In Situ Stabilization of Persistent Organic Contaminants in Sediments Using Activated Carbon

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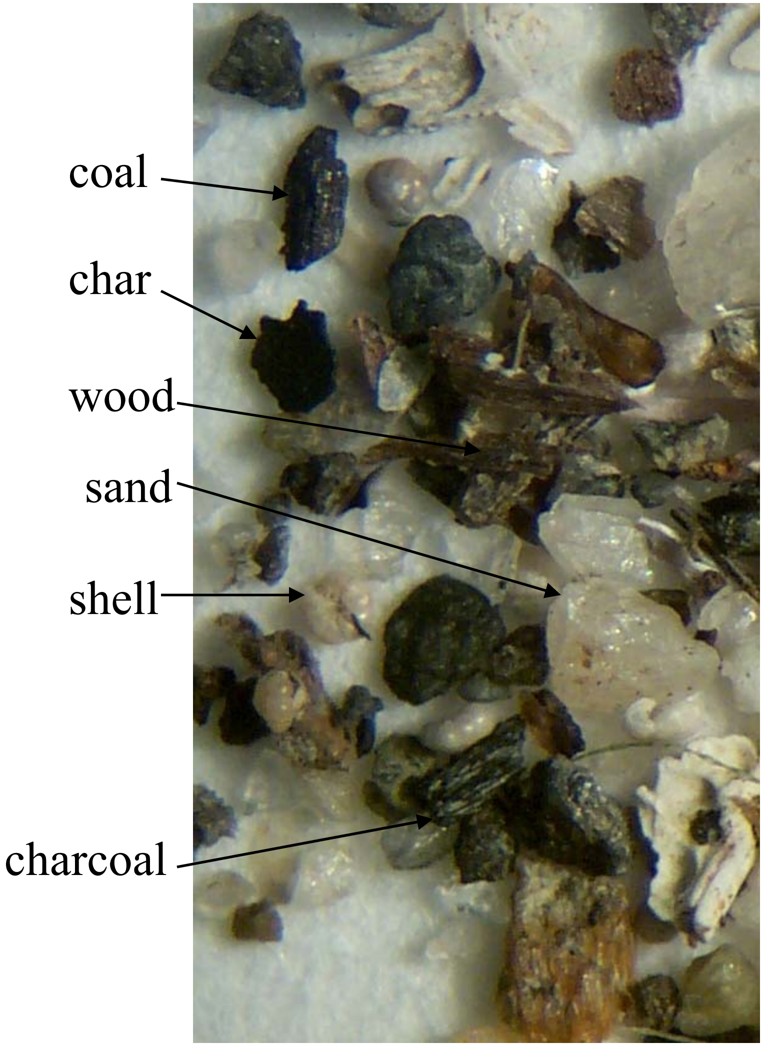
Technology Benchmarking Workshop for Sediment and Floodplain Remediation
March 25-26, 2004, University of Michigan, Ann Arbor

DoD EPA DOE SERDP
Strategic Environmental Research and Development Program
Improving Mission Readiness Through Environmental Research

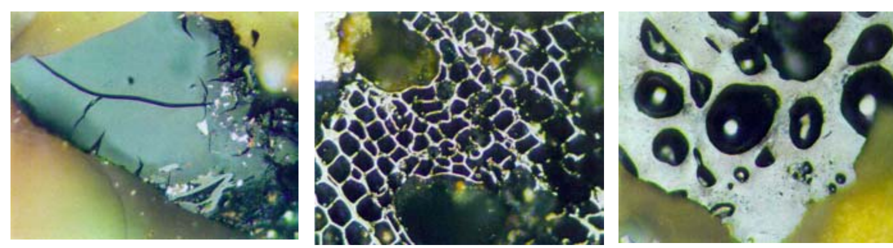
Contaminant distribution in sediment particles



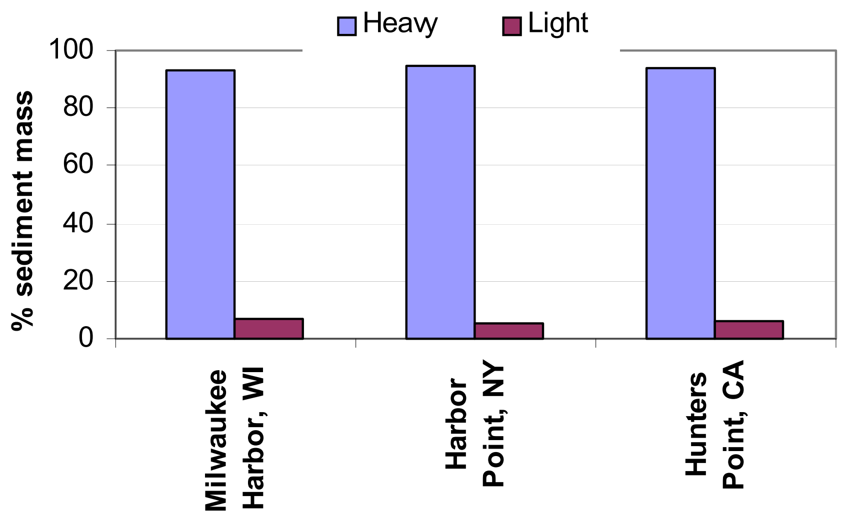
Hunters Point Sed (63-250 μm)

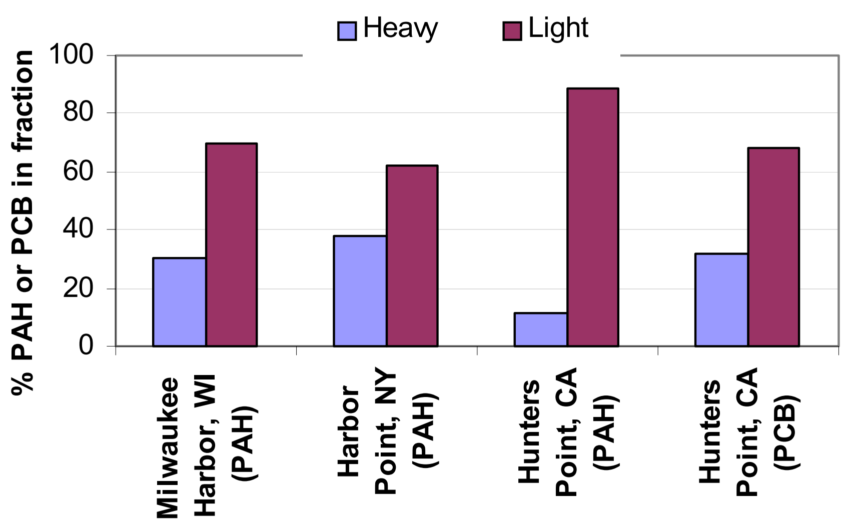
- Sediment contains sand, silt, clays, charcoal, wood, char, coal, & shells
- Coal petrography analyses identify carbonaceous particles
- Where are PCBs and PAHs located at the particle-scale?

Petrography images



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

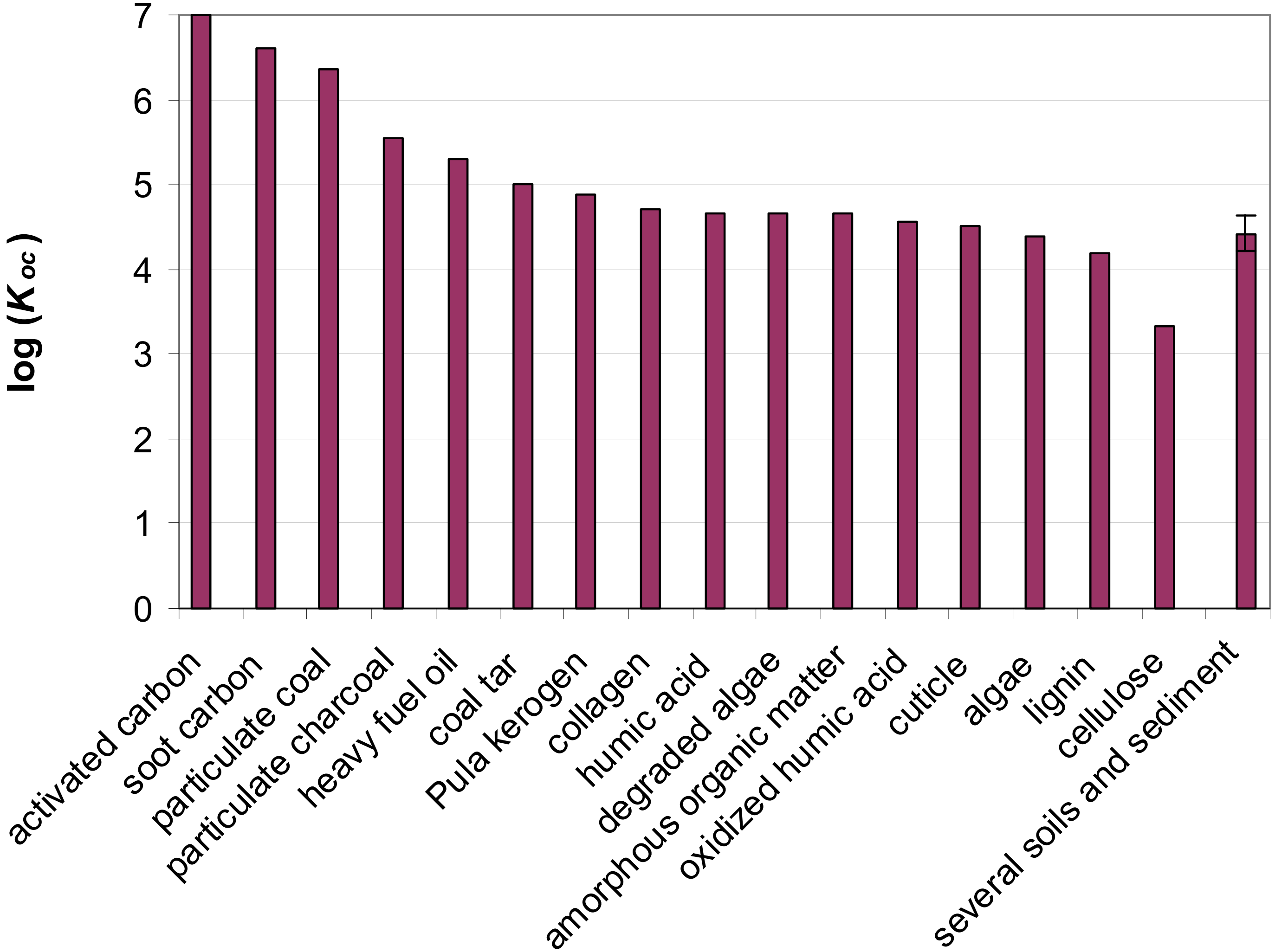
See:

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

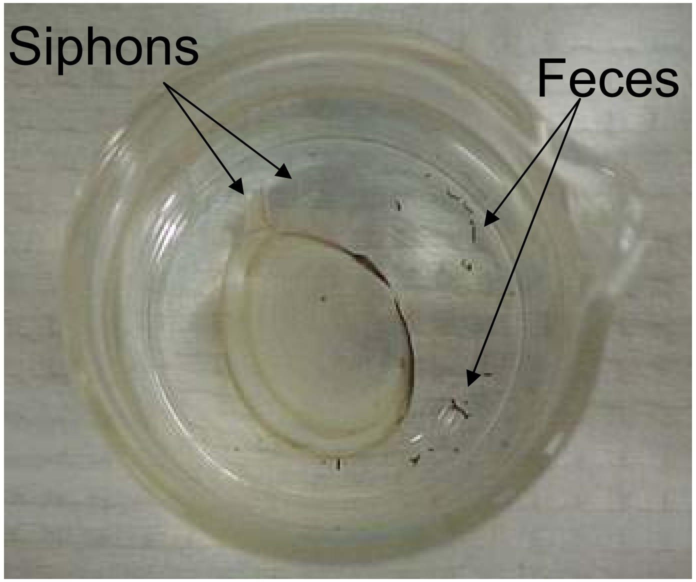
$C_s = C_{aq} \cdot K_{oc} \cdot f_{oc}$

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

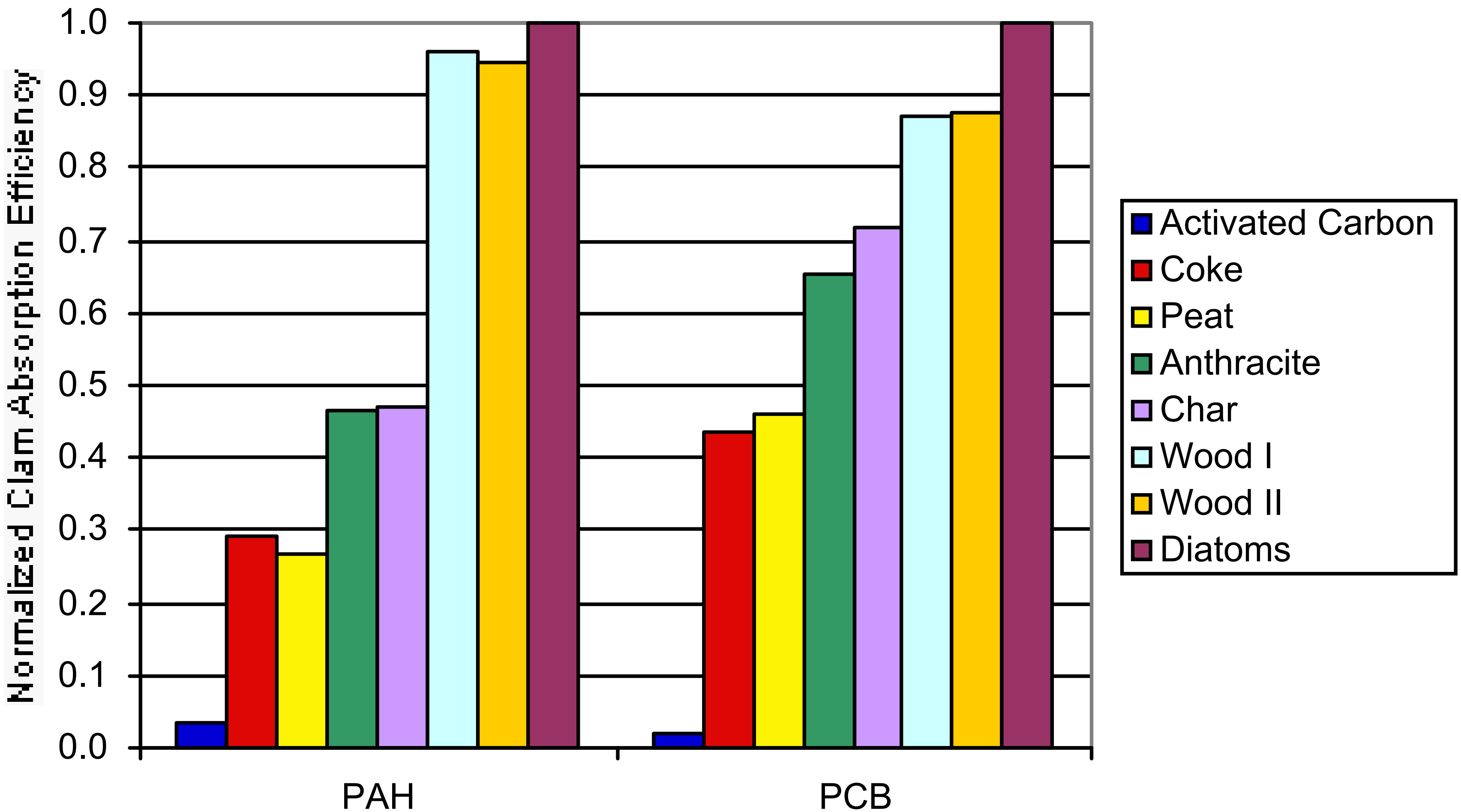


Clam absorption efficiency: controlled particle feeding

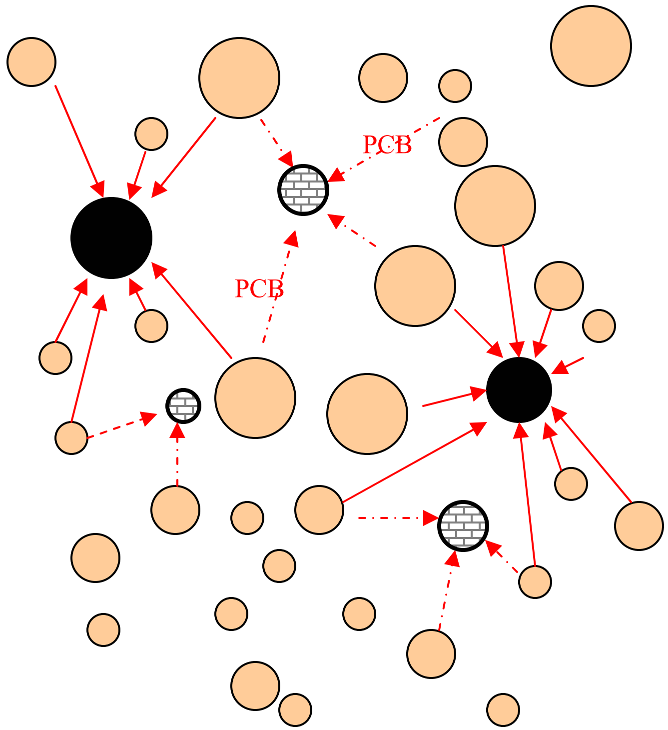
- Track ^{3}H-BaP and ^{14}C-2,2’,5,5’ PCB through a clam
- Feed 8 hours
- Depurate 4 days
- Analyze clam tissue and feces



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



PCB bioavailability control



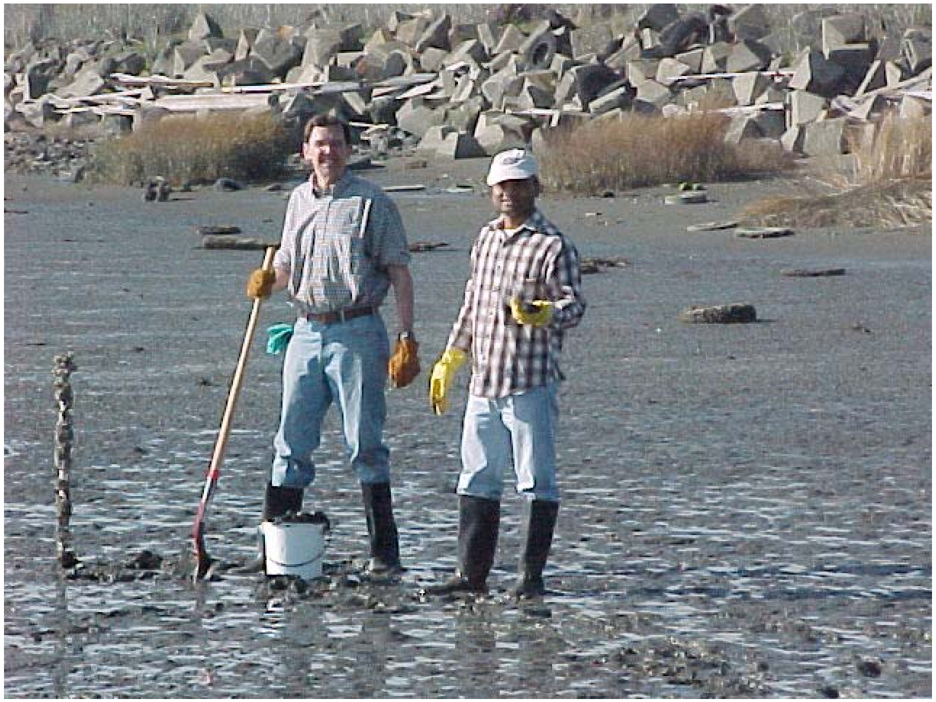
Sediment carbonaceous particles

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



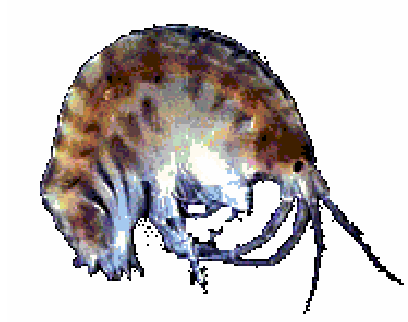
- PCB hot spot in San Francisco Bay
- Samples collected from intertidal zone in south basin

Sediment-sorbent contact

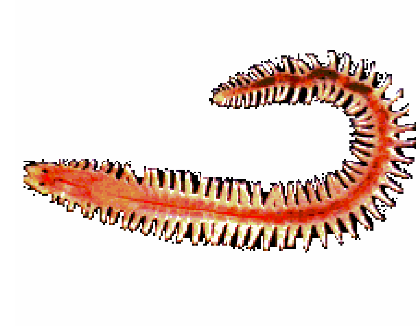
- Sediment-sorbent contact experiments to assess effect of particle size, dose, and contact time on PCB availability
- Sorbent dose: 2x TOC
- Sorbent size: 100-250 µm & 63-100 µm
- Contact time: 1 month & 6 months

Bioaccumulation and chronic bioassays

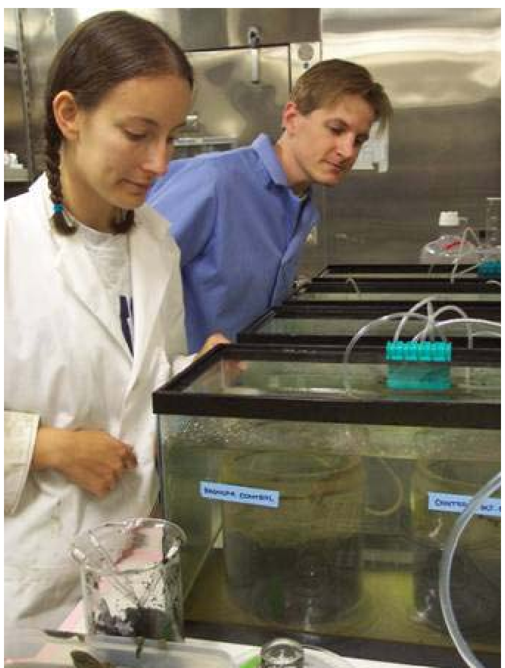
Macoma balthica
Indigenous bivalve



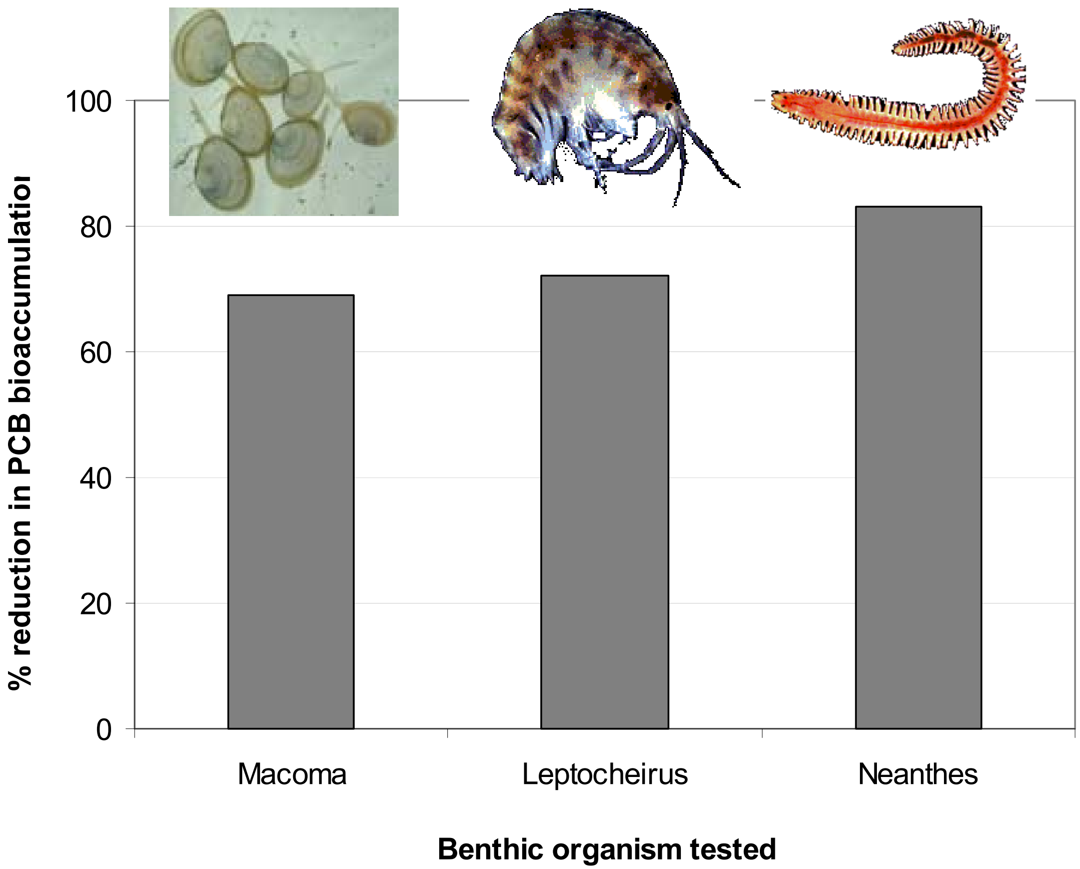
Leptocheirus plumulosus
Estuarine amphipod



Neanthes arenaceodentata
Infaunal deposit feeding polycheate worm



PCB bioaccumulation reduction



1 mo. GAC contact:

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

6 mo. GAC contact:

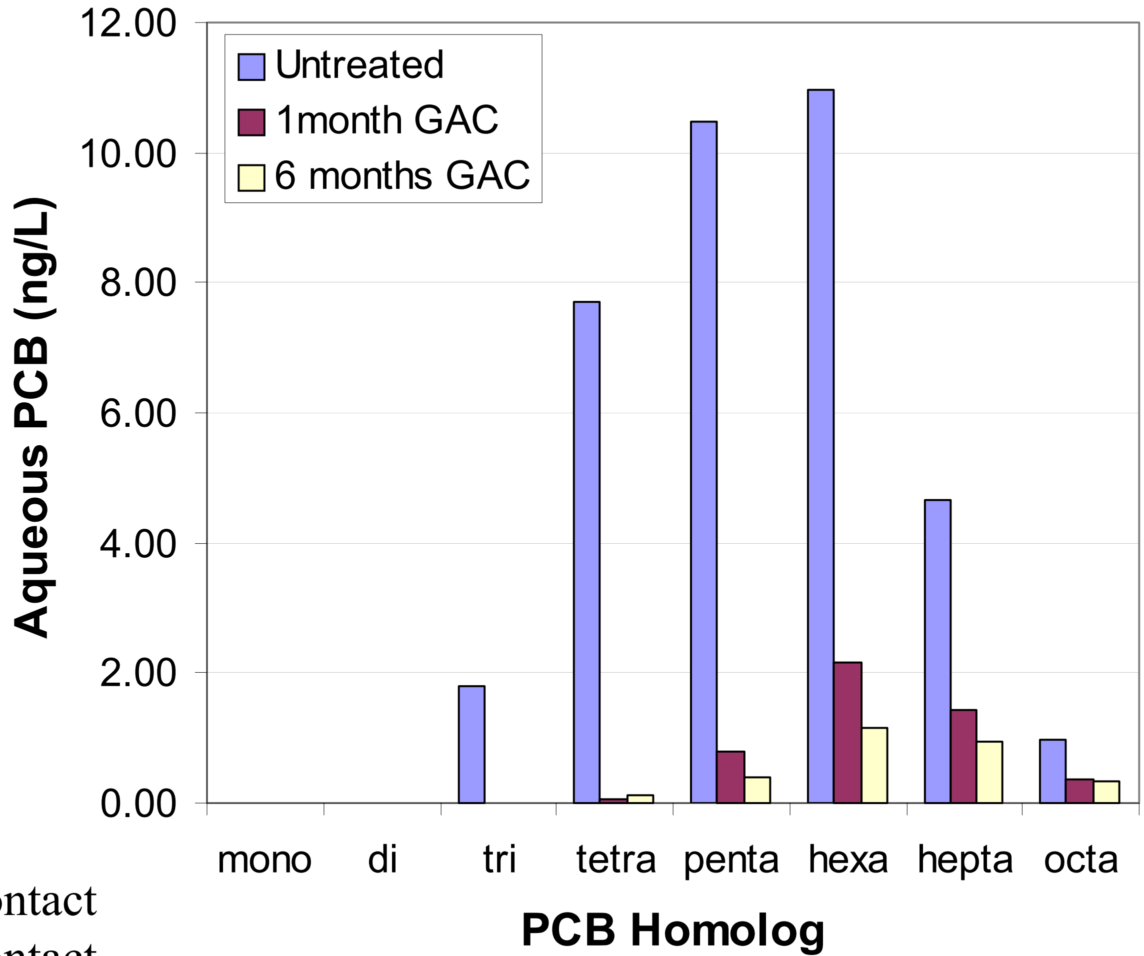
- *Leptocheirus*: 75%
- *Neanthes*: 87 %

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

Aqueous equilibrium conc. reduction

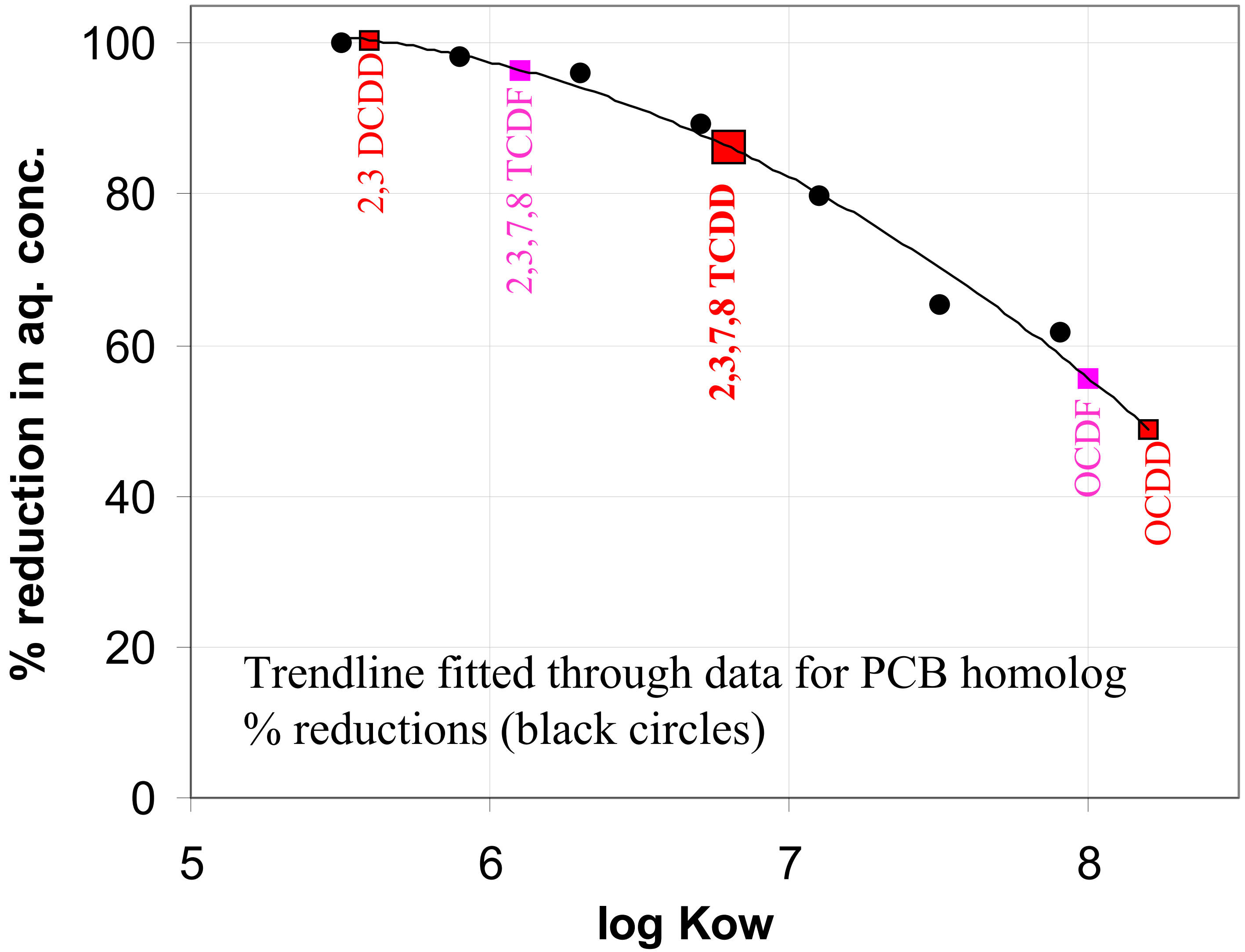
Alum-flocculation to remove colloids

Ghosh et al., ES&T 2000

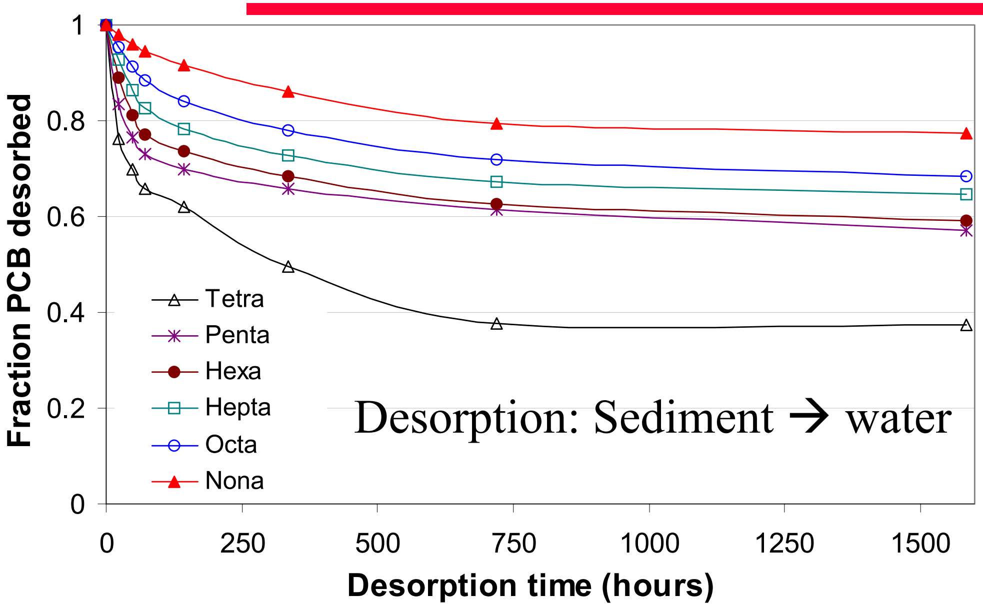


- 87% reduction with 1 mo. contact
- 92% reduction with 6 mo. contact
- More efficient reduction for lower chlorinated PCBs

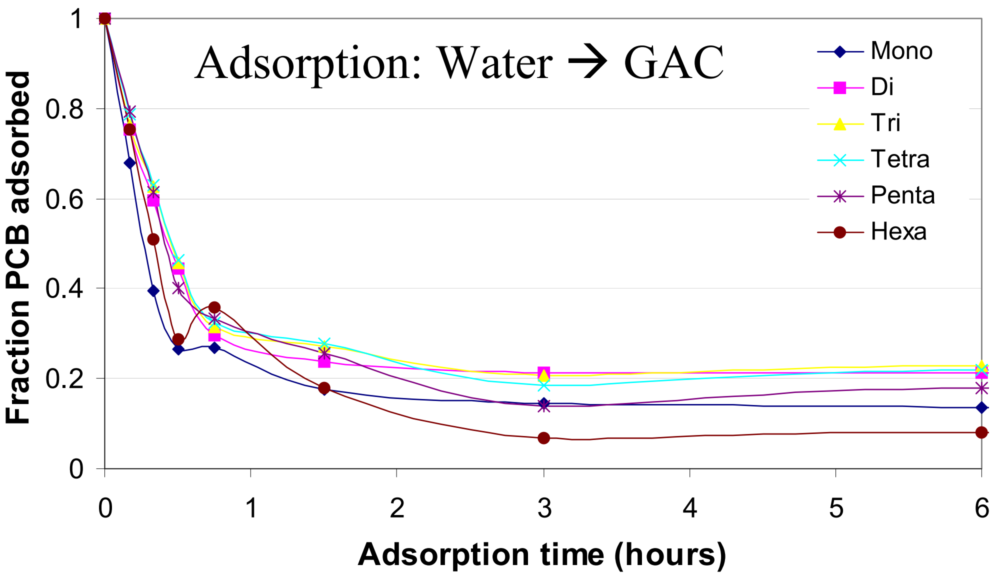
Expected reductions in dioxin/furan aq. conc. based on Kow



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.

Significant findings

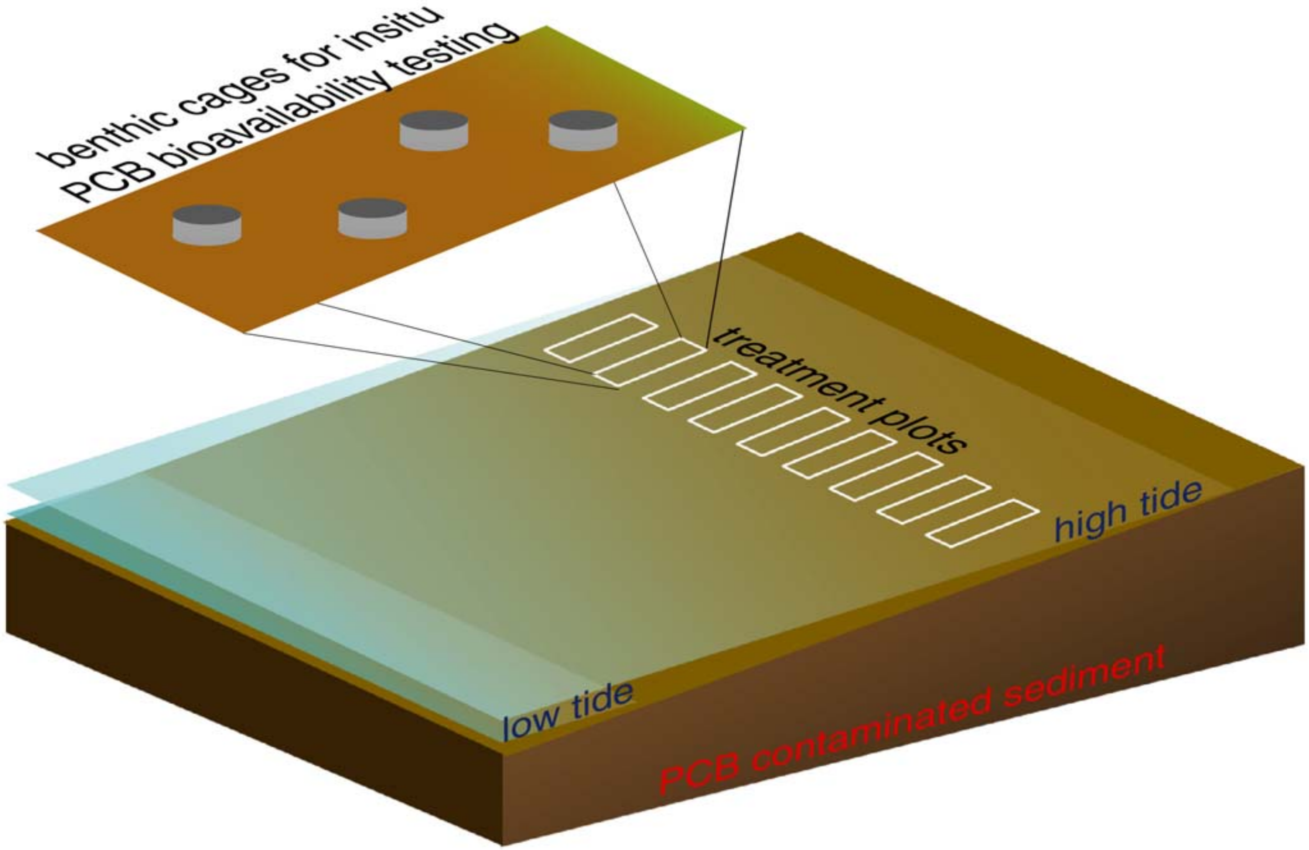
- **PCBs are transferred from sediment to GAC**
- **GAC - treatment reduces:**
  1. PCB bioaccumulation: clam, worm, amphipod
  2. Aqueous PCB concentration
  3. PCB uptake in SPMD
  4. PCB flux from sediment

- **Important ‘weight of evidence’**

Field testing challenges:

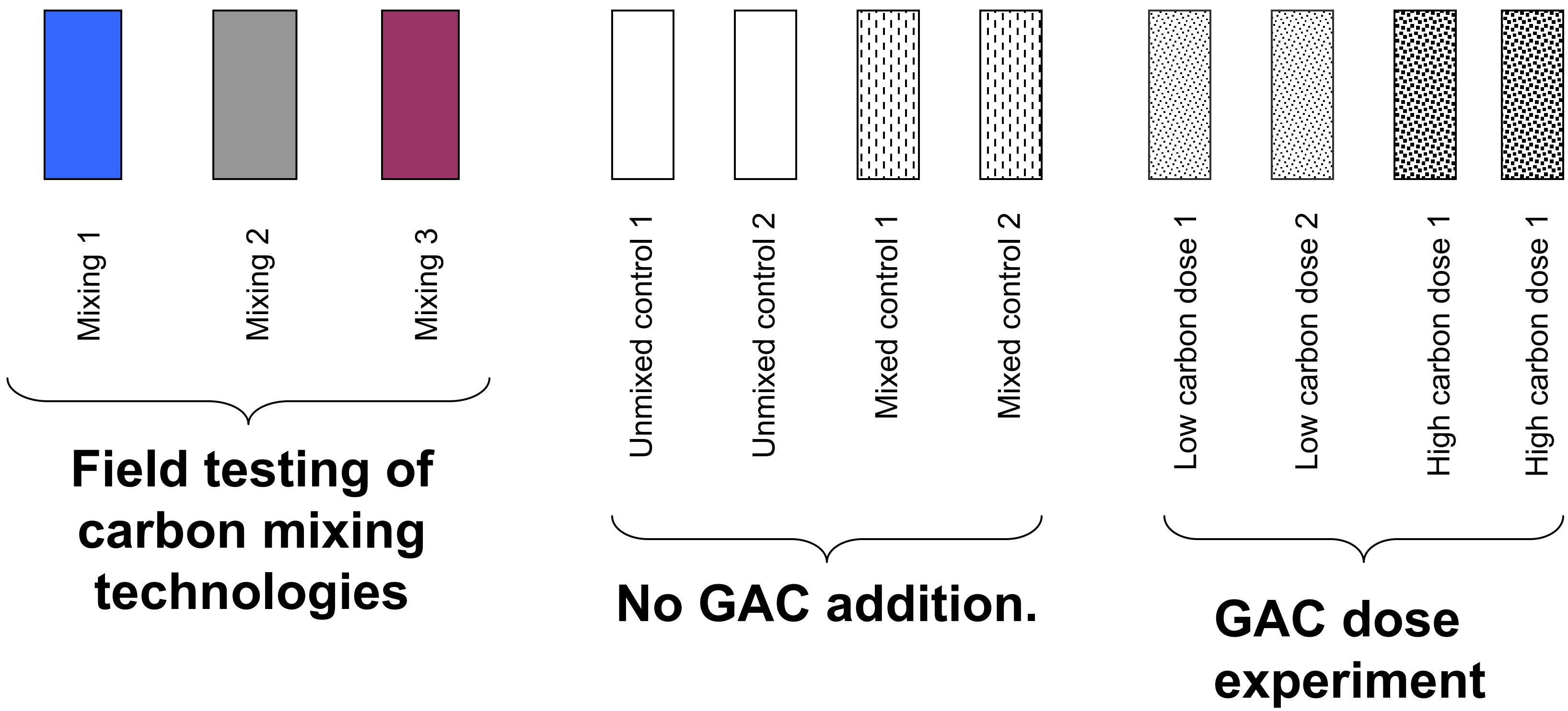
- Inter-tidal zone is exposed for a few hours during low tide
- Sediments are very soft and deployment of heavy equipment is difficult
- Need to minimize sediment resuspension and mobilization
- Need to evenly distribute the carbon with good mixing in the top 12 inches

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

Proposed field treatment plots



Main goals of field testing

- Select appropriate carbon deployment methods in the field
- Evaluate the degree of mixing of GAC practically achievable
- Measure PCB bioavailability reduction in the field
- Measure PCB mobility reduction in the field
- Assess the erosion potential of sediments mixed with GAC.
- Assess technology cost and transition to full-scale demonstration

Field Equipment for Carbon Mixing in Sediment

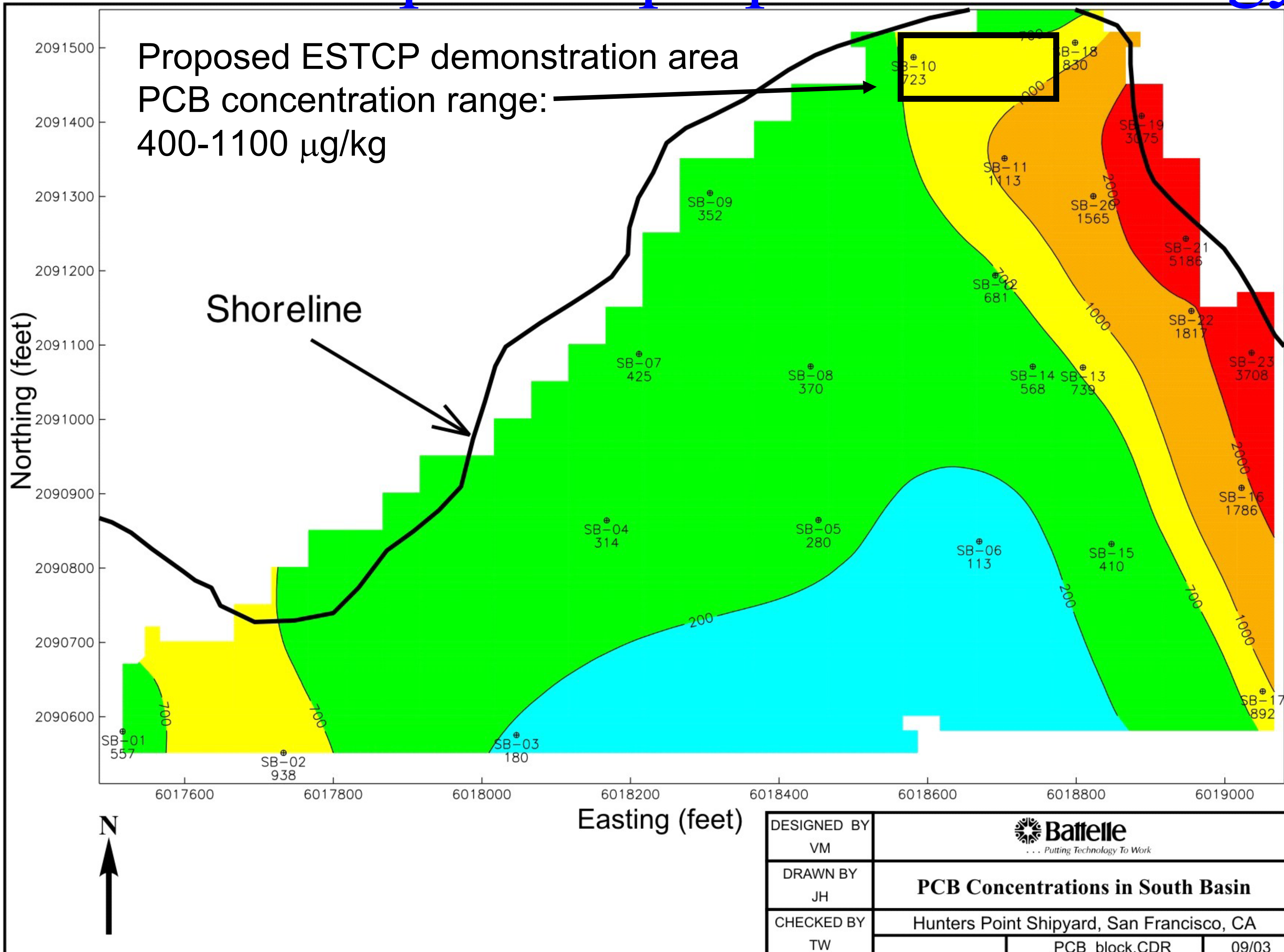
Aquamog: underwater rototiller
(Aquatic Environment)

Injection System
(Williams Environmental)

Demonstration/validation issues

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

Possible impact of proposed technology



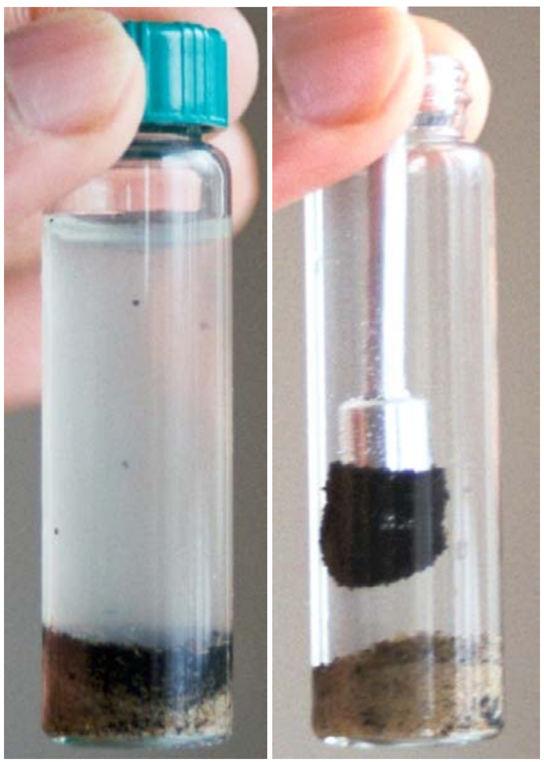
Acknowledgements

Sponsors:

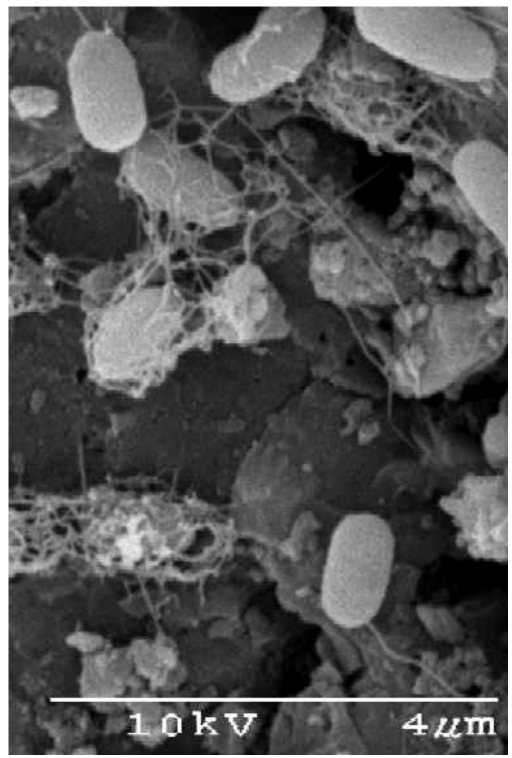
- Strategic Environmental Research and Development Program (DoD)
- Stanford Bio-X program
- Gift from Schlumberger
- UMBC faculty startup funds

Current and Proposed Research Direction

Retrievable Magnetic Activated Carbons



Bioavailability reduction and microbial dechlorination



Activated carbon amendment to sand caps