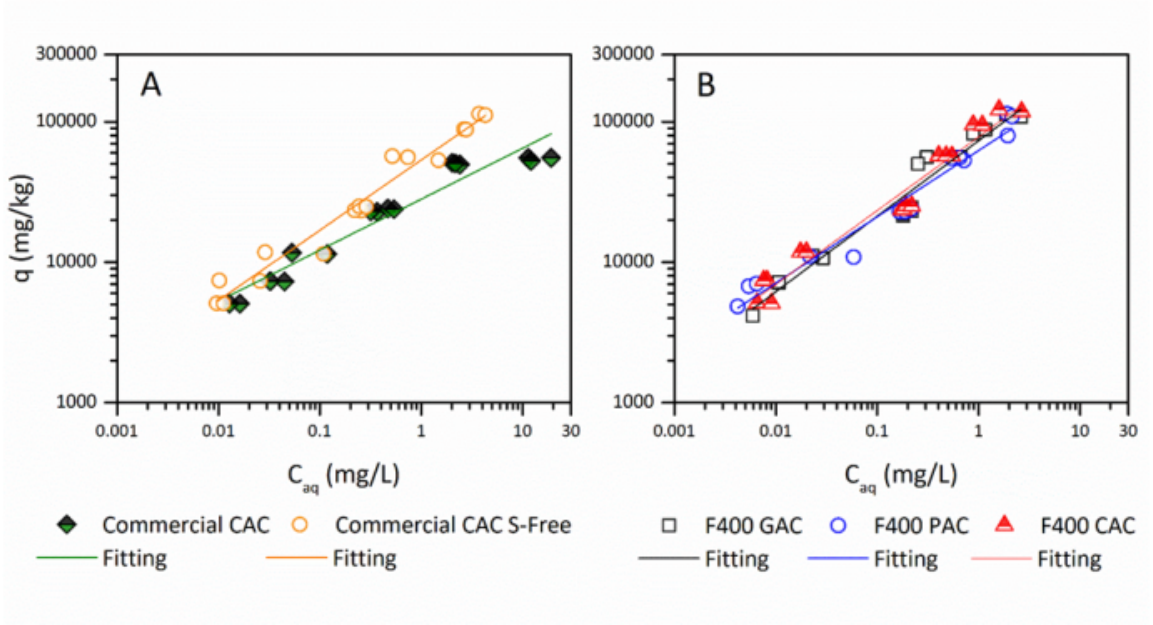


- Characterization of injectable activated carbon
- Batch Microcosm biological dechlorination with CAC
- Flow-through columns: biological dechlorination with CAC

Characterization of Injectable AC

- AC acquisition:
  - F400: granular, powder, and colloidal AC
  - Commercial CAC: Polymer and polymer free
- Physical and chemical characterizations
  - CAC has slightly higher surface area and ultra-porosity
  - CAC is more hydrophilic due to surface oxidation during milling
- Sorption isotherm of TCE
  - Particle size effect is negligible
  - Polymer decreased sorption affinity and capacity

TCE Sorption Isotherm

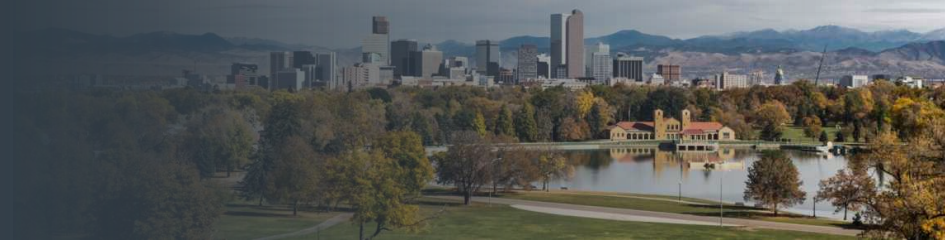


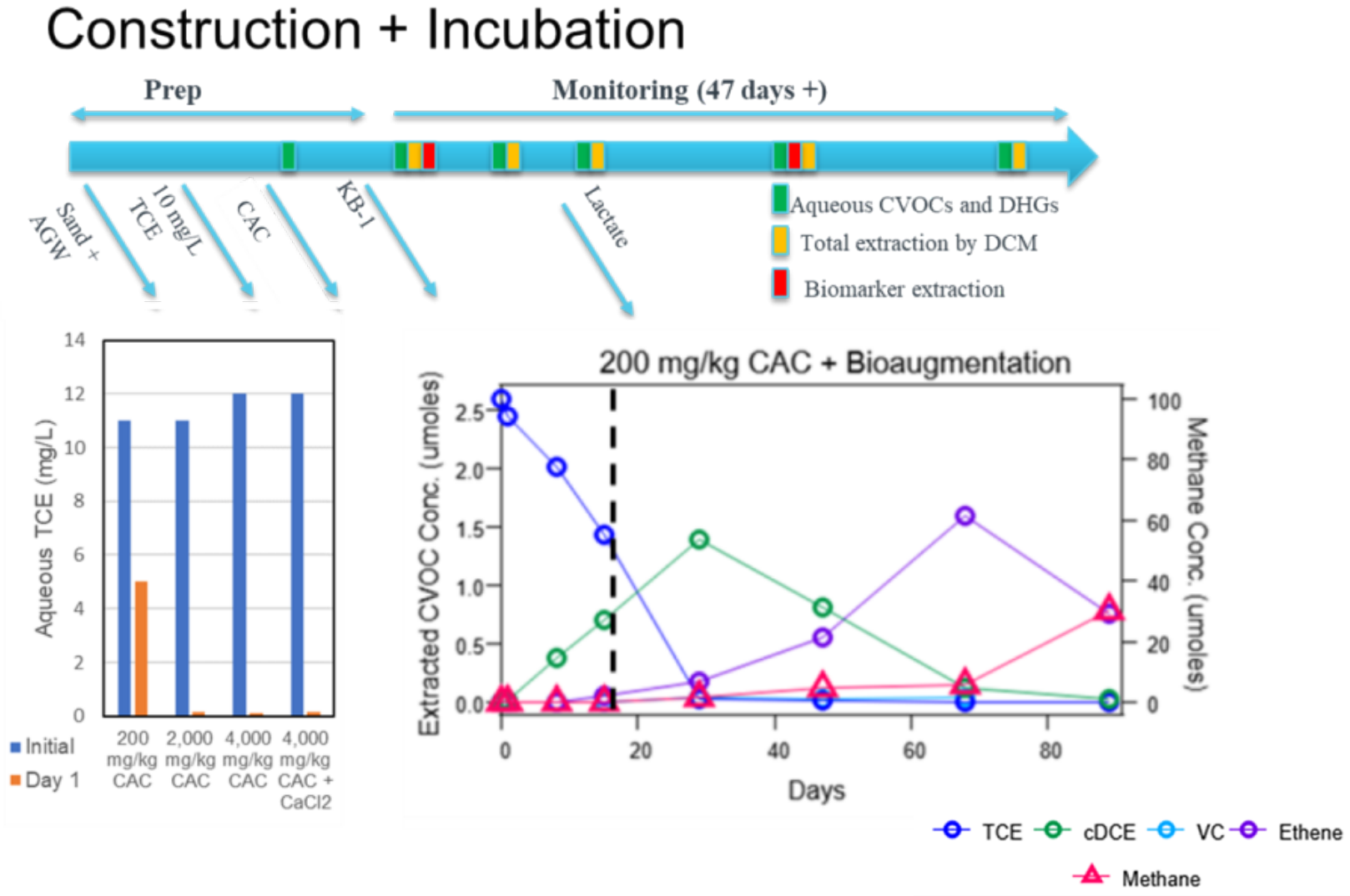
Microcosm Biological Dechlorination Experiment

	Treatment/Control	Description	Number of Replicates	Sacrificial bottles
1	Anaerobic Sterile Control	Autoclaved and amended with mercuric chloride and sodium azide	2	3 x 2
2	Intrinsic Bio Control	KB-1 bioaugmented	2	3 x 2
3	2,000 mg CAC/kg sand Sorption Control	Amended with CAC	2	6 x 2
4	200 mg CAC/kg sand/ KB-1® Bioaugmented	Amended with a low dose of CAC and KB-1® bioaugmented	2	6 x 2
5	2,000 mg CAC /kg sand/ KB-1® Bioaugmented	Amended with a medium dose of CAC and KB-1® bioaugmented	2	6 x 2
6	4,000 mg/kg CAC /kg sand/ KB-1® Bioaugmented	Amended with a high dose of CAC and KB-1® bioaugmented	2	6 x 2
7	#6 + 5 g/L CaCl2	#6 + flocculant	2	6 x 2
		Total Microcosms	14	72

Microcosms consist of 10 g sand + 30 mL of AGW sealed by mininert valves

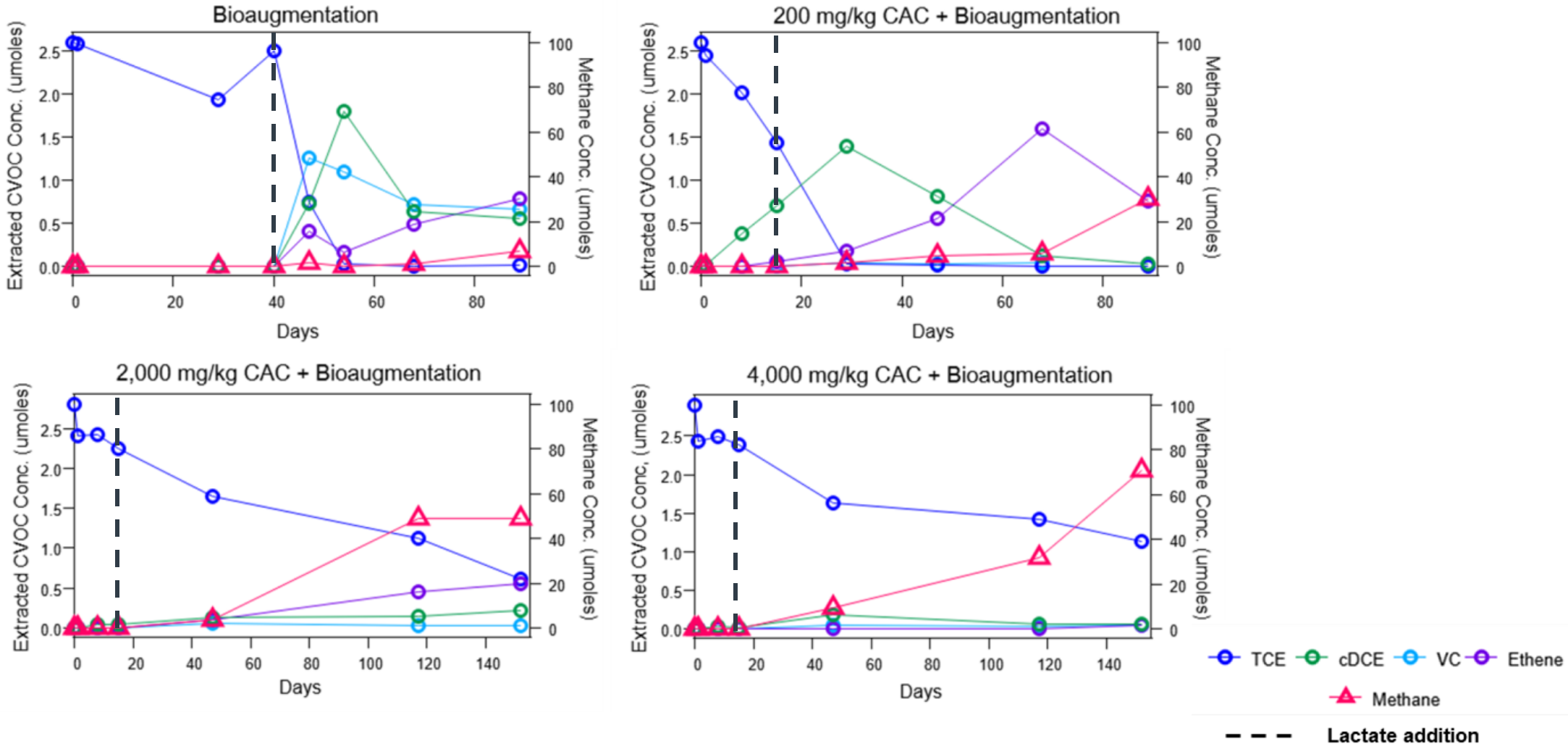
Microcosm Construction and Incubation



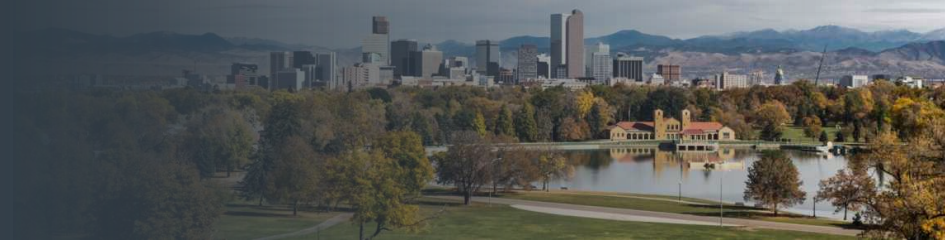


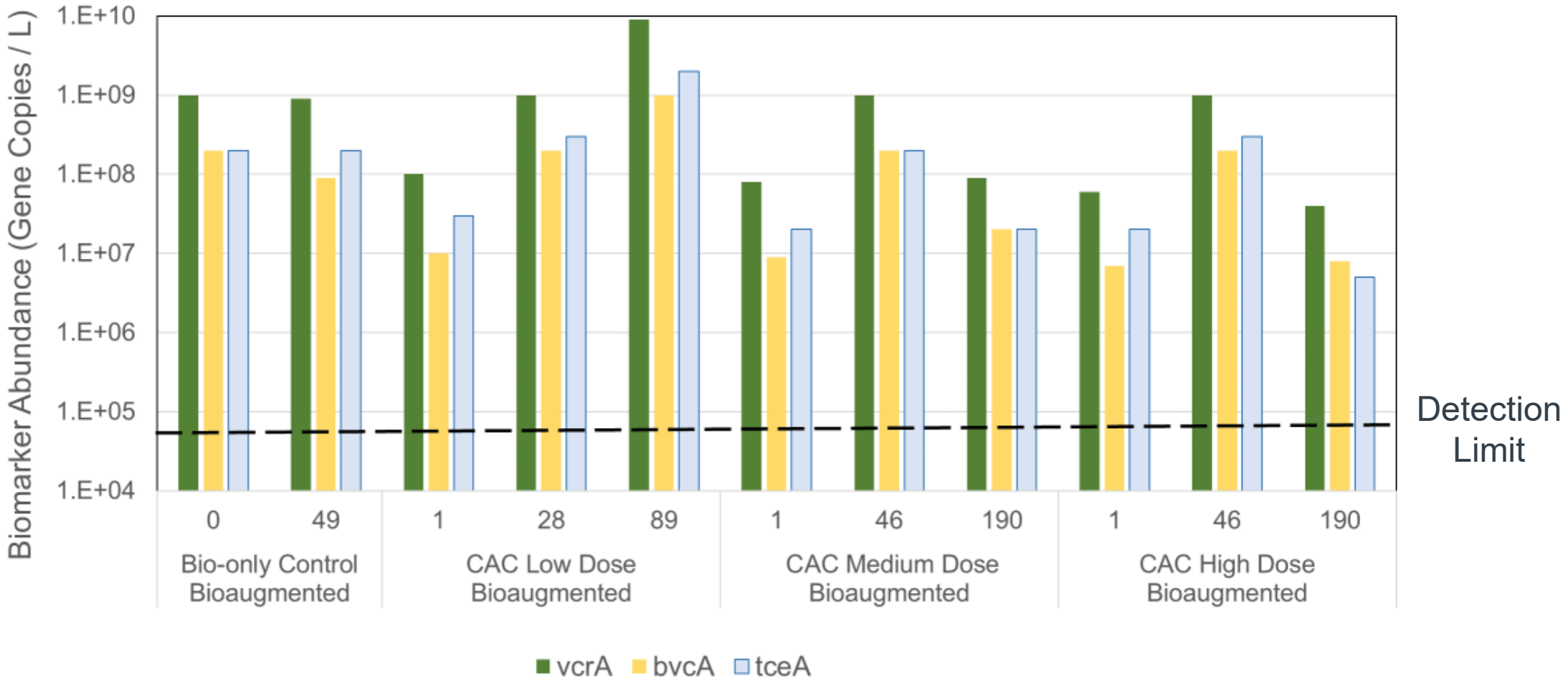
- Measure aqueous TCE 1-day after CAC addition
- KB-1 added first without lactate to assess if polymer serves as e donor
- Sampled aqueous VOCs and extracted solid VOCs

Sorption Slows Down Dechlorination – Availability Limit



Dechlorination Biomarker Abundance

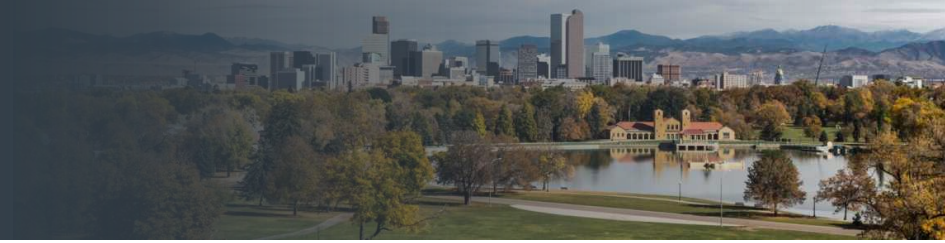


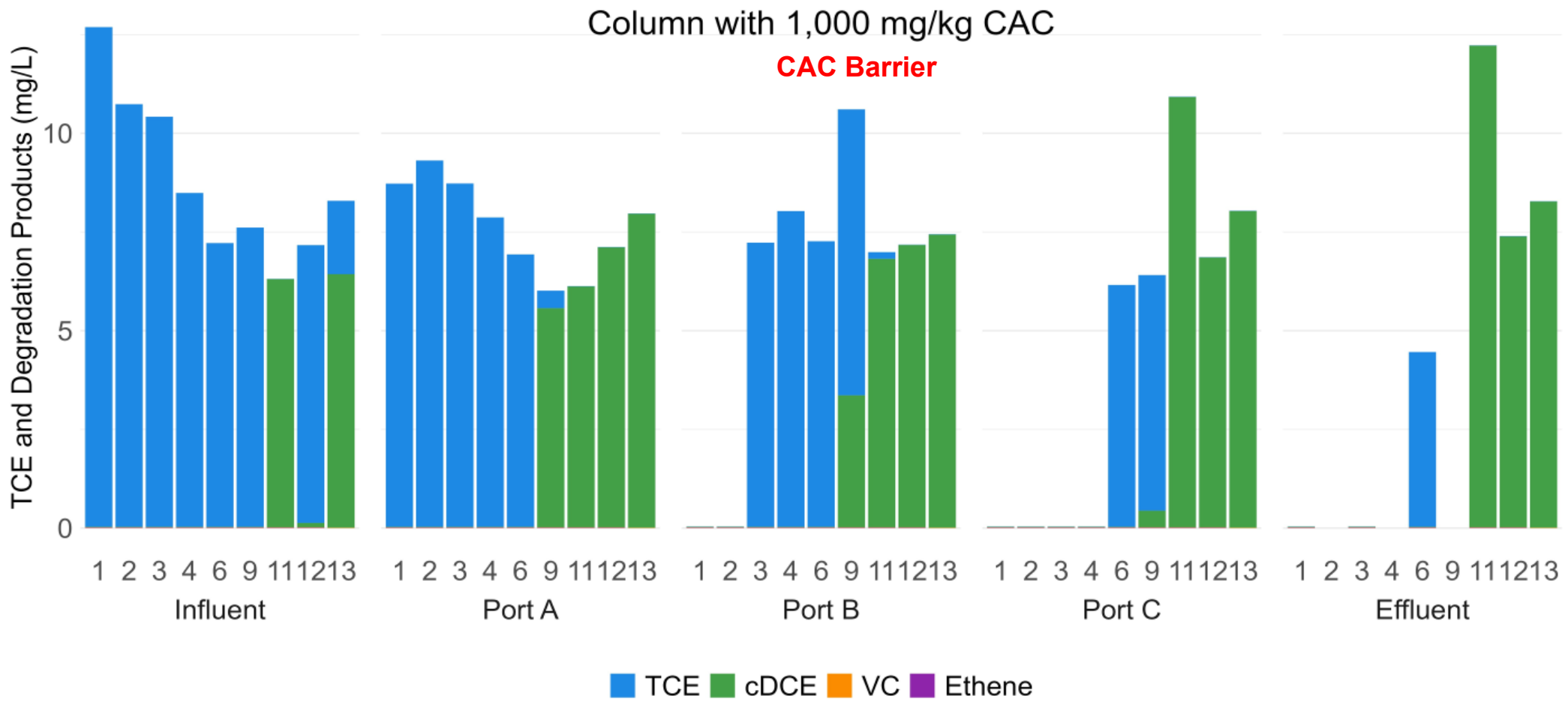


Column Biological Dechlorination Experiment

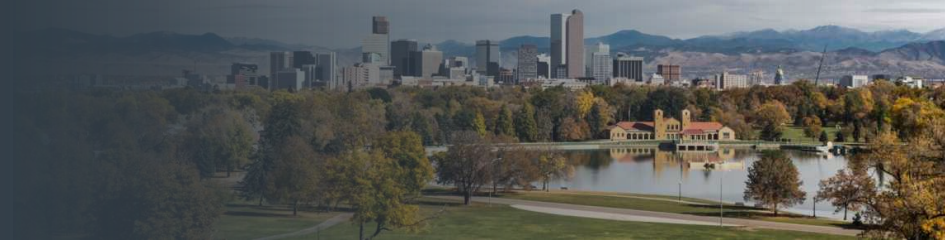
- Treatment
  - KB-1 only
  - 200 mg/kg CAC with and w/o KB-1
  - 1,000 mg/kg CAC with and w/o KB-1
- Column conditions
  - Continuously feeding ~10 mg/L TCE in artificial GW
  - Continuously feeding lactate to bio columns
  - CAC only columns: no lactate but not sterilized
  - KB-1 inoculated within CAC barrier (Port B)
  - 13-week operation with adjusted conditions
  - Post column characterizations

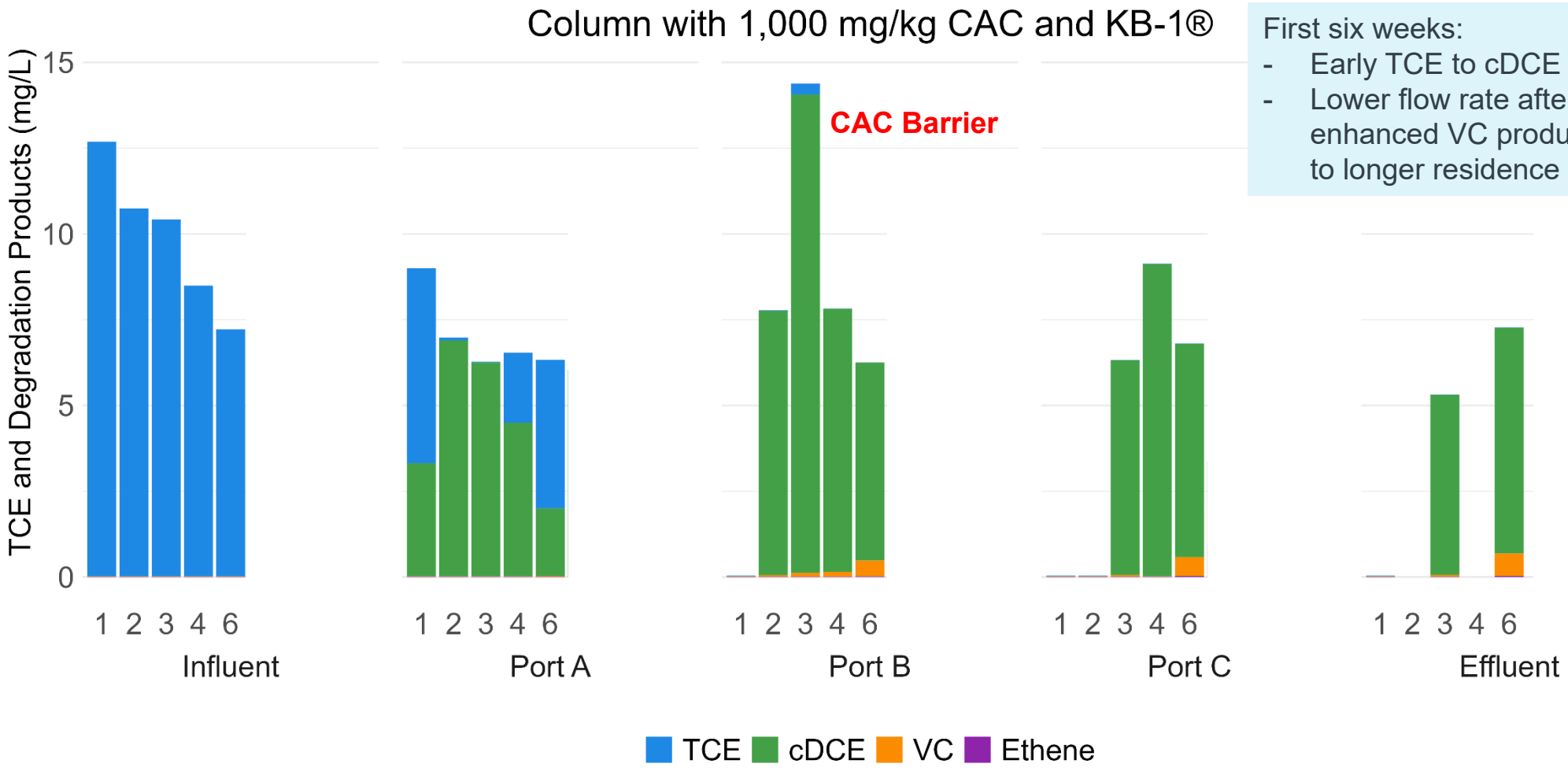
Column Results – 1,000 mg/kg CAC





Column Results – 1,000 mg/kg CAC + KB-1

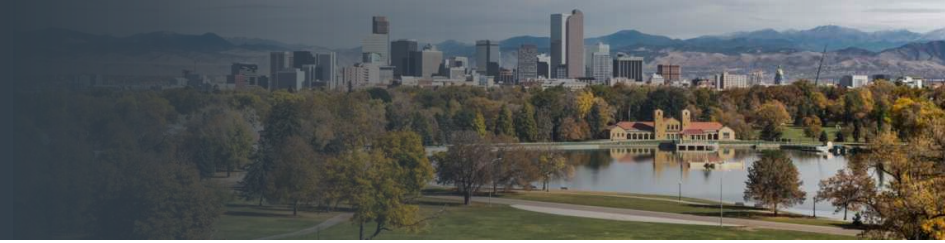


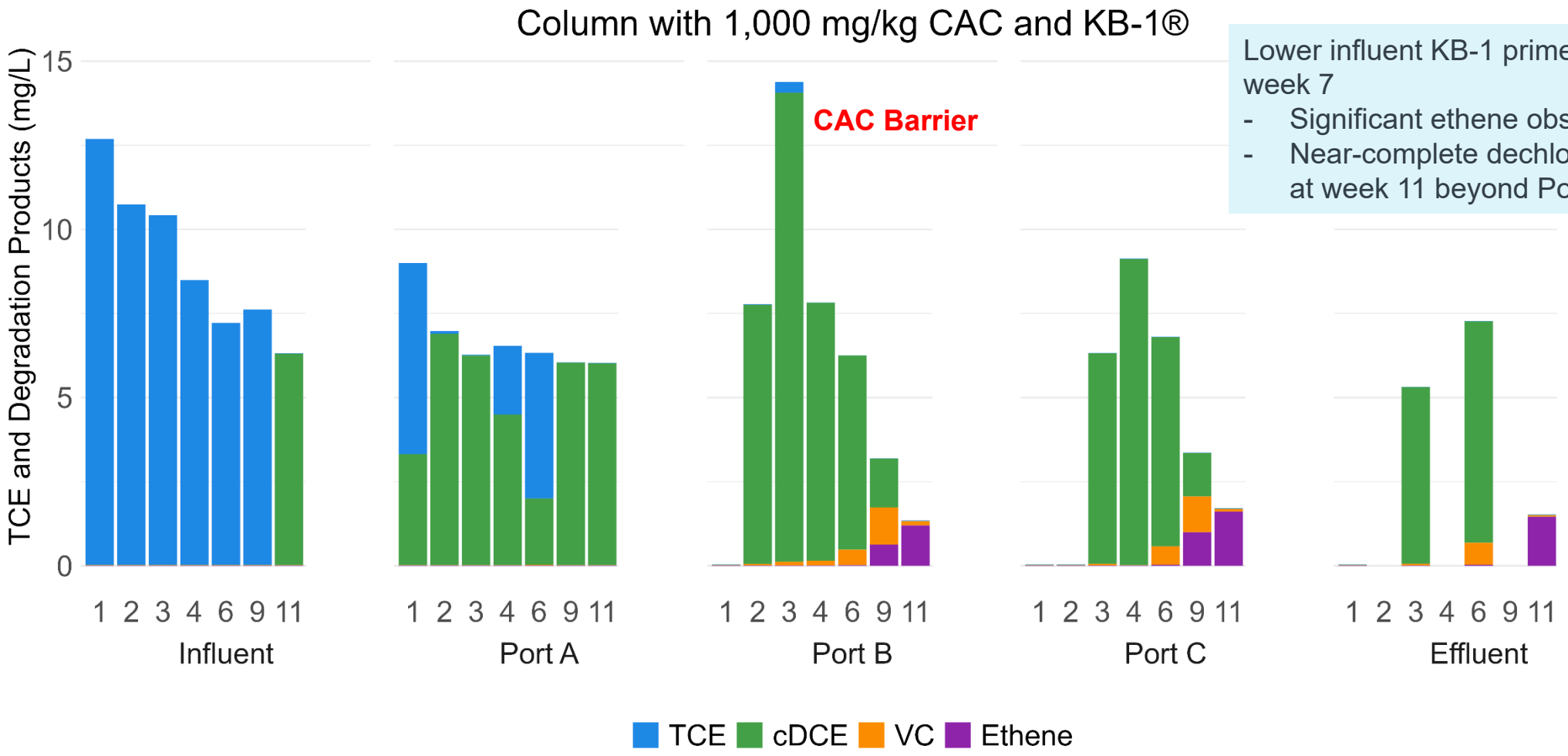


First six weeks:

- Early TCE to cDCE in Port A
- Lower flow rate after week 4 slightly enhanced VC production at week 6 due to longer residence time

Column Results – 1,000 mg/kg CAC + KB-1

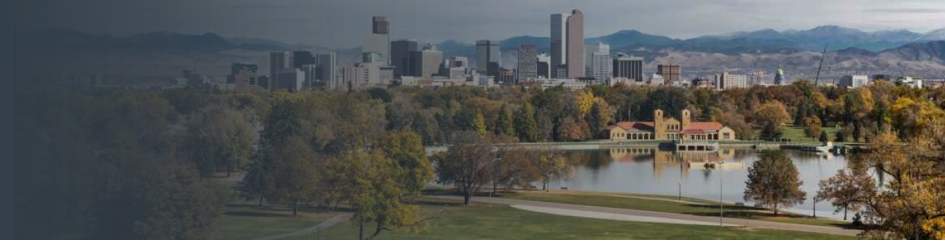


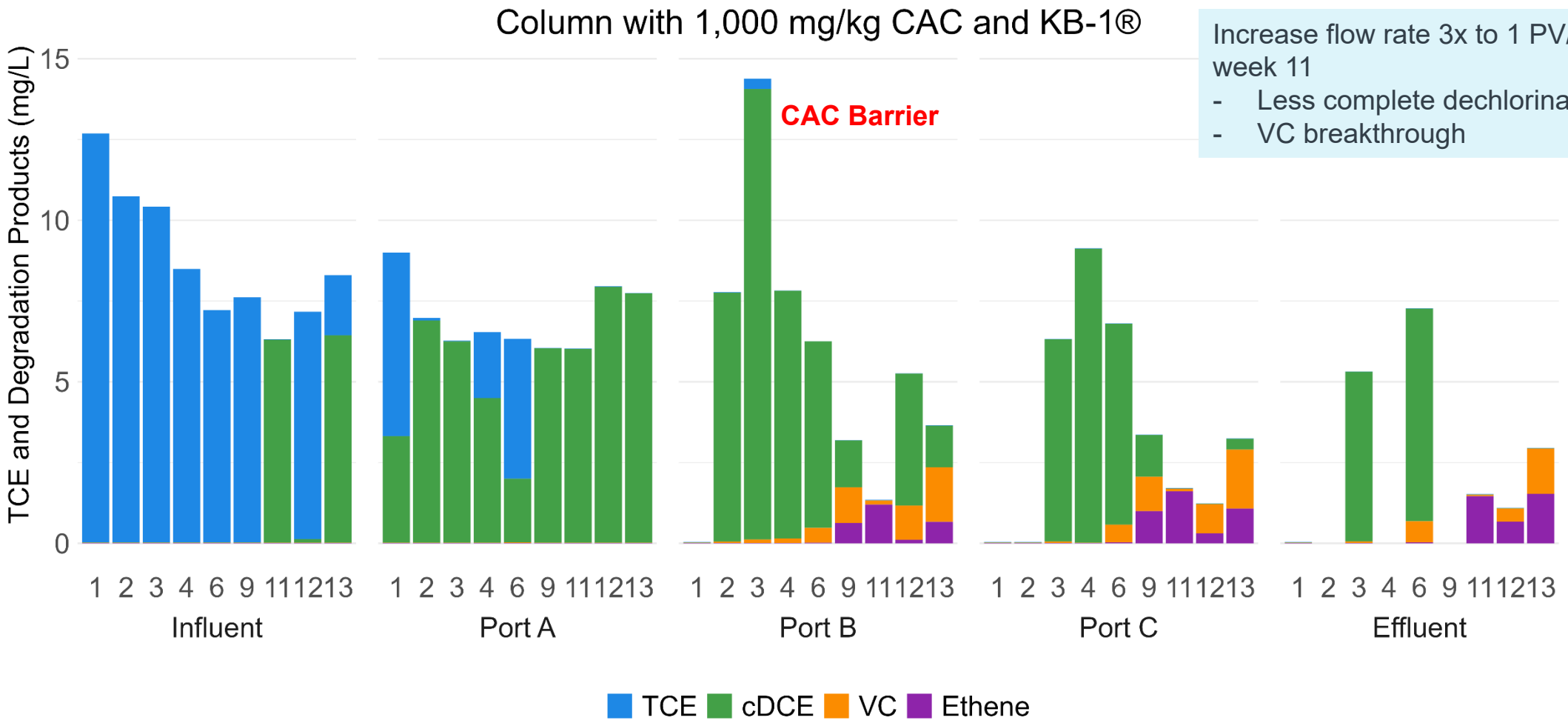


Lower influent KB-1 primer by 50% after week 7

- Significant ethene observed at week 9
- Near-complete dechlorination achieved at week 11 beyond Port B at week 11

Column Results – 1,000 mg/kg CAC + KB-1





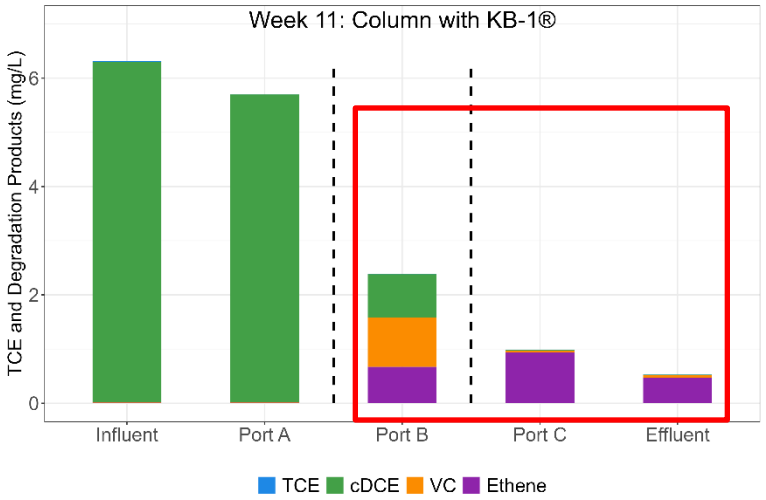
Increase flow rate 3x to 1 PV/day after week 11

- Less complete dechlorination
- VC breakthrough

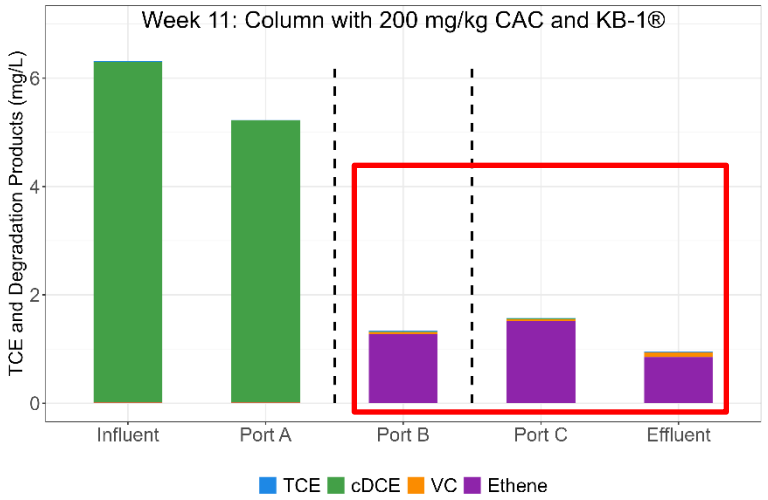
Column Results – Effect of CAC Loading on Treatment

Week 11 – 1/3 PV per day

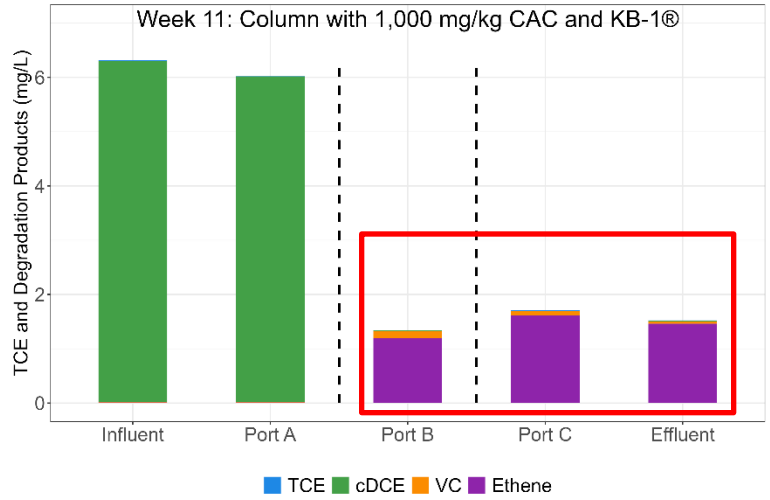
No CAC



200 mg/kg CAC



1,000 mg/kg CAC

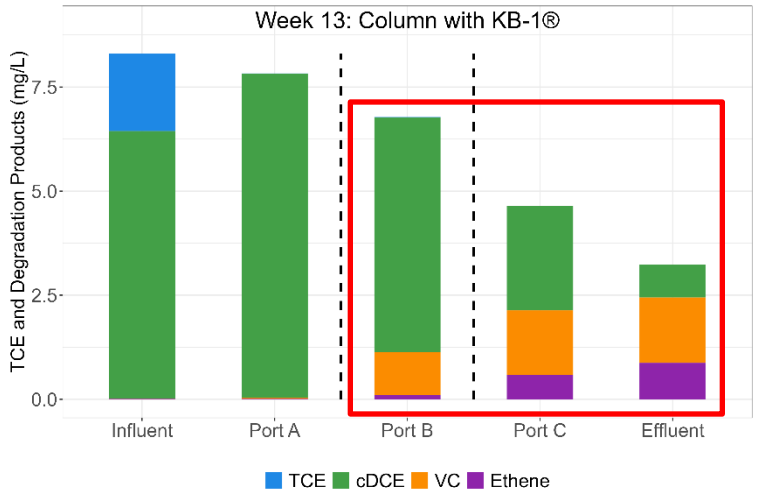


- All columns showed near complete dechlorination in Port C and effluent.
- CAC columns had no detectable aqueous cDCE in within the CAC barrier (Port B).

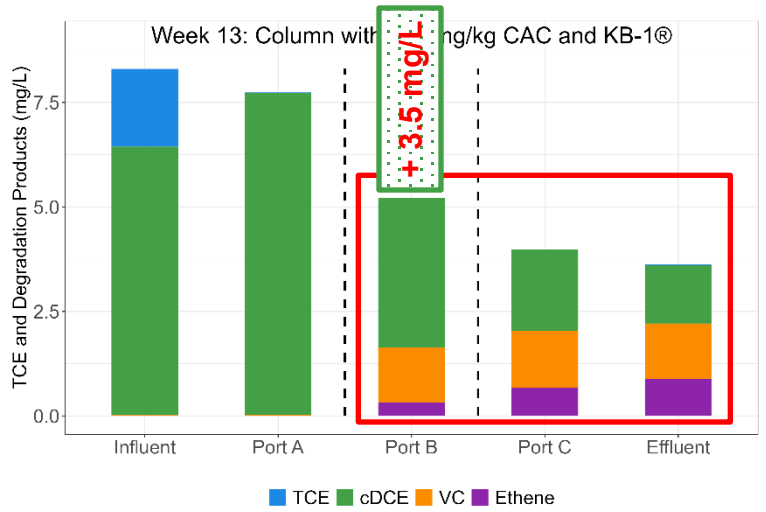
Column Results – Effect of CAC Loading on Treatment

Week 13 – 1 PV/day (Stress Test)

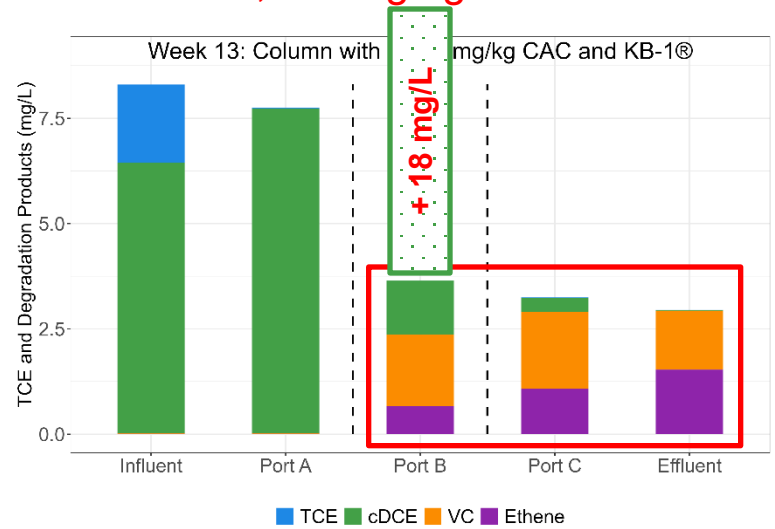
No CAC



200 mg/kg CAC

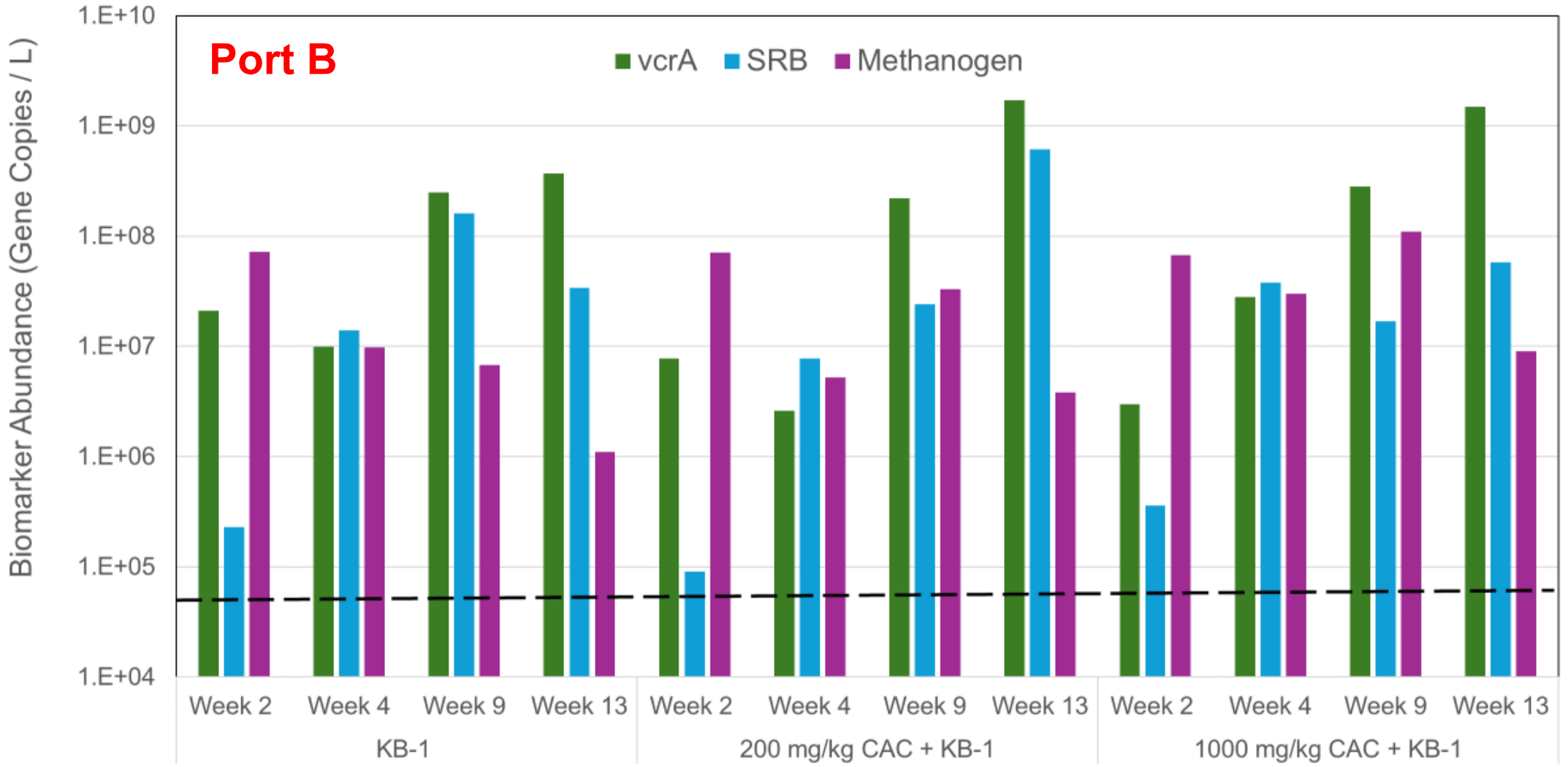


1,000 mg/kg CAC

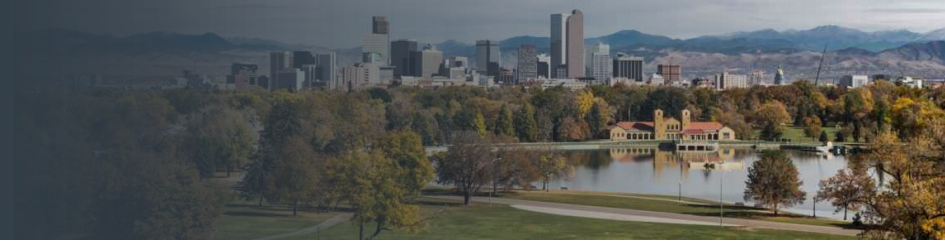


- Less dechlorination at high flow rate, but high CAC showed the lowest cDCE breakthrough.
- Significant solid cDCE mass associated with CAC.

Microbial Characterization – Dechlorinator, SRB, and Methanogens

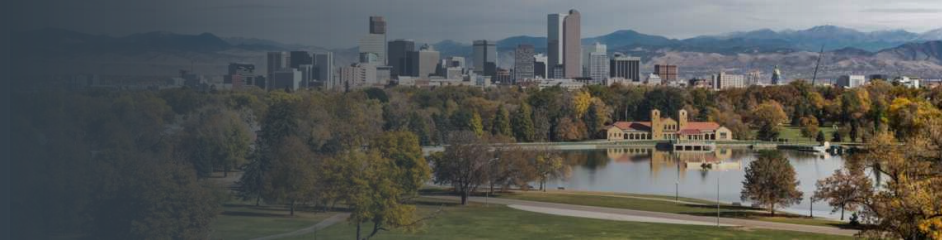


Conclusions



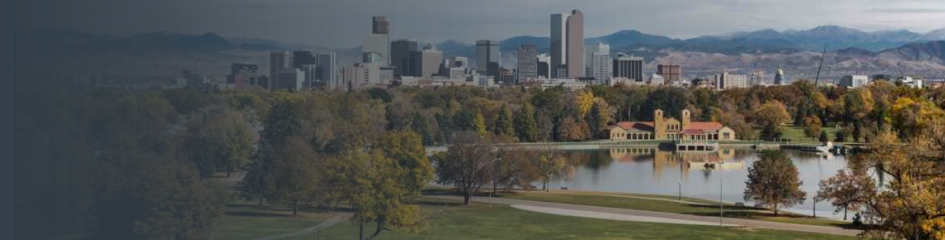
- TCE sorption was similar for different AC sizes, but polymer decreased sorption.
- Microcosm dechlorination
  - CVOC bioavailability limited biodegradation
  - Solid extraction is needed to fully assess degradation
- Flowthrough columns:
  - Observed biodegradation with high CAC loading
  - Competition from sulfate reducers
  - Treatment performance depended on the mass flux and degradation rate
  - Sorption provided additional capacity to limit breakthrough of cDCE and VC

Next Step



- Microbial and microscopic characterization of solid phases
- Additional column test
  - Lower influent concentration,
  - Sulfate,
  - Electron donor level, and
  - Different types of AC
- Develop a conceptual model to describe the pore-scale process

Acknowledgements



SERDP ESTCP

ER21-1224 (https://serdp-estcp.mil/projects/details/e57d3350-6250-4051-9eb8-aa54ceb2d1cb/er21-1224-project-overview)

Dynamic Interactions between Sorption and Biodegradation: Implications for Long-Term Performance of Activated Carbon-Based Technology for In Situ Groundwater Remediation of Chlorinated Solvents

Geosyntec consultants

engineers | scientists | innovators

Technology Advisory Council

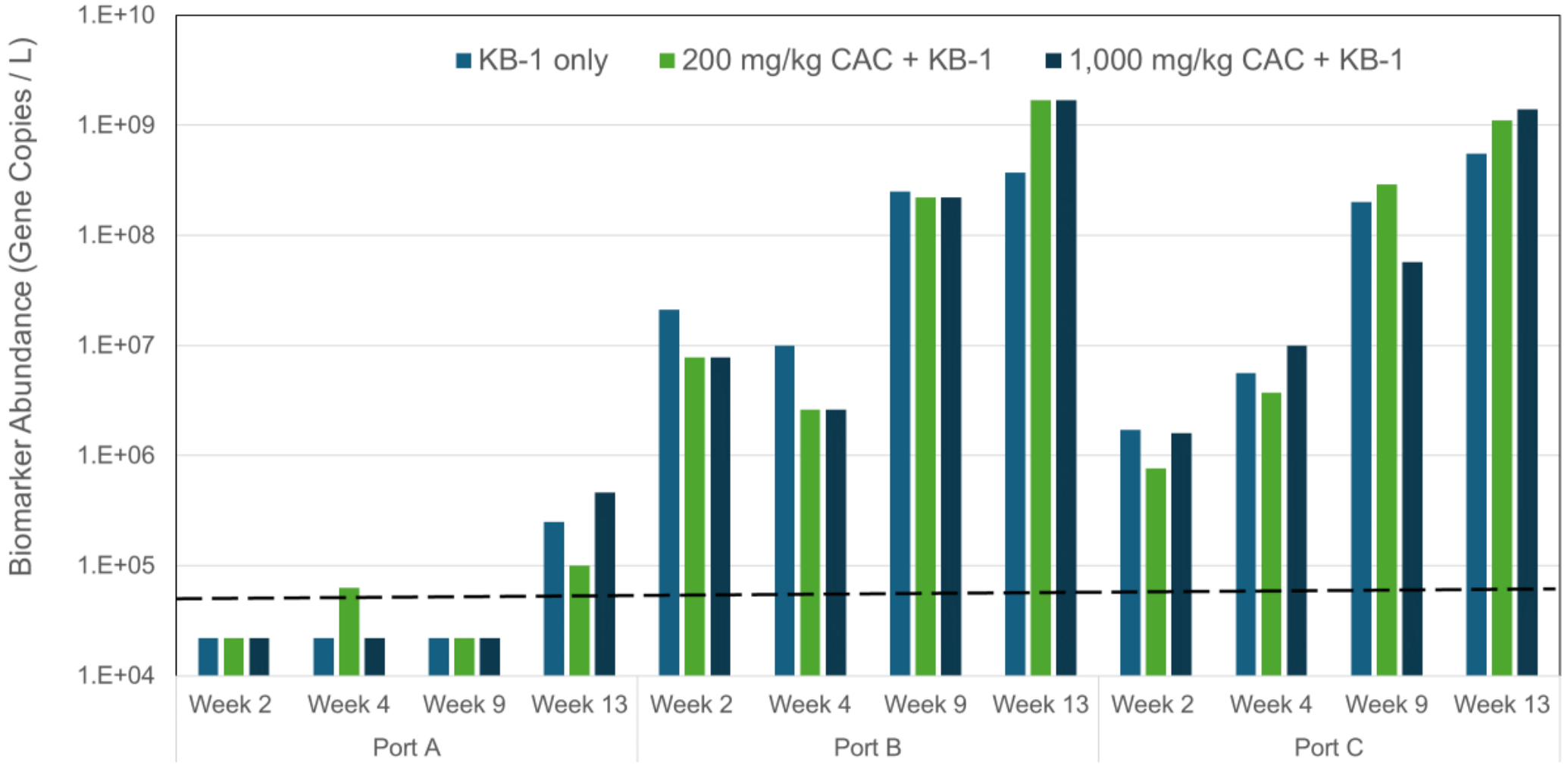
Geosyntec consultants

CREATIVE THINKING

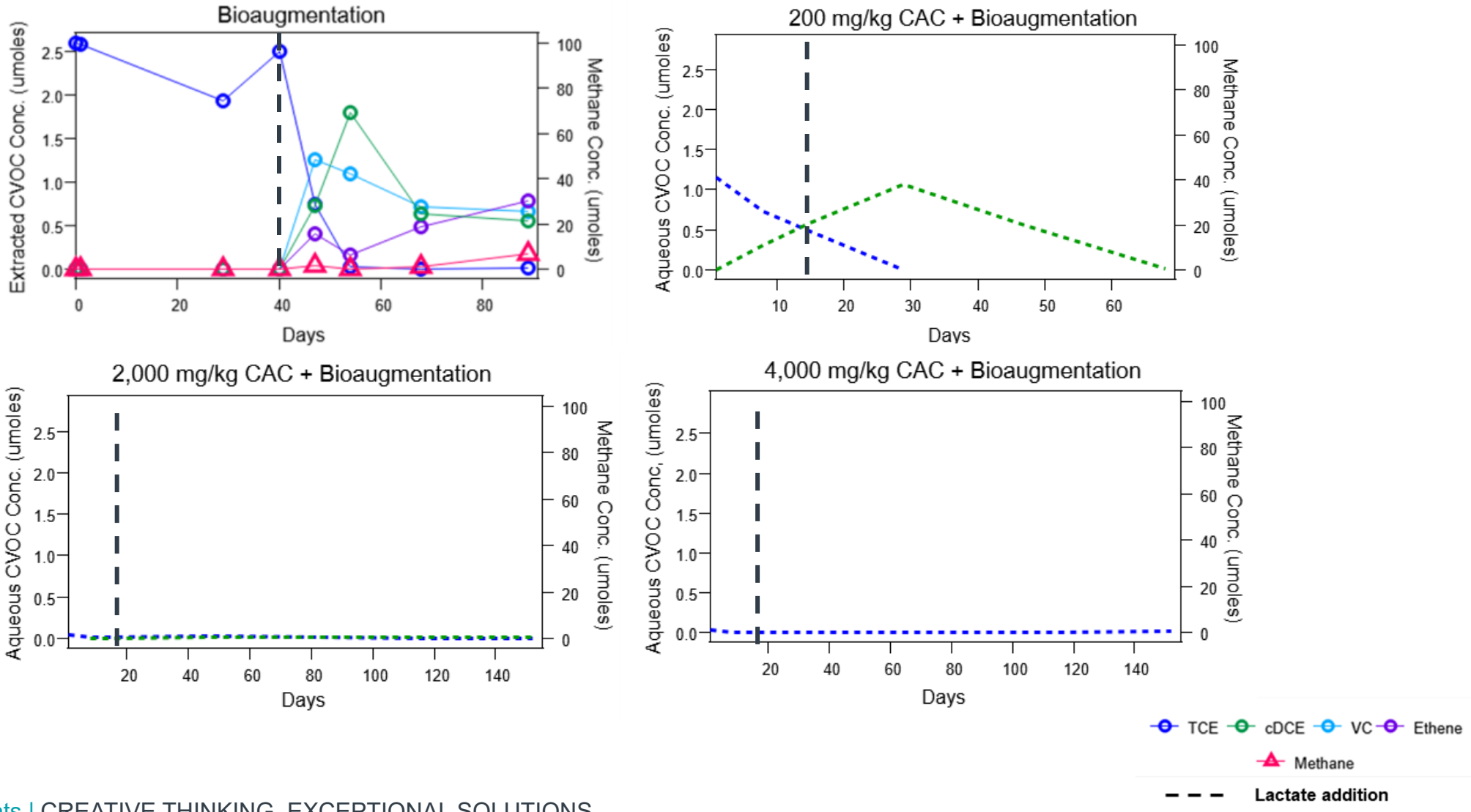
EXCEPTIONAL SOLUTIONS

dfan@geosyntec.com
443-518-8775

Microbial Characterization – Spatial Distribution of Dechlorinators



Aqueous Phase Concentrations are Not Sufficient



Dynamics between Sorption and Biodegradation