

Successful Bioremediation of Carbon Tetrachloride

Presented by:
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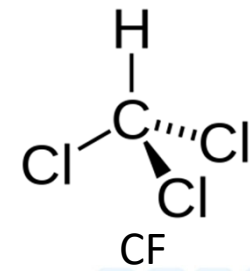
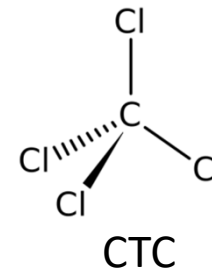
Let's Talk About...

1. Background
2. Chlorinated Methanes Degradation Pathways
3. Treatability Case Study
4. Field Case Study
5. Summary



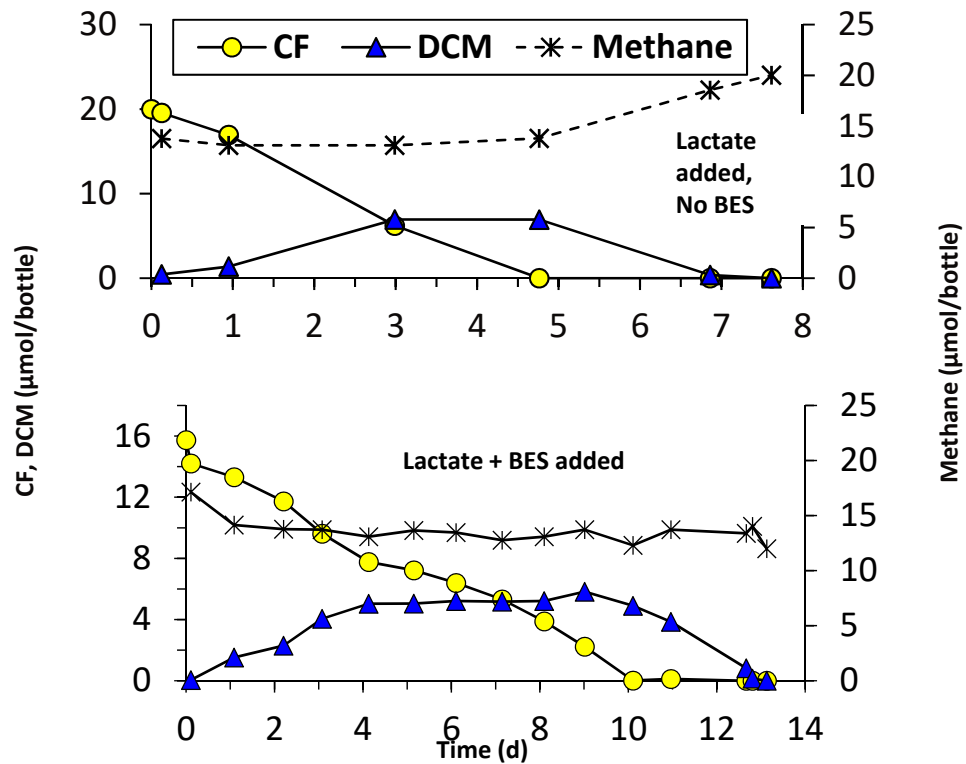
Background

- Carbon Tetrachloride (CTC) was used in fire extinguishers, as a precursor to refrigerants and as a cleaning agent
- Suspected carcinogen, can affect the central nervous system, liver and kidneys
- No microbes capable of metabolizing CTC have been reported
- CTC can be cometabolically and abiotically degraded to chloroform (CF)
- CF is more toxic and inhibitory to other anaerobic processes





KB-1 Plus with ^{14}C -CF

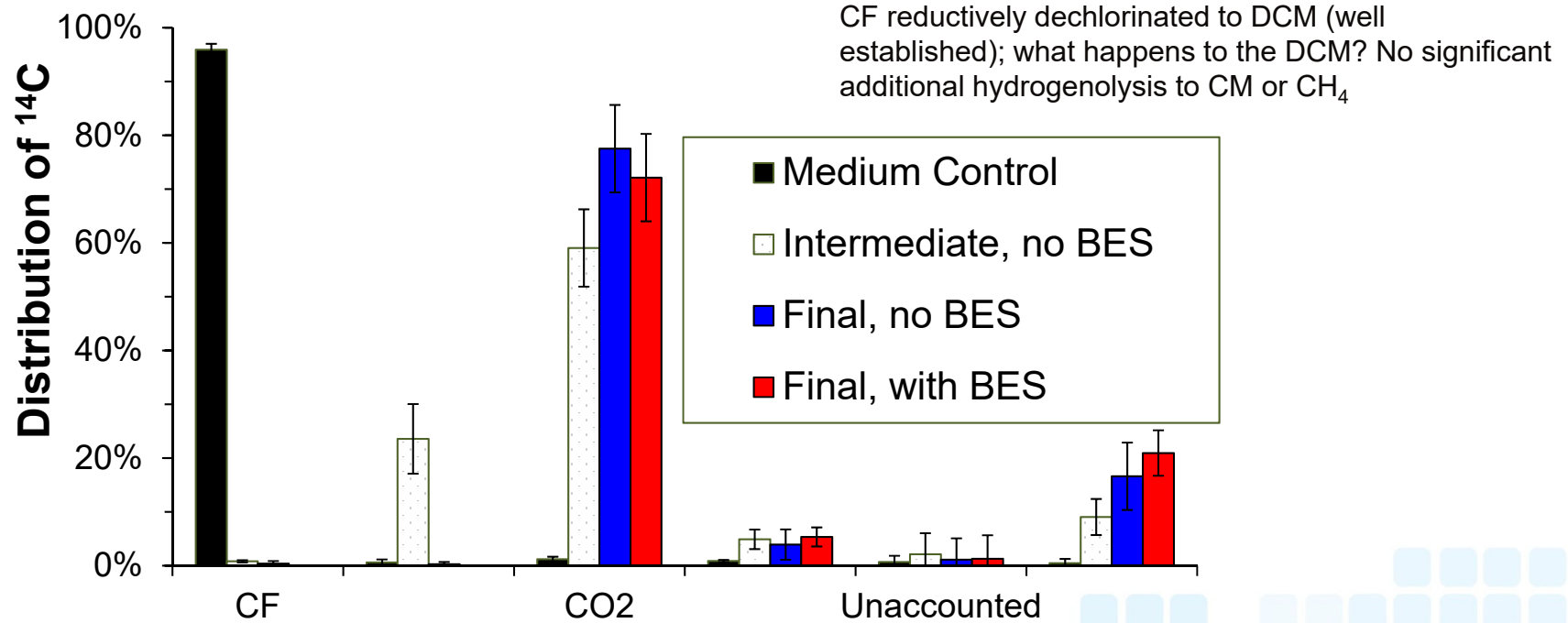


- Methane accumulated as DCM was fermented

- BES = methanogen inhibitor
- CF and DCM consumed with no products evident



Assay with ^{14}C -CF and KB-1 Plus



Courtesy of Dr. David Freedman

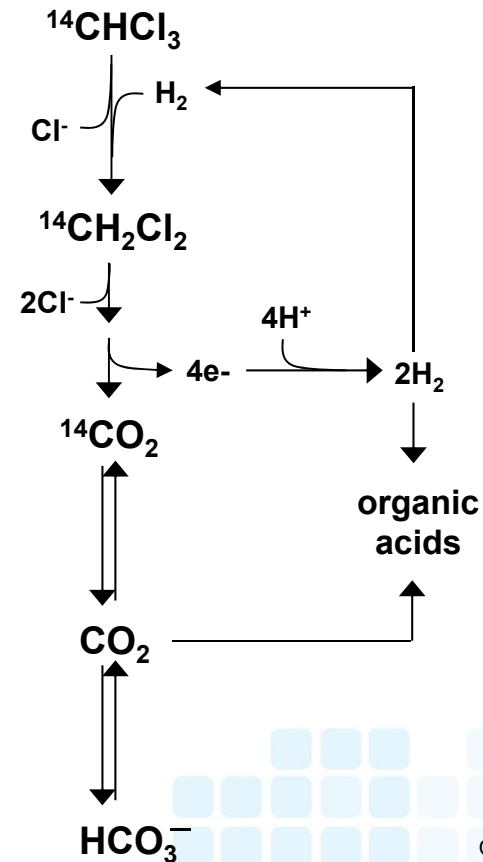




CF and DCM Pathway

Pathway prediction based on ^{14}C + HPLC results

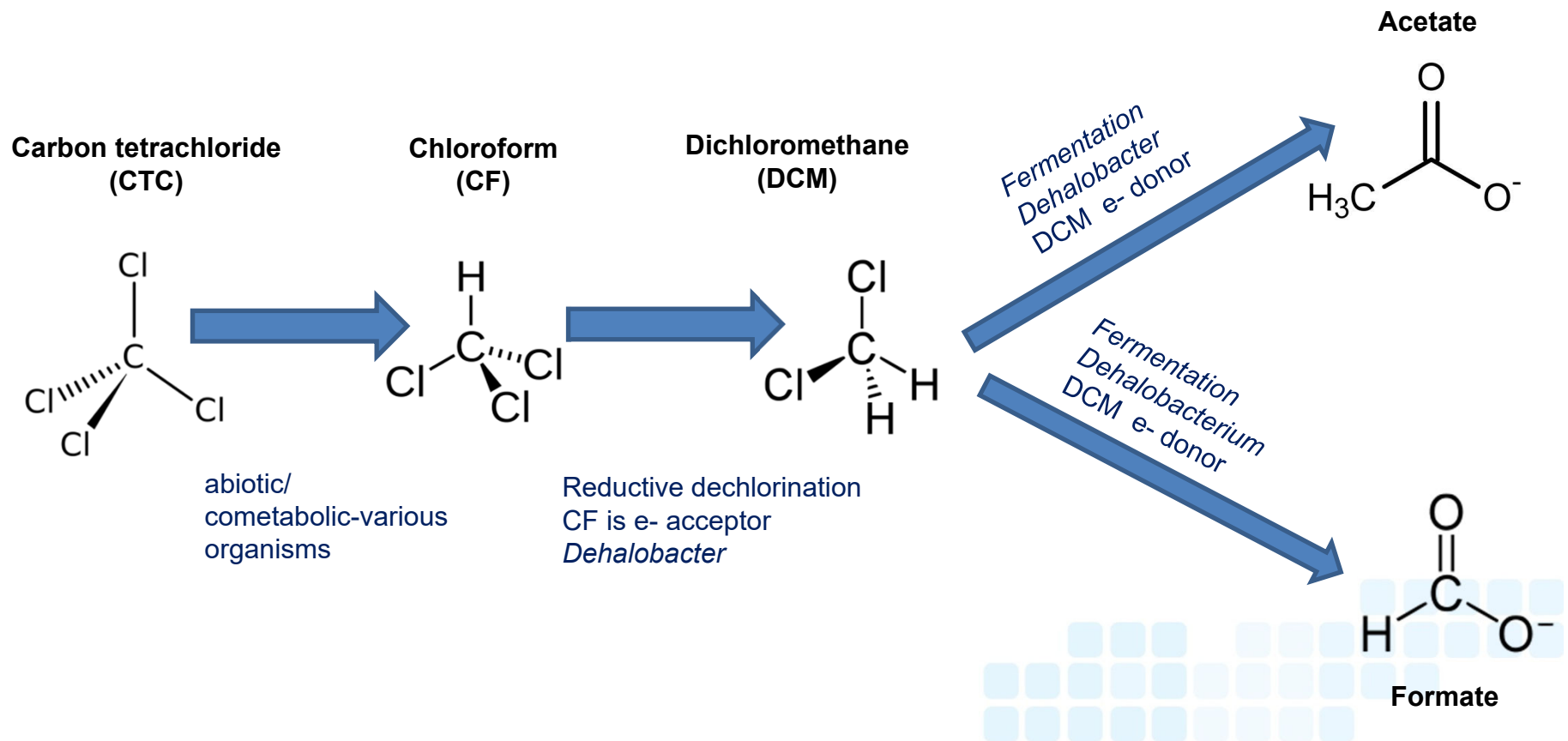
- Fermentation of DCM provides enough reducing power for hydrogenolysis of CF to DCM
- Labeled $^{14}\text{CO}_2$ is diluted by large amount of bicarbonate in the medium, so organic acids are not labeled
- Accumulation of unlabeled organic acids confirmed



Courtesy of Dr. David Freedman



Pathway for Chlorinated Methanes





TREATABILITY CASE STUDY

Treatability Case Study: Mid West Site

- Mixed chlorinated methanes and ethenes
- CTC and TCE at 2 mg/L
- Assess the effectiveness of different donors as well as zero-valent iron (ZVI) and ferrous fumerate combined with bioaugmentation

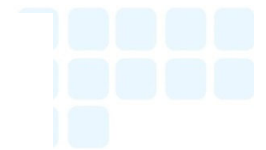
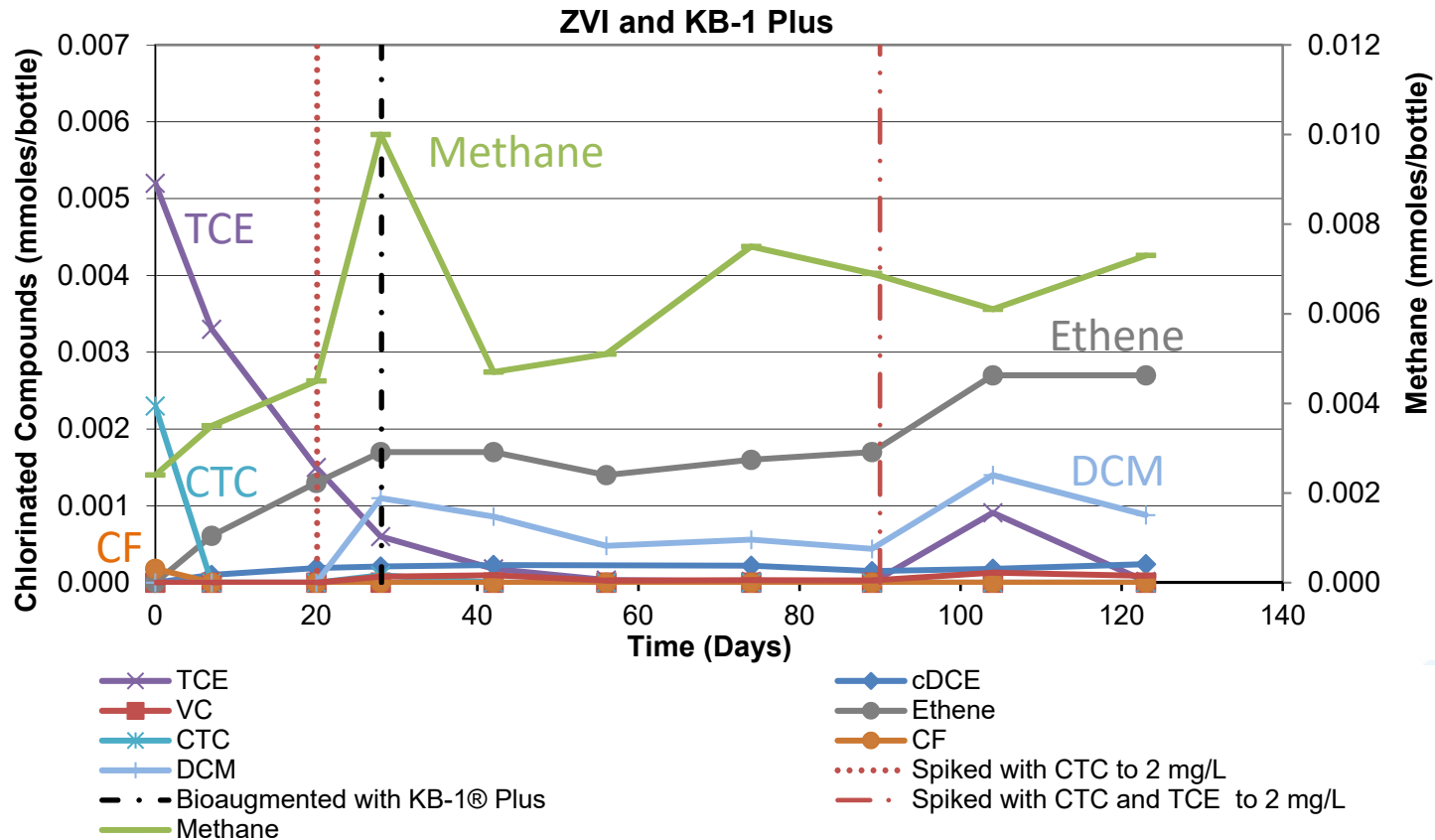
Study Design:

- Controls
- ZVI and KB-1® Plus
- EVO/ferrous fumerate/KB-1® Plus with and without ZVI
- EVO/KB-1® Plus
- EHC-L/KB-1® Plus with and without ZVI



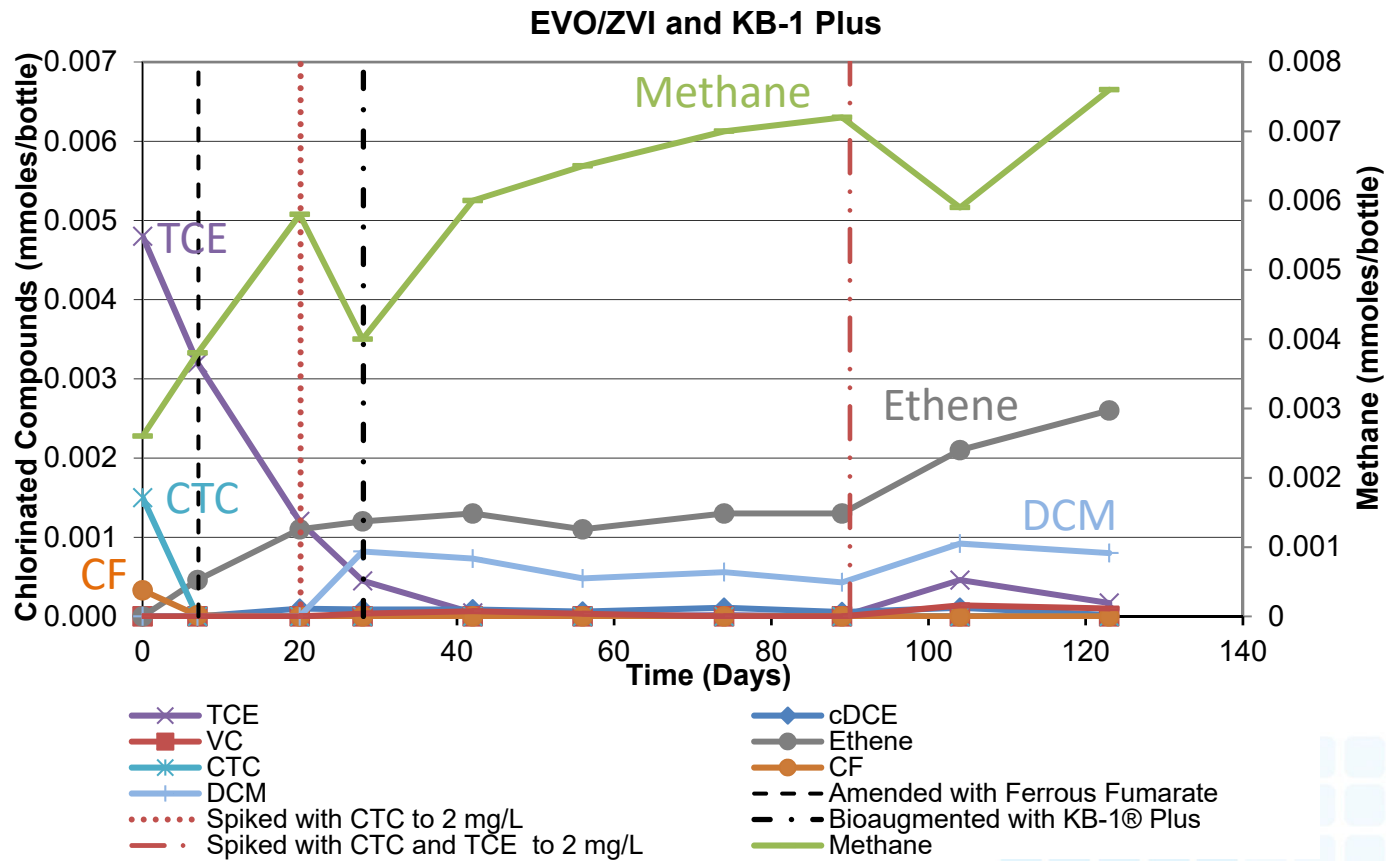


Treatability Case Study: Mid West Site





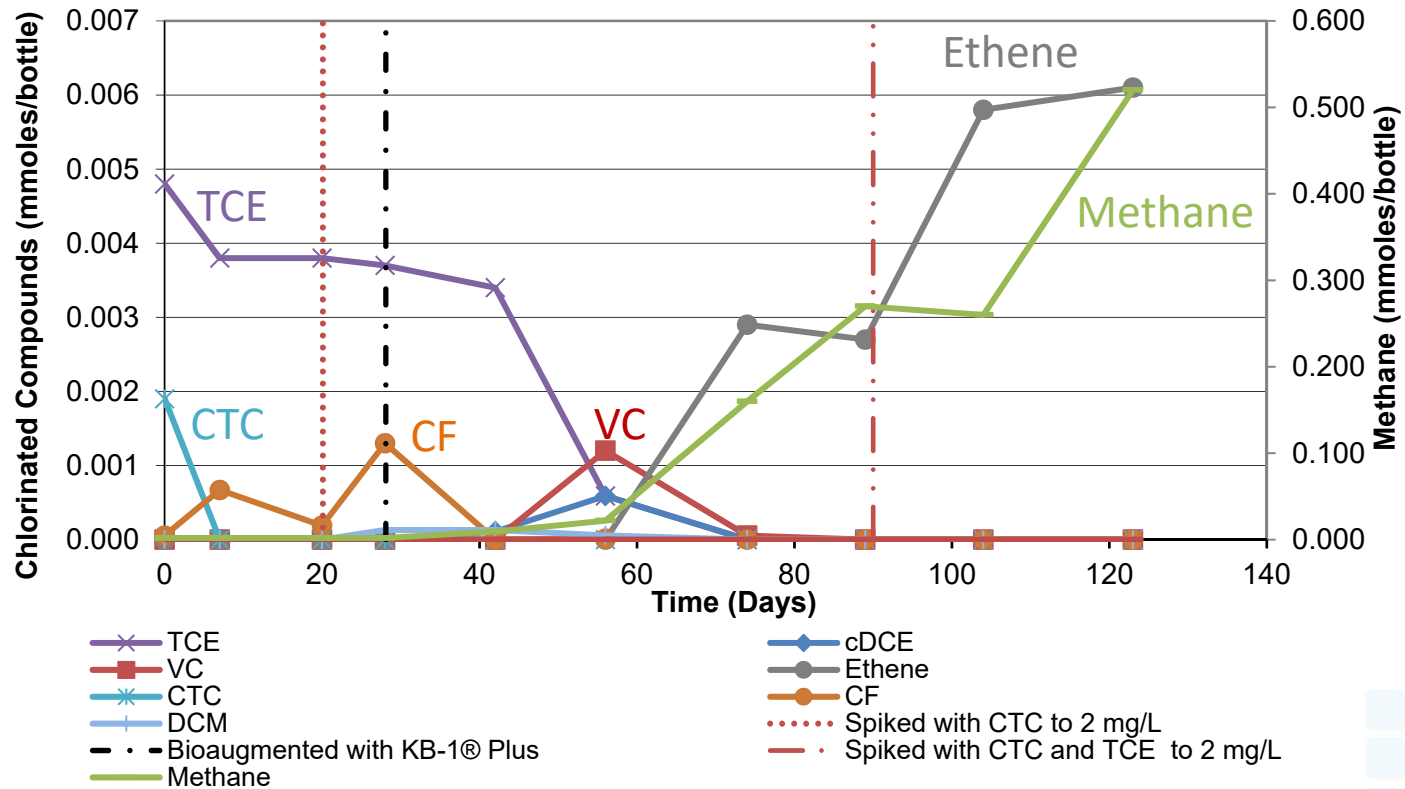
Treatability Case Study: Mid West Site





Treatability Case Study: Mid West Site

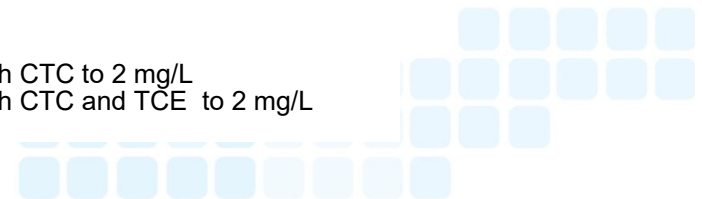
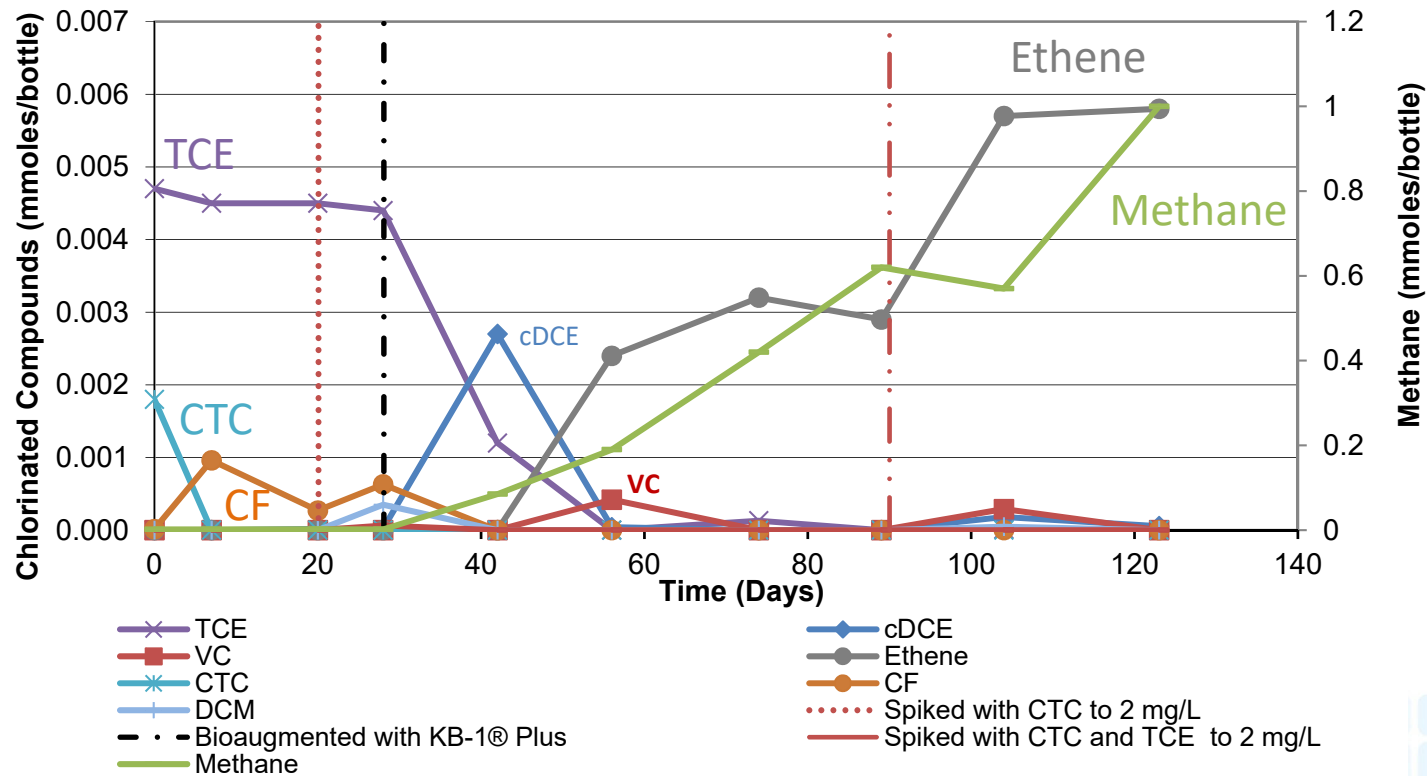
EVO/Ferrous Fumerate and KB-1 Plus





Treatability Case Study: Mid West Site

EHC-L and KB-1 Plus



Conclusions: Mid West Treatability Study

- cVOCs in the Controls remained stable
- ZVI promoted abiotic degradation of CTC and TCE, but inhibited biodegradation of DCM
- EVO with and without soluble iron and EHC-L promoted degradation of CTC and TCE to non chlorinated end products



**Based on study results
enhanced bioremediation was
selected as site remedy**





FIELD CASE STUDY

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Field Case Study – Karst Aquifer Site

- Groundwater monitoring for a potential MNA remedy was being conducted at nine wells in three different SWMUs
- Two wells in two separate SWMUs were found to have carbon tetrachloride concentrations indicative of DNAPL - MW-47D and HE-04
- Both screened approximately 55 to 65 ft bgs - NOT connected hydraulically and additional wells could not be installed in the area
- Bench-scale treatability studies with EVO and KB-1[®] Plus indicated carbon tetrachloride could be degraded to innocuous end products
- A pull-push field pilot was initiated at MW-47D in 2010



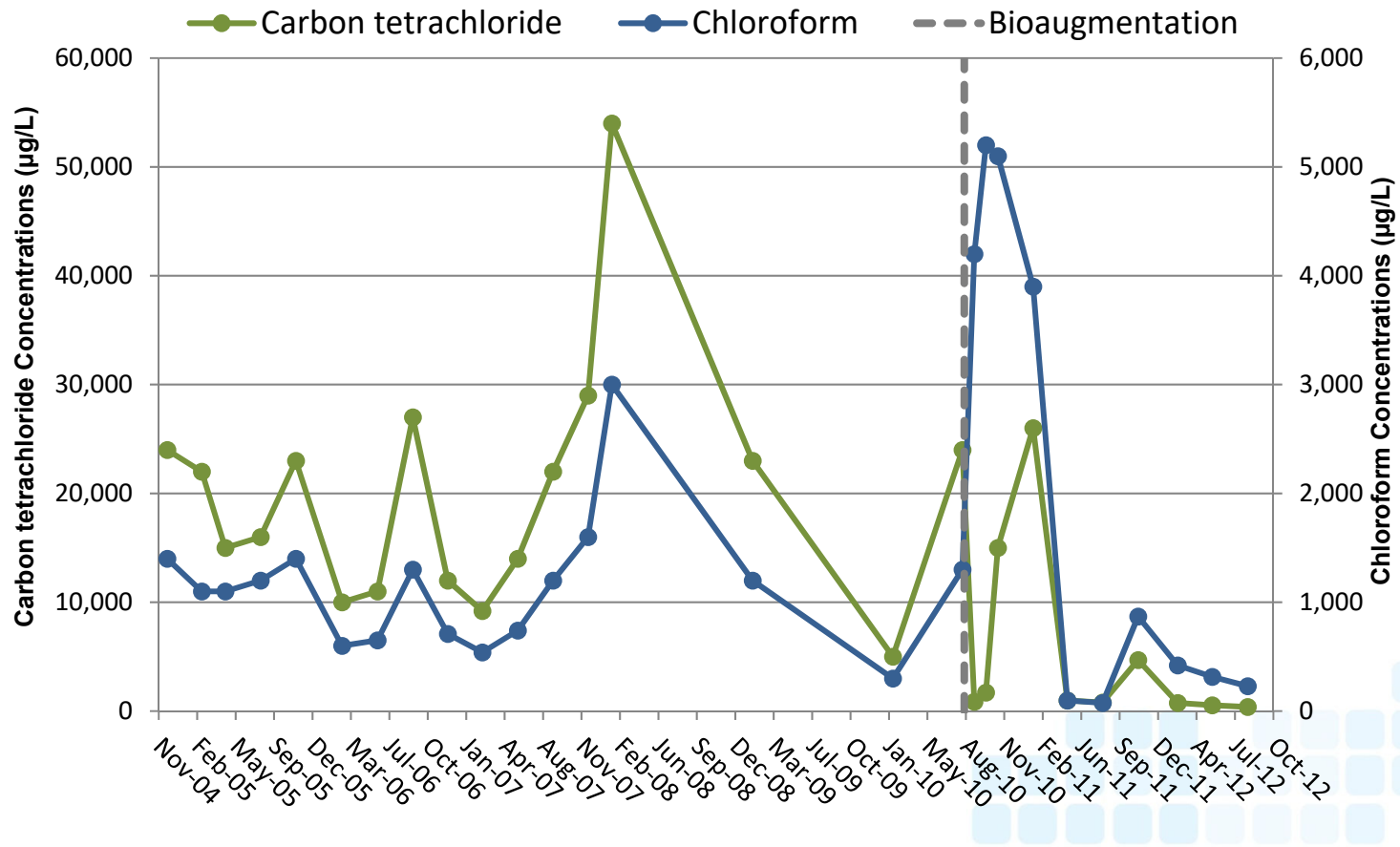
Pull-Push Amendment Injection

1. Extracted ~3,000 gals of water from MW-47D while adding lactate
2. Amended extracted groundwater with EVO, Vitamin B12 and KB-1 Plus. Bromide tracer also added.
3. Gravity fed amended groundwater & dechlorinating bacterial consortium
4. Reinstalled dedicated equipment & continued to monitor groundwater at MW-47D



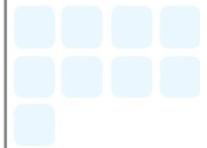
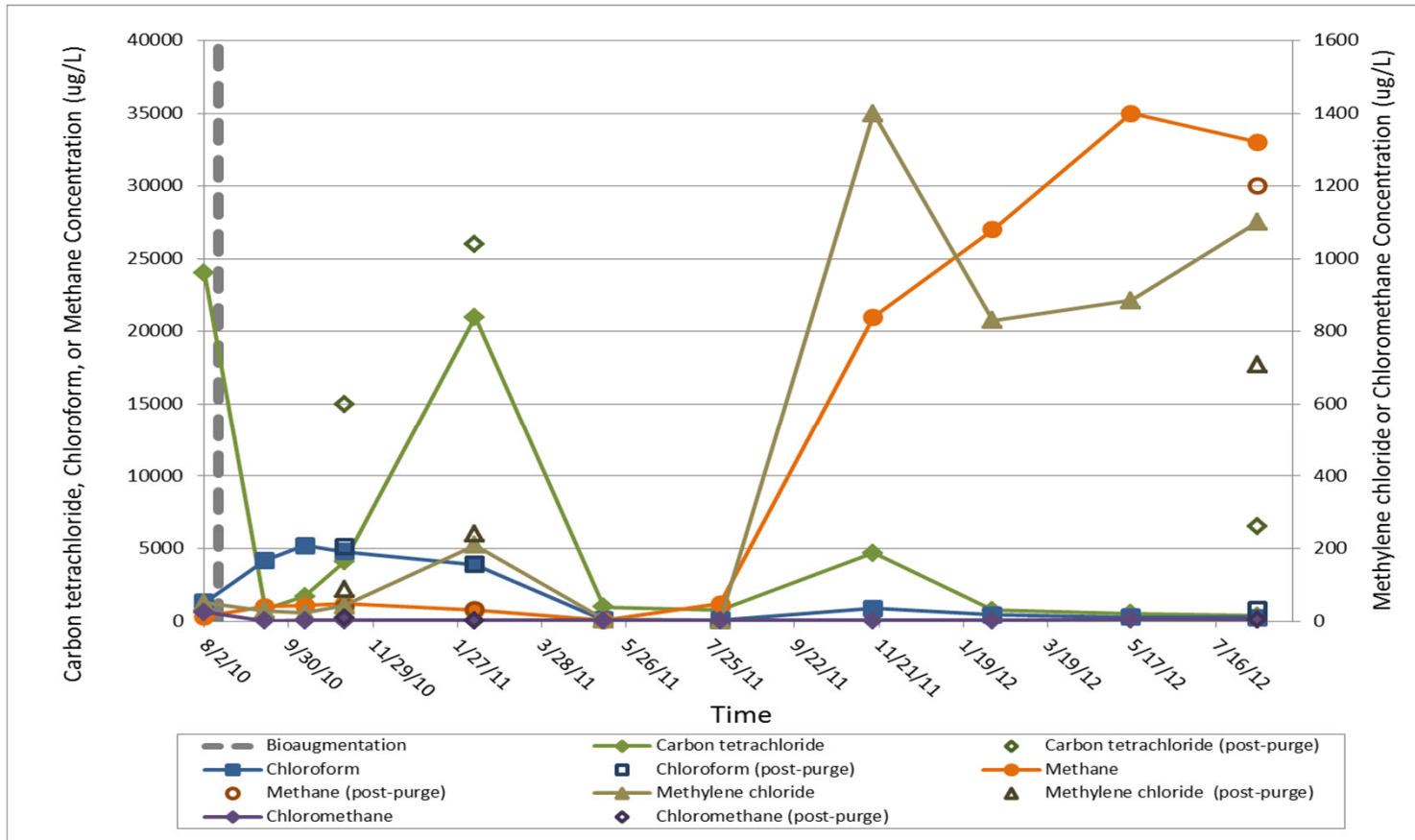


Concentrations vs. Time MW-47D



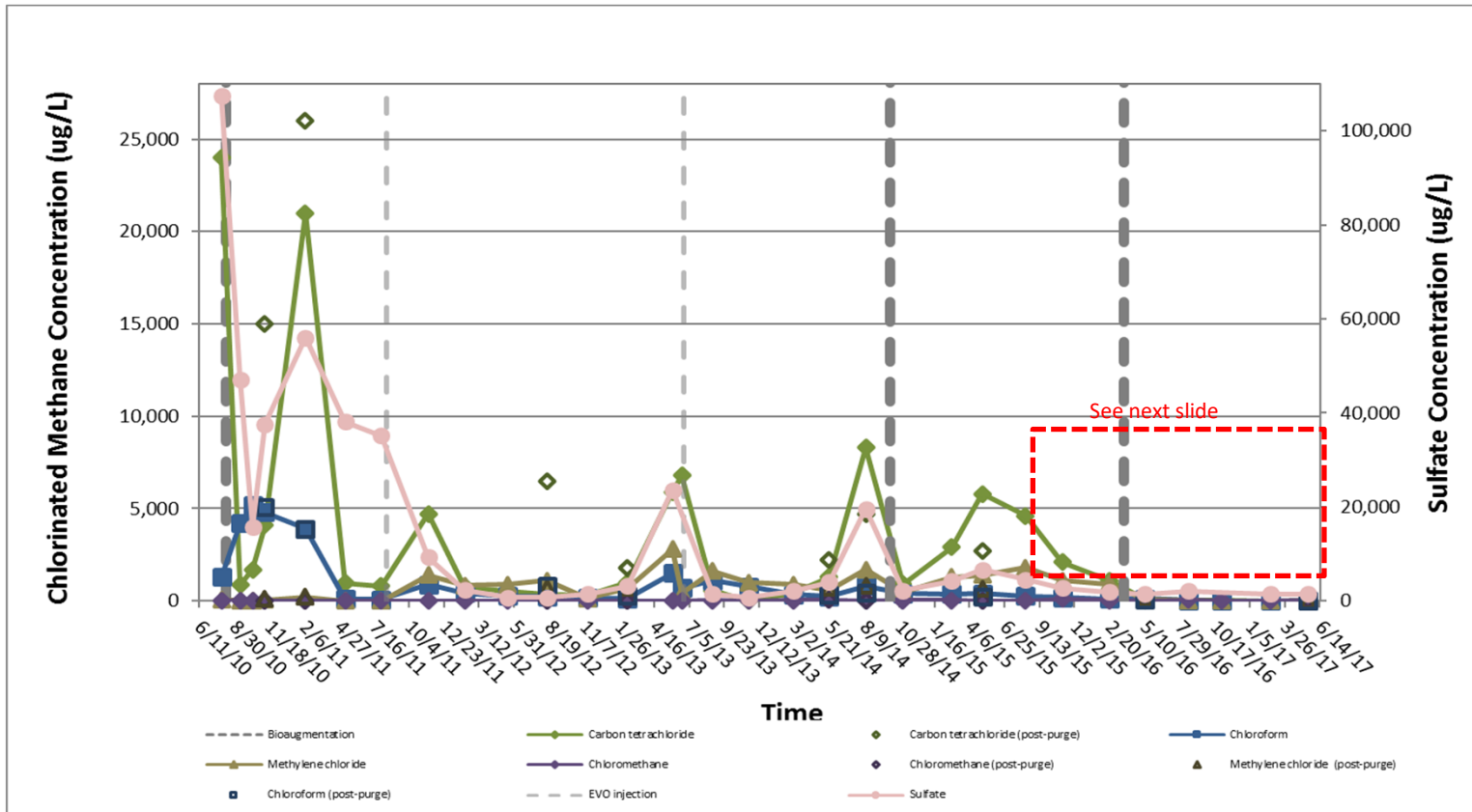


Chlorinated Methanes versus Time – MW47D



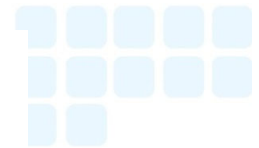
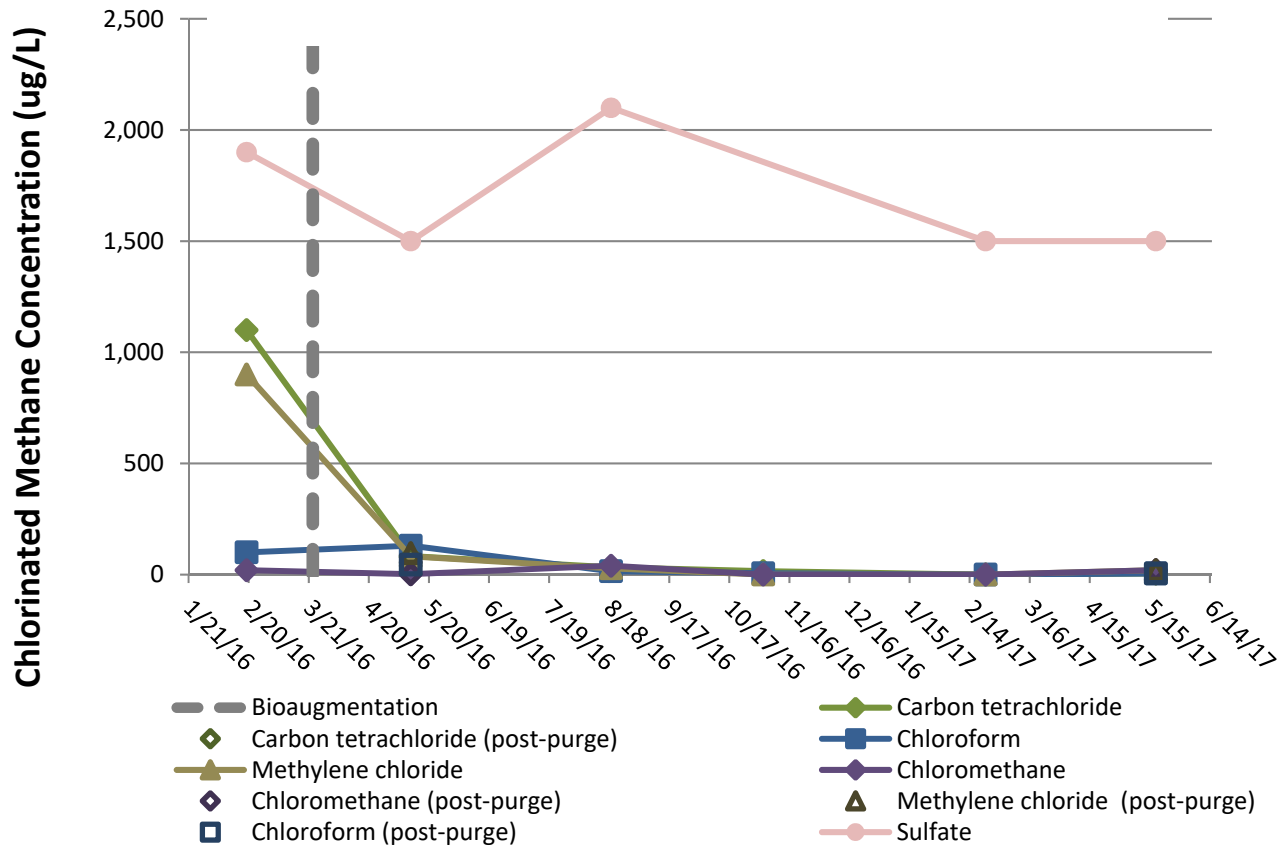


Chlorinated Methanes and Sulfate versus Time MW-47D





Chlorinated Methanes and Sulfate versus Time MW-47D



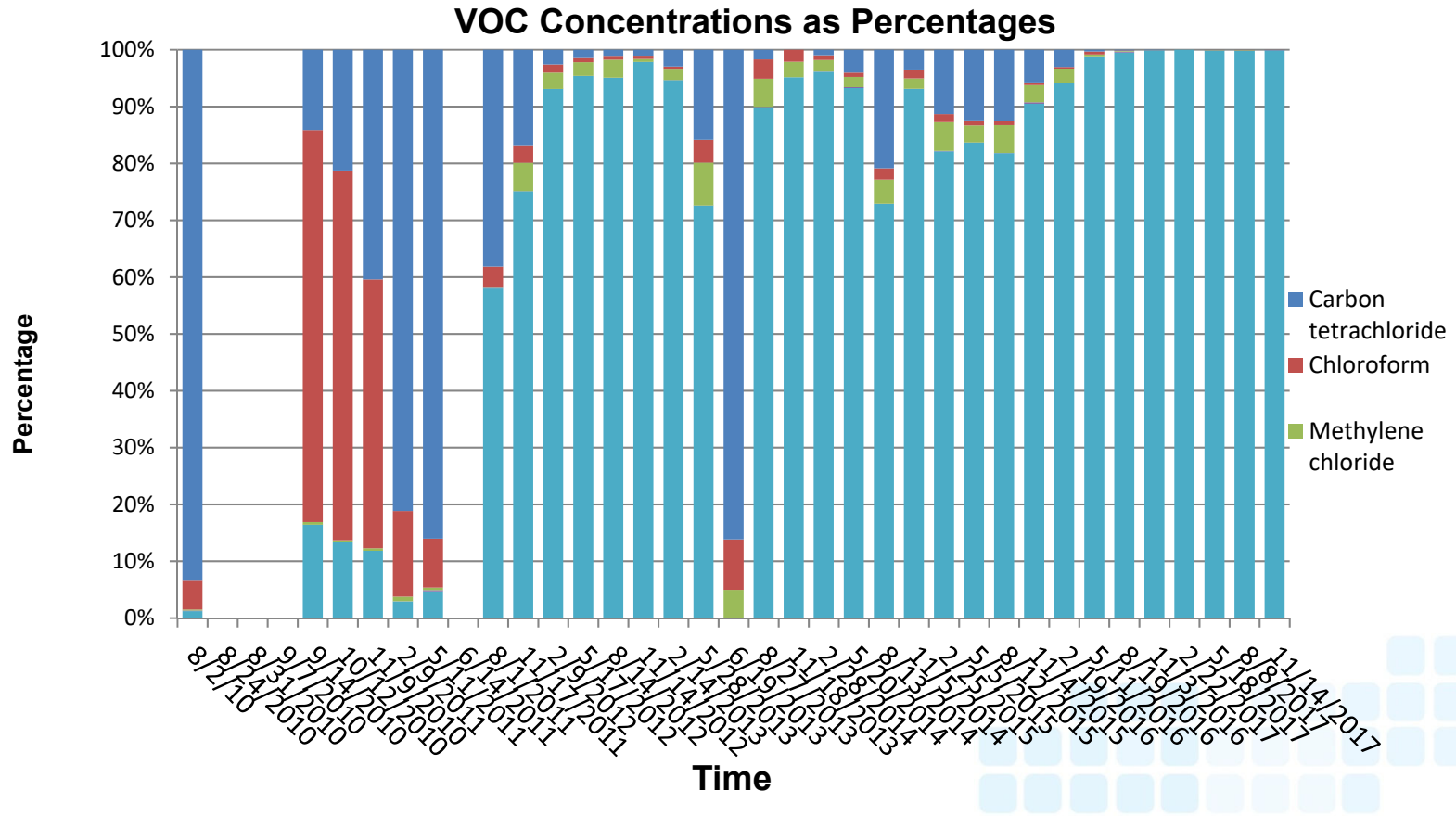


Dehalobacter in MW 47D





MW-47D VOC Concentrations as % of Total





Field Case Study Conclusions

- CVOC sources existed upgradient of the biologically active zones (BAZ) and these periodically caused high concentrations of parent CVOCs
- Use of a bromide tracer showed that the initial decrease in CVOCs was primarily due to biodegradation, not dilution
- Sulfate proved to be a valuable tracer of upgradient groundwater entering the BAZ
- Initially low levels of methane increased as concentrations of the CVOCs decreased
- Bioaugmentation was conducted more often than typical reflecting karst geology





Summary

- CTC degrades readily cometabolically and abiotically to CF
- CF toxic and inhibitory to anaerobic processes - Bioaugmentation cultures available for CF dechlorination
- Labelled ^{14}C studies showed pathway is reductive dechlorination to DCM and then fermentation to organic acids
- Treatability testing indicated ZVI inhibited DCM degradation – Bioaugmentation successful for complete dechlorination
- Field study indicated successful bioremediation of CTC in difficult Karst geology





Questions



Further Information
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