



Natural Attenuation of Toxins Released in the East Palestine, OH Train Derailment Accident



Rapid Response Research
(RAPID) grant

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Microbial Insights, Inc.



Team East Palestine



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Inter American University of Puerto Rico

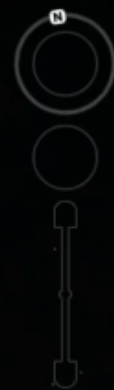
Ana Arosemena, Bryan Rosado-Maldonado,
Elizabeth Padilla-Crespo

Purdue University

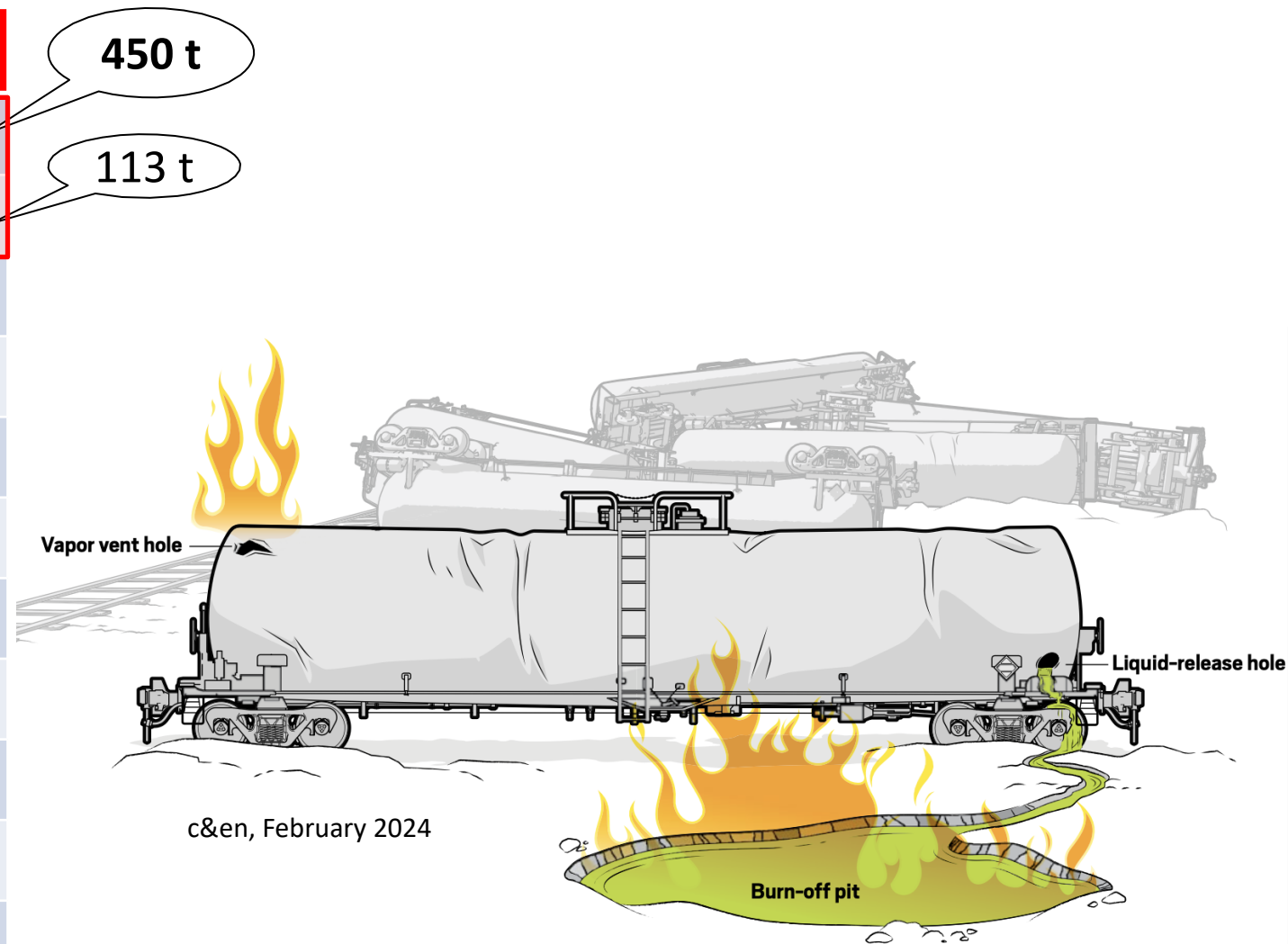
Paula Belmont Coelho, Andrew Whelton

East Palestine train derailment Feb. 3, photo taken Feb. 4, 2023





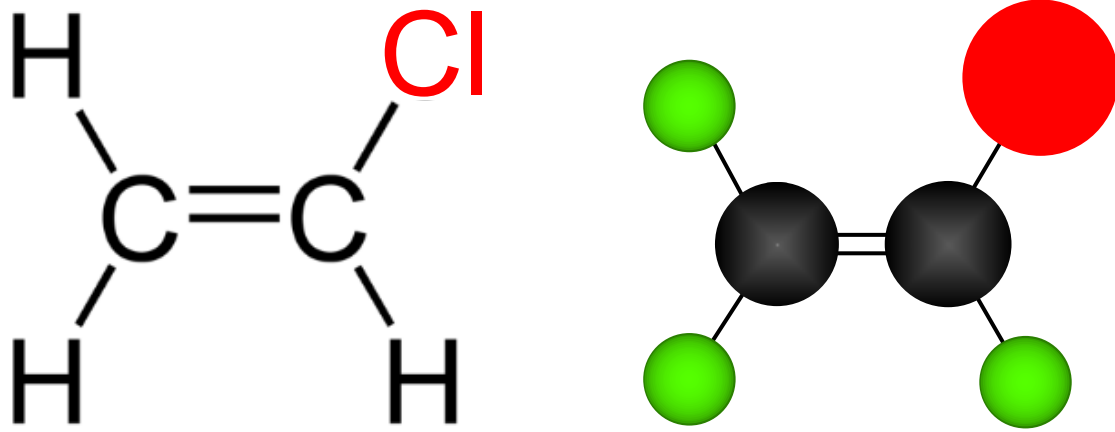
Chemical or product	Derailed cars
Vinyl chloride	5
Butyl acrylate	1
2-Ethylhexyl acrylate	1
Dipropylene glycol	1
Propylene glycol	3
Diethylene glycol	3
Polypropylene glycol	1
2-Butoxyethanol	1
Isobutylene	1
Petro oil	1
Fuel additives	1
Petroleum lube oil	4
Polyvinyl chloride (PVC)	4
Polyethylene	2







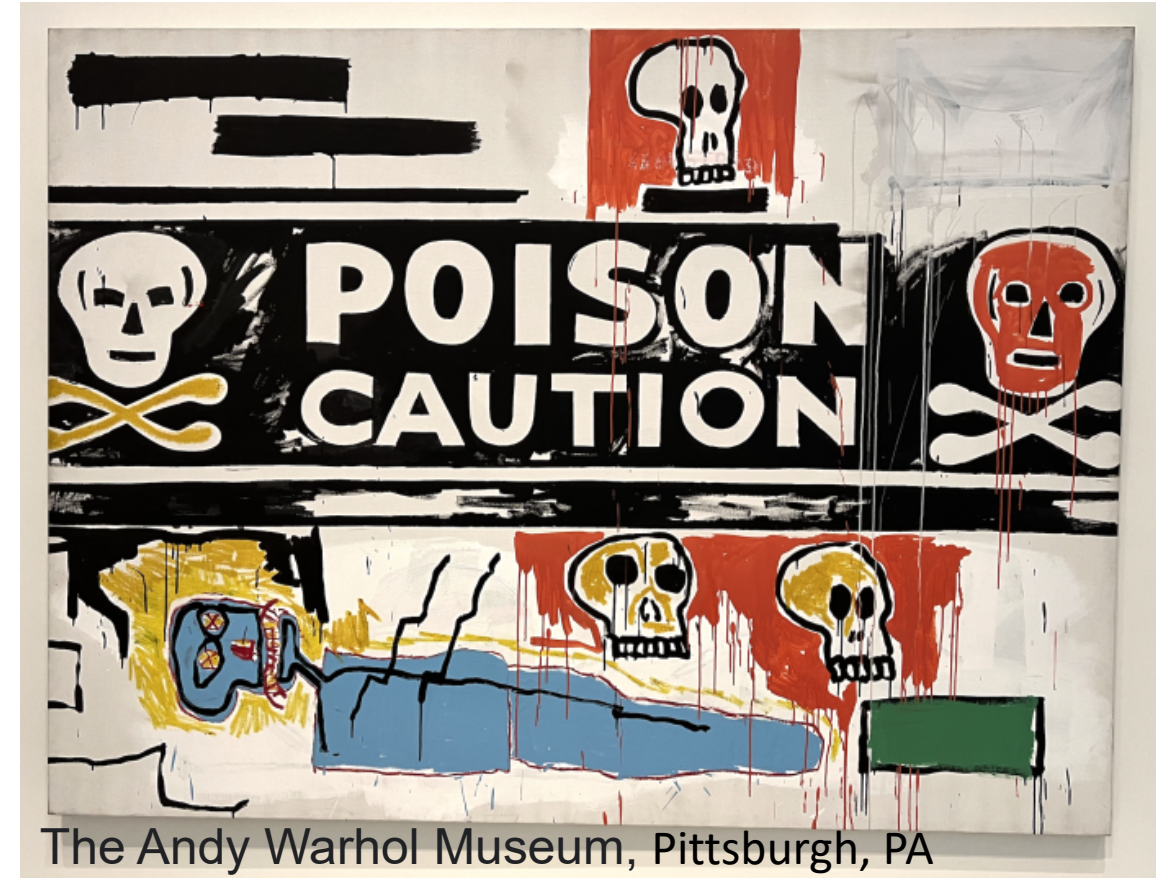
Vinyl Chloride (VC)



Boiling point: -13.4°C (colorless gas)

Solubility: 2.7 g/L (43.2 mM)

Half-life in air: 1-2 days



Health Concerns Associated with VC

Acute Effects (response to high levels of VC)

- Irritation of eyes and respiratory tract
- Dizziness, drowsiness, headaches

Chronic Effects (low levels over prolonged periods)

- Liver damage
- Nerve damage
- Immune reactions
- Reproductive/Developmental Effects
- Increased risk of liver cancer
 - VC classified as a human carcinogen

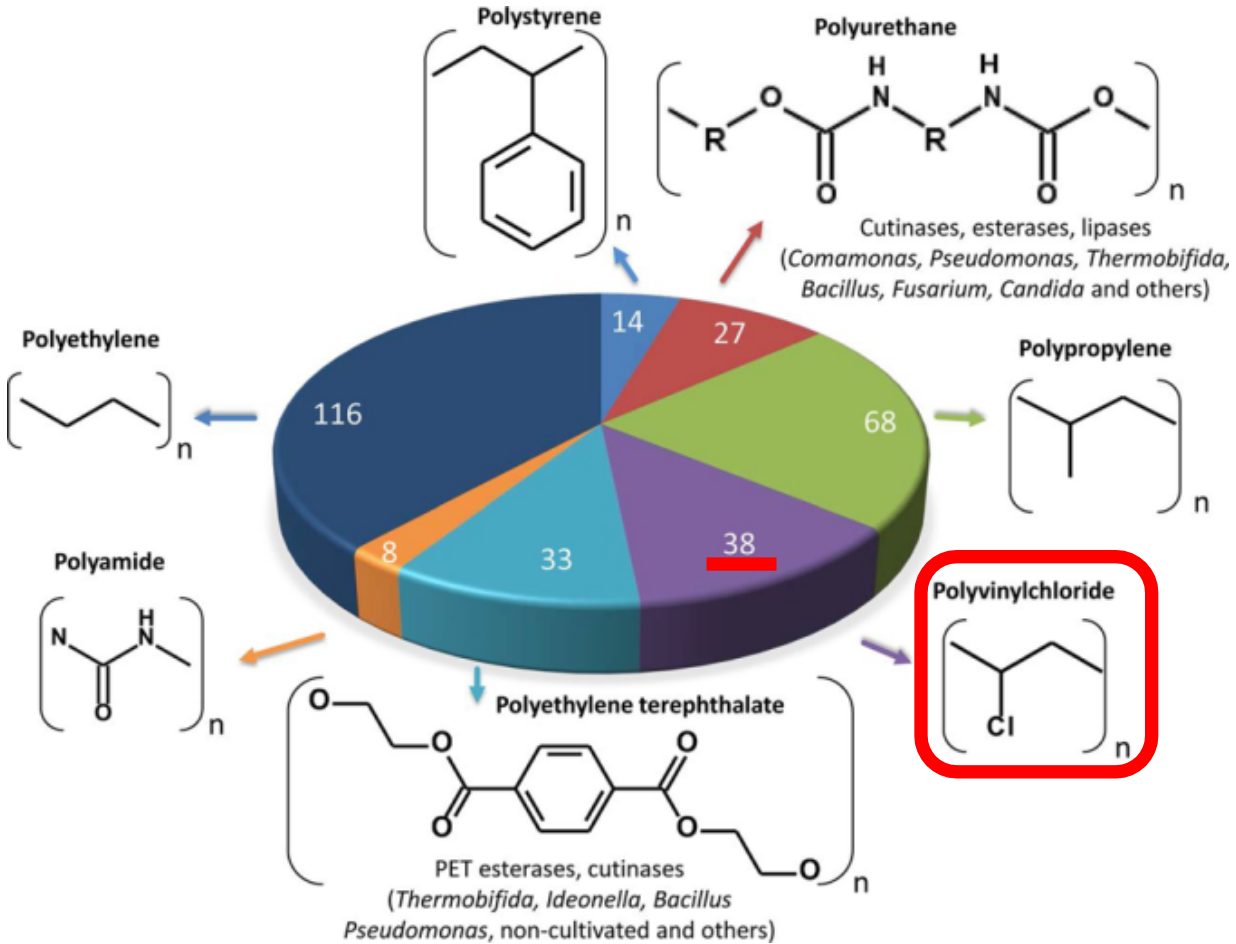
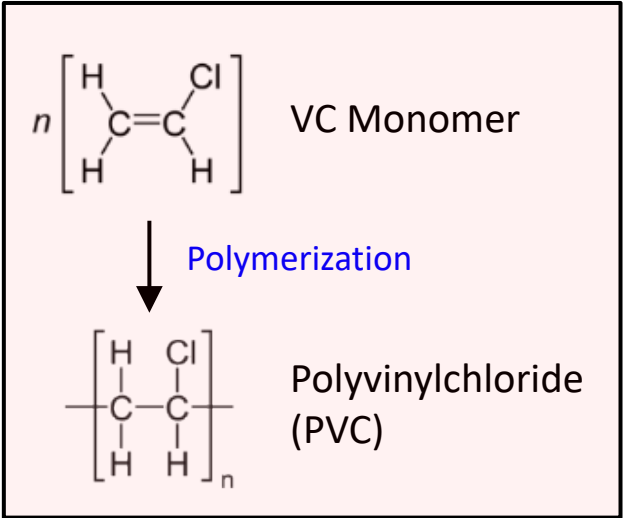


Bass et al. 2005. Vinyl chloride: A case study of data suppression and misrepresentation. Environ. Health Perspec. 113:809-812.

<https://www.epa.gov/system/files/documents/2023-06/Vinyl-Chloride-and-Health-FAQ-Document-5-31-508.pdf>



PVC - Globally Manufactured Plastic



Global annual production of synthetic polymers (in millions of tons)

Danso et al., 2019, Appl. Environ. Microbiol. 85:e01095-19

Risks Associated with VC Transportation



US: 1,164 train derailments in 2022 ($\sim 3 \text{ day}^{-1}$)

At least 29 derailments involving cars with VC since 1968
 $\sim 50\%$ resulted in VC releases $\rightarrow$ Accident every 4 years!

Beyond Plastics et al. 2024



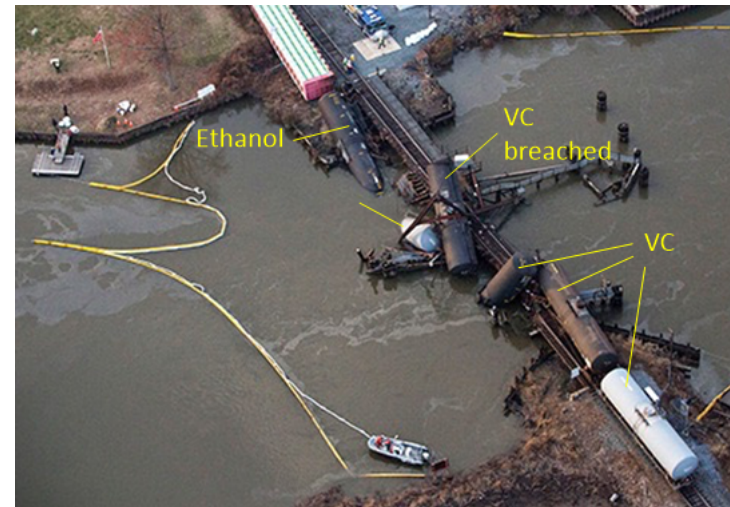
Livingston, LA, 1982

$\sim 1 \text{ million lbs VC}$



Schönebeck,
Germany, 1996

$\sim 600,000 \text{ lbs VC}$



Paulsboro, NJ, 2012

$\sim 200,000 \text{ lbs VC}$



East Palestine, OH, 2023

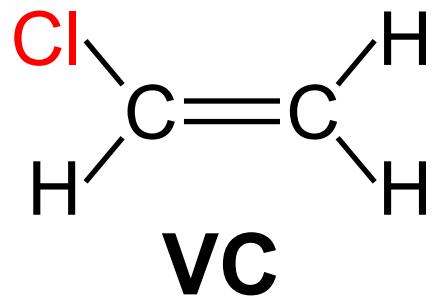
$\sim 1 \text{ million lbs VC}$



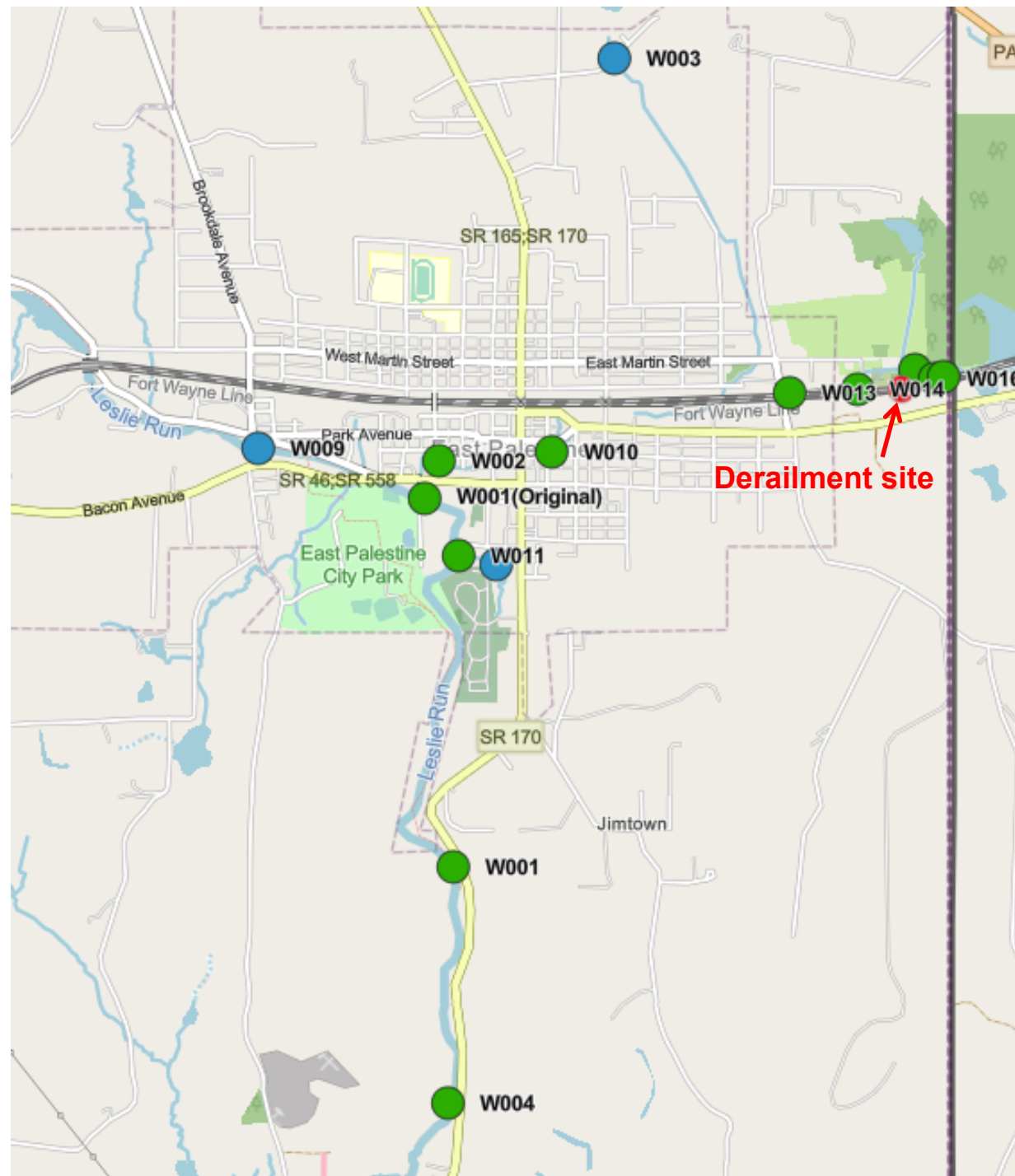
Sample Collection (June and November 2023)



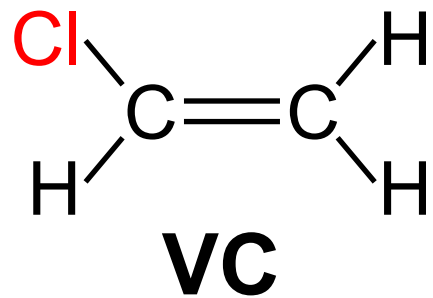
East Palestine Surface Water Monitoring - EPA



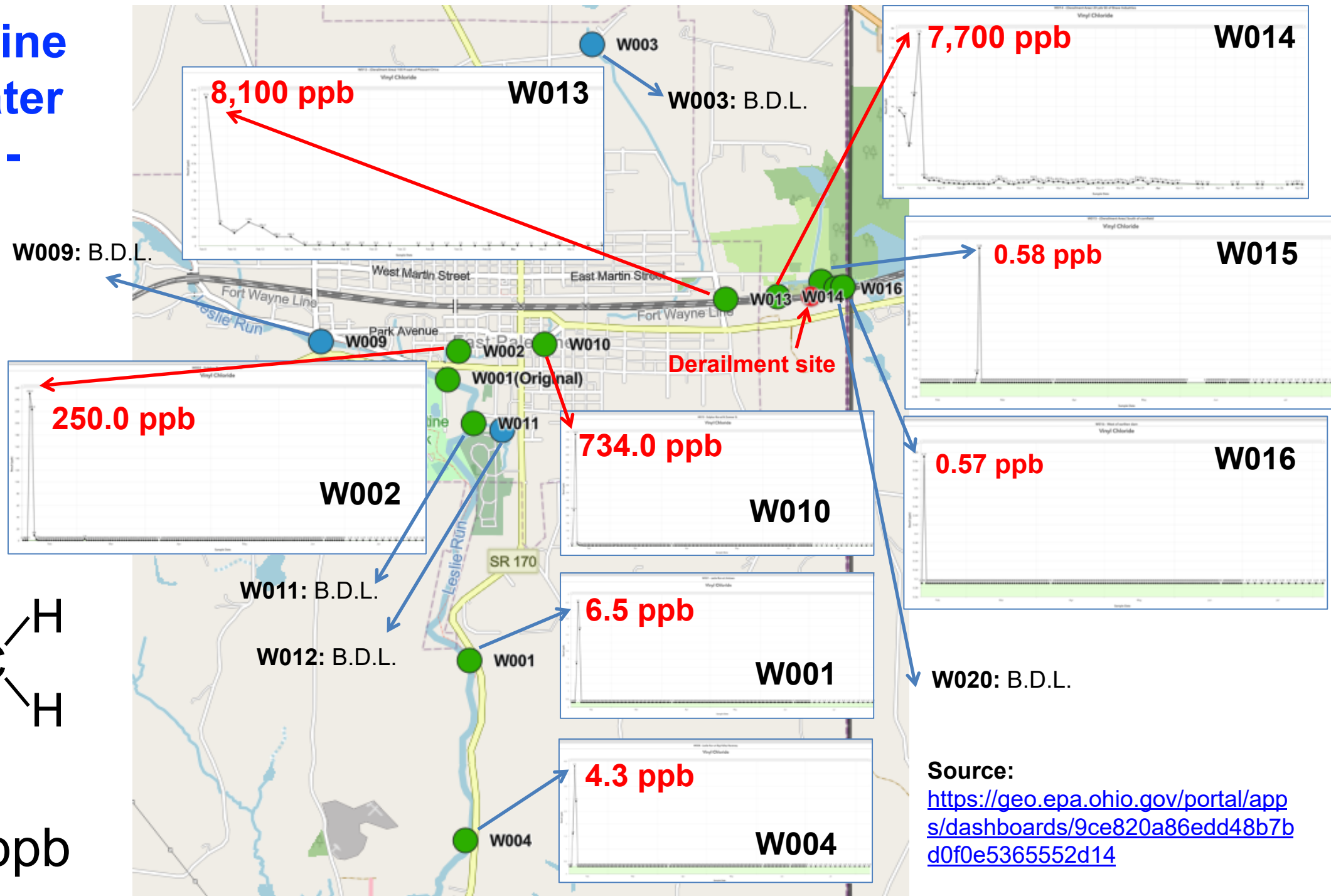
¹³ MCL: 2 ppb



East Palestine Surface Water Monitoring - EPA



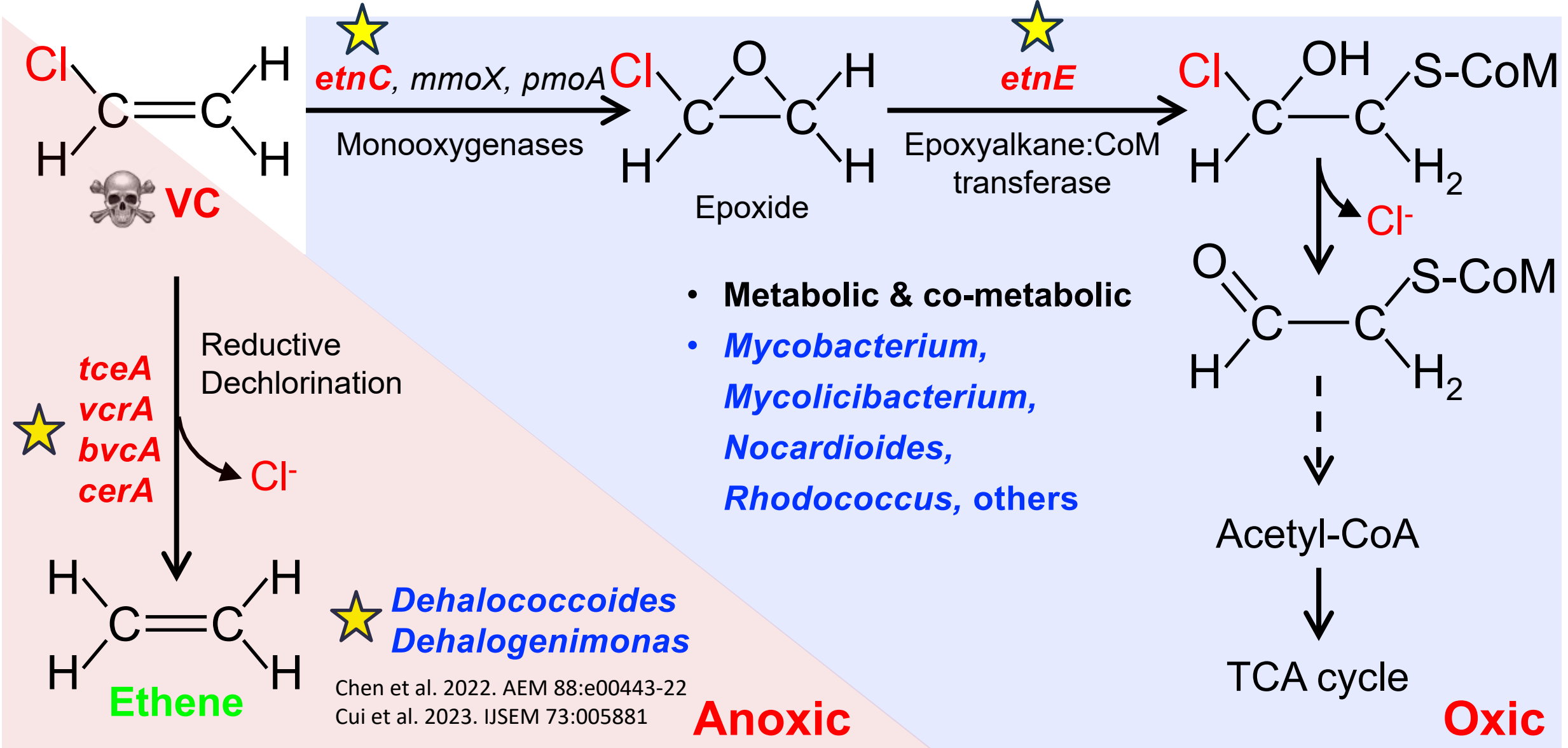
¹⁴ MCL: 2 ppb



Source:
<https://geo.epa.ohio.gov/portal/apps/dashboards/9ce820a86edd48b7bd0f0e5365552d14>

Microbial Degradation of VC

MBTs: ★



Sample Collection

Sediment

June 11, 2023

Surface water

November 6, 2023

Drinking water wells



QuantStudio
qPCR system

- **Molecular Biological tools (MBTs)**

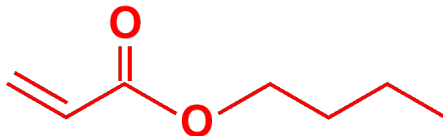


- **Microcosm Treatability Studies**

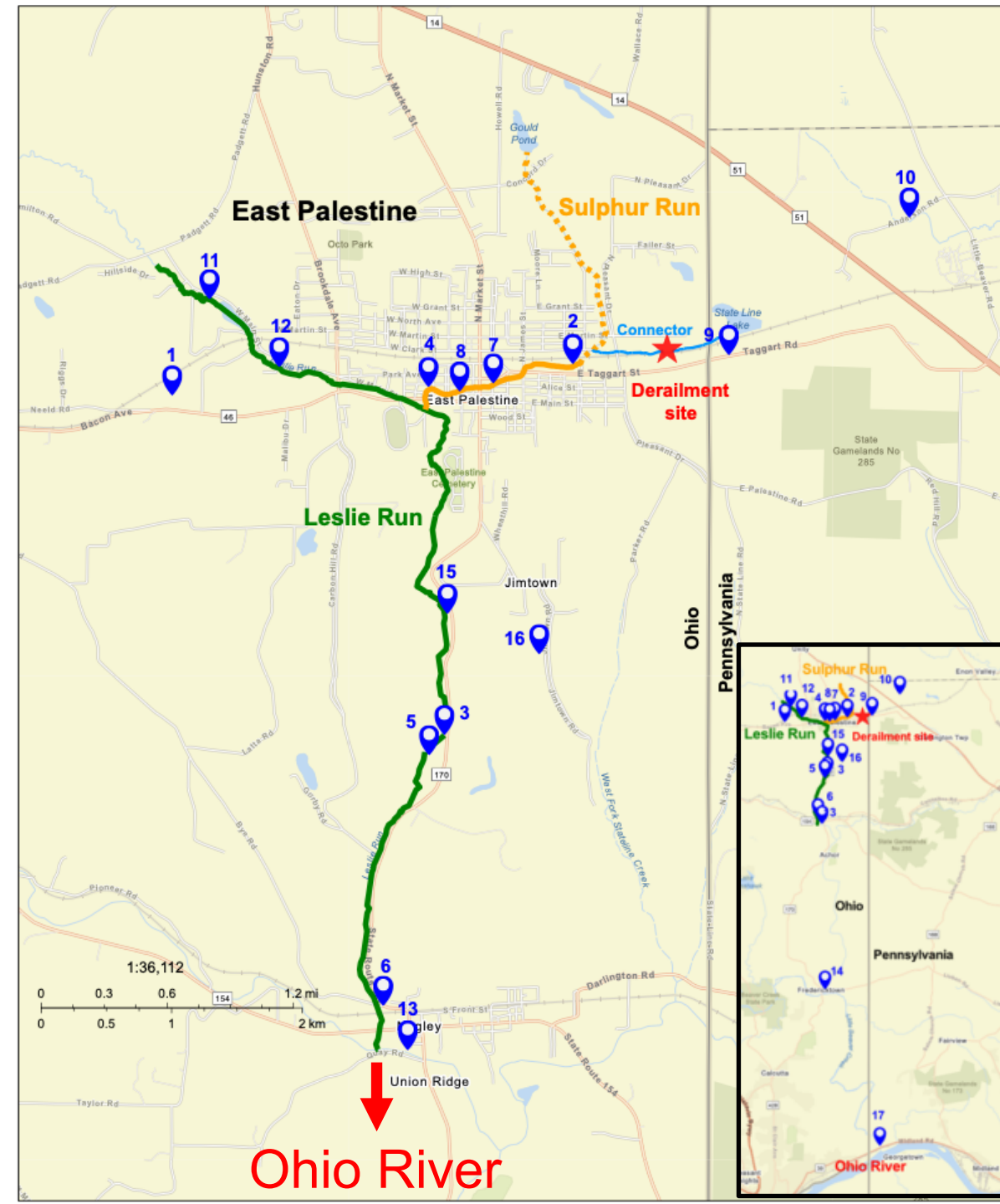


Vinyl chloride

16



Butyl acrylate



Detection of VC Degradation Biomarkers

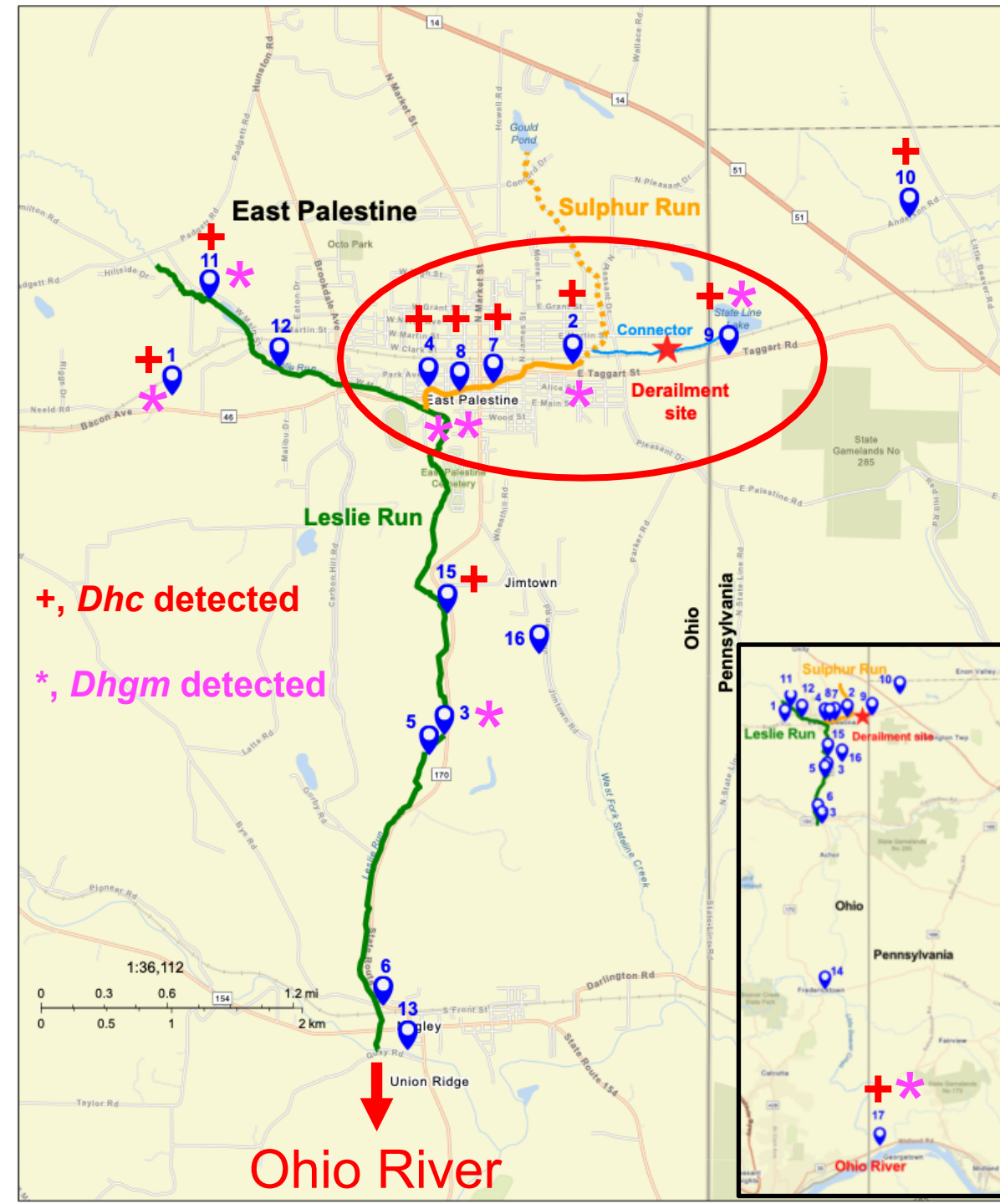
Targeted qPCR



22 Sediment & 22 surface water (SW) samples

Dhc: 64% (28 out of 44 samples)
 $4 \times 10^2 - 1 \times 10^6$ copies g^{-1} sediment
 $0.2 - 4.5 \times 10^1$ copies mL^{-1} SW

Dhgm: 55% (24 out of 44 samples)
 $1.5 \times 10^3 - 1 \times 10^7$ copies g^{-1} sediment
 $0.1 - 4 \times 10^2$ copies mL^{-1} SW



Detection of VC Degradation Biomarkers

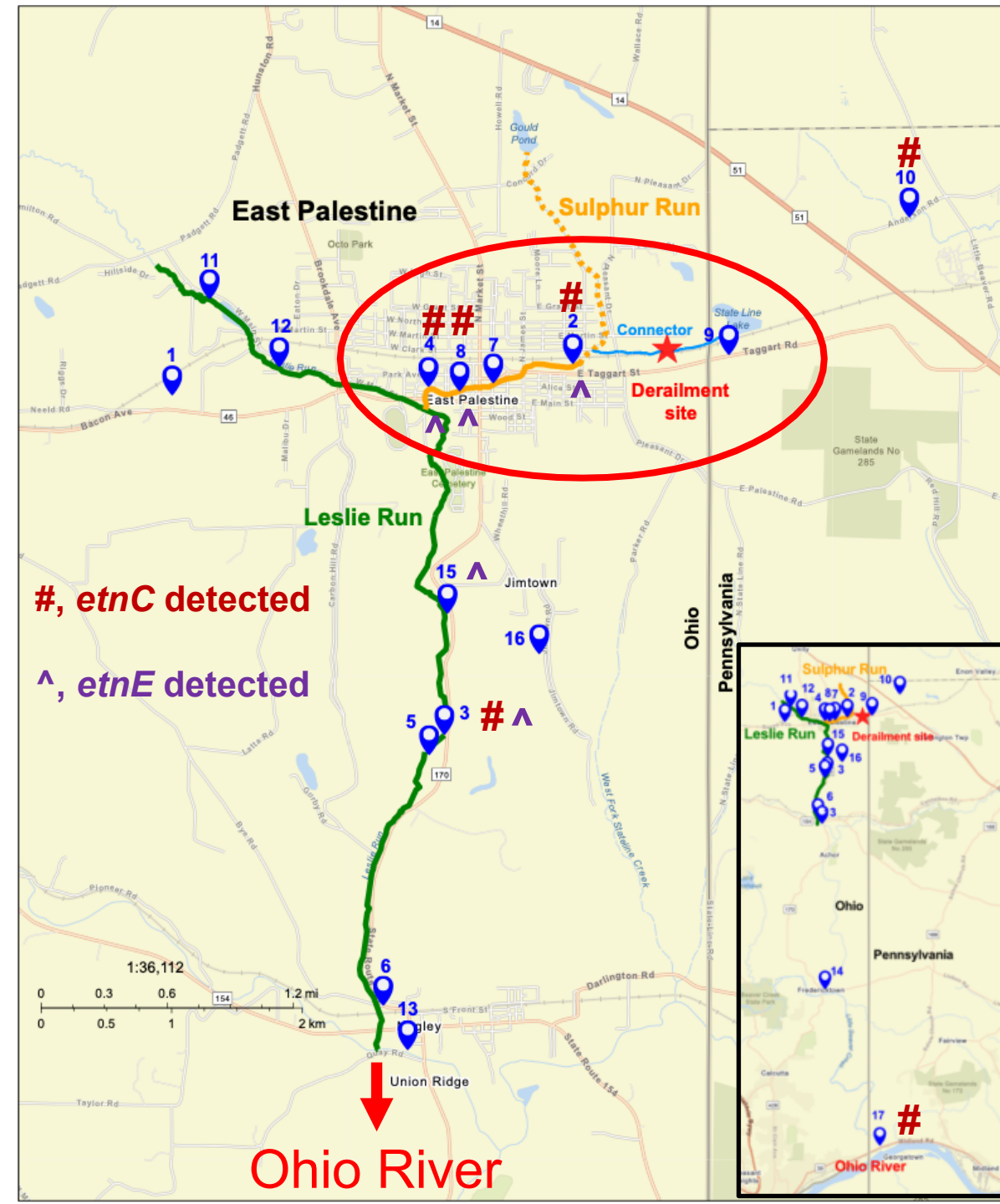
Targeted qPCR



22 Sediment & 22 surface water (SW) samples

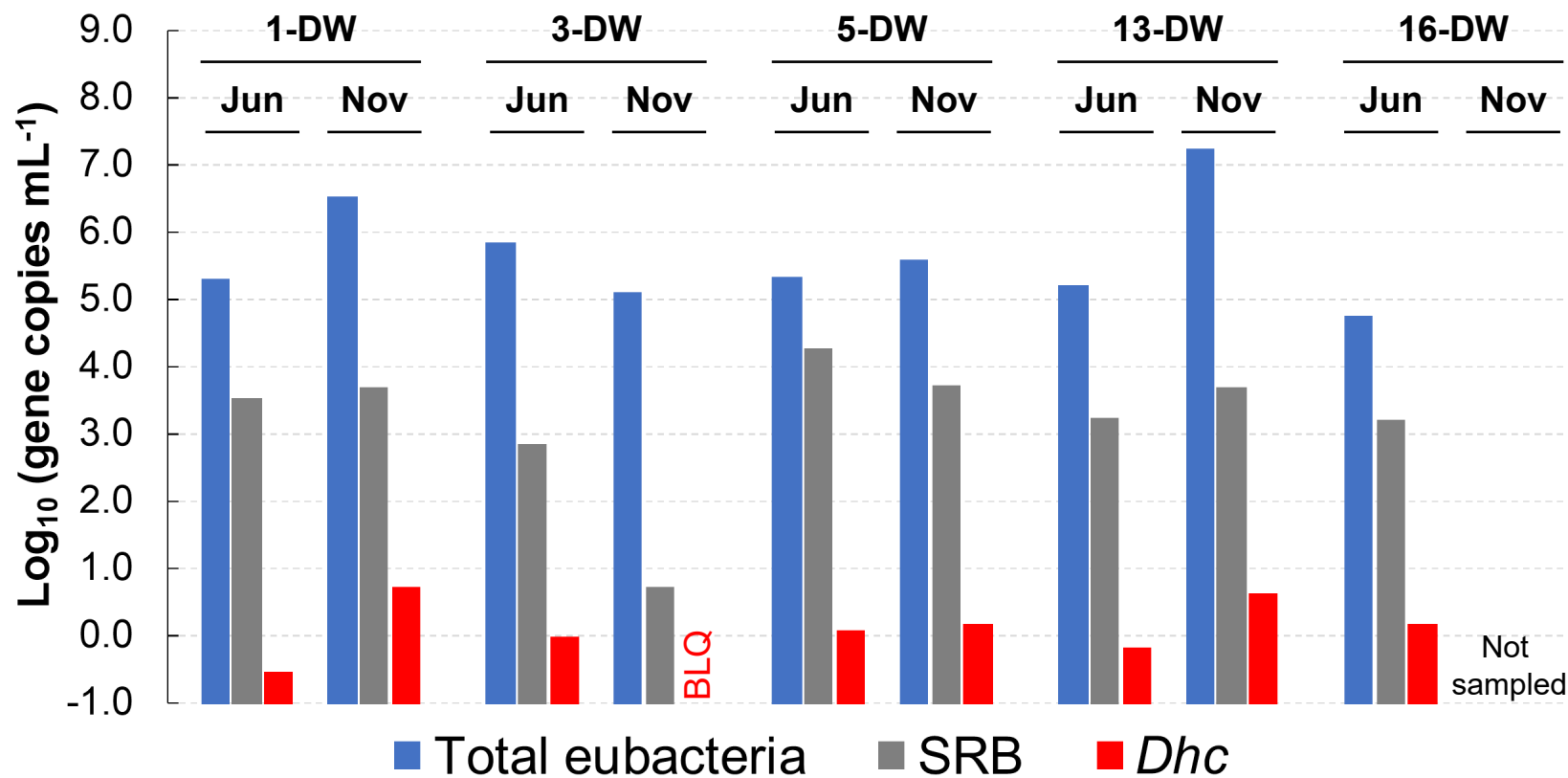
etnC: 21% (9 out of 44 samples)
 $3 \times 10^3 - 1 \times 10^5$ copies g^{-1} sediment

etnE: 14% (6 out of 44 samples)
 $1 \times 10^5 - 6 \times 10^5$ copies g^{-1} sediment



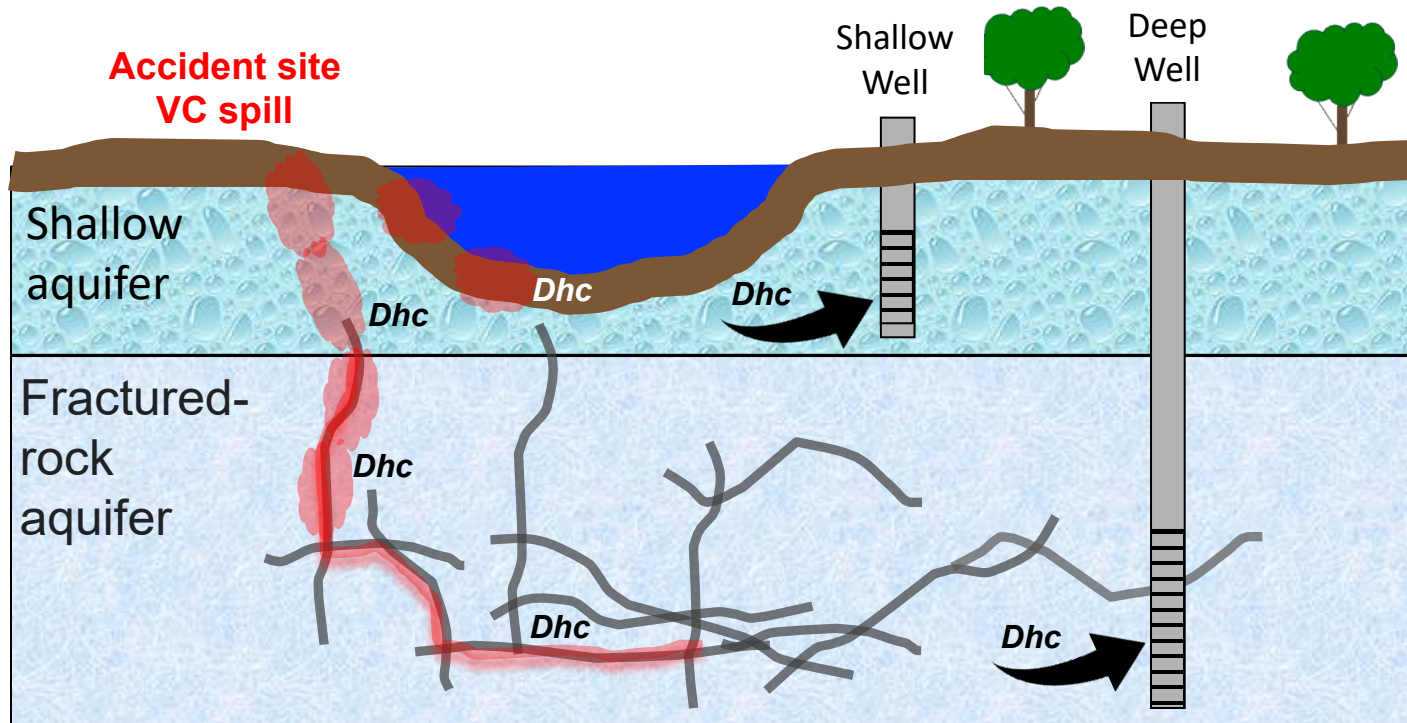
Detection of *Dhc* in Well Water Samples

Dhc: 0.3 – 5.6 cells mL⁻¹



Dhc detected in all drinking well water samples

Detection of *Dhc* in Well Water Samples

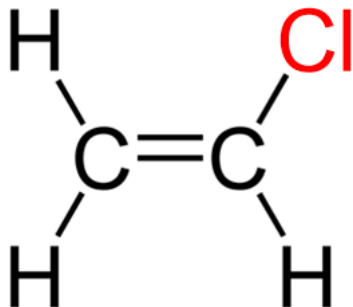


VC was never detected in well water

Detection of *Dhc* in well water suggest a *Dhc* bloom in the aquifer

Residents reported deteriorated well water quality (e.g., rotten egg smell) following the accident

Microcosm Treatability Study



VC

Oxic



e^- donor: VC
 e^- acceptor: O_2
 Sediment
 Mineral salt medium

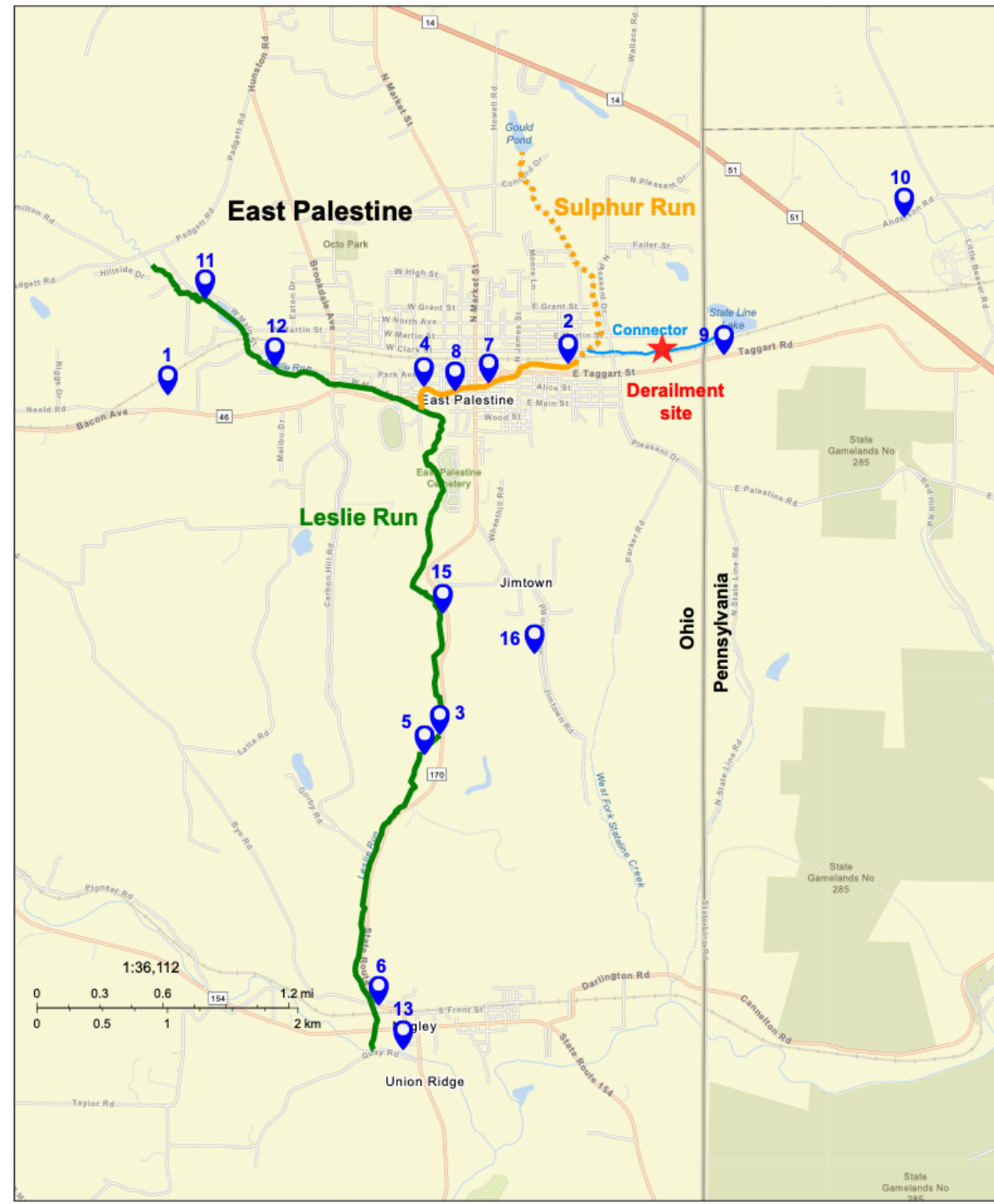
Anoxic



e^- donor: Lactate
 e^- acceptor: VC
 Sediment
 Mineral salt medium



GC-FID

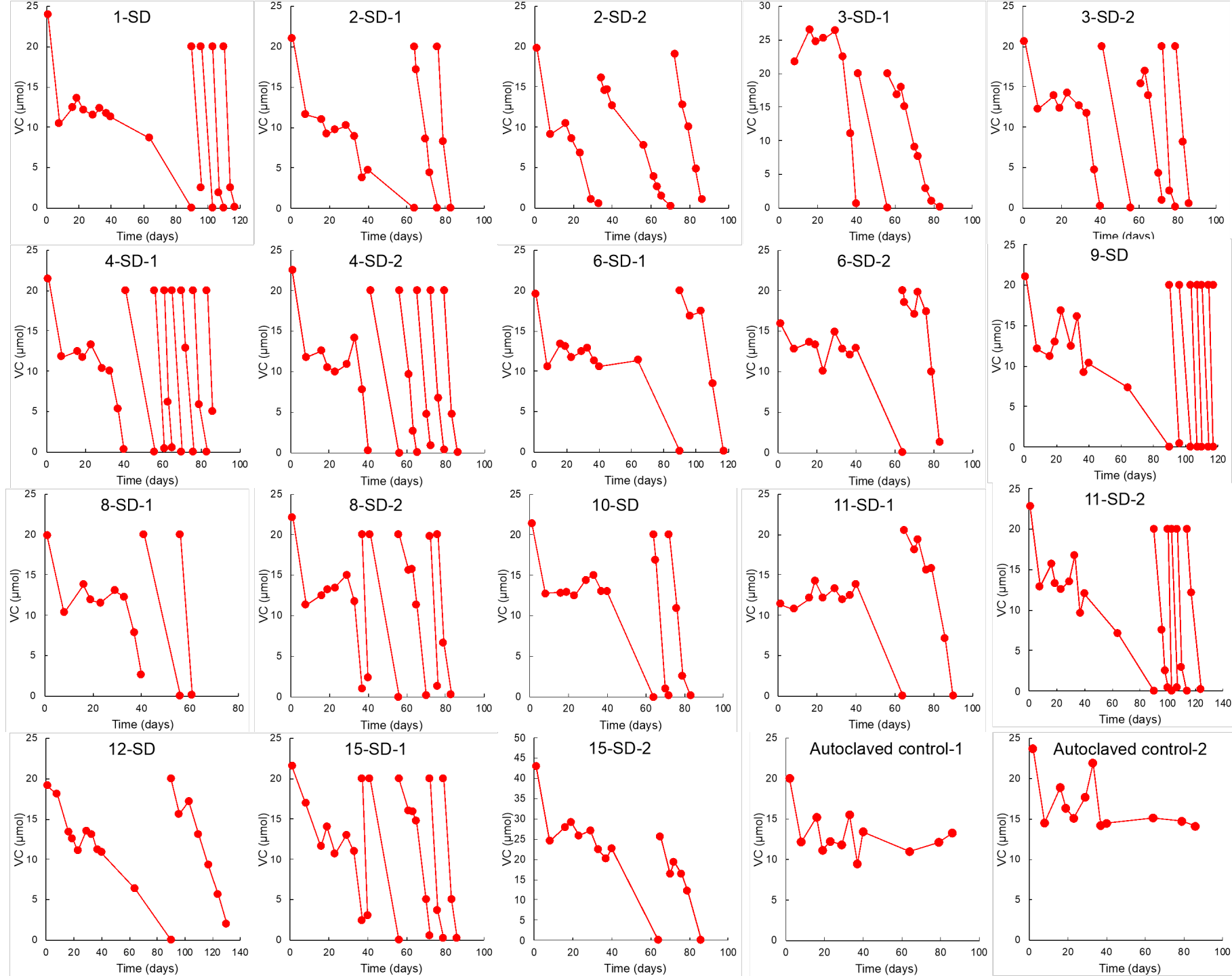


VC Degradation in Oxic Microcosms

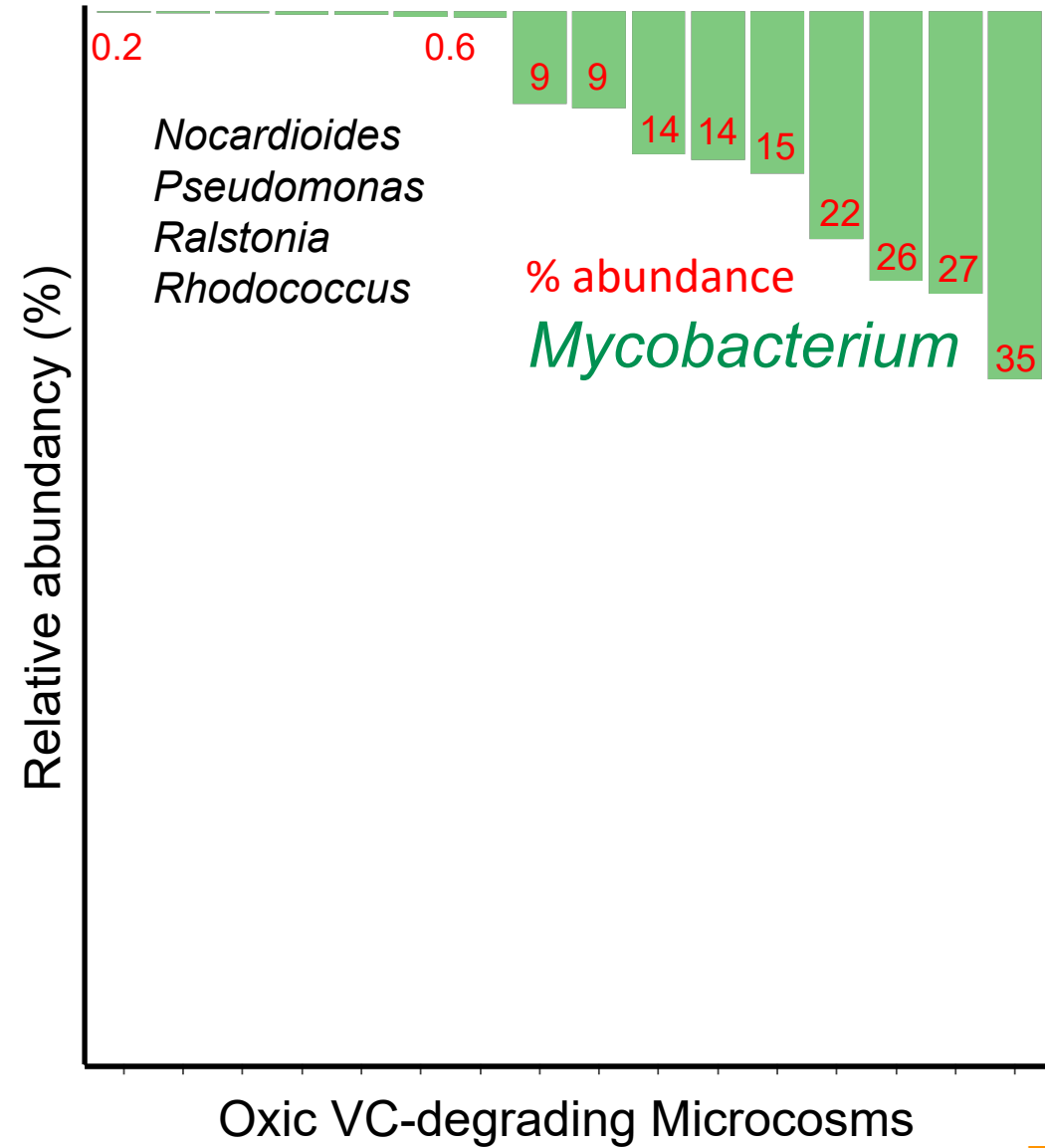
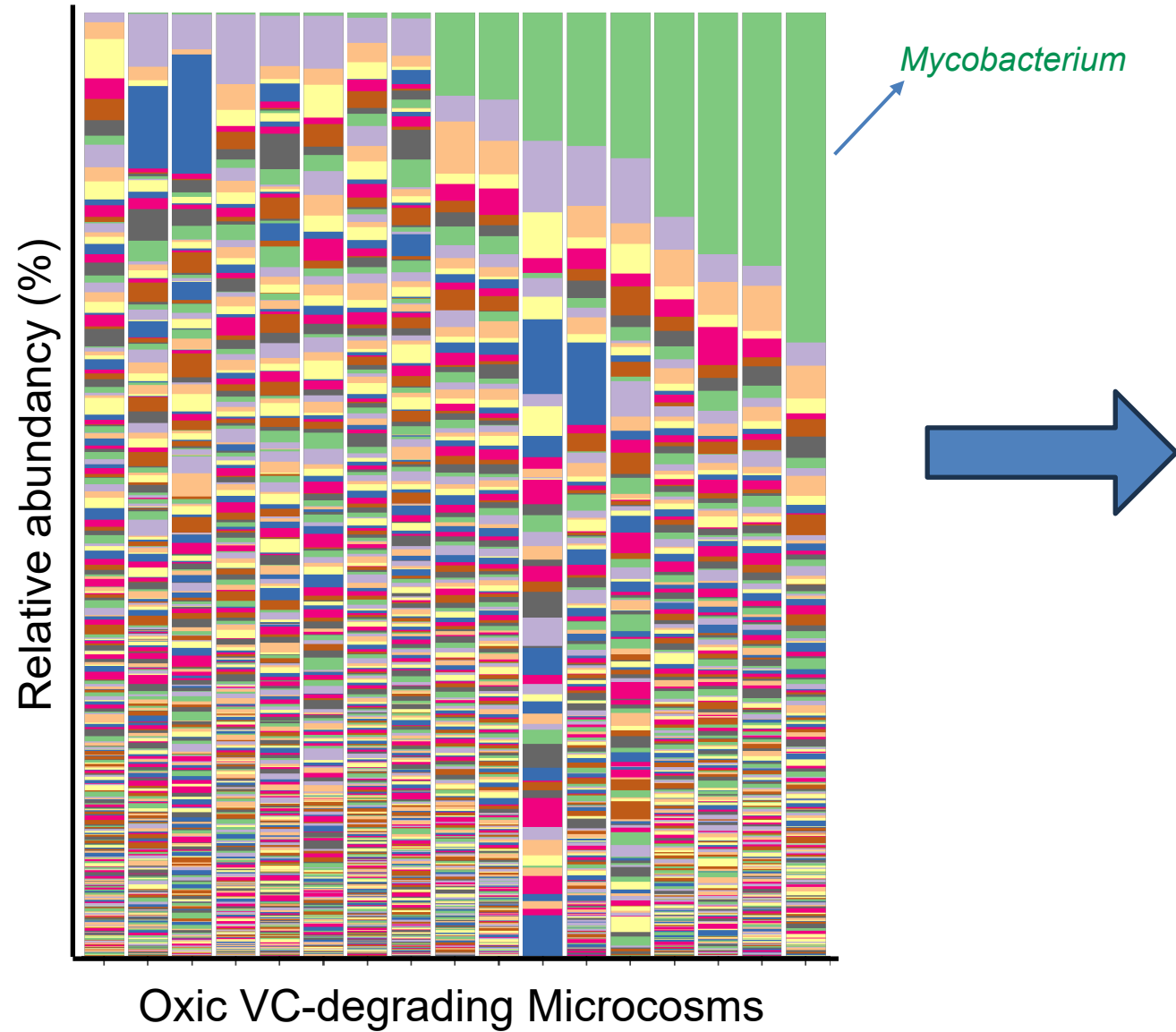


Aerobic VC degradation occurred in all sediment microcosms

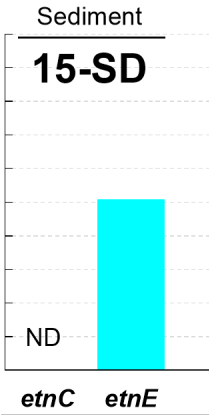
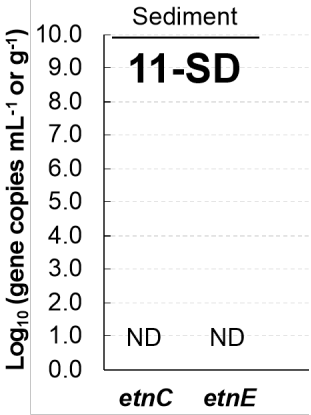
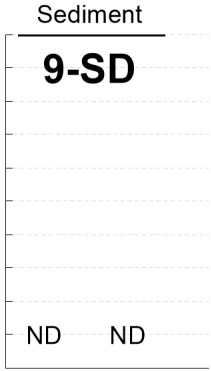
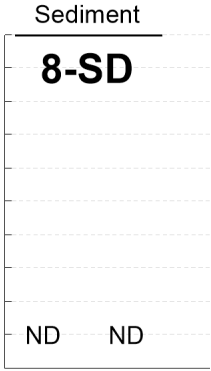
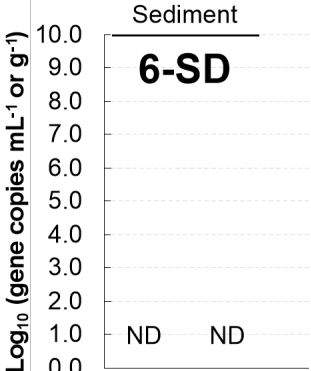
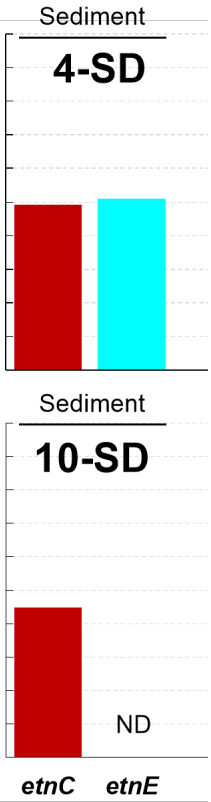
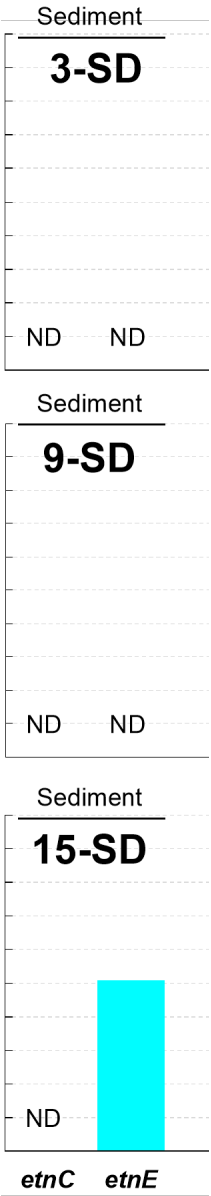
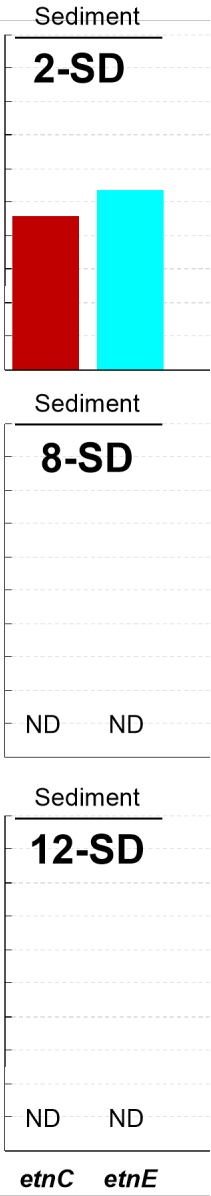
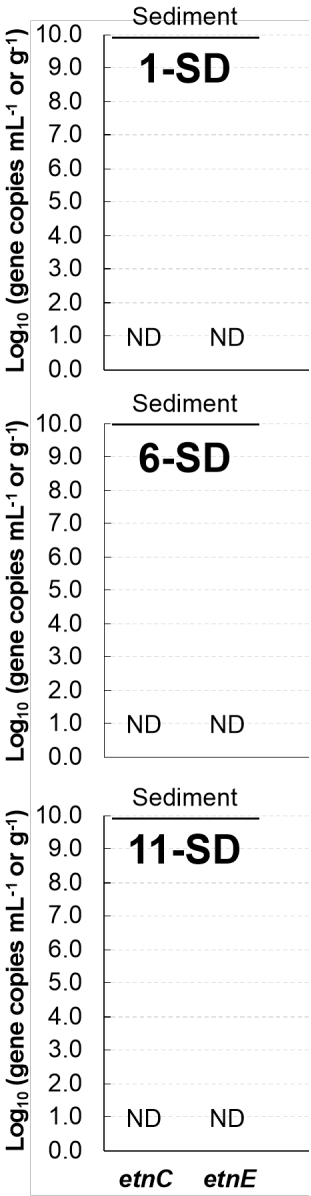
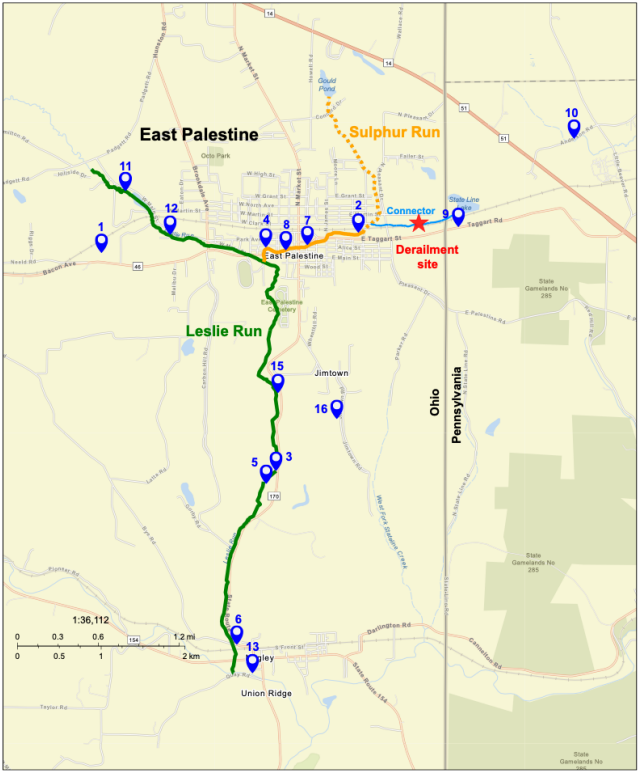
Lag phase: 20 – 40 days



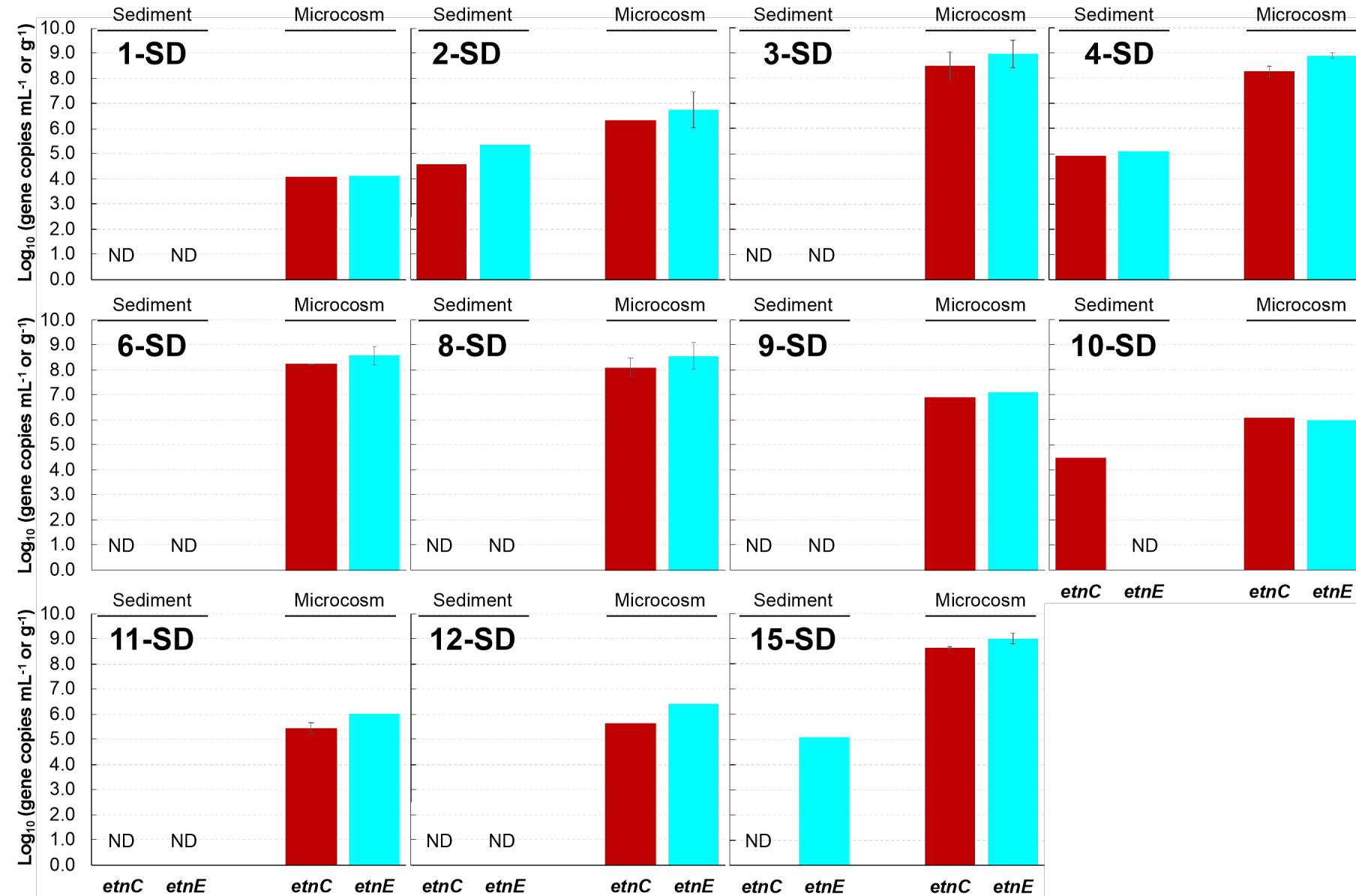
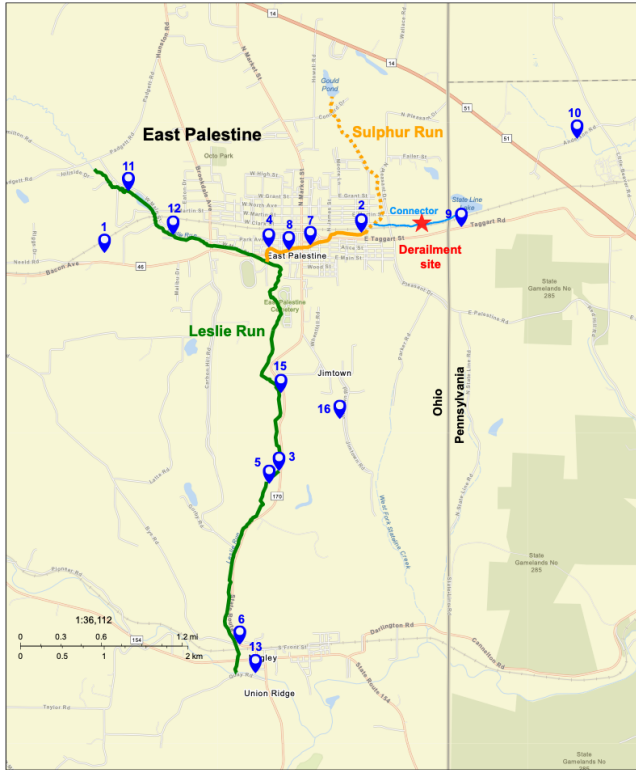
Enrichment of *Mycobacterium* in Oxidic VC Microcosms



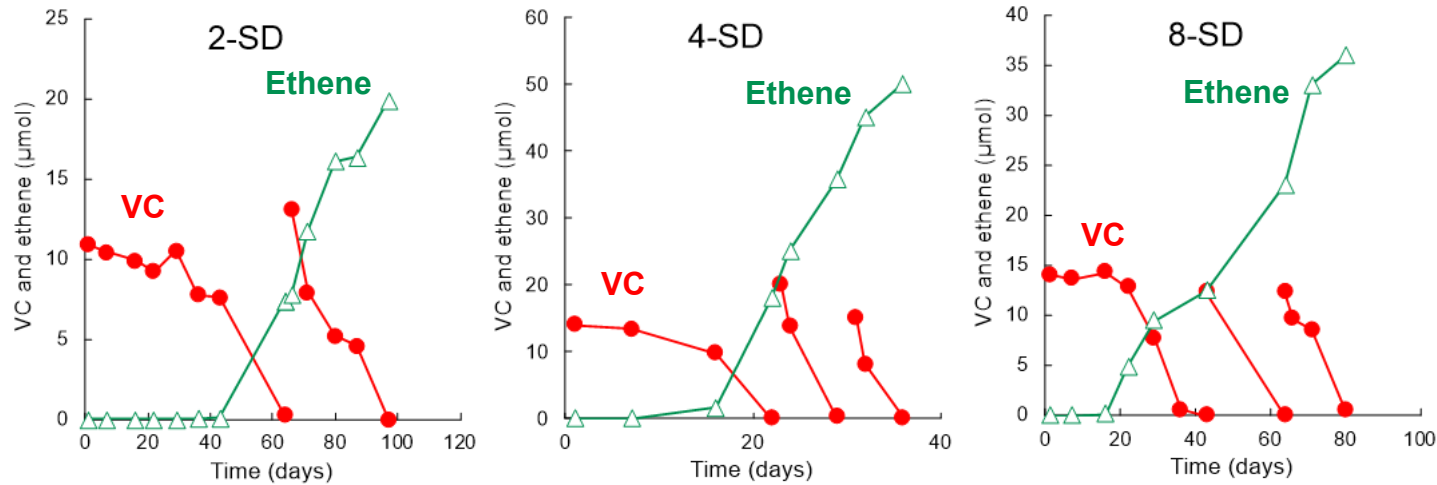
Detection of *etnC* and *etnE* Genes (qPCR)



Detection of *etnC* and *etnE* Genes (qPCR)

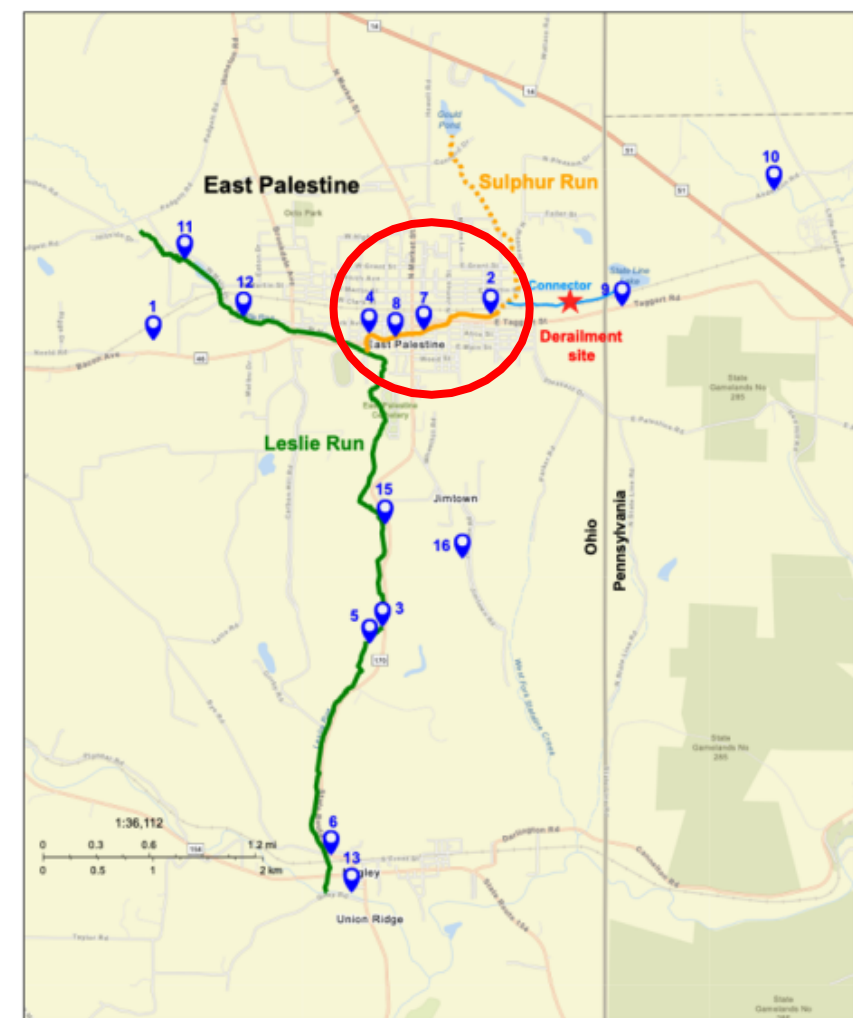


VC Degradation in Anoxic Microcosms



16S rRNA gene amplicon sequencing

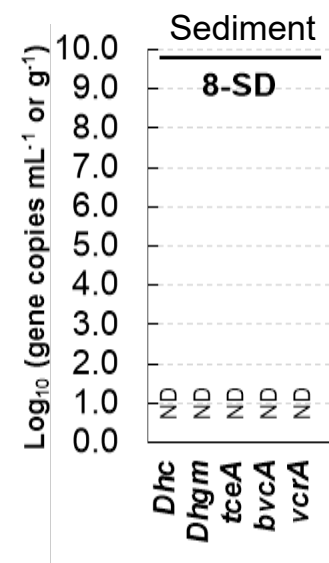
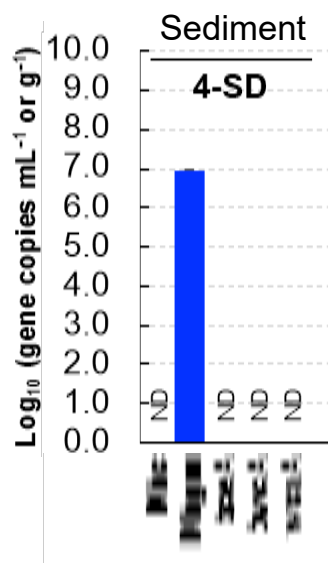
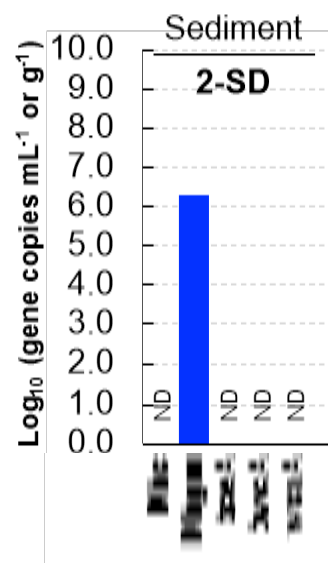
Microcosms & Transfer cultures	Relative abundance (%)	
	<i>Dehalococcoides</i>	<i>Dehalogenimonas</i>
Anoxic_2-SD	0.2	0.2
Anoxic_4-SD	0.5	ND
Anoxic_8-SD	0.3	ND
Anoxic_4-SD_1 st transfer	3.6	ND
Anoxic_8-SD_1 st transfer	5.7	ND



- *Dhc* and *Dhgm* were not detected in original sediment samples from location 2, 4, and 8
- *Dhc* were enriched in anoxic VC-degrading microcosms

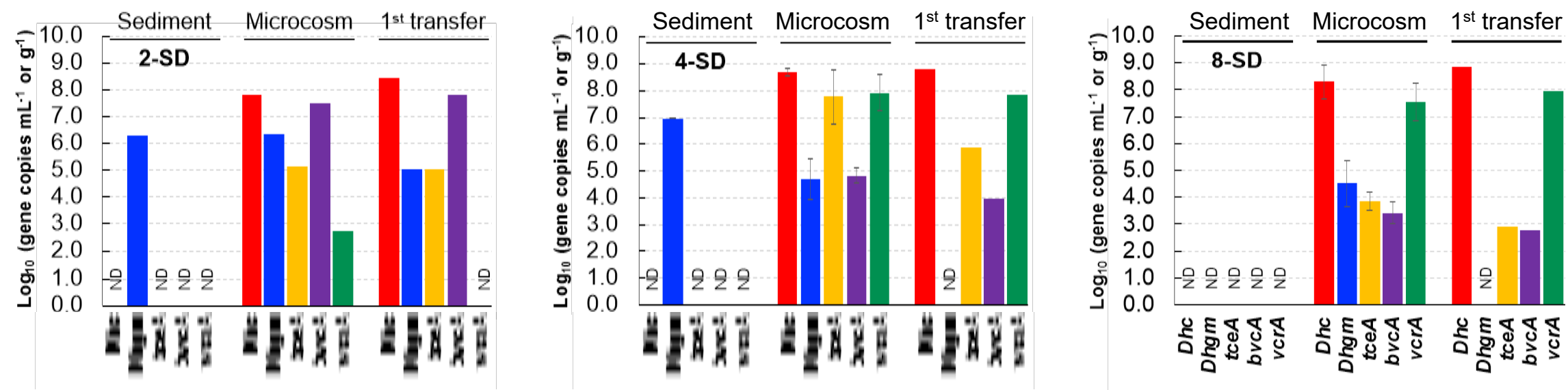
Detection of *Dhc* and VC RDase genes

qPCR

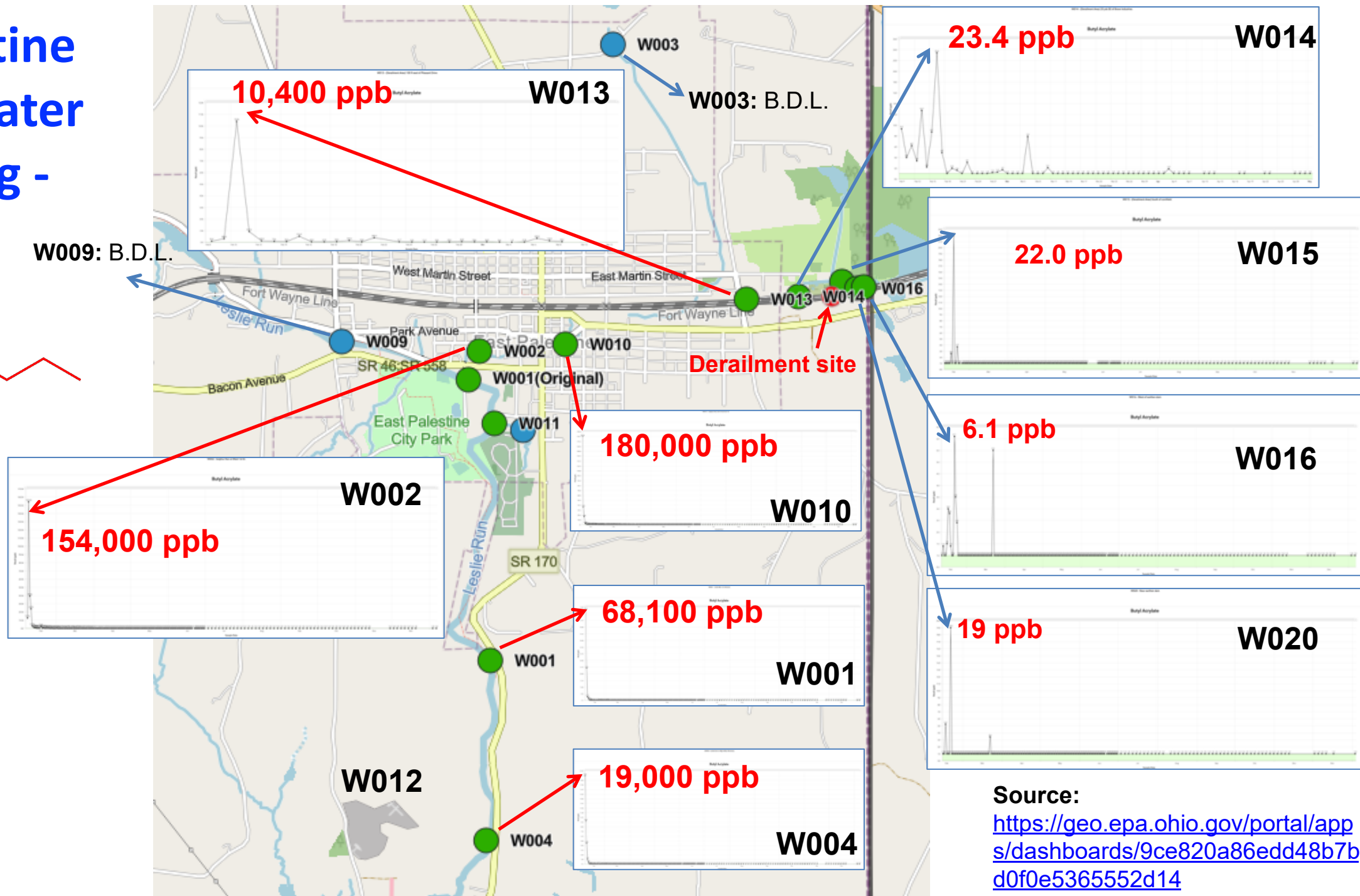
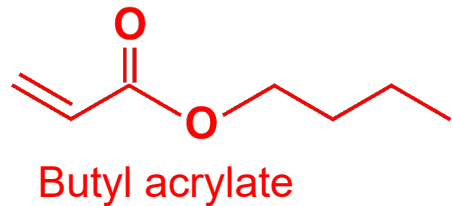


Detection of *Dhc* and VC RDase genes

qPCR

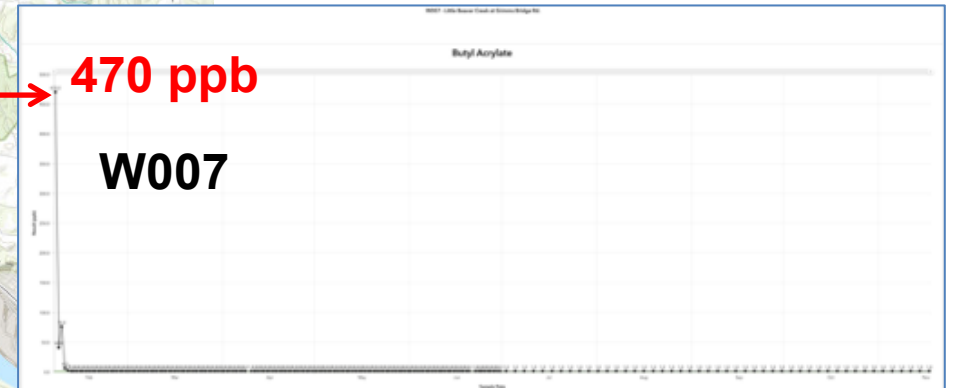
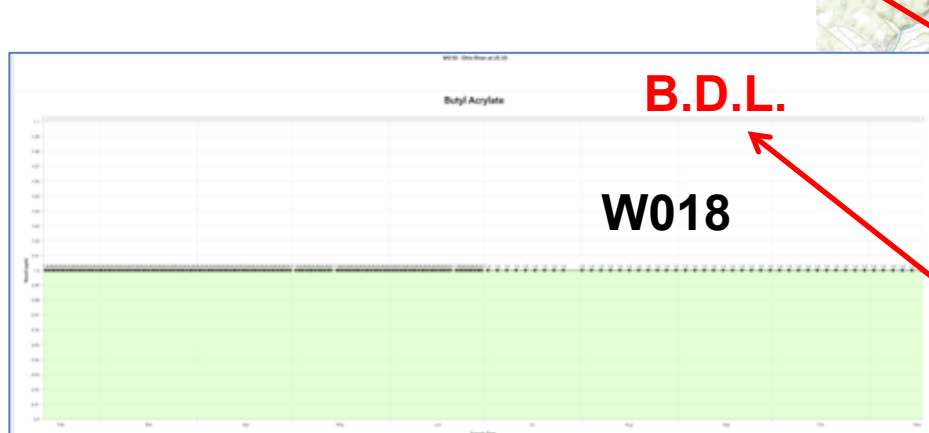
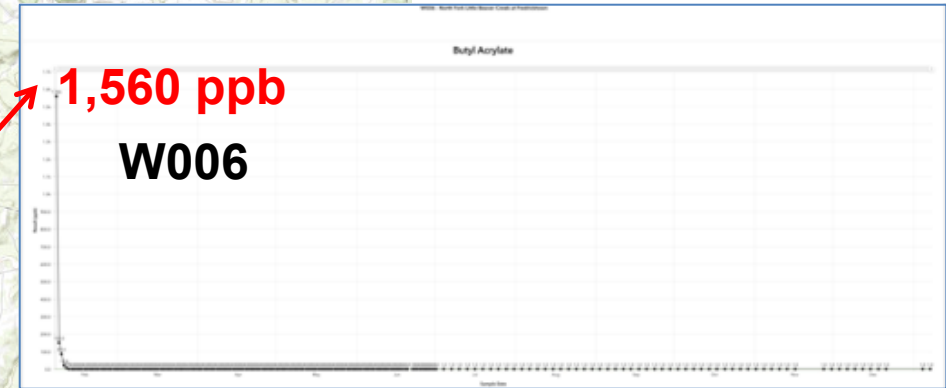
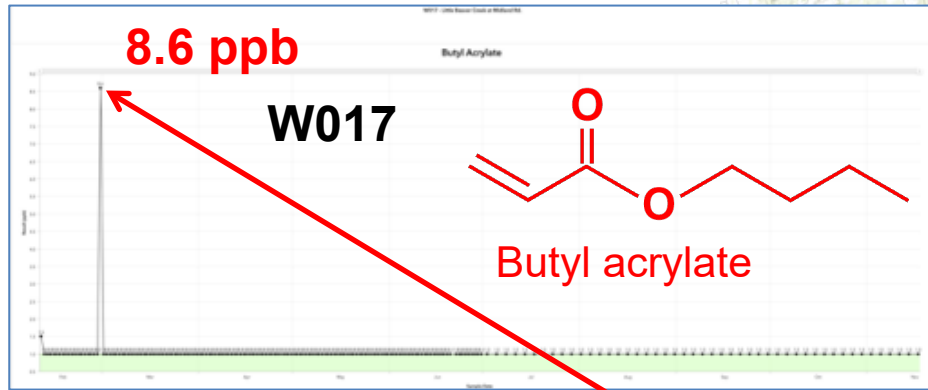
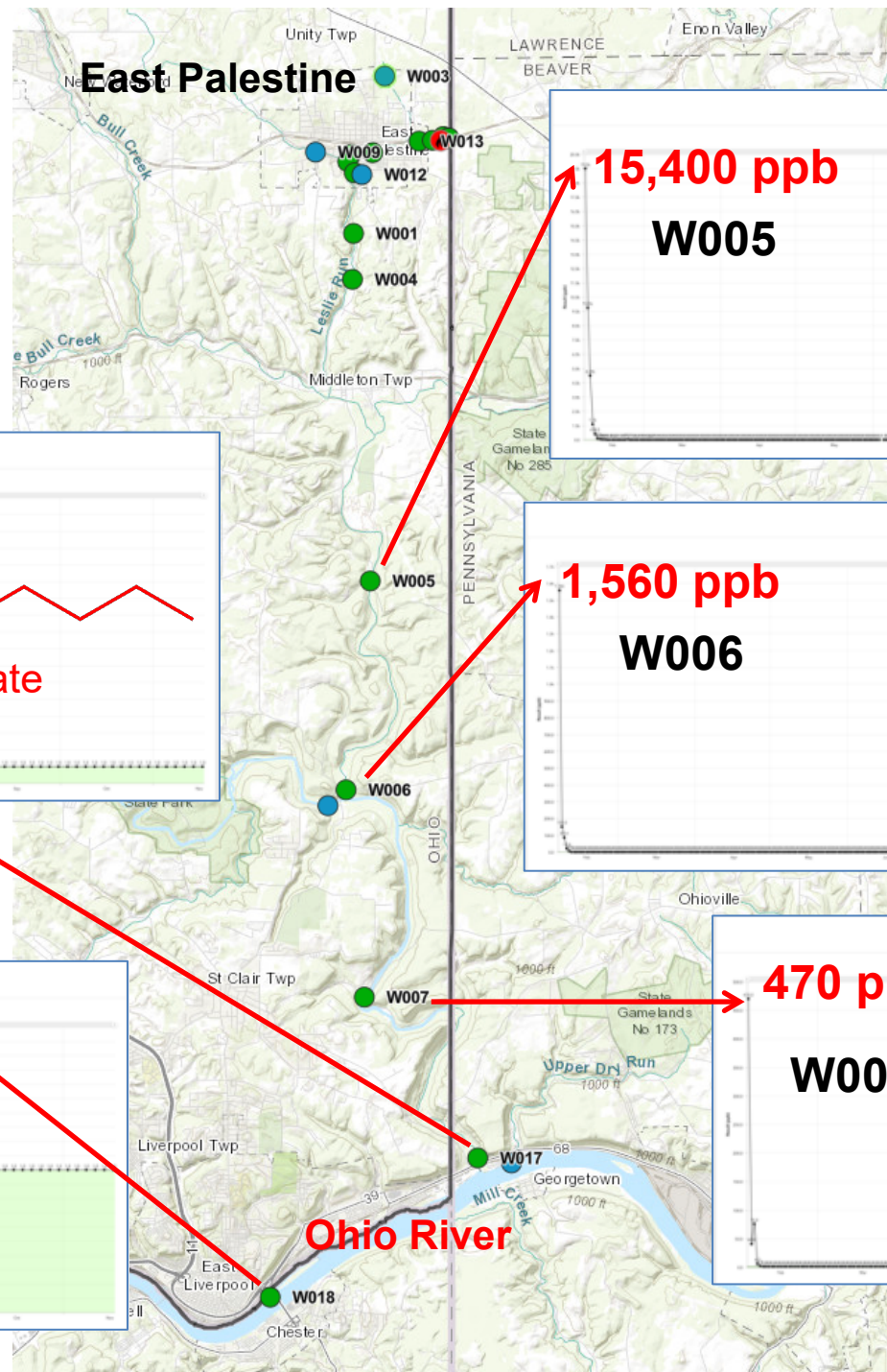


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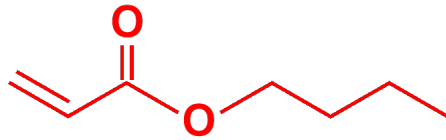


Source:
<https://geo.epa.ohio.gov/portal/app/s/dashboards/9ce820a86edd48b7bd0f0e5365552d14>

East Palestine Surface Water Monitoring - EPA



Microcosm Treatability Studies



Butyl acrylate

Anoxic

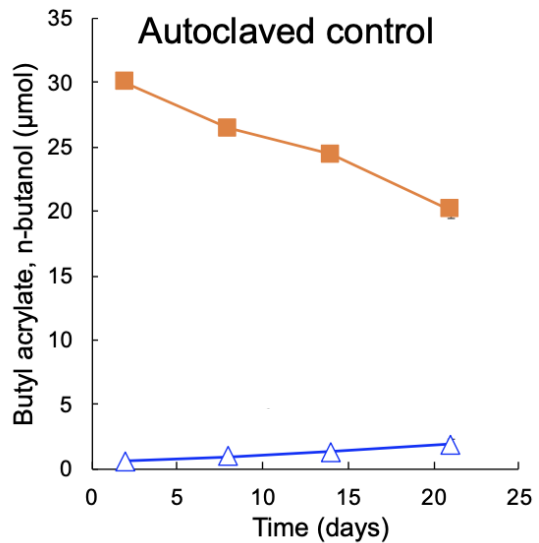
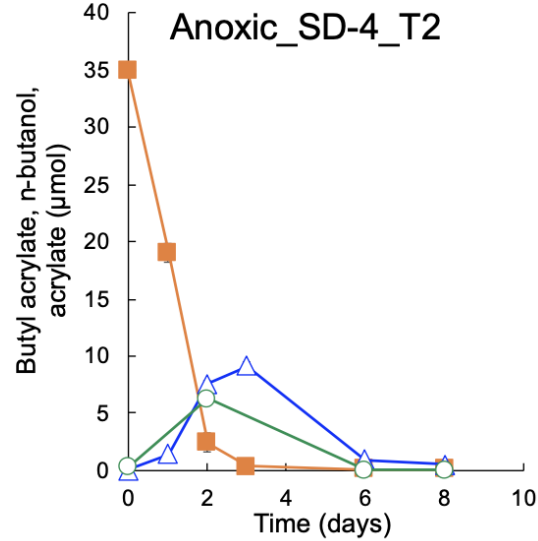
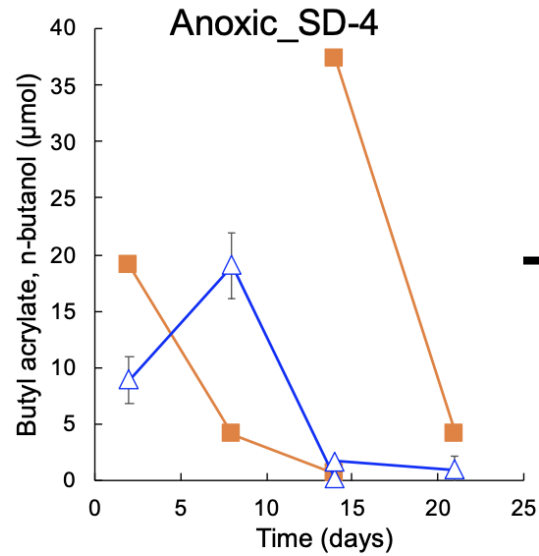


- e⁻ donor: Butyl acrylate (BA)
- No e⁻ acceptor added
- Sediment
- Mineral salt medium

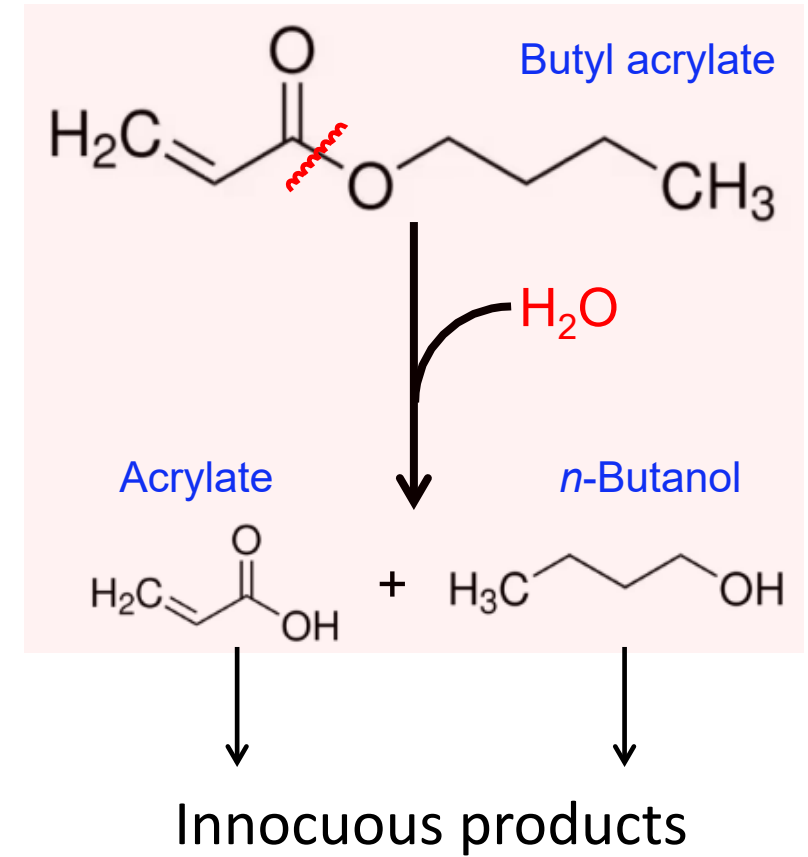
➡ GC-FID



Butyl Acrylate Degradation in Anoxic Microcosms



—■— Butyl acrylate
—△— n-butanol
—○— Acrylate





Zhang et al. 2015. Dioxins and polyvinyl-chloride in combustion and fires. *Waste Management & Research*, 33:630-643.

UNEP. 2013. Toolkit for identification and quantification of releases of dioxins, furans and other unintentional POPs under Article 5 of the Stockholm Convention. Geneva, Switzerland: UNEP Chemicals.

Accidents

- Seveso, Italy
- Fires

Intentional

- Controlled burn of PVC and VC

Unintentional Formation

- Incinerators
- Chemical Synthesis

Forest Fires

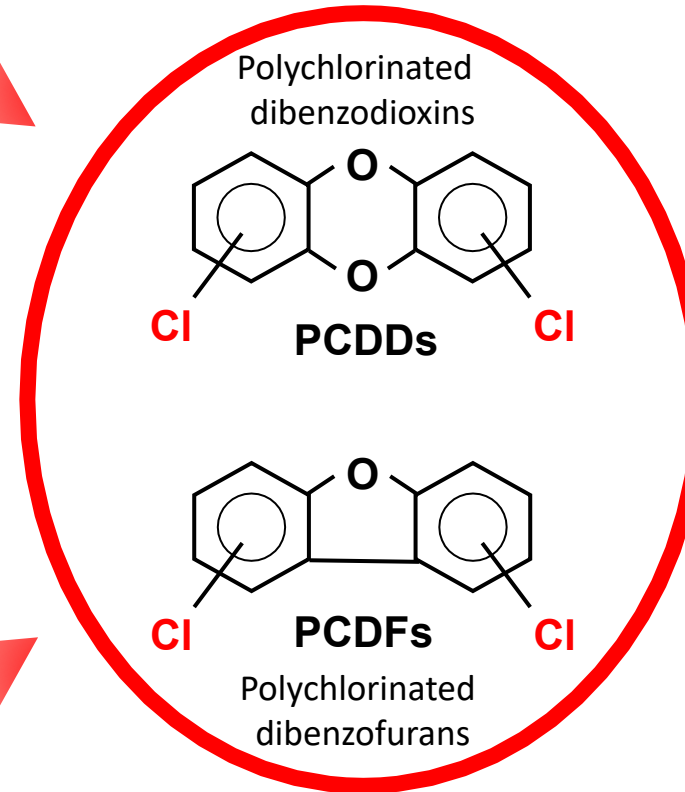
Sheffield, 1985.
Chemosphere 14: 811-814

Geologic Formation

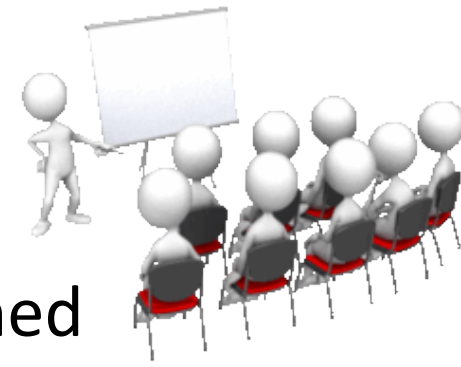
Ferrario & Byrne, 2000.
Environ. Sci. Technol.
34:4524-4532.

Biological Processes

Öberg et al. 1992
Arch. Environ. Contam. Toxicol.
19:930-938



Take Home Messages



- Strong natural attenuation potential for VC and BA in EP watershed
- Natural attenuation should be considered in response actions
- MBTs a powerful tool for assessment and monitoring
- Knowledge of biomarkers crucial for implementation of MBTs
- NSF RAPID funding mechanism is fast, but not fast enough
- Access to the site and to information challenging; major improvements can be envisioned
- Accident response guidance documents are needed (ITRC?)
- Community outreach and communication is crucial
- PCDD and PCDF monitoring program





Natural Attenuation

Natural Attenuation relies on natural processes (physical, chemical, biological) within the context of a (monitored) site cleanup strategy that will reduce contaminant concentrations to levels that are protective of human health and the environment within a reasonable time frame.

U.S. Environmental Protection Agency, 1999