# In-Situ PCB Dechlorination & Degradation with Bioamended GAC

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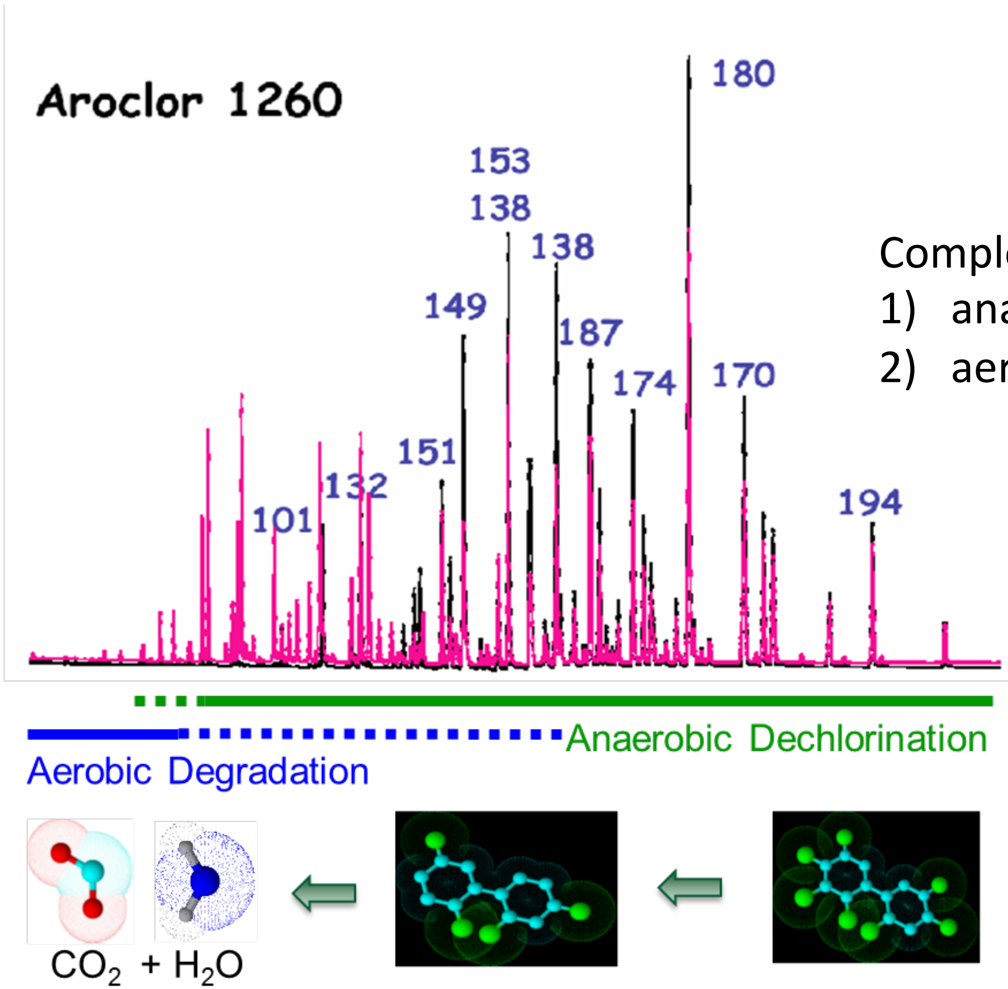
# Advantages of Bioamended GAC

- Both sequesters & degrades PCBs
- Rapidly deployed and minimally invasive
- Minimal sediment disruption
- Reduced carbon footprint compared with other technologies
- No extensive waste management or habitat restoration

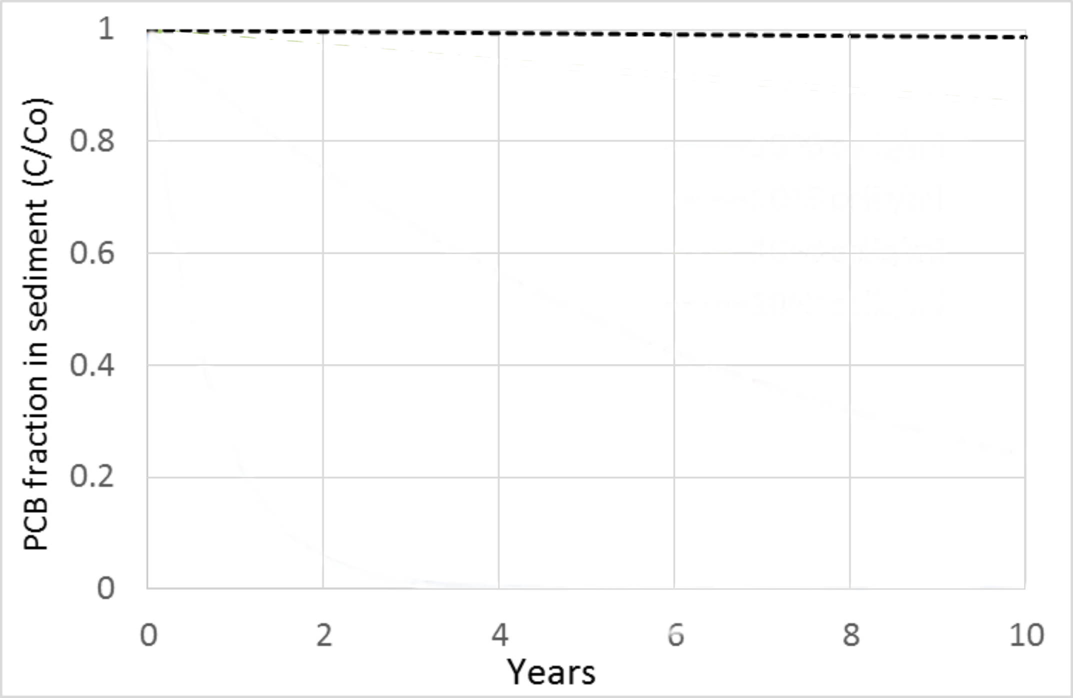
# How Bioremediation of PCBs Works




Complementary activities of:

1) anaerobic halorespiring bacterium
2) aerobic oxidizing/dechlorinating bacterium

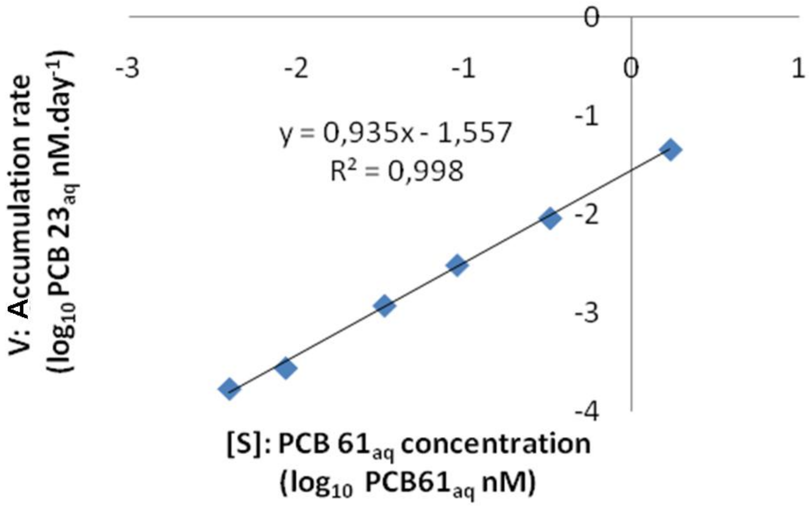
# Why is Natural Attenuation of PCBs Slow?



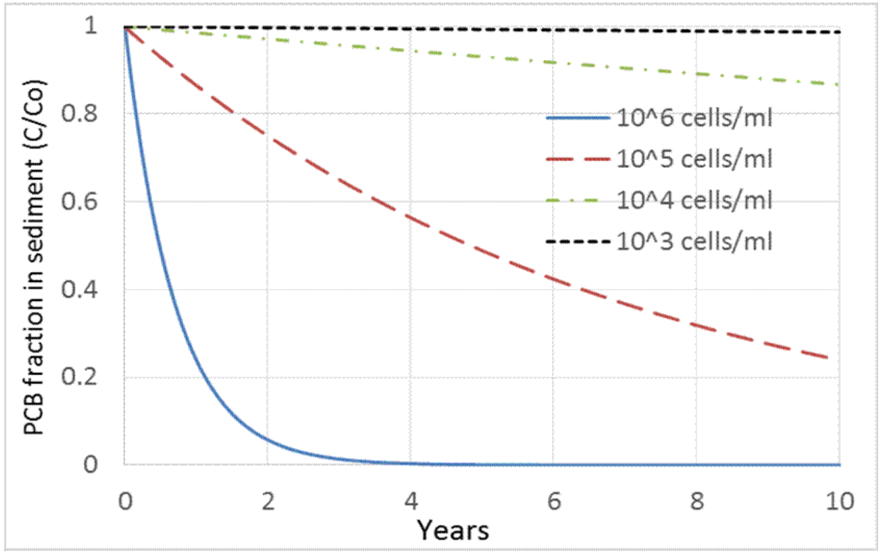

Typical reduction in total mass of PCBs by MNA

# Effect of Bioaugmentation

Halorespiration = 1st order rate kinetics



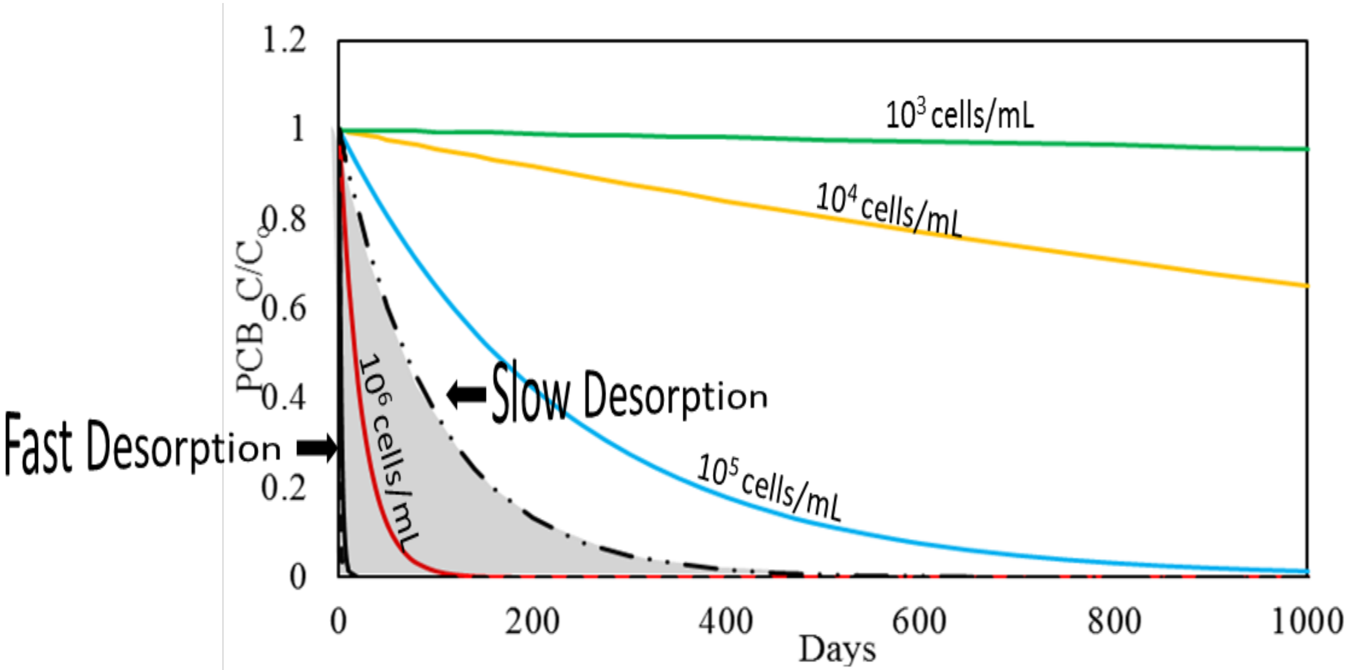

Modeled effect of cell titer on halorespiration rate




- PCB dechlorinating population typically $<10^3$ cells $mL^{-1}$
- Aqueous PCB concentrations too low to support large indigenous population
- Increasing cell number = increased rate

Lombard *et al.* 2014 ES&T 48, pp 4353–4360

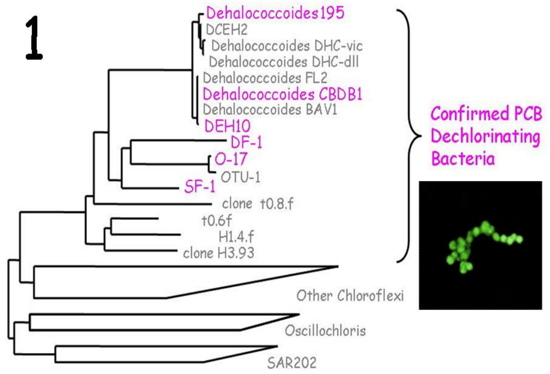
# Desorption Rate vs Dechlorination Rate




- PCB desorption rates exceed dechlorination rates of indigenous halorespiring populations
- Bioaugmentation increases dechlorination at rates similar to desorption rates

Needham *et al.* 2019 ES&T 53:7432-7441

# Technology/Methodology Description

1
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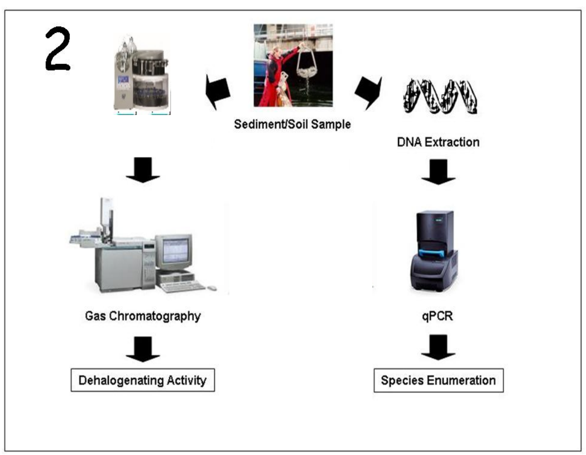



3


4

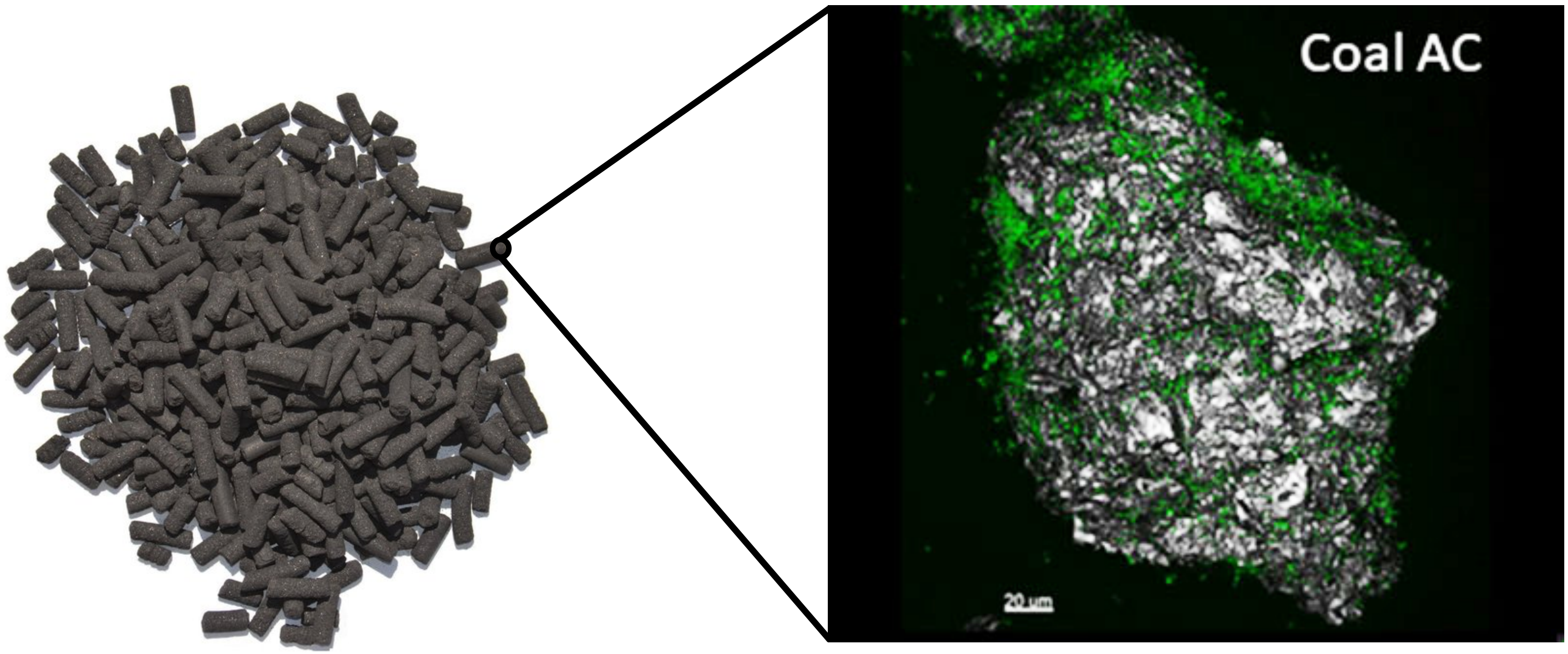

1) PCB anaerobic halorespirer and aerobic degrader available

2) Assays developed for monitoring treatment and bioamendments

3) Methods developed for biomass scale-up of bioamendments w/o PCB

4) System developed for *in situ* deployment of bioamendments on activated carbon agglomerate (SediMite)

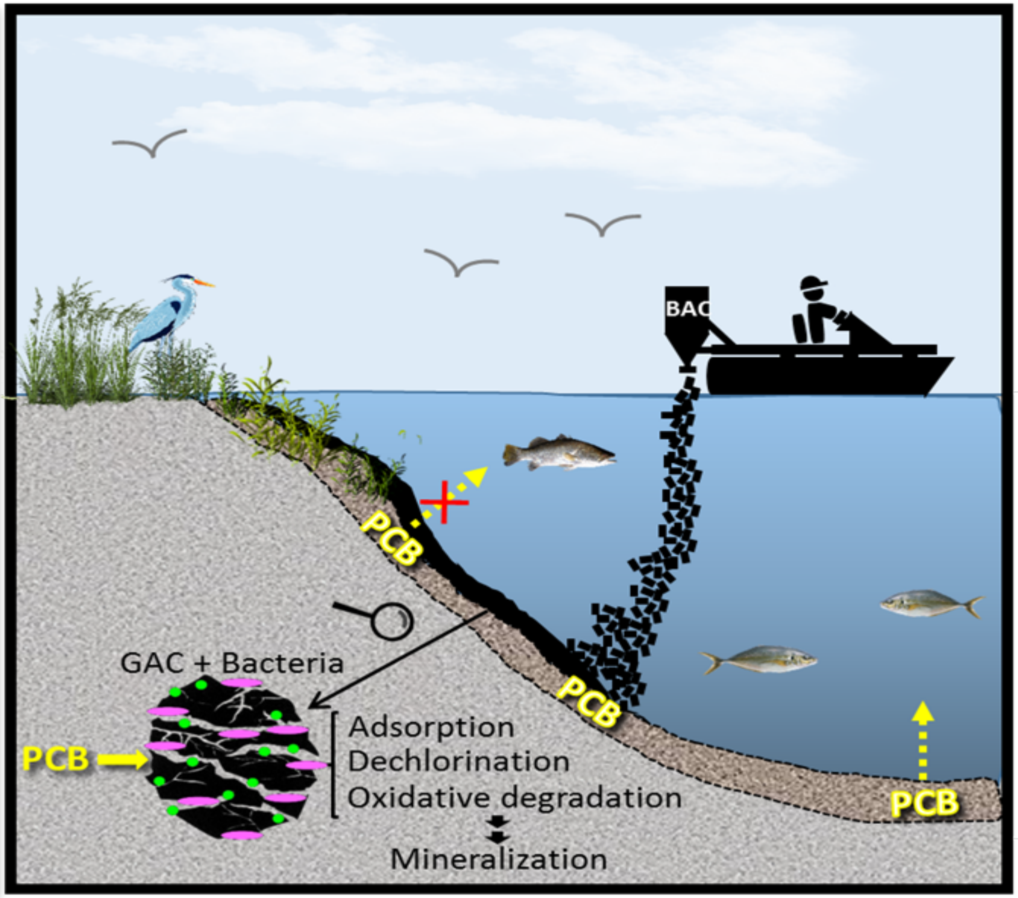
# Bioamended Activated Carbon




- CLSM of SediMite™ loaded with PCB transforming microorganisms stained with SYBR green

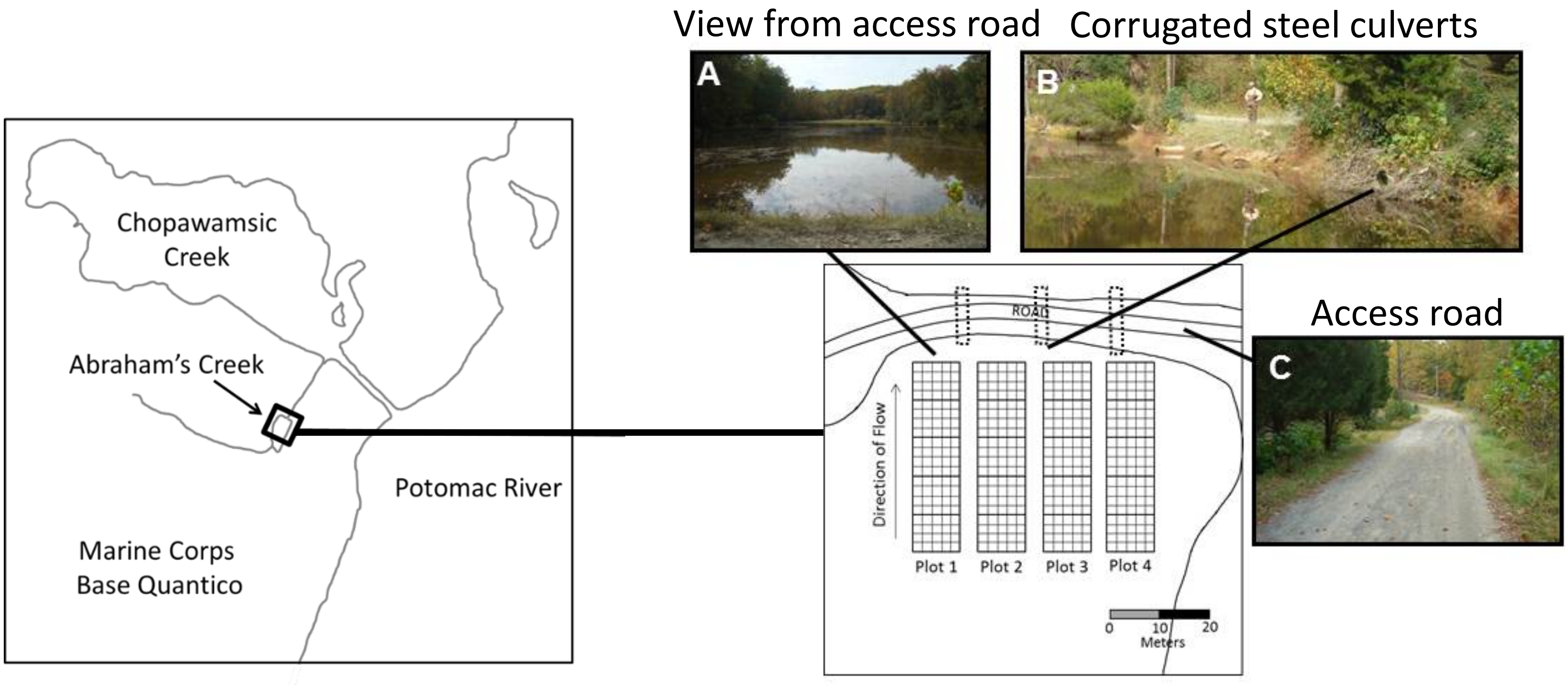
*Capozzi et al., 2019. Biofouling: 10.1080/08927014.2018.1563892*

# Application of Bioamended GAC



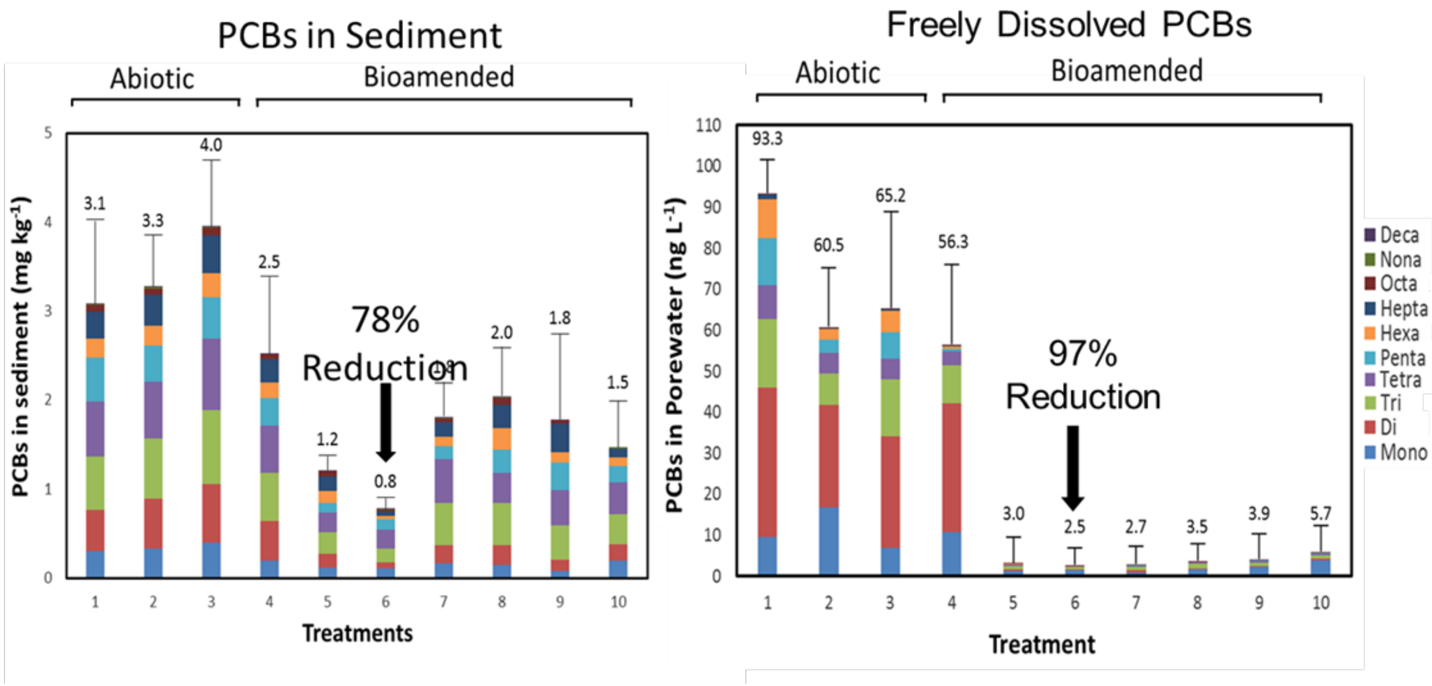

- various application methods available

# Abraham's Creek VA – April 2015



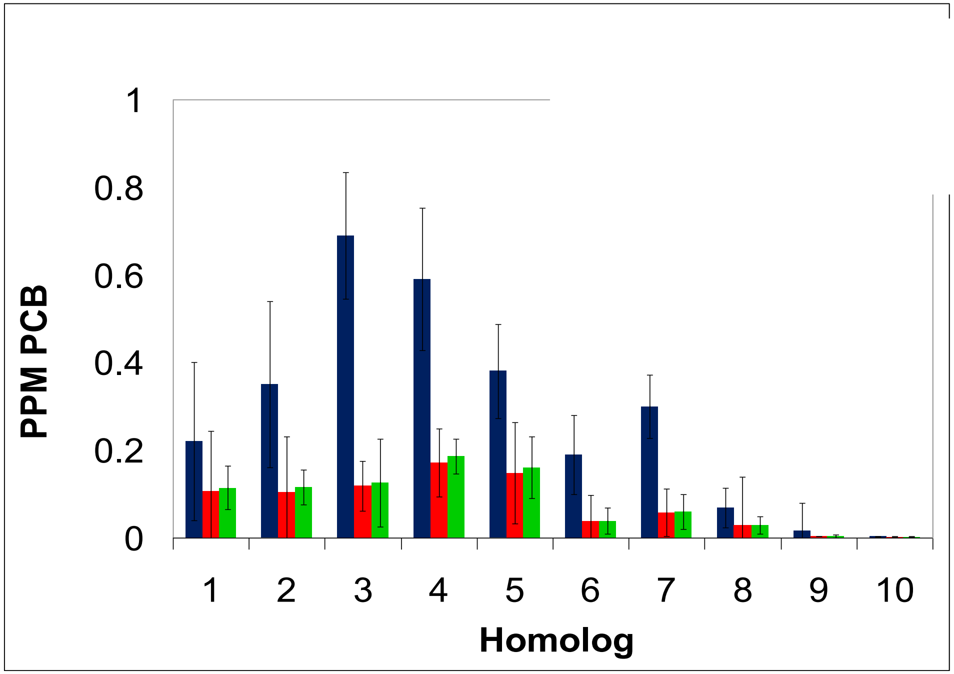

- Abraham's Creek MCBQ is an 8 acre/32,000 $m^2$ watershed outflow
- Original contaminant likely Aroclor 1260
- Currently contaminated with an average 5 ppm PCB
- Treatments in four 400 sq. m plots
- Loading rate = 1 ton SediMite + $10^{12}$ cells/400 $m^2$

# Treatability Study-Results

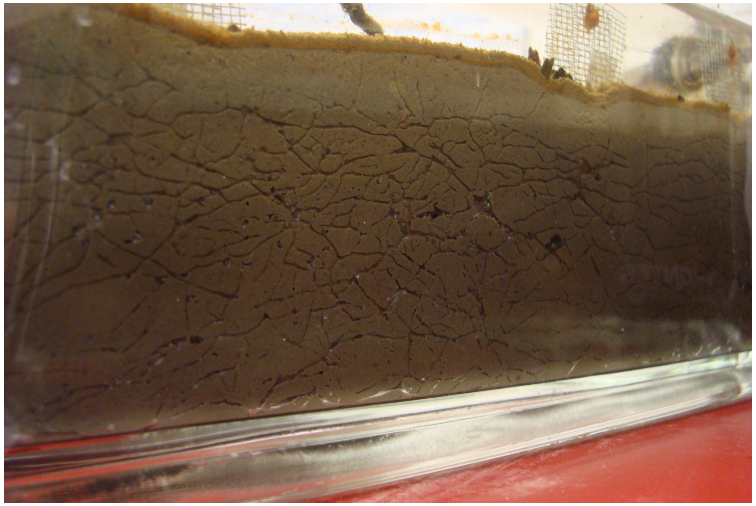



- Bioamending with $10^5$ cell/g yielded greatest reduction of PCBs after 375 days
- DF1 and LB400 were most robust bioamendments
- Addition of carbon source (cellulose) only slightly stimulated PCB degradation
- Mono- to nona-chlorobiphenyls were reduced = anaerobic & aerobic activity

# Effect of Treatments with Depth




Channeling by benthic organisms

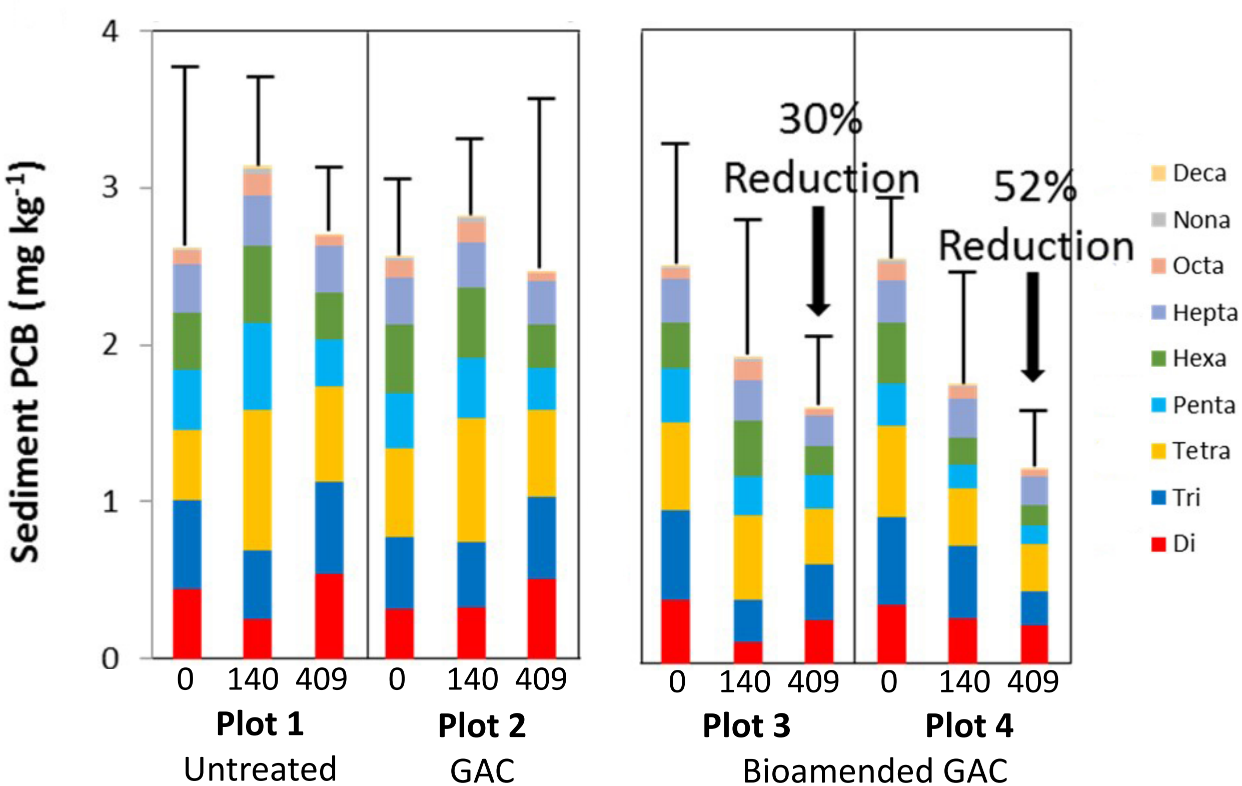


- Decrease in PCBs observed throughout 8 cm depth
- Bioturbation provided cycling of redox potential throughout sediment column

# Field Test-Deployment

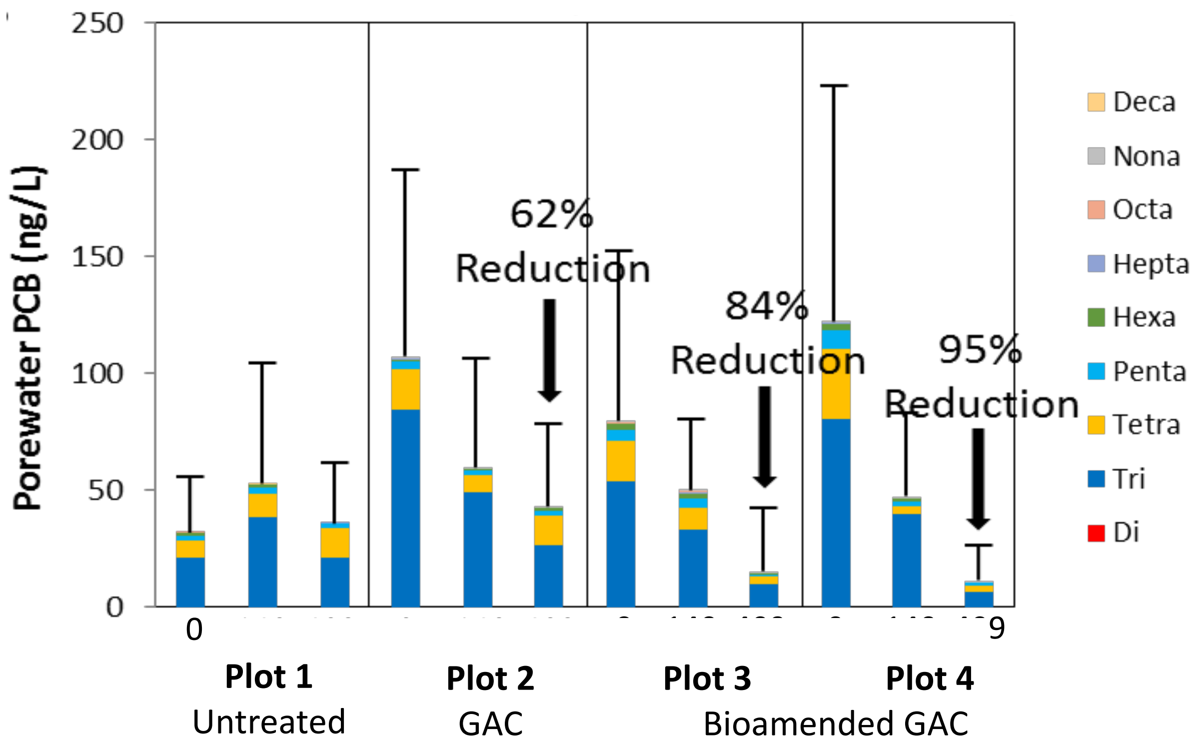
- 3000 kg SediMite deployed with modified venturi air mover
- Final SediMite concentration = 0.3g/10 g sediment
- Final bioamendment concentration = $10^6$ cells/10 g sediment

# Performance Assessment-Total PCBs




- Significant decrease observed in both bioamended plots after 409 days
- 80% reduction in total mass of coplanar PCBs in plot 4
- No significant change in non-bioamended plots

# Performance Assessment-Dissolved PCBs




- Significant decrease observed in bioamended plots after 409 days
- Decrease with AC due to adsorption, but significantly less than bioamended plots
- No significant change in untreated plot or below 7.5 cm

# Cost Comparison of Remediation Technologies

| Treatment Alternative | Total Capital Cost (2017 dollars) | Capitol Cost ($/acre) |
|---|---|---|
| Alt 1: No further action | 0 | 0 |
| Alt 2: Monitored Natural Attenuation | 130,000 | 16,666 |
| Alt 3: Isolation cap | 4,030,000 | 516,667 |
| Alt 4: Excavation & on-site CDF | 17,030,000 | 2,183,333 |
| Alt 5: Excavate & off-site disposal | 25,090,000 | 3,216,667 |
| Alt 6: Partial excavation & off-site disposal | 11,570,000 | 1,483,333 |
| Alt 7: Capping and wetland creation | 5,850,000 | 750,000 |
| Alt 8: Reactive cap | 4,030,000 | 516,667 |
| Alt 9: SediMite™ only | 1,096,720 | 140,605 |
| **Alt 10: Bioamended SediMite™** | **1,767,920** | **226,656** |

*Comparison of implementation of remediation technologies for 7.8 acre pond in Abraham's Creek.*
*Costs for Alt 1-8 are based on 2008 Feasibility Study for the site (Battelle 2008).*
*Site-specific monitoring costs would be additional.*

# Other Treatment Sites

### Baltimore Harbor MD

Primarily Aroclor 1260 contaminated sediment.
Bioremediation resulted in an **80%** decrease by mass of PCBs, from **8 to <2 mg/kg** after 180 days.
Status – treatability study

### Superfund River Sediments Southeast MI

Aroclor 1248 contaminated sediment.
Bioremediation resulted in a **78 %** decrease by mass of PCBs in 180 days and porewater PCB levels by **93%.**
Status – treatability study

### Waste Water Treatment Pond, Altavista VA

Aroclor 1248 contaminated sediment.
Bioremediation resulted in an **80%** decrease in mass of PCBs, from **275 to 49 mg/kg** after 2.7 years.
Status – ongoing pilot study.

### Green Island, Kure Atoll, HI

Aroclor 1260 contaminated soil.
Bioamended by spraying excavated soil that resulted in **48%** decrease by mass of PCBs in 2.8 years.
Status – full-scale treatment completed; monitoring results.

### South Wilmington Wetland Park, DE

Mouth of drainage outlet (14,150 sf)
Completed May 2019
Status – full-scale treatment completed; monitoring results

### Anne Arundel County, MD.

Former laminate plant cooling pond (32,336 sf).
Status: Full-scale treatment scheduled Spring 2020

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# Summary

- Bioamended AC reduces both the total mass and soluble fractions of PCBs
- Significant reduction in toxic equivalency (TEQ) of coplanar PCBs
- PCB transforming bacteria mix into sediments by natural bioturbation
- Different application methods available depending on site
- Well suited for environmentally sensitive sites, difficult to reach areas such as under piers, water margins, dredged materials and sites where dredging or capping are not options

# Acknowledgements


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**Disclosure Statement:** K. Sowers is a co-inventor of patents related to the technology for which he is entitled to receive royalties. The patents include U.S. Patent Nos. 6,946,248 and 7,462,480 B2 issued to the University of Maryland Baltimore County (UMBC) and Medical University of So. Carolina. and U.S. Patent No. 8,945,906 issued to UMBC. In addition, K. Sowers and U. Ghosh are partners in a startup company (RemBac Environmental) that has licensed the three technologies and is transitioning the technology to the field.