Using Reactive Caps for Dissolved and NAPL Contaminants

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EPA ORD Webinar
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Chemical
Biochemical and
Environmental
Engineering

OUTLINE

- Pollutant bioavailability in sediment
- Strategies of engineering pollutant bioavailability
- Pilot and full-scale demonstrations

PROBLEM: MANAGING EXPOSURE FROM HISTORIC DEPOSITS OF CONTAMINATED SEDIMENTS

- Contaminated sediment sites are large
- How do you clean up an ecologically sensitive site without destroying it?
- Current technologies are expensive and disruptive
- Need for innovative techniques that reduce risks
- **CAN WE ENGINEER SEDIMENT GEOCHEMISTRY TO ALTER BIOAVAILABILITY?**

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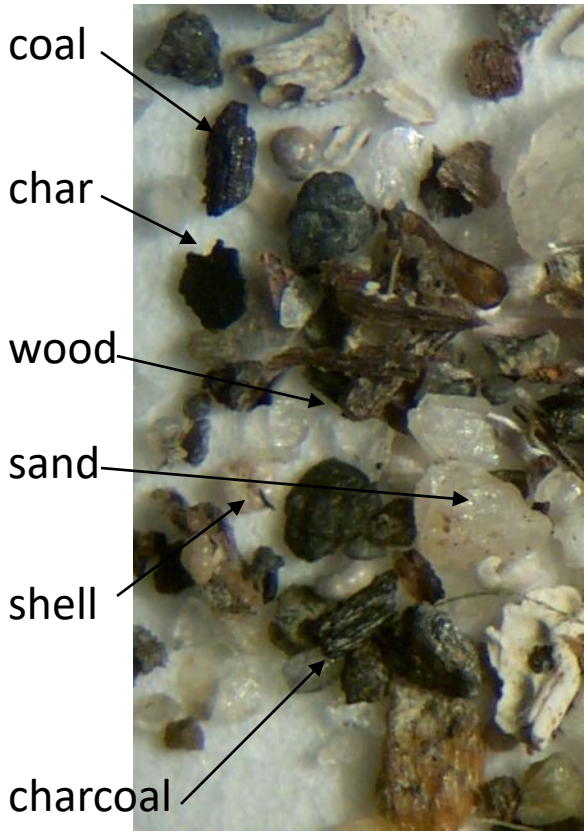
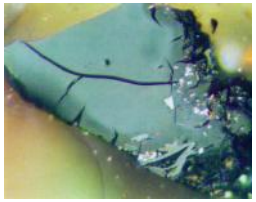
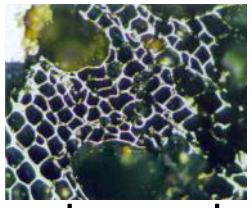
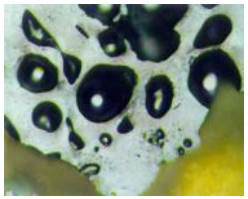
ORGANIC CARBON TYPE CONTROLS PARTITIONING

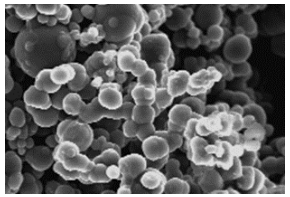


- Sediment contains a range of inorganic, organic, and anthropogenic particles
- Pollutants can be associated with various source materials and carbon types
- Hydrophobic pollutants associated with minerals, natural organic matter, and NAPL phase mostly mobile and bioavailable
- Hydrophobic pollutants bound to **black carbon** particles less bioavailable


coal


charcoal


coke


soot


NAPL

From: Ghosh et al. Environ. Sci. Technol. 2003

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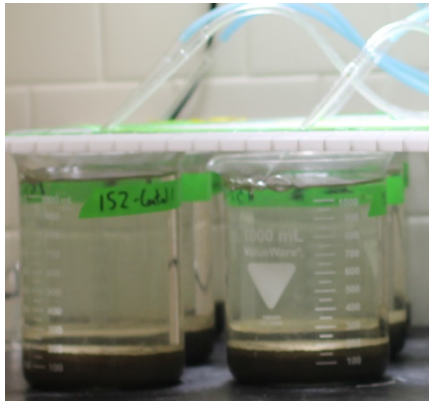
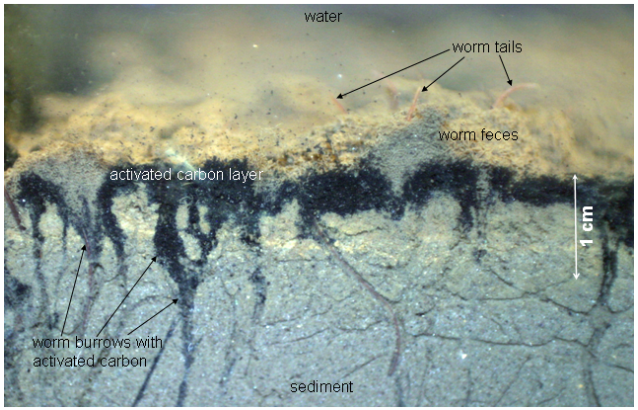
STRONG SORPTION REDUCES PCB UPTAKE IN WORMS





Environmental Science & Technology
FEATURE
pubs.acs.org/est

In-situ Sorbent Amendments: A New Direction in Contaminated Sediment Management†

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Stanford University, Stanford, California, United States
Gerard Cornelissen
Norwegian Geotechnical Institute, Oslo, Norway, University of Life Sciences, Ås, Norway; Stockholm University, Stockholm, Sweden
David Werner
Newcastle University, Newcastle upon Tyne, United Kingdom
Charles A. Menzie
Exponent, Alexandria, Virginia, United States

- Laboratory studies demonstrated reduction of PCB biouptake
- Surface application is worked into sediments through bioturbation
- Powdered AC works much better than granular AC
- Led to several pilot-scale demonstrations

Zimmerman et al. ES&T 2003
Sun & Ghosh, ES&T 2007
Ghosh et al. ES&T 2011

Bailey Cr. Ft. Eustis, VA Pilot Study

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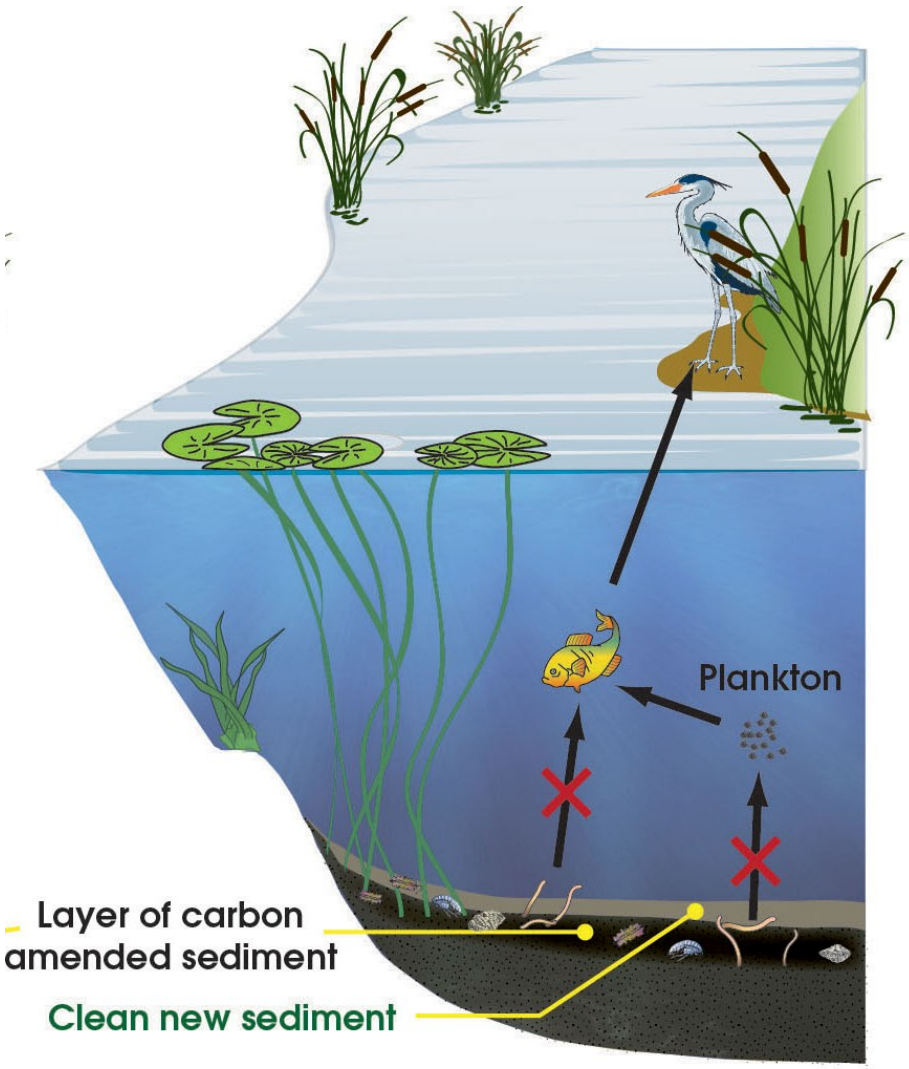
CONCEPTUAL MODEL OF IN-SITU TREATMENT WITH AC



AC amendment reduces exposure to food chain through:

1) Reduced bioaccumulation in benthic organisms

2) Reduced flux into water column and uptake in the pelagic food web.

3) In the long-term, the carbon amended layer is covered with clean sediment.

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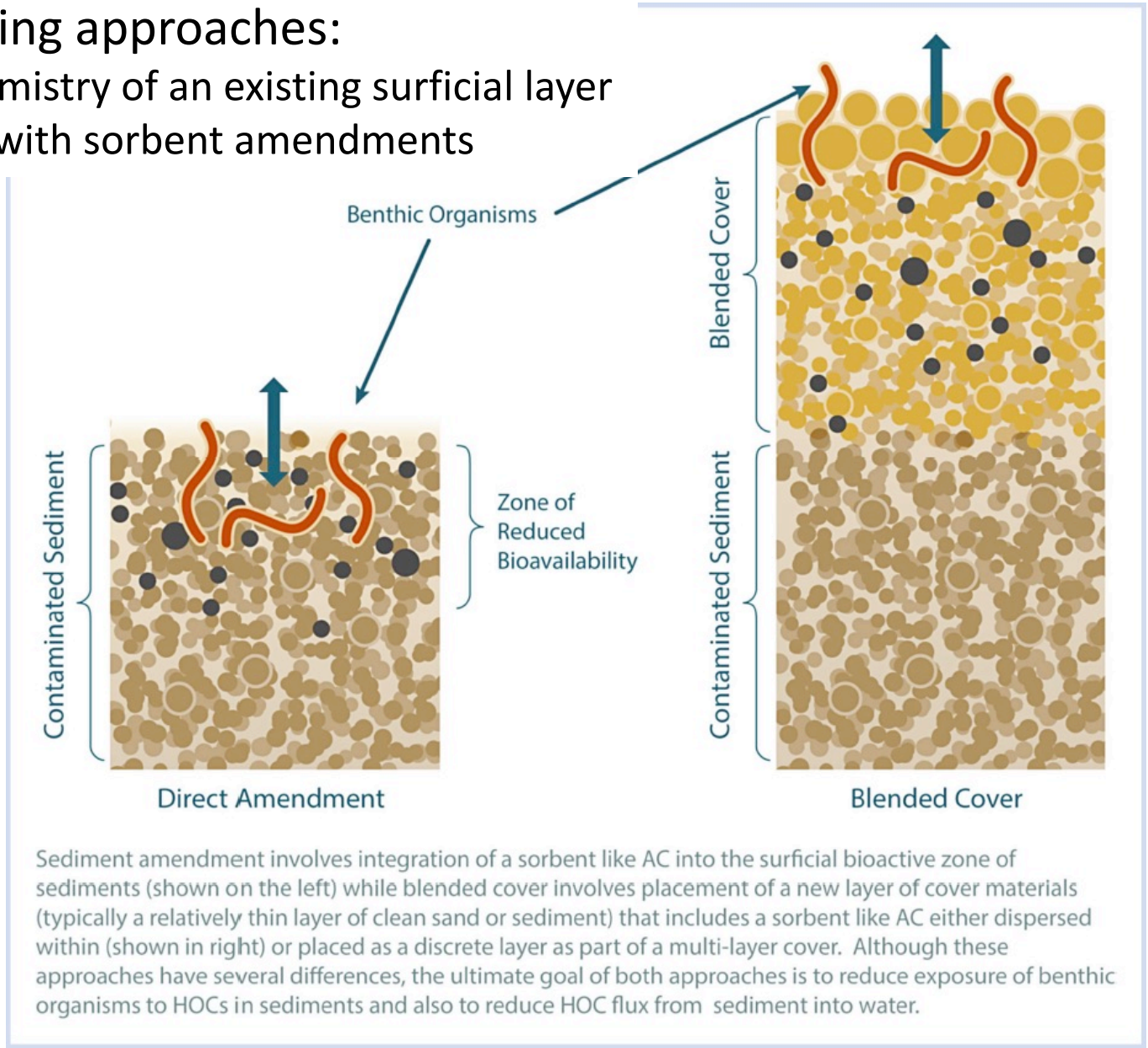
BROADENING THE CONCEPT OF TRADITIONAL CAPS

Exposure control

Two basic engineering approaches:

- Altering the geochemistry of an existing surficial layer
- Tailoring sand caps with sorbent amendments



From Patmont, Ghosh et al. IEAM 2015

Sediment amendment involves integration of a sorbent like AC into the surficial bioactive zone of sediments (shown on the left) while blended cover involves placement of a new layer of cover materials (typically a relatively thin layer of clean sand or sediment) that includes a sorbent like AC either dispersed within (shown in right) or placed as a discrete layer as part of a multi-layer cover. Although these approaches have several differences, the ultimate goal of both approaches is to reduce exposure of benthic organisms to HOCs in sediments and also to reduce HOC flux from sediment into water.

Would like to get feedback from audience

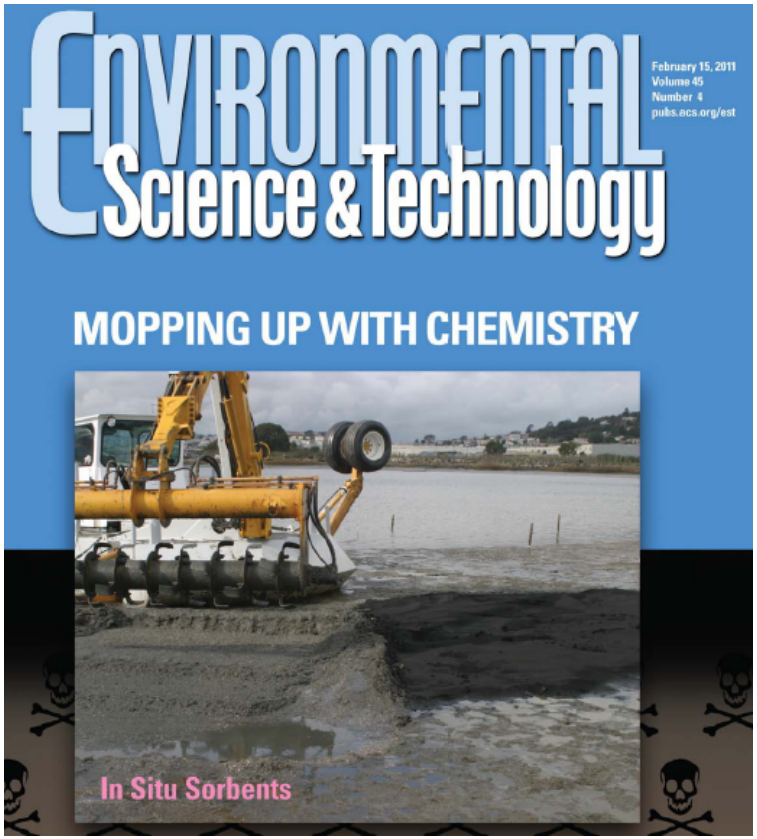
How often do you incorporate concepts of pollutant bioavailability in your sediment assessment/remediation work?

- Always
- Sometimes
- Never

KEY PUBLICATIONS: MOVING TECHNOLOGY FORWARD

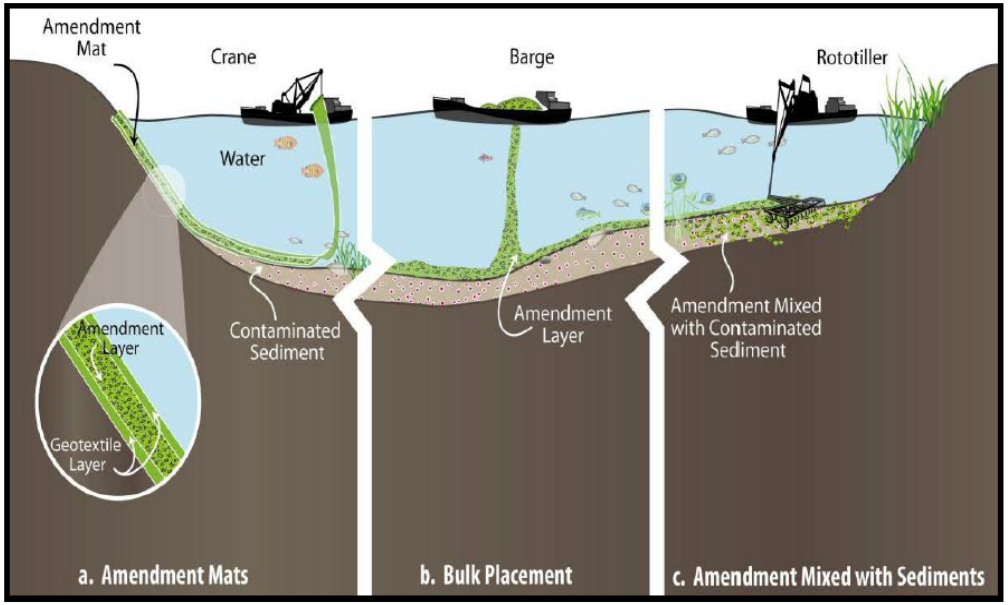
In-situ Sorbent Amendments: A New Direction in Contaminated Sediment Management

Environ. Sci. Technol. 2011, 45, 1163–1168



USE OF AMENDMENTS FOR IN-SITU REMEDIATION OF SUPERFUND SEDIMENT SITES

USEPA OSWER Directive 9200.2-128FS; April 2013



Several recent RODs have included AC amendment as a component of the proposed remedy

SEVERAL DEMONSTRATION PROJECTS

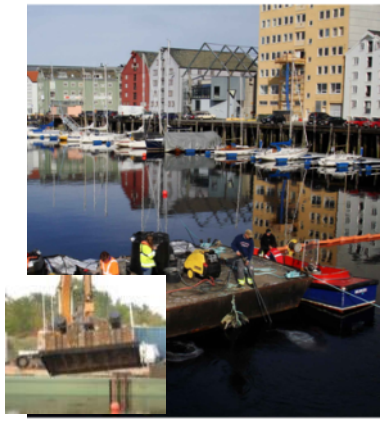
San Francisco Bay,
CA, USA, 2006

SLURRY INJECTION AND ROTOTILLER.

Grasse River,
NY, USA, 2006

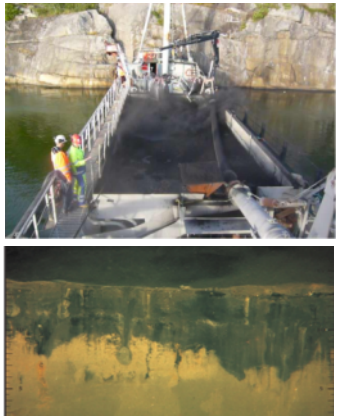
SLURRY INJECTION AND COVERED ROTOTILLER

Trondheim Harbor,
Norway, 2006



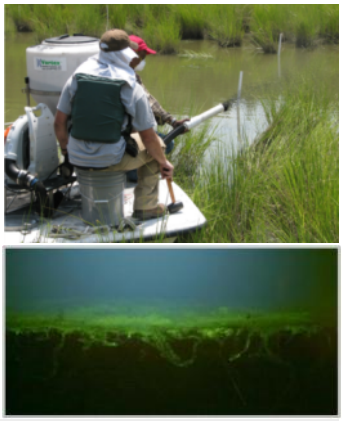
SLURRY INJECTION WITH AND WITHOUT CLAY

Grenlandsfjords,
Norway, 2009



ACTIVE CAP OF SITE CLAY AND ACTIVATED CARBON MIXTURE

Bailey Creek,
VA, USA, 2009



PELLETIZED CARBON DELIVERY (SEDIMITE)

Canal Creek,
MD, USA, 2010

PELLETIZED CARBON DELIVERY (SEDIMITE)

Berry's Creek,
NJ, USA, 2012

PELLETIZED CARBON DELIVERY (SEDIMITE)

Abraham's Creek,
MD, USA, 2014

PELLETIZED CARBON WITH DEGRADERS DELIVERY (SEDIMITE)

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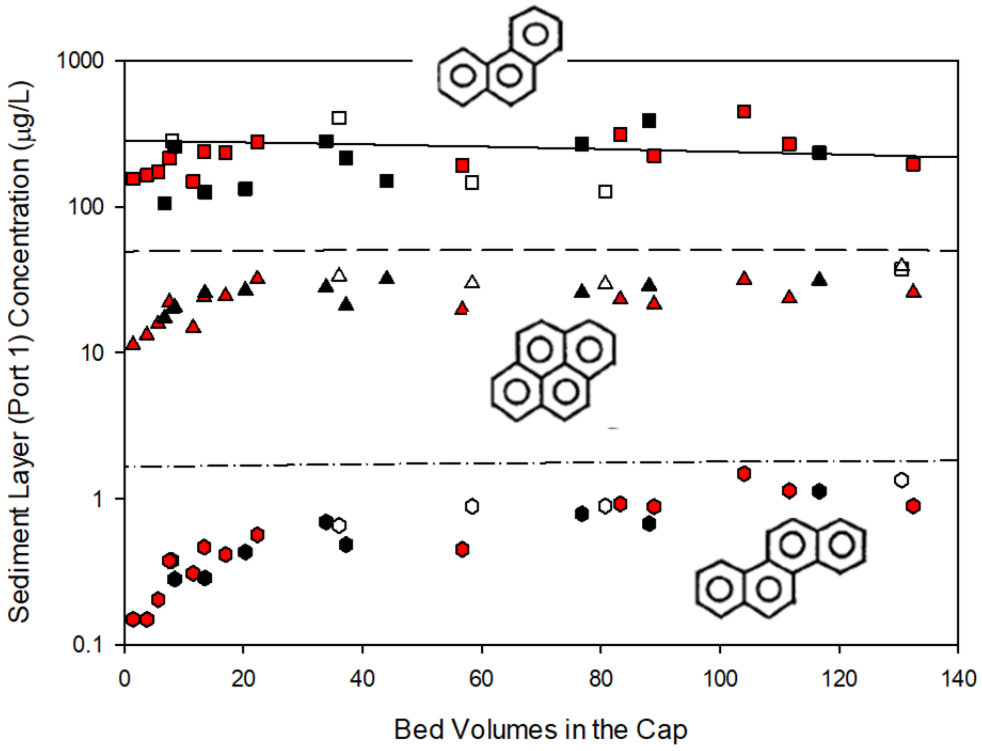
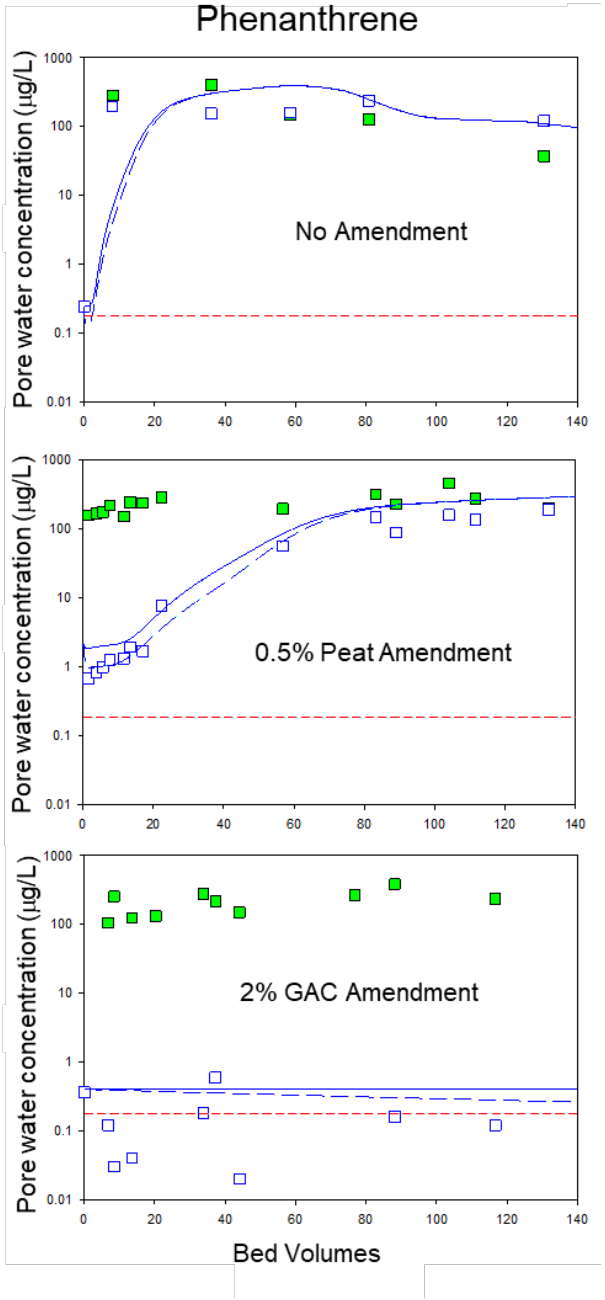
PAH NAPL AT SOURCE AND MIGRATION THROUGH CAPS



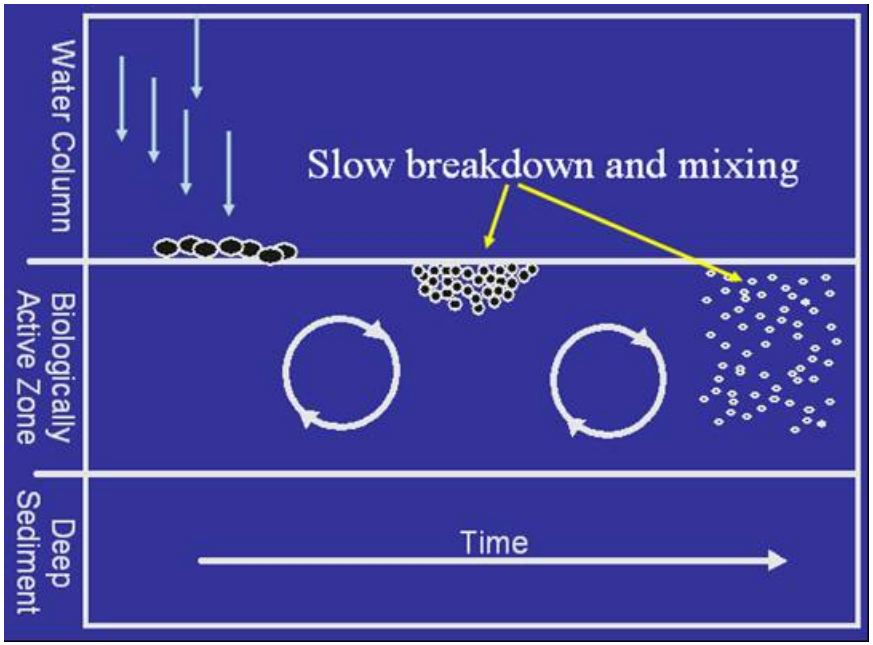
Dissolved PAHs in source sediments well predicted by a NAPL partitioning model

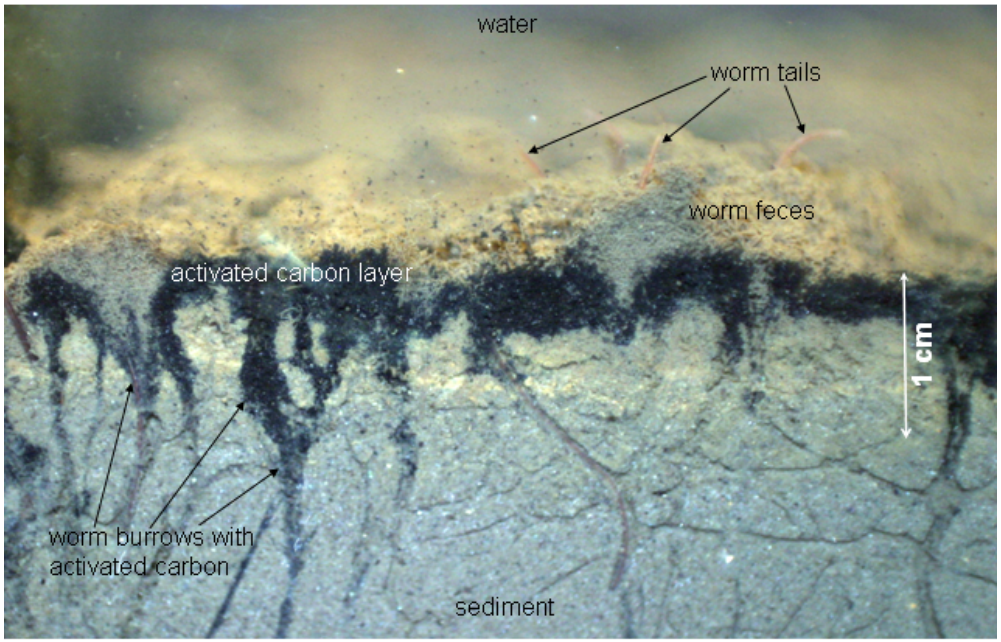


Measured and predicted PAH breakthrough in caps

Gidley et al. *Environ. Sci. Technol.* 2012, 46, 5032−5039

TECHNOLOGY TRANSITION : NEW PRODUCTS





1. AC works best in powdered form – difficult to apply directly
2. Agglomerates delivered from water surface
3. Sinks to sediment surface and resists resuspension
4. Breaks down slowly & mixed into sediment by bioturbation
5. Developed at UMBC in collaboration with Dr. Charlie Menzie - **EPA SBIR**

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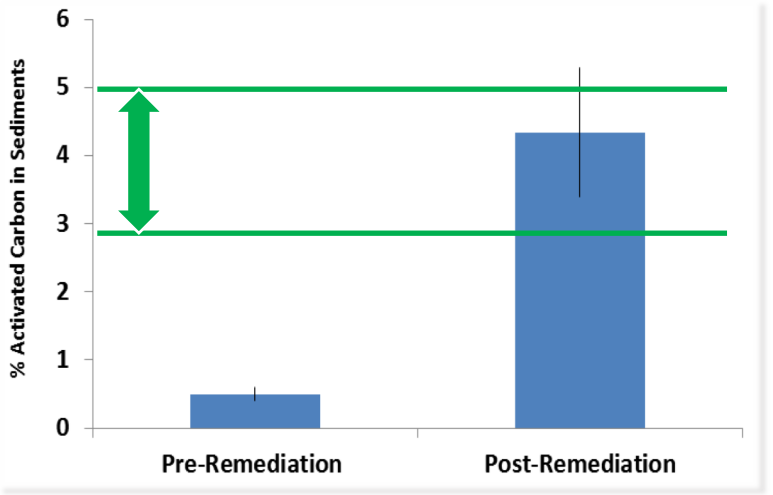
FULL-SCALE: RESTORATION & REMEDIATION OF A LAKE

- Urban lake sediments impacted with PCBs and PAHs
- Ecological restoration included removal of sand bar and creation of wetlands
- In-situ treatment of surface sediments with AC to reduce exposure.
- Monitoring includes PCBs in porewater, surface water, benthic invertebrates, and fish.
- In addition, ongoing inputs are being tracked.
- Optimum dose of 3 – 5% met



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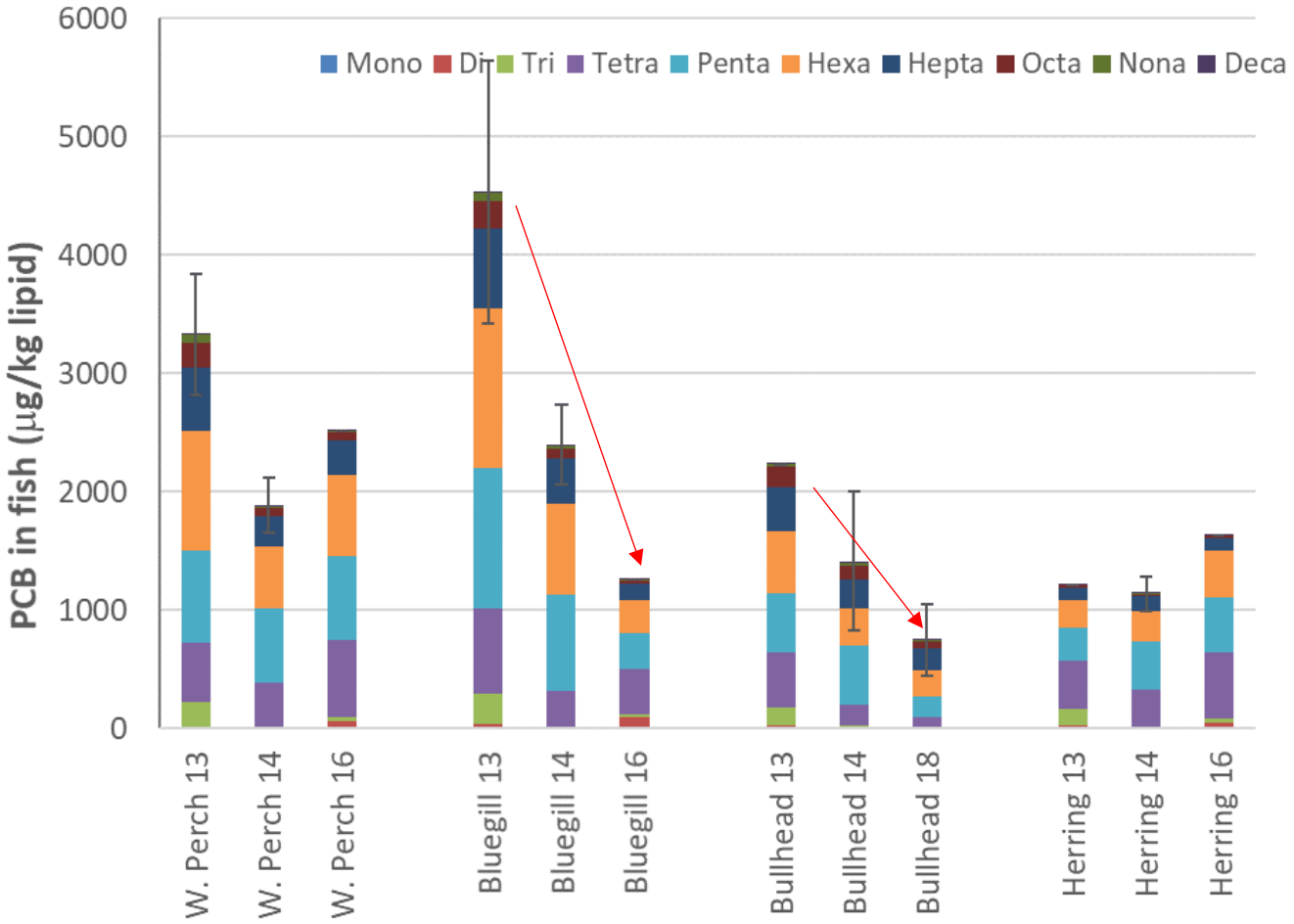
http://www.youtube.com/watch?v=l88oE6aTHK8&feature=youtu.be

PCB IN FISH TISSUE



- Nearly 70% reduction in resident fish (brown bullhead and bluegill)
- Resident fish PCB levels now below consumption advisory for DE
- Less reductions in migratory white perch and blueback herring

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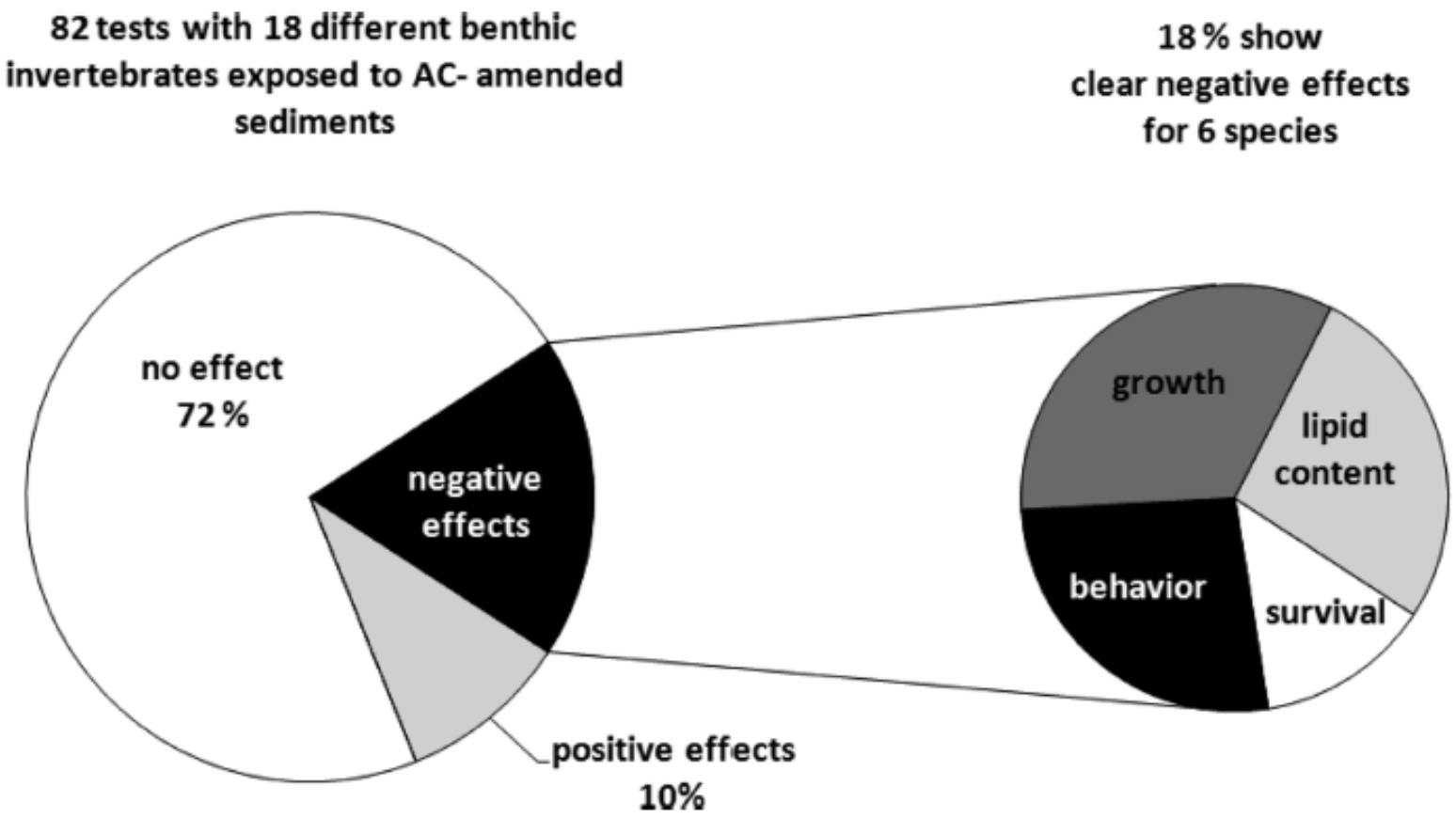
Patmont et al. ASCE J. Environ. Engr. 2019

IMPACT ON BENTHIC COMMUNITY

- Very limited AC effects, mostly in lab setting at high doses



Jansen and Beckingham 2013. Environ. Sci. Technol. 47:7595-7607

KEY MESSAGES

- Pollutant bioavailability can be altered in-situ by altering sediment geochemistry
- Two basic approaches:
  - Direct AC amendment to sediment
  - AC-amended sand cap
- AC particle size a key factor for performance
- Works in full-scale
- Persistence and performance demonstrated long-term

Would like to get feedback from audience

Do you have a site in mind that would benefit from exploring the use of an active cap or in-situ treatment as described in this presentation?

- Yes
- No

What do you see as the most important barrier(s) for implementing in-situ amendment of AC?

ACKNOWLEDGEMENTS

Students and post docs:

Hilda Fadaei, Mandar Bokare, James Sanders, Barbara Beckingham, Trevor Needham, Nathalie Lombard

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Collaborators:

Allen Place, IMET; Richard Greene and John Cargill, Delaware Dept of Natural Resources and Environmental Control; Brightfields Inc. Kevin Sowers; Richard Luthy, Stanford.

Disclosure statement:

Upal Ghosh is a co-inventor of two patents related to the technology described in this paper for which he is entitled to receive royalties. One invention was issued to Stanford University (US Patent # 7,101,115 B2), and the other to the University of Maryland Baltimore County (UMBC) (U.S. Patent No. 7,824,129). In addition, UG is a partner in a startup company (Sediment Solutions) that has licensed the technology from Stanford and UMBC and is transitioning the technology in the field.

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