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BIODEGRADATION OF BIS(2-CHLOROETHOXY)METHANE IN SUPPORT OF A FIELD PILOT AT AN HISTORIC CHEMICAL PRODUCTION FACILITY

MATT WHALEY, PHD

*Claudia Walecka-Hutchison, Todd Tambling, Nikki Anderson, Rick Wenzel, Robert Stuetzle
(Dow)*

Eleanor Jennings, Jack Bunton (Parsons)

Paul Hatzinger, Simon Vainberg (Aptim)

OUTLINE

- Site Background
 - Site Description
 - COCs
 - Geochemistry
- Previous Bioremediation Bench Studies
- Current Study – Answering Questions Ahead of Pilot
 - Biostimulation of Native Degraders
 - Effect of pH and Salinity on Bioaugmentation
 - Inoculation Cell Density
- Summary and Path Forward

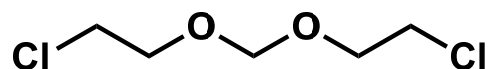


SITE INTRODUCTION

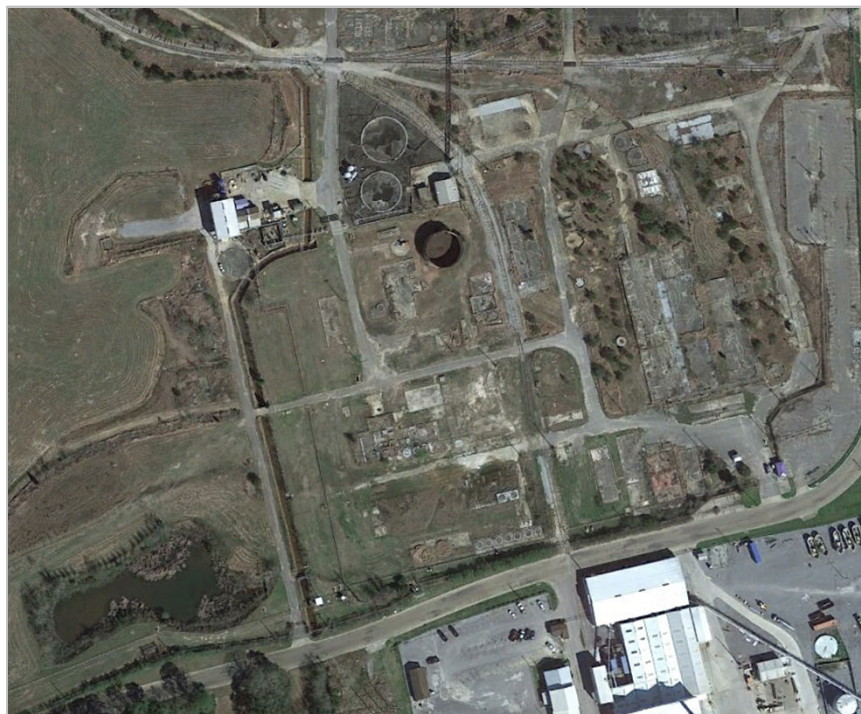
- Historic, former manufacturing plant for specialty chemicals and adhesives
- Operations began in 1952, discontinued in 2001
- Currently decommissioned and dismantled, undergoing active remediation in some target areas



Bis(2-CHLOROETHOXY)METHANE (BCEM)



- Used as solvent and chemical intermediate
- >95 % of polysulfide rubber was made from BCEM
- “Site-limited production of 10-50 million lbs...” (USEPA 1977)



GEOCHEMICAL CONDITIONS AT THE SITE

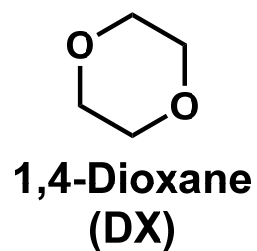
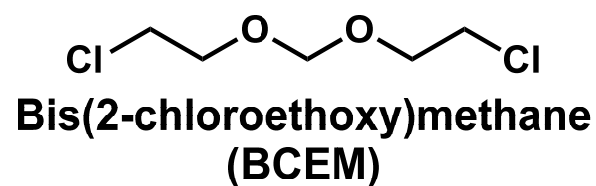
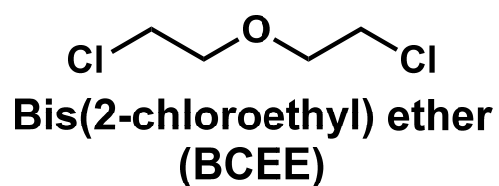
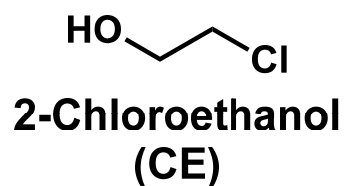
	Range
pH	3.11 – 7.20
Specific Conductance (iS/cm)	382 – 37400
Temperature (°C)	23.8 – 26.6
Dissolved Oxygen (mg/L)	0.38 – 3.0
ORP (mV)	-262 – +283
Iron (mg/L)	5 – 200

Site groundwater is ***predominately acidic and hypoxic with variable TDS***, depending on aquifer and proximity to receptor.



SITE COCs

The site is impacted by COCs related to the production of BCEM:



ENVIRONMENTAL BCEM DEGRADATION PROCESSES

“...not expected to readily biodegrade in the environment...”

“...underwent **0 % biodegradation** using a settled domestic wastewater inoculum...”

“...**estimated** hydrolysis half-life of bis(2-chloroethoxy)methane was reported as 0.5 to 2 years (pH independent).”

TOXNET



2015 PARSONS BIOREMEDIATION STUDY FINDINGS

- 1,4-Dioxane, BCEE, BCEM:
 - Not reduced by either biostimulation or bioaugmentation
- 2-Chloroethanol:
 - Reduced by both biostimulation and bioaugmentation
- 1,2-DCA:
 - Was reduced by both biostimulation and bioaugmentation
 - Effectiveness possibly reduced by 1,4-dioxane and BCEM concentrations



Enhanced Bioremediation of a Consortium of Contaminants at a Historic Chemical-Production Facility

Eleanor M. Jennings, M.S., PhD



BIOAUGMENTATION CULTURES

***Pseudonocardia* sp. strain ENV478:**

Appl. Environ. Microbiol. **2006**, 72, 5218.

- Capable of growth on propane, propanols, THF, sucrose
- Exhibits cometabolic degradation of 1,4-dioxane, BCEE, MTBE

***Xanthobacter* sp. strain ENV481:**

Appl. Environ. Microbiol. **2007**, 73, 6870.

- Metabolizes BCEE by a hydrolysis pathway (↓ pH)
- Does not degrade 1,4-dioxane



PILOT-FOCUSED BENCH STUDY

Treatment	pH	Soil	Water	Amendment	Culture	Cell Density (cells/mL)
Abiotic Control	5.5	MW-103 (25-30' bgs)	MW-103 (20' bgs)	CuCl ₂ (2.5 g/L)	NA	NA
Live Control	5.5	MW-103 (25-30' bgs)	MW-103 (20' bgs)	NA	NA	NA
pH Tolerance	6, 5, 4	MW-103 (25-30' bgs)	MW-103 (20' bgs)	NaOH/HCl	ENV478 ENV481	10 ⁷
Salinity	5.5	MW-103 (25-30' bgs)	MW-103 (20' bgs)	K ₂ SO ₄ NaCl	ENV478 ENV481	10 ⁷
Biostimulation	6	MW-103 (25-30' bgs)	MW-103 (20' bgs)	DAP + Carbon Source	NA	NA
Cell Density	7	NA	Basal Salt Medium	NA	ENV478 ENV481	10 ¹ -10 ⁷



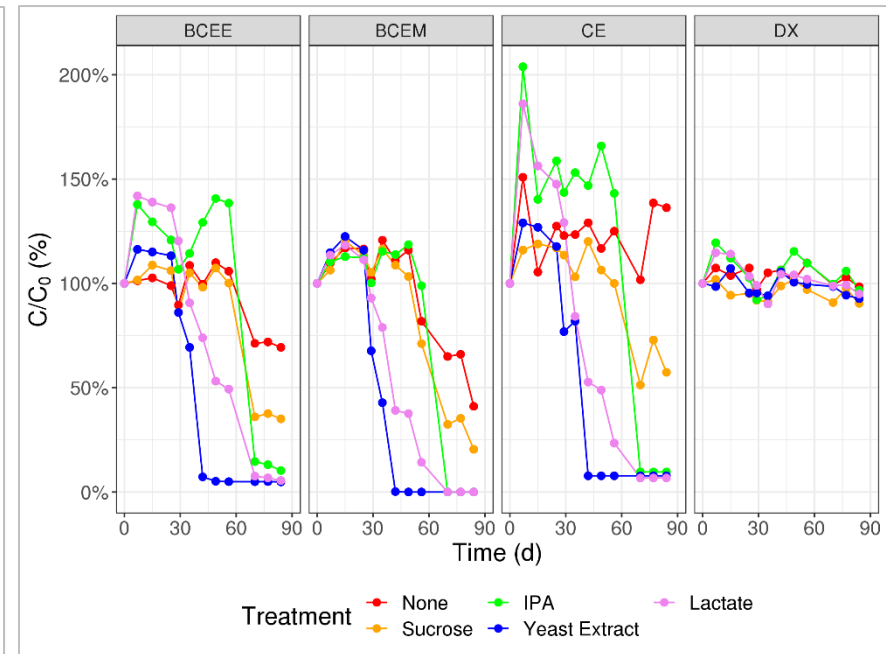
BIOSTIMULATION: ACTIVITY OF NATIVE DEGRADERS

Aerobic Treatments:

- Soil + groundwater
- Added carbon sources

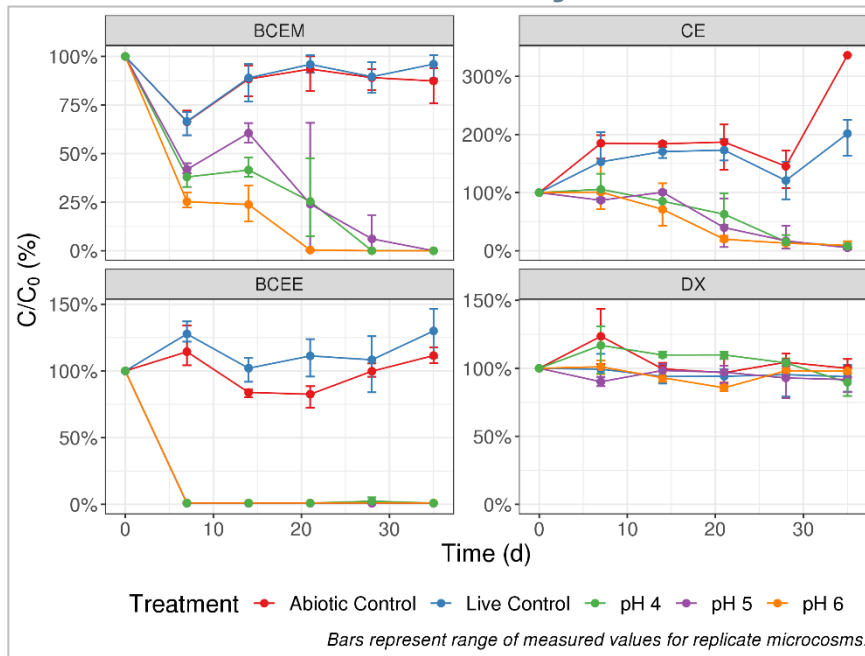
Degradation of chlorinated COCs observed after ≥ 3 week lag

Addition of carbon sources did *not* stimulate cometabolic DX degradation

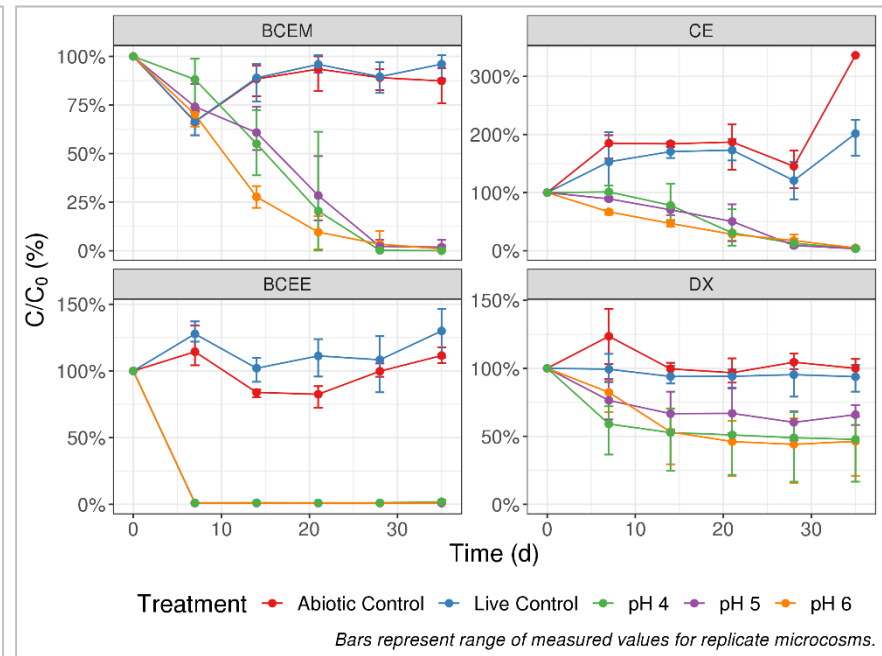


EFFECT OF pH ON BIOAUGMENTATION IN SOIL AND GROUNDWATER

ENV481 Only



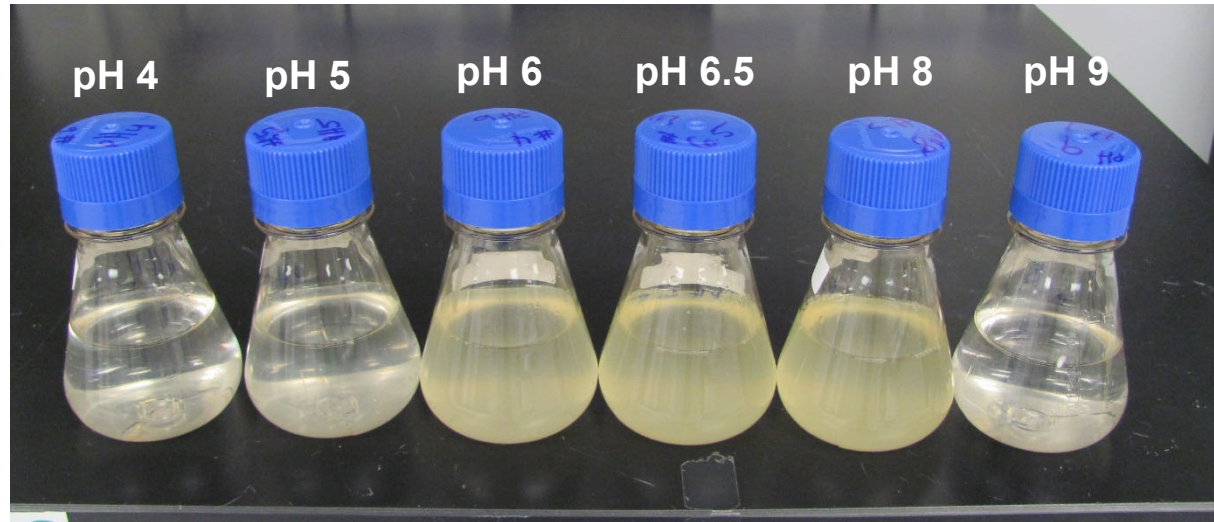
ENV478 + ENV481



Biodegradation occurred at low pH but is unlikely to be sustainable in the field



BACTERIAL GROWTH IS SLOW IN SITE-RELEVANT pH RANGE

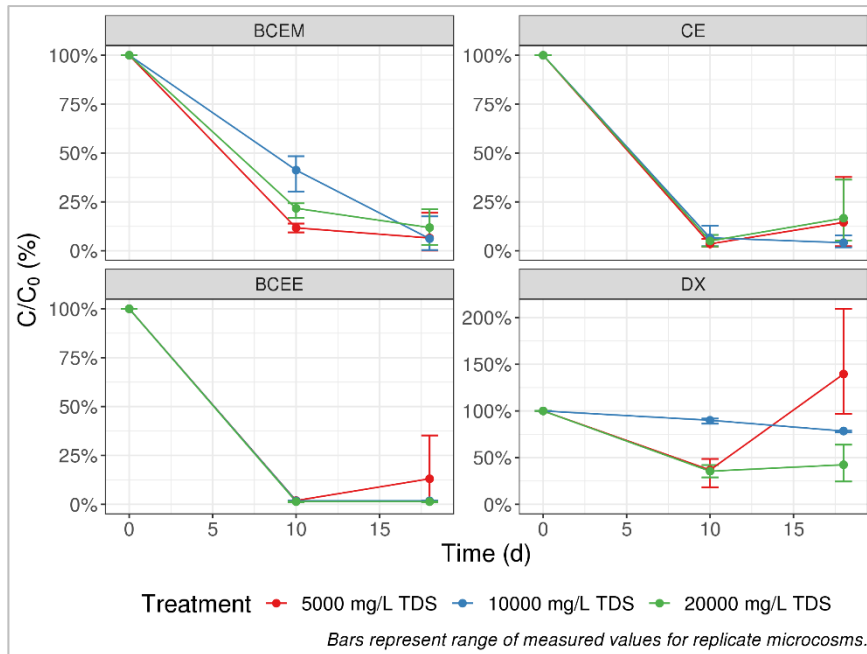


- Site pH varies between pH 3 and 6.5
- Buffering necessary for sustainable bioaugmentation
- Bicarbonate recommended



GROUNDWATER SALINITY DOES NOT IMPACT BIODEGRADATION

ENV478 + ENV481



- Site located near Gulf Coast
- Salinity varies with receptor proximity and season
- Range: 100-12000 mg/L TDS



INOCULATION CELL DENSITY STUDY

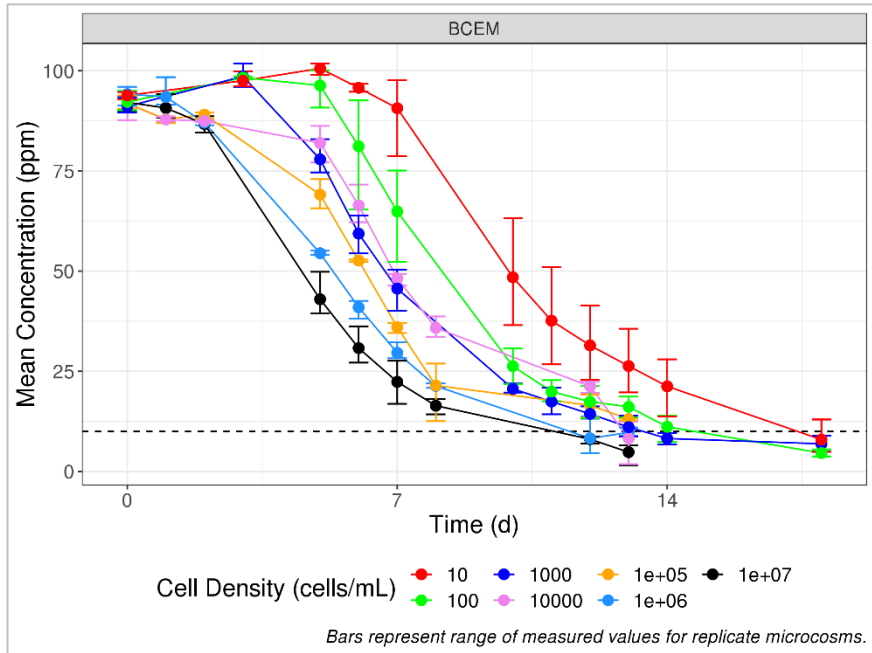
Objective: Evaluating effect of cell density on biodegradation rates is necessary to assess application costs

Conditions:

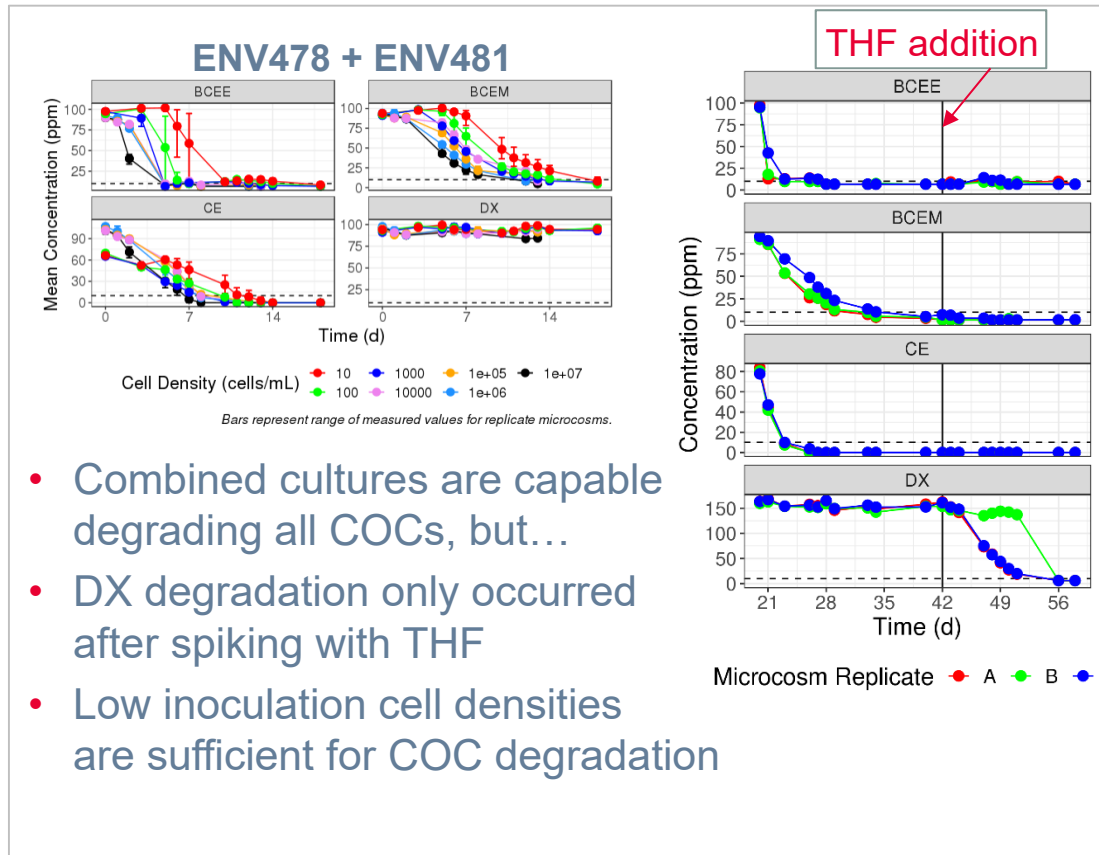
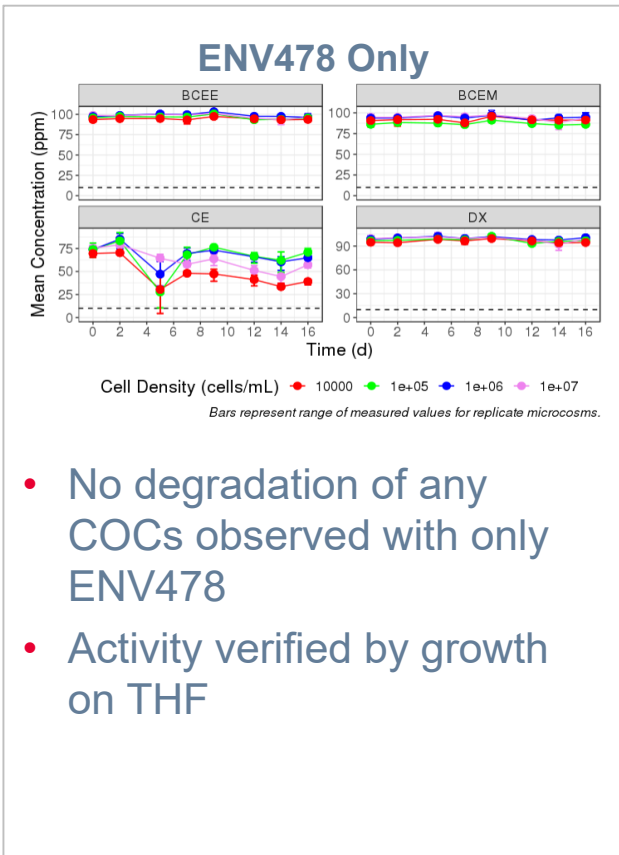
- 100 mL BSM (growth medium)
- Spiked with 100 ppm COCs
- CD: 10^1 - 10^7 cells/mL
- ENV478 + ENV481

Results:

- Rapid degradation of chlorinated COCs within 3 weeks for all CDs
- Lower CDs have longer lag but reach similar degradation rates



BOTH CULTURES NEEDED FOR DEGRADATION OF ALL COCs



SUMMARY

- Native organisms and strain ENV481 are capable of aerobically degrading BCEM and other chlorinated site COCs
- Successful bioremediation will require groundwater buffering due to low site pH
- Biodegradation was not impacted by high salinity
- Low cell densities can be applied without dramatically impacting speed of COC removal
- Cometabolic DX degradation can be accomplished by treatment with strain ENV478, but more work is needed to identify a suitable carbon source



REMAINING QUESTIONS

- What are the native organisms that are responsible for degrading the chlorinated COCs?
- What field applicable carbon sources will induce cometabolic DX degradation by ENV478 in site groundwater and soil?
- What is the minimum DO concentration for biodegradation in this system, and what is the oxygen uptake rate?
 - Preliminary data suggest that >2 mg/L is probably necessary
 - No biodegradation at 1 mg/L
- What concentrations of COCs are toxic to these organisms? How close to the source can we apply?



Questions?

Matt Whaley

Associate Research Scientist
Core R&D – Chemical Science

cmwhaley@dow.com

