IN SITU BIOAVAILABILITY REDUCTION OF PCBS IN SEDIMENTS:

FROM BENCH-SCALE TO FIELD DEMONSTRATION

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SERDP Strategic Environmental Research and Development Program
Improving Mission Readiness Through Environmental Research

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Sediment Remediation Action Team Meeting,
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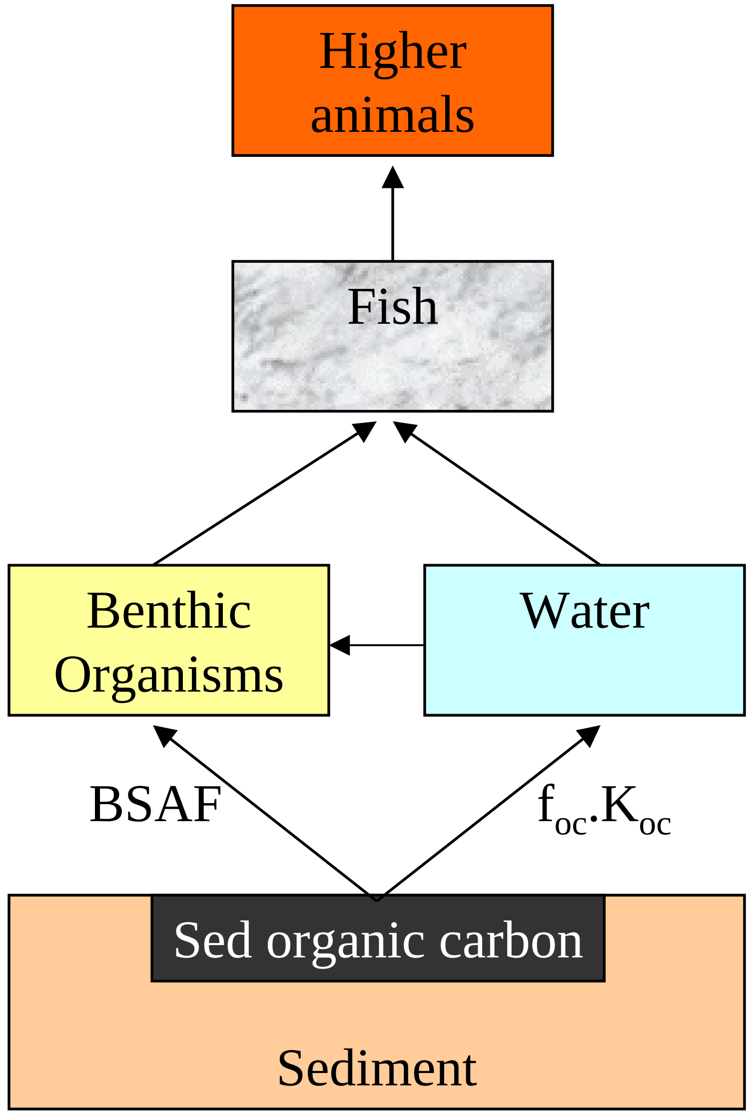
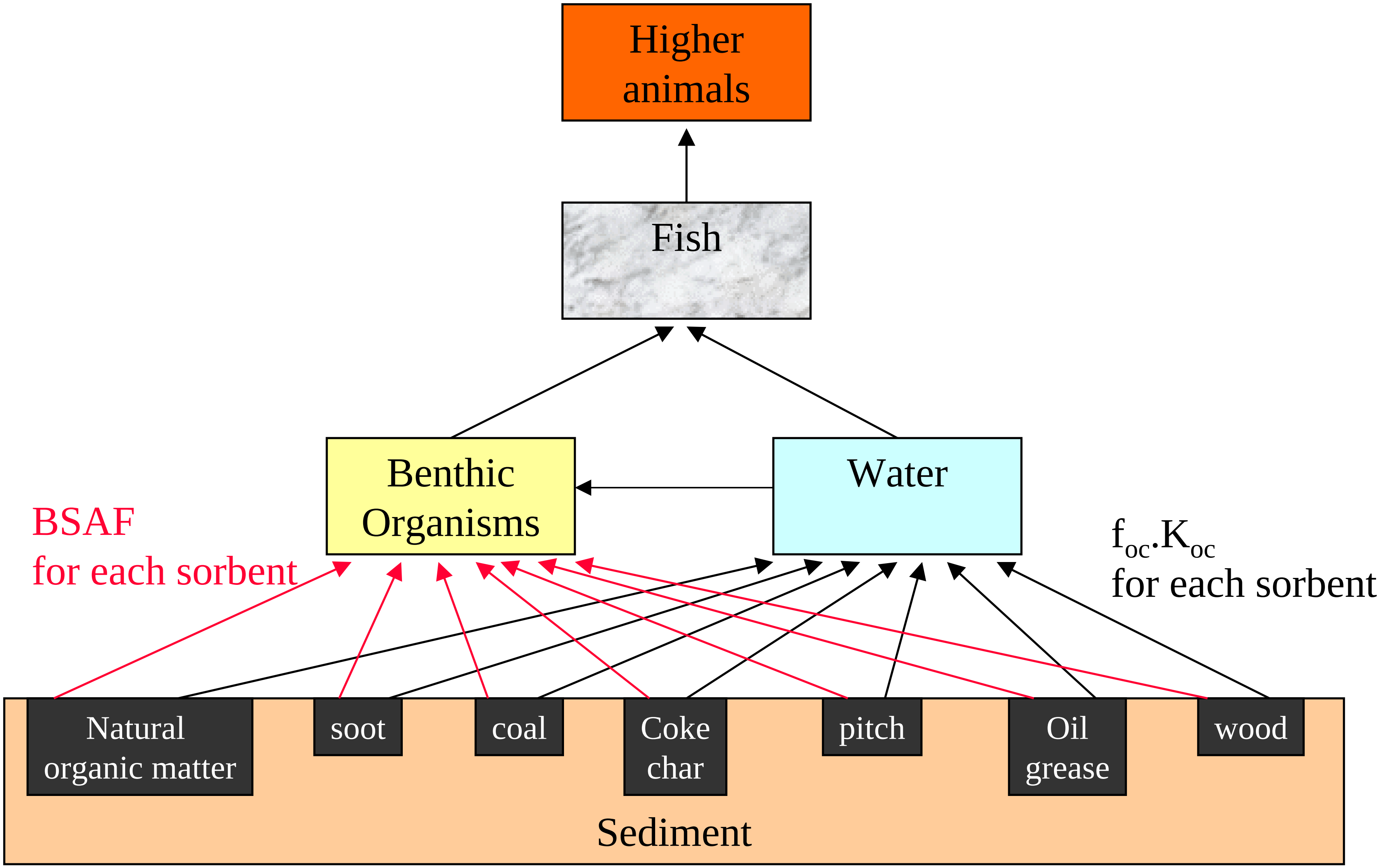
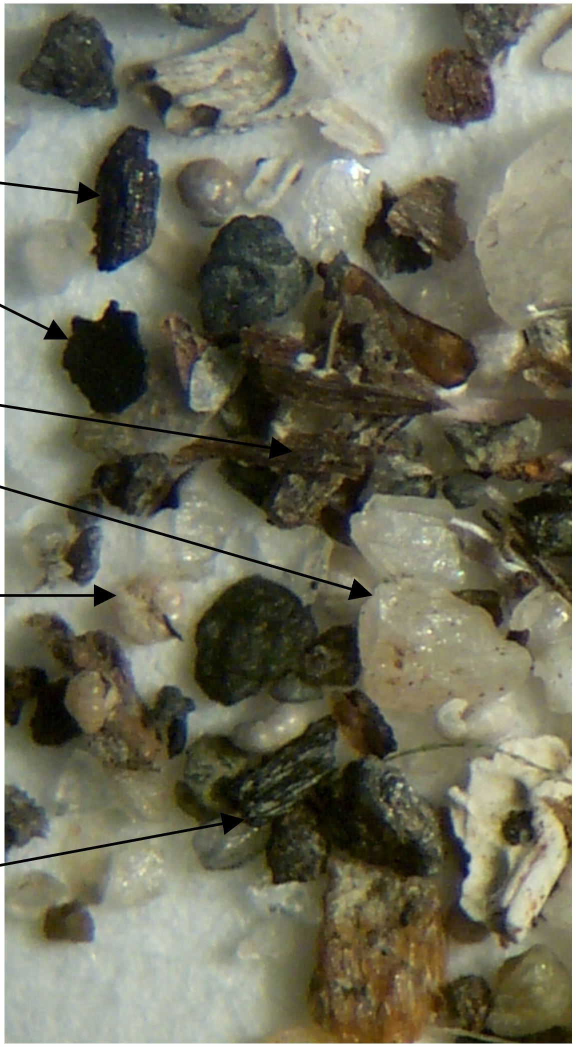
Traditional view of contaminant biouptake



Emerging understanding of contaminant biouptake



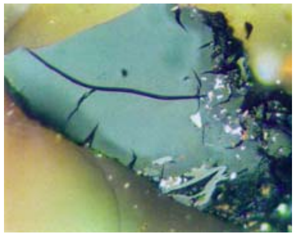
Contaminant distribution in sediment particles



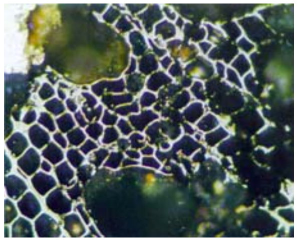
Hunters Point Sed (63-250 μm)

- Sediment contains sand, silt, clays, charcoal, wood, char, coal, & shells
- Coal petrography analyses identify carbonaceous particles
- Where are PCBs and PAHs located at the particle-scale?

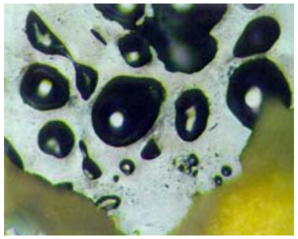
Petrography images



coal

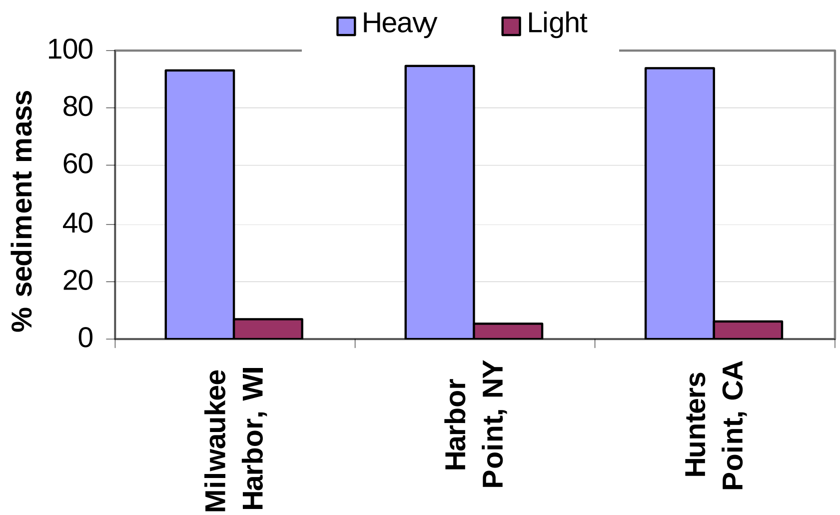


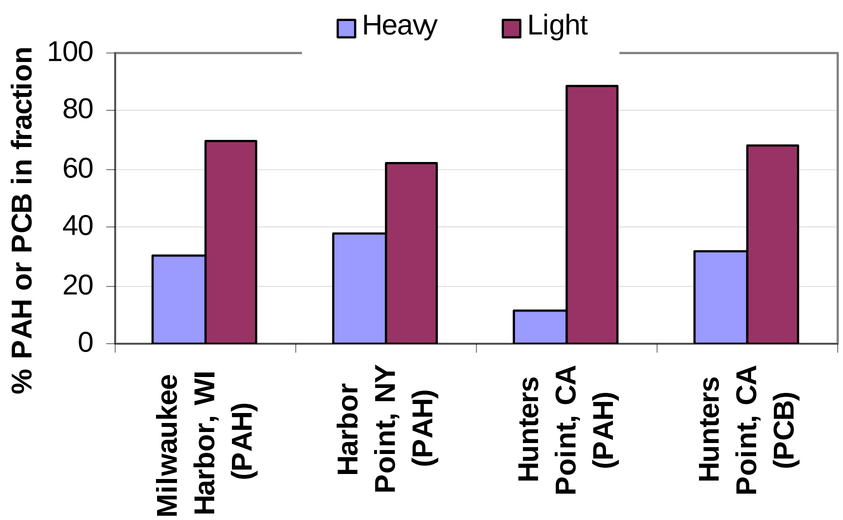
charcoal



coke

Distribution of PCB/PAH in sediments





Three sites show 5-7% wt. lighter density carbonaceous matter (coal/charcoal/wood)

PCBs and PAHs associated with lighter density fraction (60-90%)

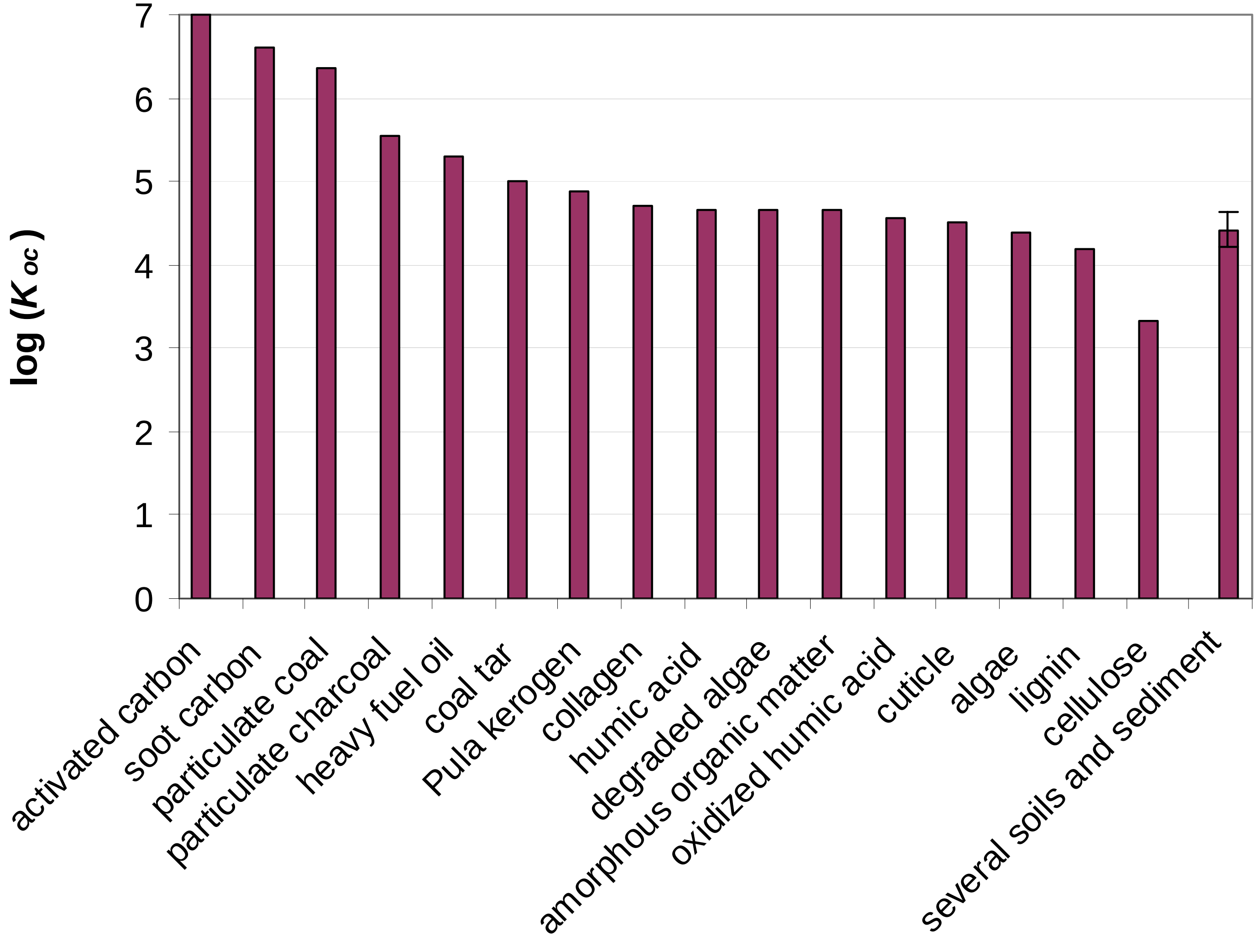
Lesson:
Over time PCBs [and PAHs] preferentially accumulate in coal/charcoal/coke where they are strongly bound and less bioavailable

See:
Ghosh et al., 2000, *ES&T*, 34, 1729-1736
Ghosh et al., 2001, *ES&T*, 35, 3468-3475
Talley et al., 2001, *ES&T*, 36, 477-483.

Sediment-water partitioning of phenanthrene

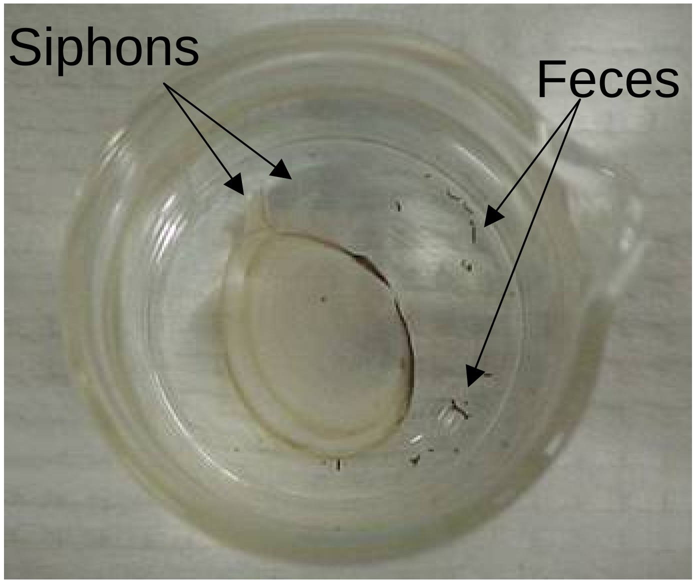
$$C_s = C_{aq} \,.\, K_{oc} \,.\, f_{oc}$$

Need to identify sediment component(s) that have major influence on contaminant availability

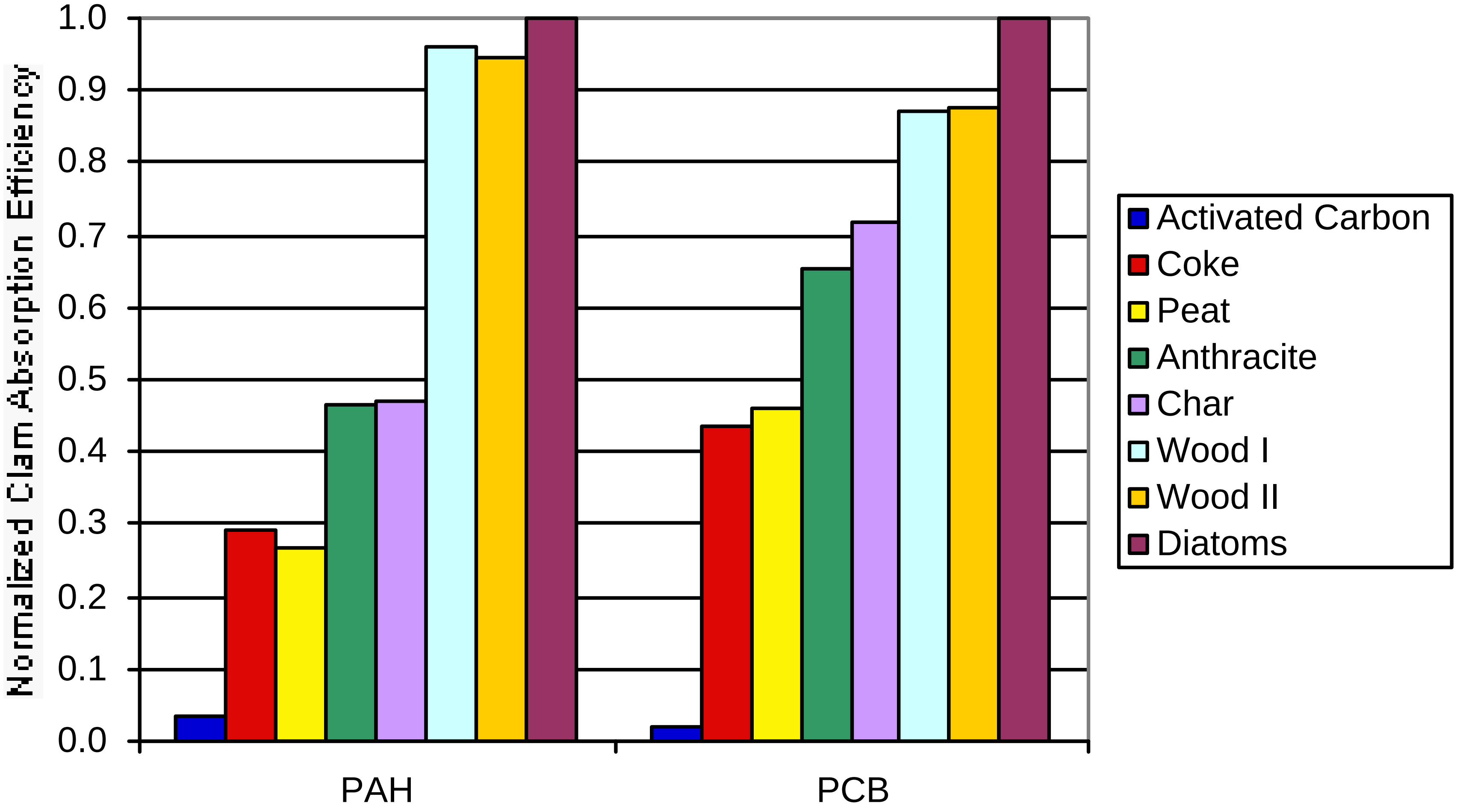


Clam absorption efficiency: controlled particle feeding

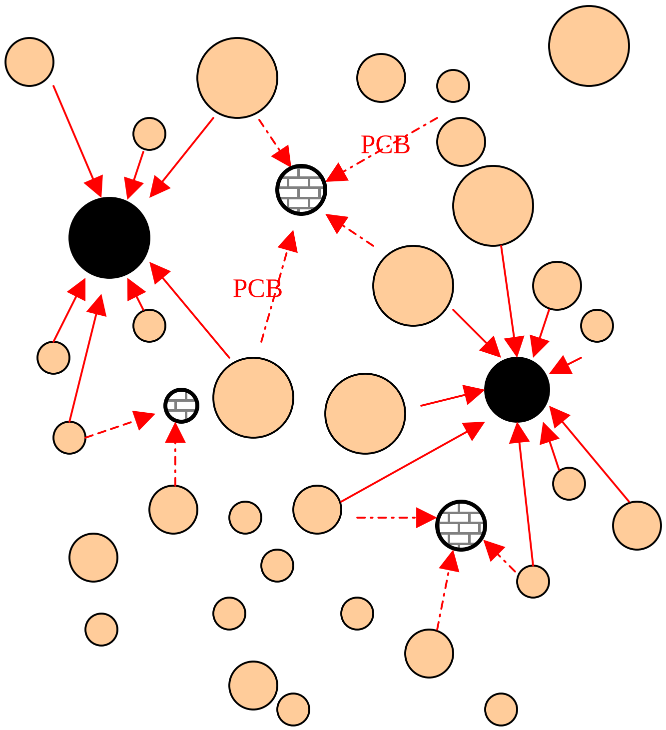
- Track ^{3}H-BaP and ^{14}C-2,2',5,5' PCB through a clam
- Feed 8 hours
- Depurate 4 days
- Analyze clam tissue and feces



Absorption efficiency: PCB/PAH on granular carbon is not absorbed by clams



PCB bioavailability control



Sediment carbonaceous particles

Other sediment particles containing PCBs

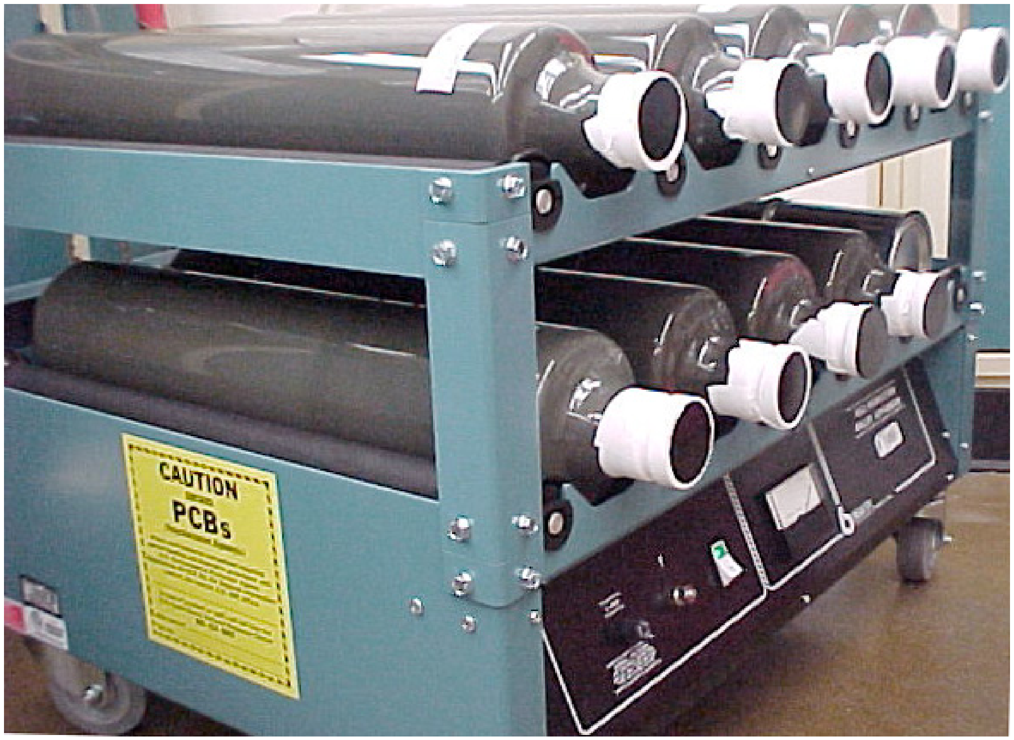
Introduced activated carbon particles

- The bioavailability of PCBs, depends on sorbent particle.
- Natural carbonaceous particles sequester PCBs, reduce bioavailability
- Alter PCB bioavailability by introducing strongly sorbing carbonaceous particles.
- New strategy for sediment management using in situ stabilization

Sediment sampling at Hunters Point

- PCB hot spot in San Francisco Bay
- Samples collected from intertidal zone in south basin

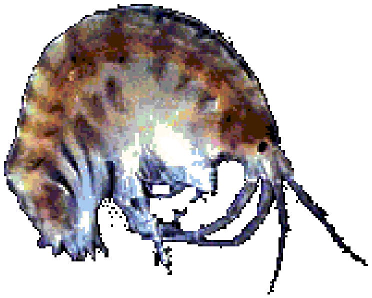
Sediment-sorbent contact



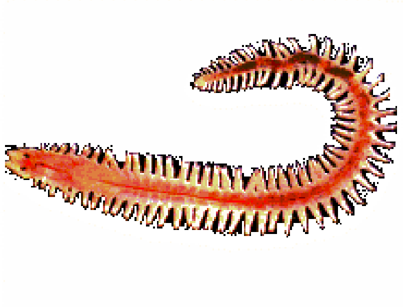
- Sediment-sorbent contact experiments to assess effect of particle size, dose, and contact time on PCB availability
- Sorbent dose: 2x TOC
- Sorbent size: 100-250 μm & 63-100 μm
- Contact time: 1 month & 6 months

Bioaccumulation and chronic bioassays

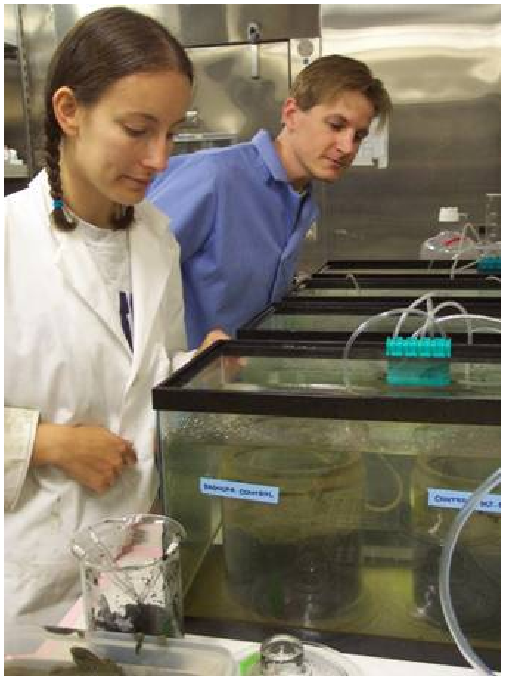
Macoma balthica
Indigenous bivalve



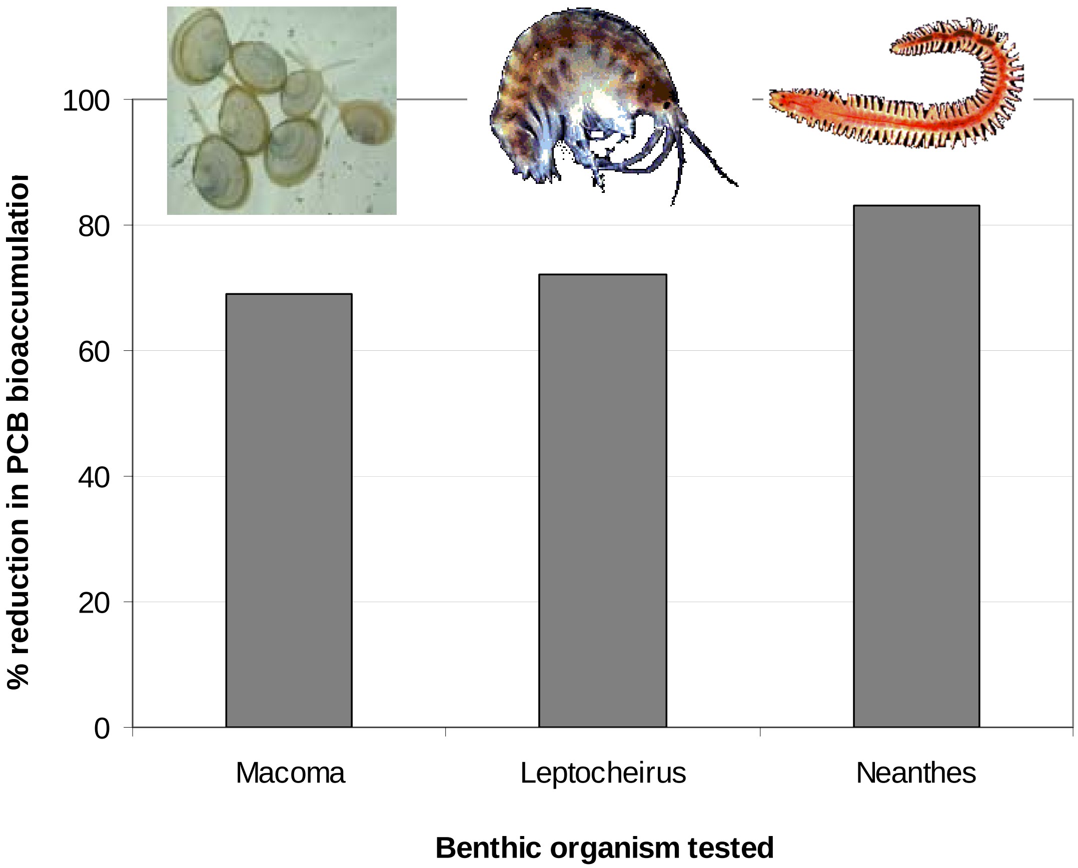
Leptocheirus plumulosus
Estuarine amphipod



Neanthes arenaceodentata
Infaunal deposit feeding polycheate worm



PCB bioaccumulation reduction



1 mo. GAC contact:

- *Macoma*: 69%
- *Leptocheirus*: 70%
- *Neanthes*: 82%

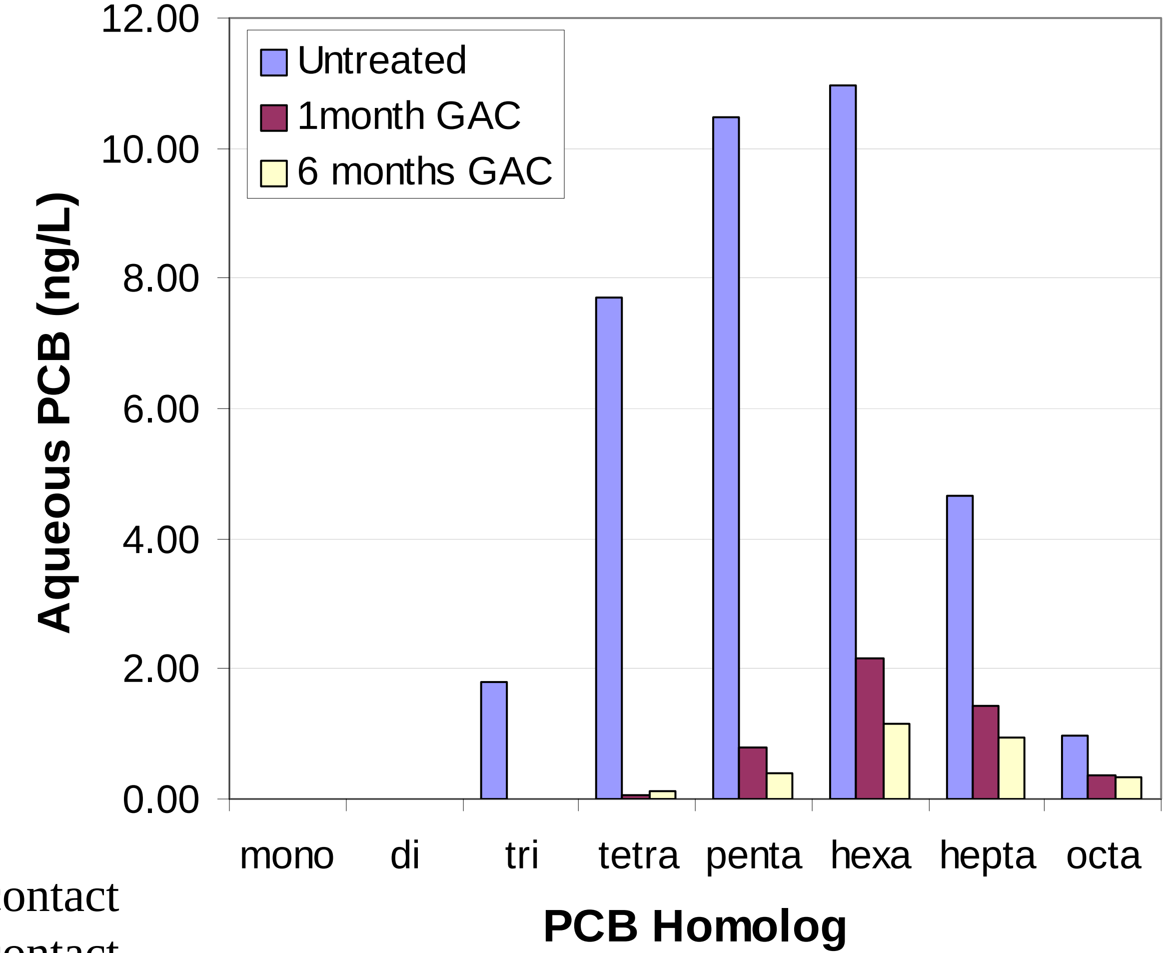
6 mo. GAC contact:

- *Leptocheirus*: 75%
- *Neanthes*: 87 %

Effect manifested quickly under optimum mixing and benefit not lost with time

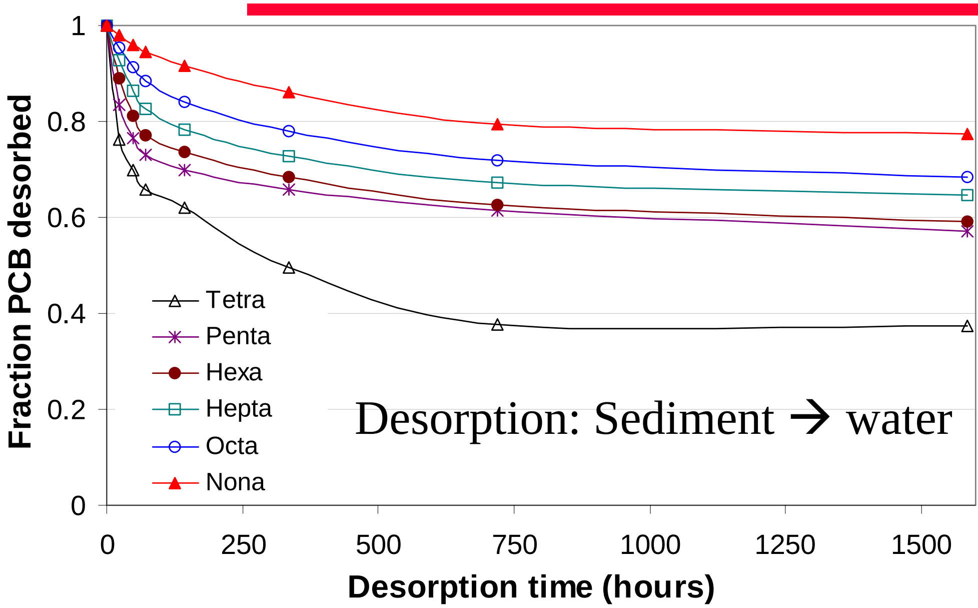
Aqueous equilibrium conc. reduction

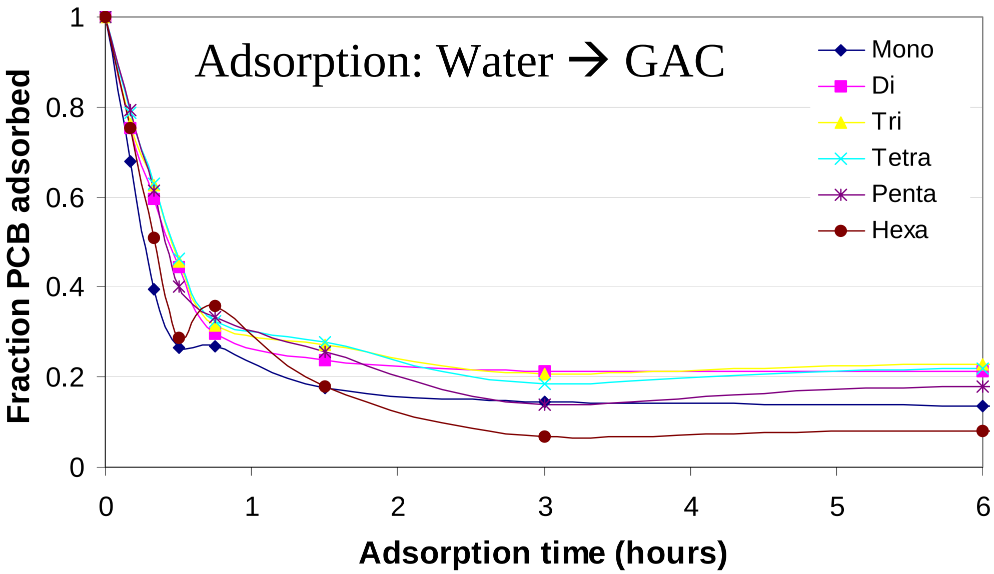
Alum-flocculation to remove colloids
Ghosh et al., ES&T 2000



- 87% reduction with 1 mo. contact
- 92% reduction with 6 mo. contact
- More efficient reduction for lower chlorinated PCBs

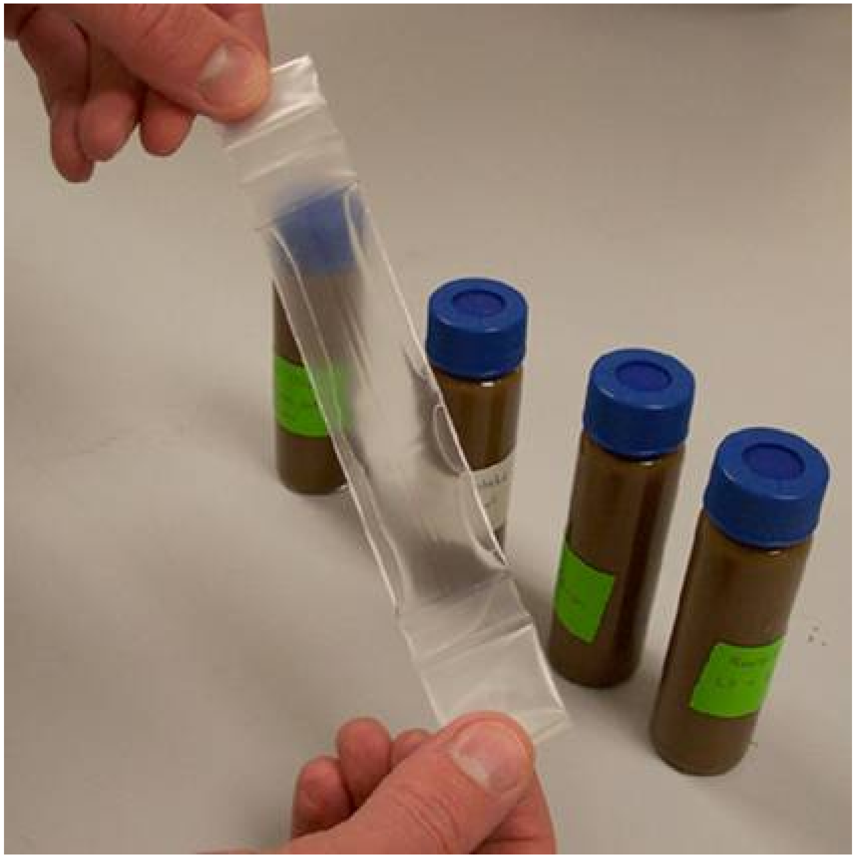
Rates of PCB desorption and adsorption





- PCB desorption rate decreases with increasing PCB chlorination
- Rates of PCB desorption from sediment are slow and may control overall mass transfer rates to GAC
- Initial PCB adsorption rates into GAC not significantly affected by PCB chlorination
- Rates of PCB adsorption into GAC from water is 2 orders of magnitude faster than desorption rates.

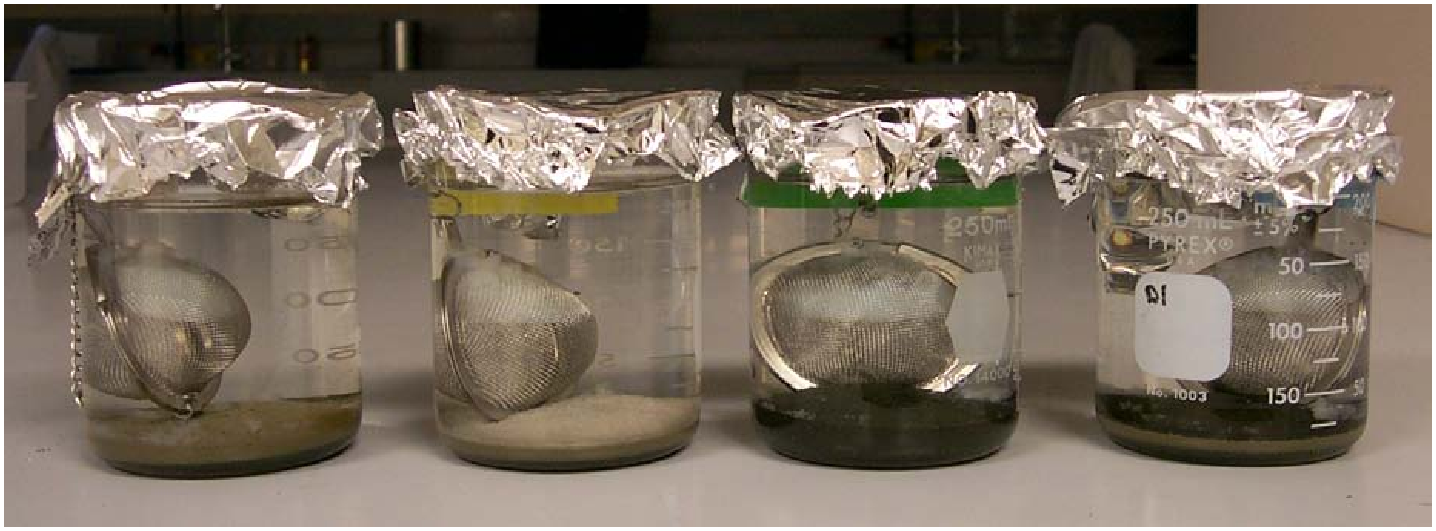
SPMD uptake reduction



Semi-permeable membrane device

- PCB diffusion and accumulation in lipid
- Useful screening tool
- **73% reduction with 1 mo. GAC contact**
- **77% reduction with 6 mo. GAC contact**

Sediment PCB flux reduction



No treatment   Sand cap   GAC mixed   GAC cap

- XAD resin in stainless steel baskets absorb aqueous PCBs
- Three treatments; 3.4 wt% GAC; 4 month triplicate tests

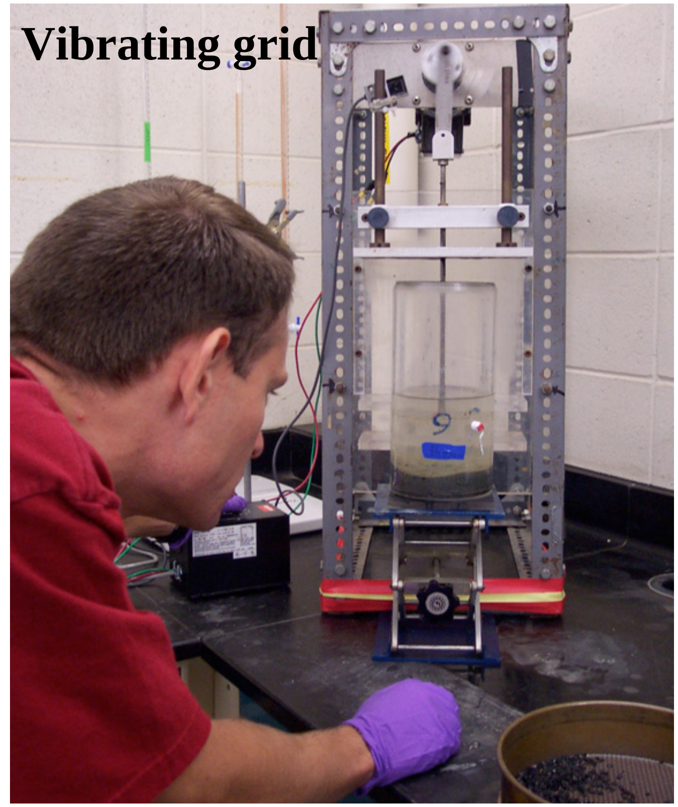
78% flux reduction with GAC mixed

89% flux reduction with GAC cap

Significant findings

- **PCBs are transferred from sediment to GAC**
- **GAC - treatment reduces:**
  1. PCB bioaccumulation: clam, worm, amphipod
  2. Aqueous PCB concentration
  3. PCB uptake in SPMD
  4. PCB flux from sediment
- **Important ‘weight of evidence’**

Sediment resuspension studies

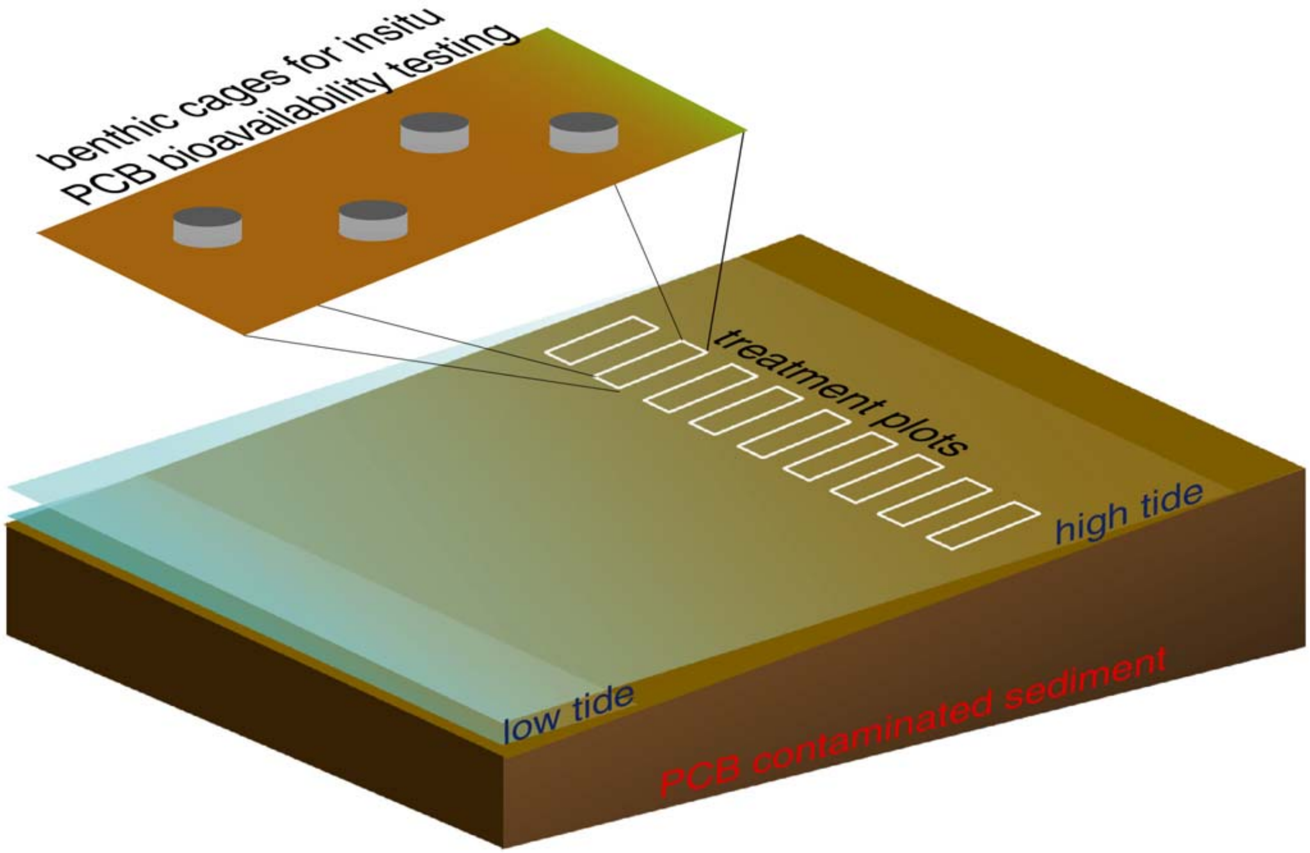


- Particle stability
- Lab tests of shear force required to suspend sediment
- GAC stability in cohesive sediment
- Field measurement of fluid shear forces

Proposed demonstration site: Hunters Point South Basin

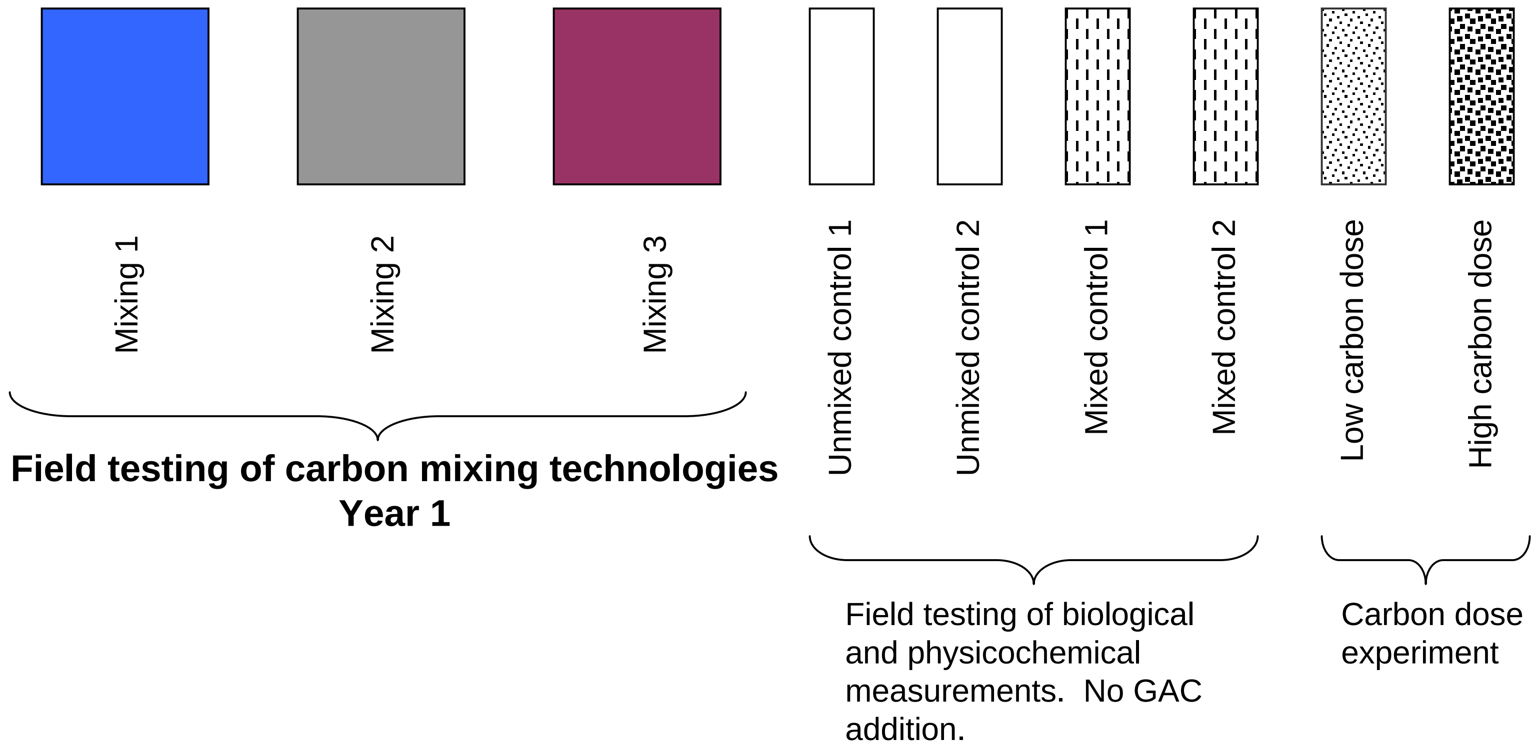
- Broad, mudflat region with PCBs

Technical description



- Field test at Hunters Point inter-tidal zone
- GAC mixed will be mixed into upper layer using different technologies
- Deployments appropriate for Hunters Point

Field treatment plots



Main goals of year 1 field testing

- Select the appropriate mixing equipment and vendors for carbon deployment.
- Evaluate the degree of mixing of GAC and sediment that is practically achievable in field tests using commercially available (and modified) equipment.
- Assess the erosion potential of sediments mixed with GAC.
- Cost assessment of technology and transition to technology demonstration

Field testing challenges:

- Inter-tidal zone is exposed for a few hours during low tide
- Sediments are very soft and deployment of heavy equipment is difficult
- Need to minimize sediment resuspension and mobilization
- Need to evenly distribute the carbon with good mixing in the top 12 inches

Mixing technology 1: Rotovator

- Aquamog equipped with a rotovator
- Traditionally used for underwater weeding
- Can be used on exposed sediments and on submerged shallow sediments

Mixing technology 2: Tilling/disking

- A track loader/dump truck can be used for carbon spreading
- A tilling/disking attachment can be used to mix the carbon

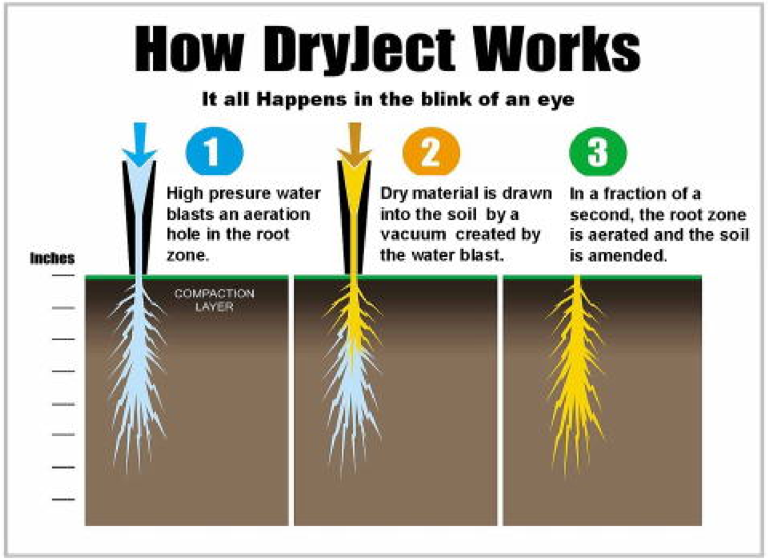
Figure 15-11 Used for high solids stabilization not requiring high-energy mixing. (Harmon Environmental Services, Inc.)

Mixing technology 3: Low ground pressure vehicles

- ArgoATV can be fitted with tracks for low ground pressure ~ 0.67 psi
- Can be used for spreading carbon and dragging tillers or injectors

Mixing technology 4: Dry solid injection

- Currently used to introduce sand for lawn maintenance
- High pressure water jet blasts a hole in the soil
- Dry material is drawn by the jet into the hole
- May need modification for deployment in sediments
- Working with manufacturer to evaluate feasibility for carbon application



(From: www.dryject.com)

Mixing technology 5: Slurry injection

- Used for soil/sediment stabilization with cement mortar

Figure 15-10 In situ injection system. (Harmon Environmental Services, Inc.)

From: Chemical Fixation and Solidification of Hazardous wastes, J. R. Conner, Van Nostrand Reinhold, NY.

Mixing technology 6: Auger mixer

- Used for soil or sediment stabilization with cement mortar

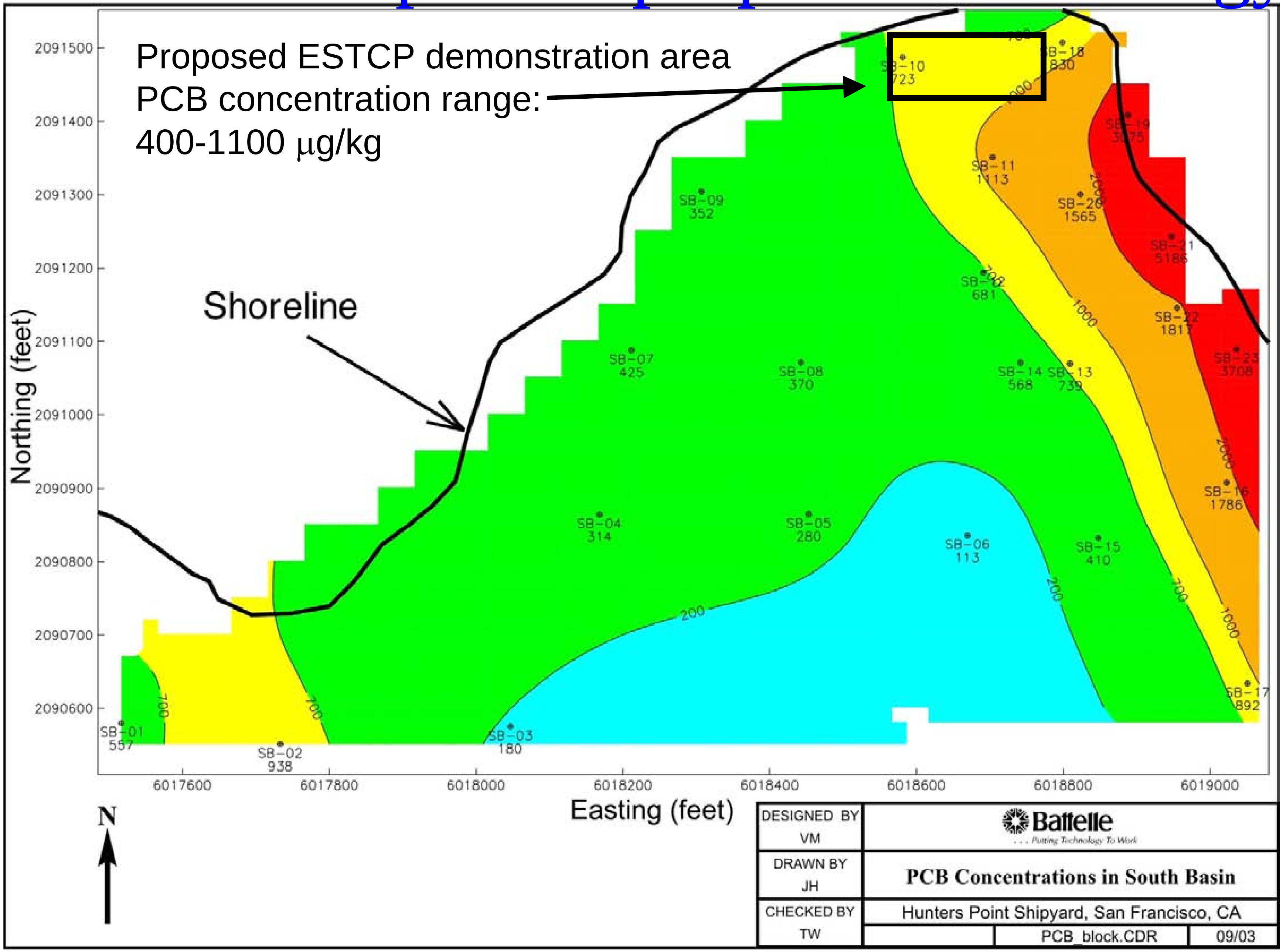
Figure 7-13 Auger-type sludge homogenization machine.

From: Chemical Fixation and Solidification of Hazardous wastes, J. R. Conner, Van Nostrand Reinhold, NY.

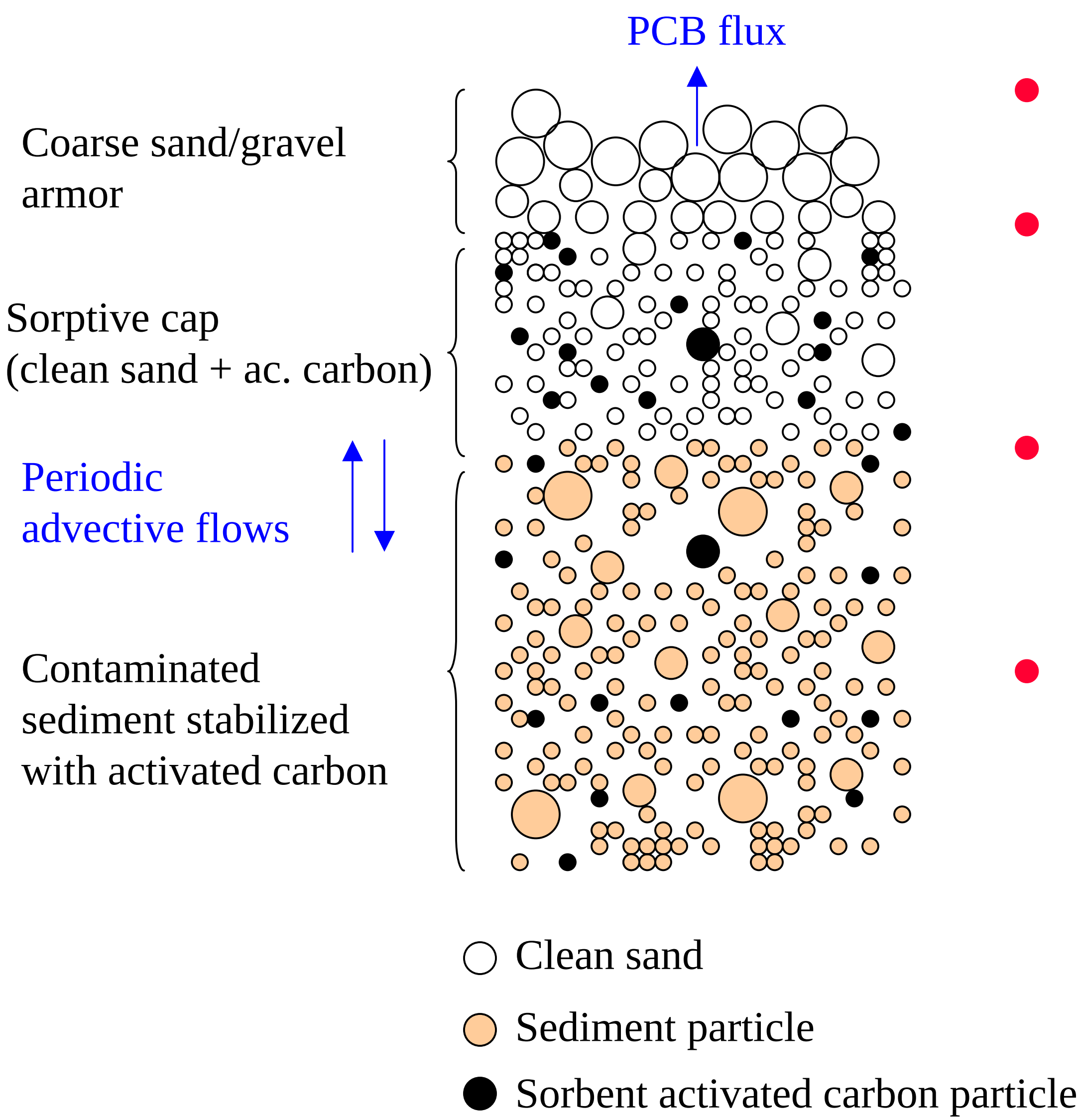
Demonstration/validation issues

- Reduce PCB uptake in test benthic organisms
- Reduce PCB aqueous concentrations

Possible impact of proposed technology



Future work: new sorptive cap design



- Sorptive cap design
- Reduce PCB flux to water column
- Reduces porewater PCB in bioactive zone
- Transfer of PCBs into activated carbon over time

Acknowledgements

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- Strategic Environmental Research and Development Program (DoD)
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