Welcome to the CLU-IN Internet Seminar

Contaminated Sediments: New Tools and Approaches for in-situ Remediation - Session II

Sponsored by: National Institute of Environmental Health Sciences, Superfund Research Program

December 8, 2010, 2:00 PM - 4:00 PM, EST (19:00-21:00 GMT)

Instructors:

Dr. Joel Burken, Professor of Civil, Architectural & Environmental Engineering and Interim Director of the Environmental Research Center (burken@mst.edu)

Dr. Upal Ghosh, Associate Professor and Graduate Program Director at the Department of Civil and Environmental Engineering, University of Maryland Baltimore County (ughosh@umbc.edu

Moderator:

Steve Ells, Leader of the Sediments Team in EPA's Office of Superfund Remediation and Technology Innovation (ells.steve@epa.gov)

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Housekeeping

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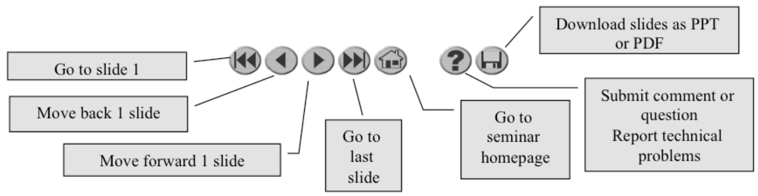

- This event is being recorded
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Sorbent amendments to reduce contaminant bioavailability in sediments

Upal Ghosh

Department of Civil & Environmental Engineering,

University of Maryland Baltimore County, Baltimore, MD

ughosh@umbc.edu

The Superfund Research Program

Risk e-Learning Web Seminar Series:

Contaminated Sediments: New Tools and Approaches for in situ Remediation.

December 8, 2010

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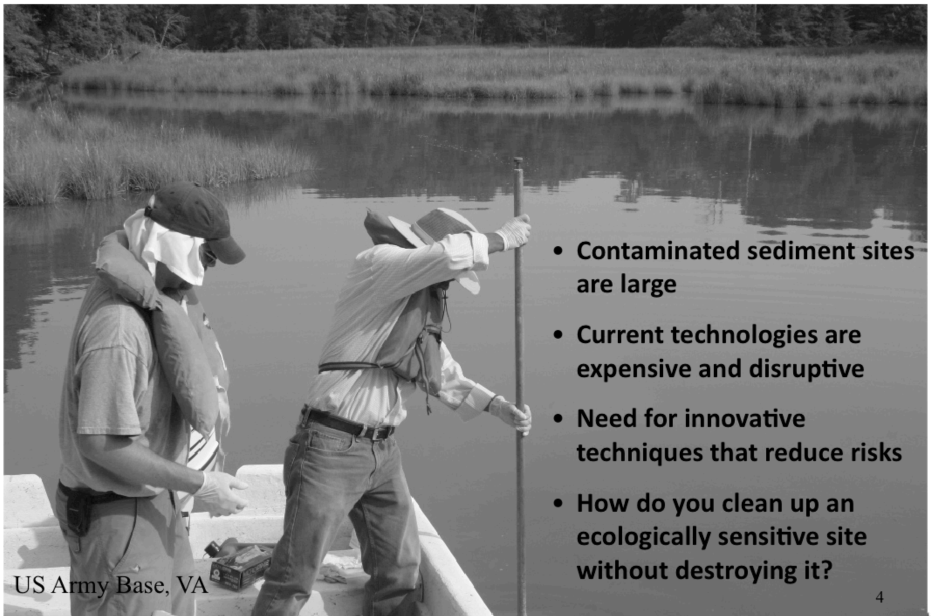
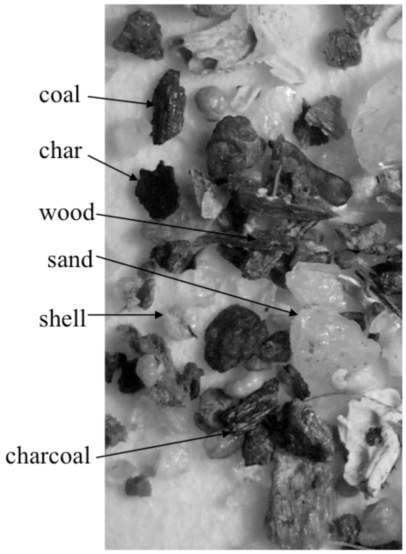
MANAGING EXPOSURE FROM HISTORIC DEPOSITS OF CONTAMINATED SEDIMENTS



NATURE OF SEDIMENT PARTICLES

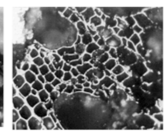


Hunters Point Sed (63-250 μm)

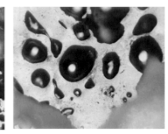
- Sediment contains sand, silt, clays, charcoal, wood, char, coal, & shells
- Coal petrography analyses identify carbonaceous particles
- PCBs/PAHs bound to carbonaceous particles less bioavailable

Petrography images

coal



charcoal



coke

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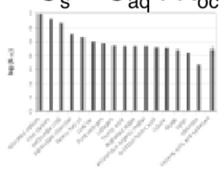
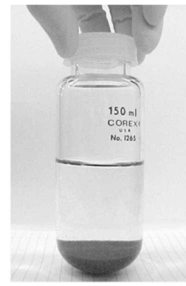
WATER PARTITIONING OF PHENANTHRENE FOR VARIOUS ORGANIC CARBONS

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



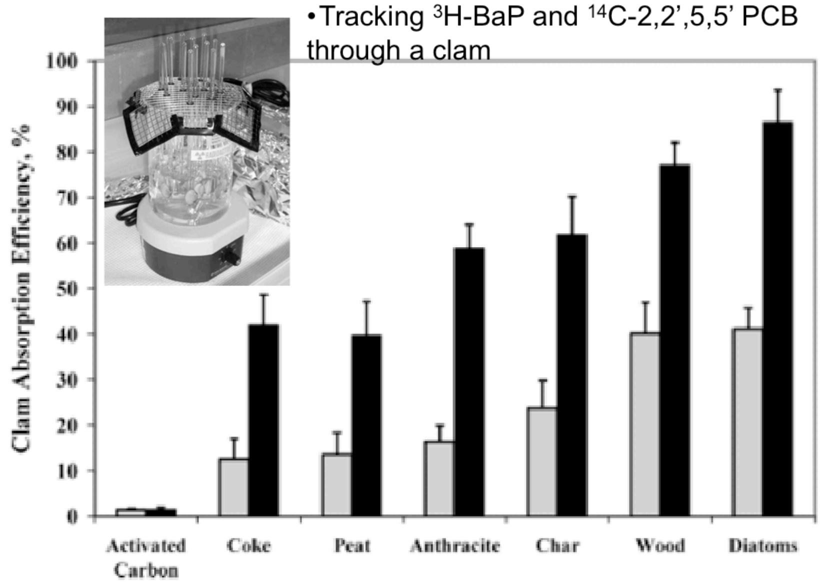
Need to identify sediment component(s) that have major influence on contaminant availability



6

PAH AND PCB ABSORPTION EFFICIENCY IN CLAMS

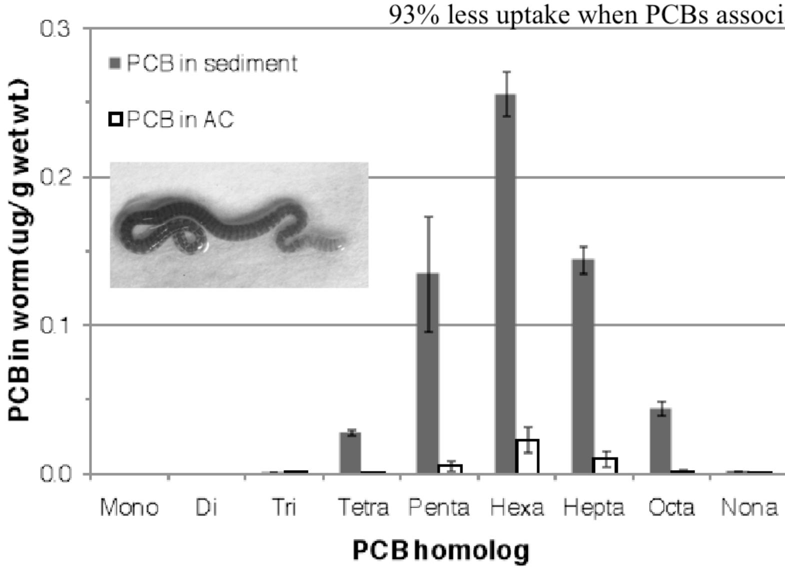
•Tracking ^{3}H-BaP and ^{14}C-2,2',5,5' PCB through a clam



From: McLeod et al. Environ. Sci. Technol. 2004

PCB ABSORPTION EFFICIENCY IN WORMS

PCB spiked to sediment or
PCB spiked to AC and added to sediment
93% less uptake when PCBs associated with AC



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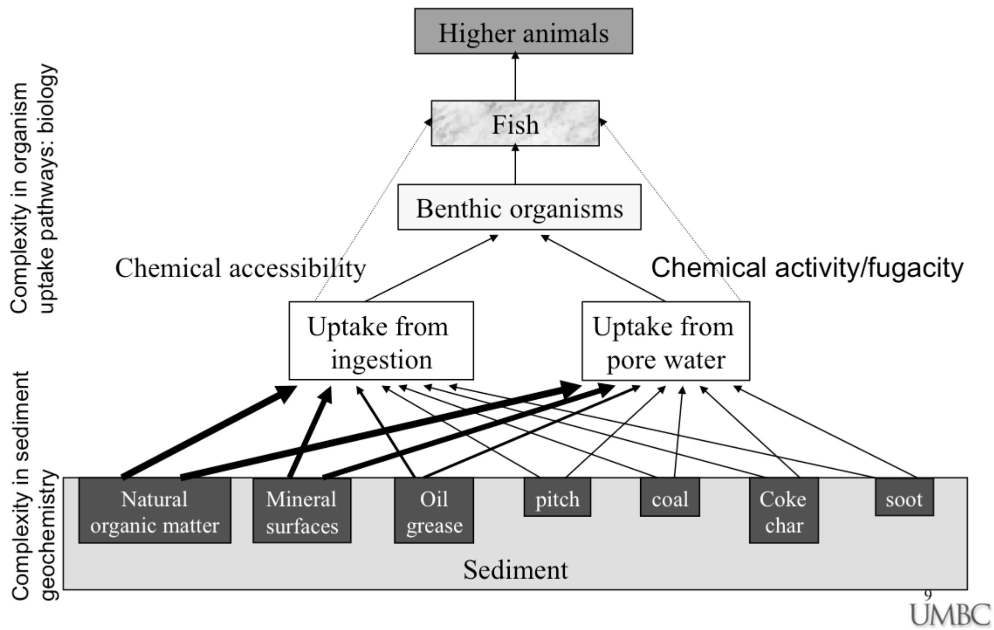
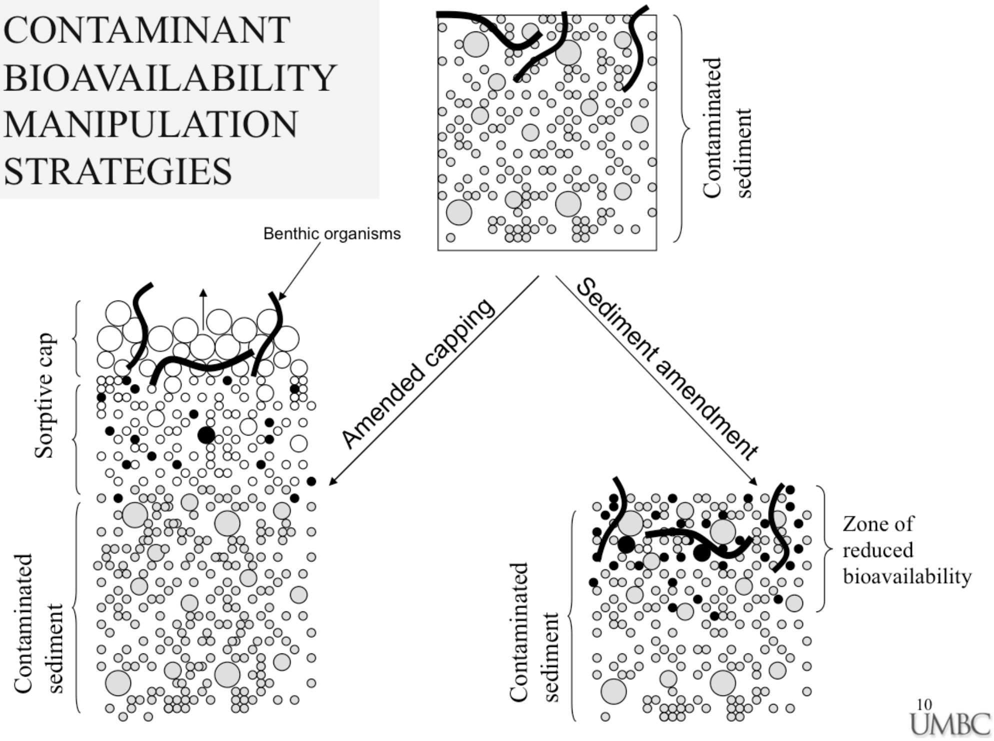
EMERGING UNDERSTANDING OF BIOAVAILABILITY



CONTAMINANT BIOAVAILABILITY MANIPULATION STRATEGIES



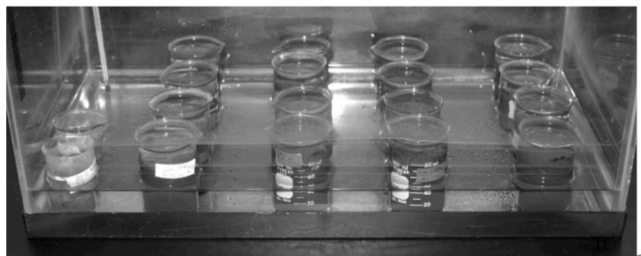
DIFFERENT MODES OF CARBON ADDITION:

- Our previous work mixed AC into sediment for 1-6 months
- Field application will typically involve little mechanical mixing
- Need to evaluate short-term or no mixing of AC

Different AC application modes:

Control	:no GAC added
Mixed 2.6%	:50×200 mesh GAC ; 2 min
Layered 2.6%	:50×200 mesh GAC; no mixing
Mixed 2.6%	:80×325 mesh GAC; 2 min.
Mixed 2.6%	:50×200 mesh GAC; 1 month.

Bioaccumulation testing based on USEPA 2000 using *Lumbriculus variegatus*



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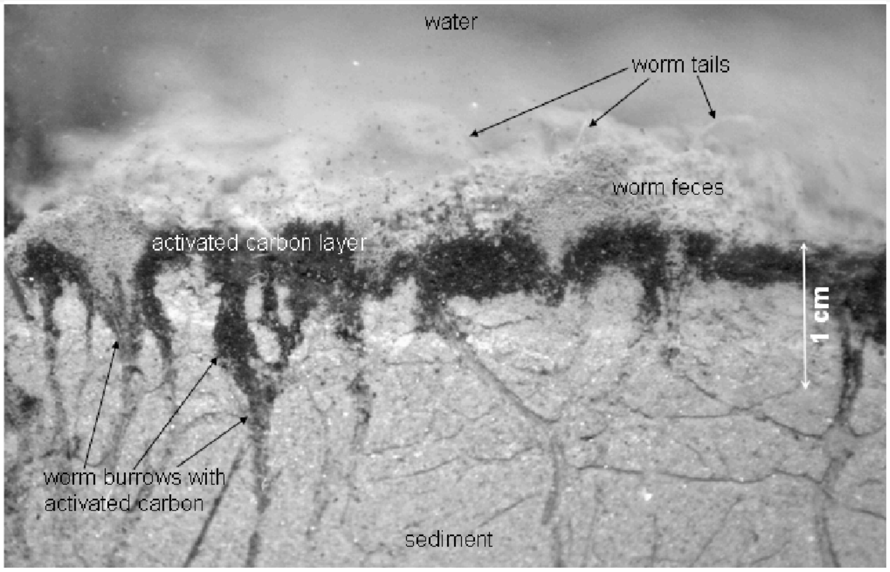
MIXING OF AC LAYER BY BIOTURBATION

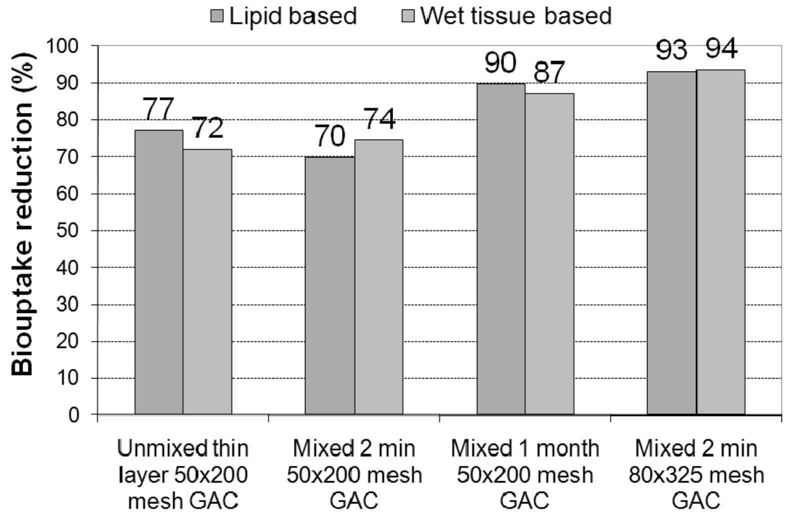


-Side view of a lab microcosm 2 days after placing a layer of AC on sediment
-AC is slowly worked into the sediment through bioturbation

Sun & Ghosh, ES&T 2007

12

REDUCTION IN TOTAL PCB BIOUPTAKE:



Sun and Ghosh, ES&T 2007

- > 70% reduction in PCB biouptake after brief or no mixing of AC
- PCB biouptake reduction enhanced with AC contact time
- Finer AC works better

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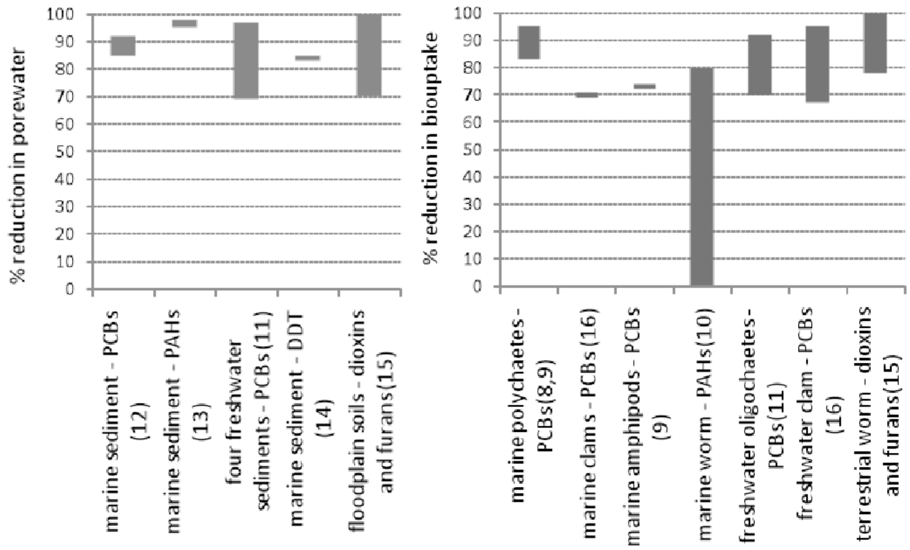
SUMMARY RESULTS FROM LABORATORY STUDIES



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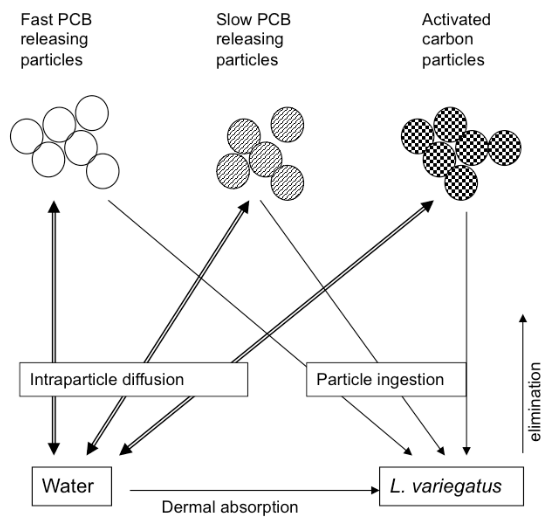
CONCEPTUAL MODEL OF CONTAMINANT MASS TRANSFER IN SEDIMENTS



Sun et al, ES&T 2009

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MODELING PCB BIOUPTAKE

- 1st order bioaccumulation model for *L. variegatus*

- 2 major routes:
    - adsorption from water
    - sediment ingestion

$$\frac{d}{dt}C_b(t) = k_{derm} \cdot C_{aq}(t) + \sum \alpha_i \cdot S_i \cdot f \cdot C_{s,i}(t) - k_{elim} \cdot C_b(t)$$

Measure parameters experimentally: k_{derm}, k_{elim} , α

Couple biouptake model with a PCB inter-particle mass transfer model:

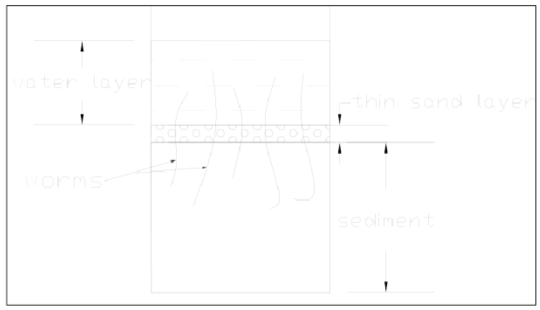
$$\frac{dC_{aq}}{dt} = -\frac{V_{fp}}{V_{aq}}\frac{d}{dt}\left[\frac{3}{R_{fp}^3}\int_0^{R_{fp}} r^2 C_{fp}(r)dr\right] - \frac{V_{hp}}{V_{aq}}\frac{d}{dt}\left[\frac{3}{R_{hp}^3}\int_0^{R_{hp}} r^2 C_{hp}(r)dr\right] - \frac{V_{ac}}{V_{aq}}\frac{d}{dt}\left[\frac{3}{R_{ac}^3}\int_0^{R_{ac}} r^2 S_{ac}(r)dr\right]$$

Sun et al, ES&T 2009

INGESTION RATE AND EXTRACTION EFFICIENCY

- Transfer sediment into 100 ml beaker
- Place thin layer of sand on the top of sediment
- Surface water: 2-3 cm
- Collect feces collected above sand layer
- Calculation:

$$\alpha = (1 - \frac{C_{feces}}{C_{sed}}) \times 100$$



Sun et al, ES&T 2009

17

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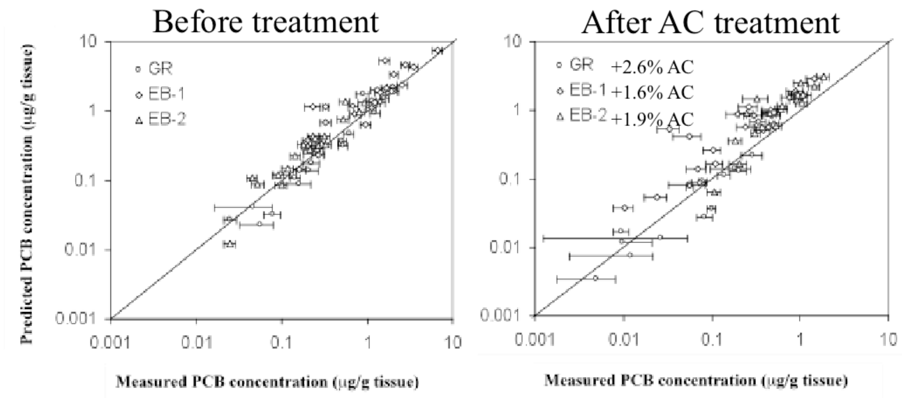
MEASURED AND PREDICTED BIOACCUMULATION



AC dose = 0.5X native TOC of sediment

PCB biouptake model can predict tissue concentration in untreated and AC-treated sediment

Sun et al, ES&T 2009

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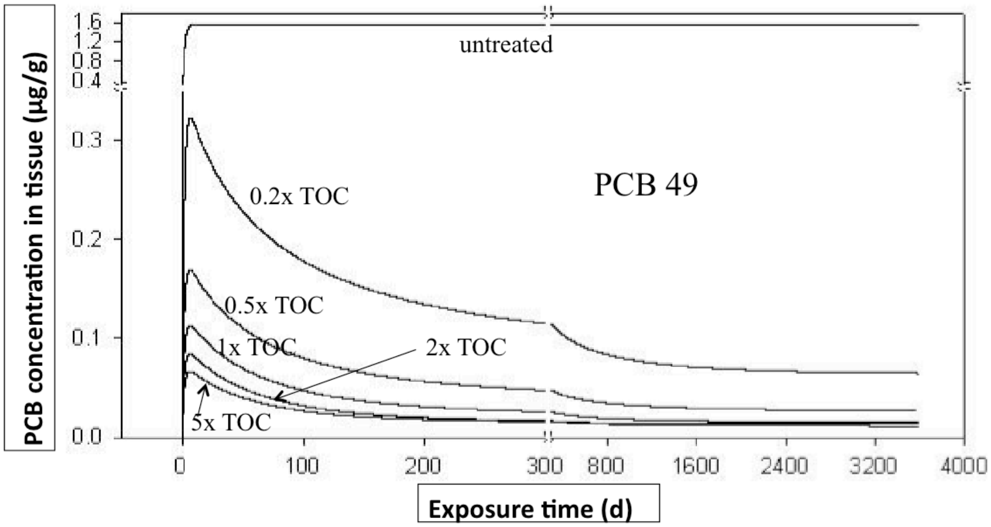
LONG-TERM PREDICTION OF PCB BIOUPTAKE REDUCTION AS A FUNCTION OF AC DOSE



> 90% reduction in PCB biouptake in 1 year with 1XTOC dose

Sun et al, ES&T 2009

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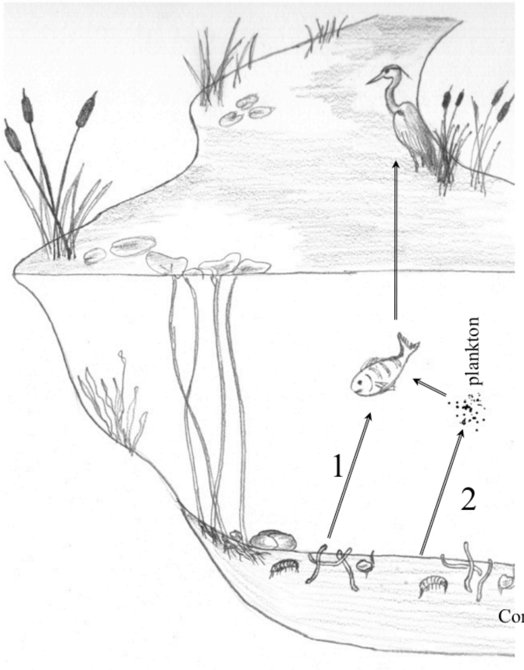
CONCEPTUAL MODEL: BEFORE TREATMENT



Legacy contaminants in exposed sediment contaminates the food chain through:

1) bioaccumulation in benthic organisms
2) flux into the water column, and uptake in the pelagic food web.

20

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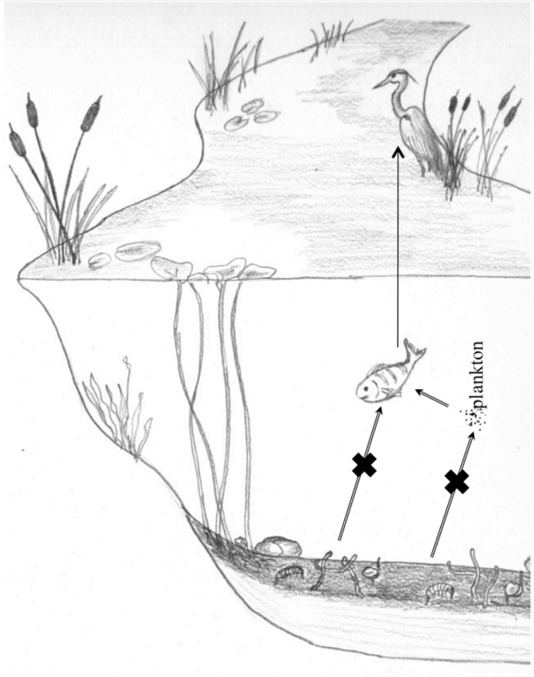
CONCEPTUAL MODEL: AFTER TREATMENT



Activated carbon amended to surficial sediments reduces contaminant 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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ONGOING AC DEMONSTRATION PROJECTS

San Francisco Bay, CA, USA 2006

Grasse River, NY, USA 2006

Trondheim Harbor, Norway 2006

Bailey Creek, VA, USA 2009

Grenlandsfjords, Norway 2009

Figure 2 a) Application of activated carbon in a tidal mud-flat at Hunters Point Navy Shipyard, San Francisco Bay, CA using two application devices. The Aquamog (top) using a floating platform approached the site from water and used a rototiller arm while the slurry injection system (bottom) was land based and applied a carbon slurry directly into sediment.

b) Application of activated carbon under 15 feet of water at Grasse River, NY, USA. The site was enclosed with a silt curtain and application was performed using a barge mounted crane. Placement and mixing of the AC was achieved using two devices: 1) a 7-by-12-foot rototiller-type mixing unit (bottom left); and 2) a 7-by-10-foot tine sled device (bottom right)

c) Application of activated carbon slurry directly onto sediments at Trondheim Harbor, Norway. AC-salt water slurries with/without powdered bentonite clay were pumped 3-5 ft above the sediment bed under 20 ft of water. Part of the AC-only field was successfully covered with 5 mm sand to protect from erosion.

d) Application of activated carbon in a pelletized form using an air blown dispersal device over a vegetated wetland impacted with PCBs near James River, VA, USA. Picture below illustrates bioturbation induced breakdown and mixing of pelletized carbon with a fluorescent tag in a laboratory aquarium

e) Application of AC-clay mixture at 100 and 300 ft depth, Grenlandsfjords, Norway. A hopper dredge was used to pick up clean clay from a site and use it in reverse to mix and place a AC-clay mixture on the site. Sediment-profile imaging and sediment coring (bottom figure) showed that placement of an even active cap was successful

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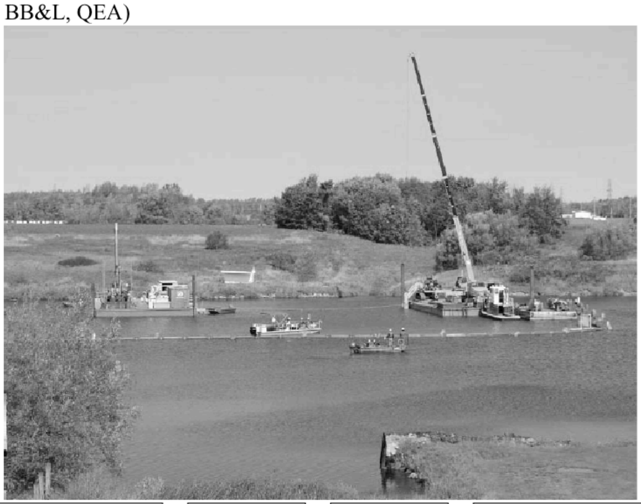
PILOT DEMONSTRATION IN GRASSE RIVER

(Participants: Alcoa, EPA, UMBC, Stanford University, Anchor Env., Brennan, Tetra Tech, Arcadis-BB&L, QEA)



Mixed Tiller (75' x 100')

Unmixed (50' x 50')

Tine Sled (50' x 60')

Initial testing area (50' x 100')

- L-shaped silt screen to minimize suspended particle transport
- Equipment mobilized on barges
- Target dose of activated carbon = 0.5x TOC in surficial sediments (+50% safety factor)
- No measurable change in water-column PCBs downstream
- Post-treatment monitoring for 3 years

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DELIVERY DEVICES USED AT GRASSE RIVER, NY

Tine injection system
Designed and built by Brennan with inputs from collaborators

Injection and mixing in an enclosed rototiller
Designed and built by Brennan with inputs from collaborators

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GRASSE RIVER ACTIVATED CARBON PILOT BASELINE AND LONG-TERM MONITORING

Parameter	Baseline (Aug/Sep '06)	After Placement (Oct '06)	Year 1 (Fall '07)	Year 2 (Fall '08)	Year 3 (Fall '09)
Black carbon in sediment cores	√	√	√	√	√
Field PCB biouptake	√		√	√	√
Lab PCB biouptake	√		√	√	√
Equilibrium	√		√	√	√
Desorption	√		√	√	
Benthic community	√		√	√	√
Erosion potential	√		√	√	
Impact of AC on aquatic plant growth					√

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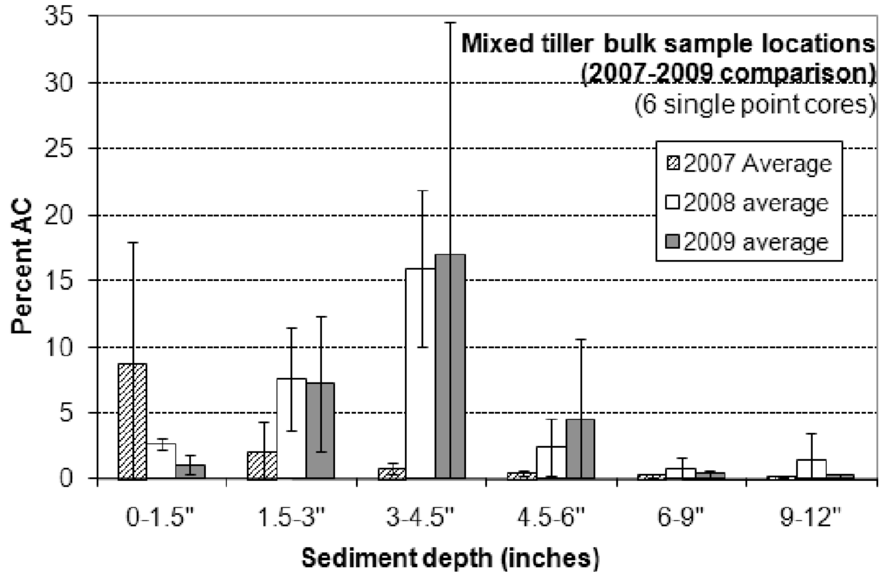
CARBON PROFILE WITH TIME



26
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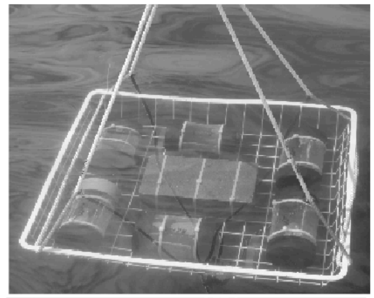
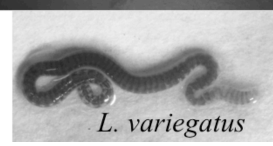
IN-SITU PCB MONITORING STUDIES



In-river deployment of field exposure cages with *L. variegatus* for baseline study (method adapted from Burton et al. 2005)



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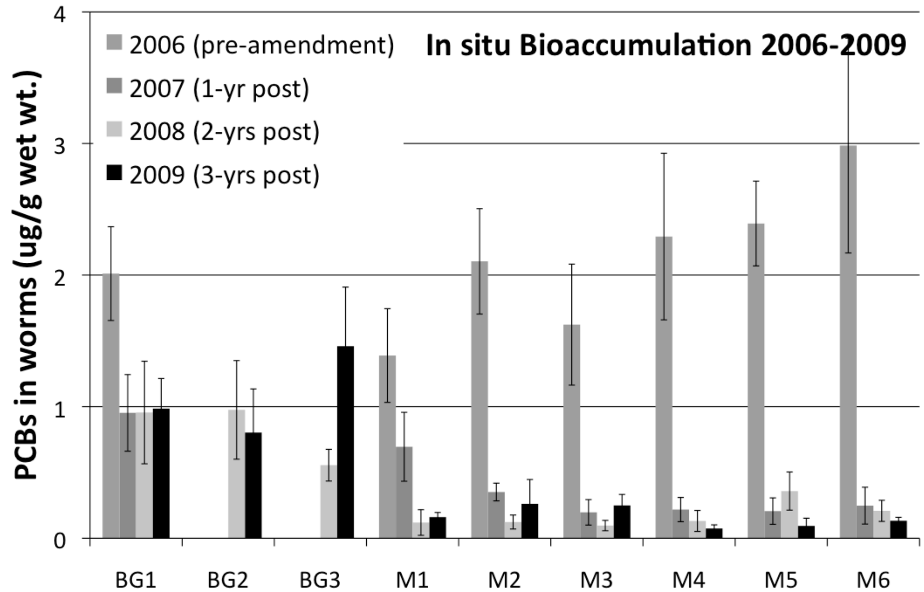
PCB IN L. VARIEGATUS IN-SITU EXPOSURE



Background sites Mixed treatment sites

- % reduction over 3 years: 46% in BG sites and 92% for Mixed Tiller sites

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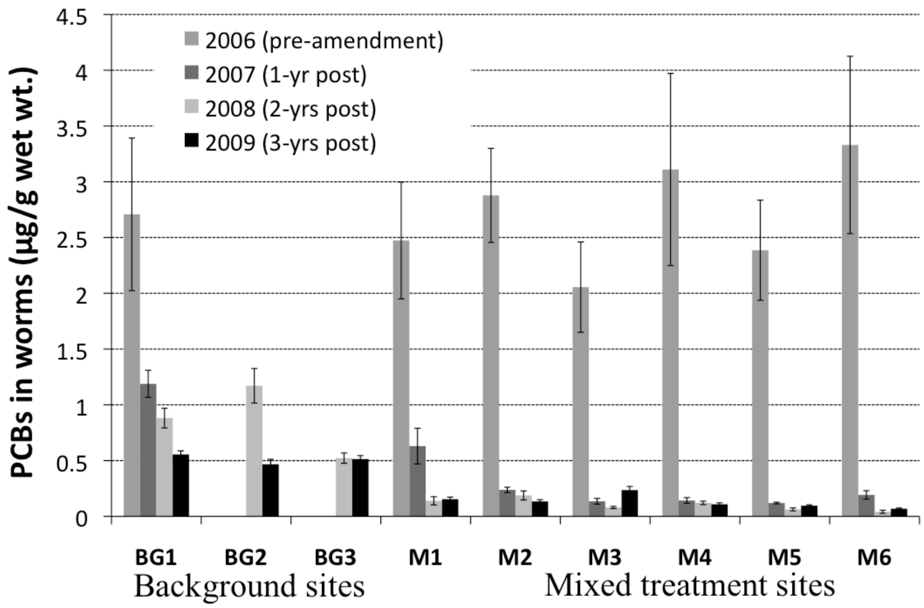
PCB IN L. VARIEGATUS EX-SITU EXPOSURE



- % reduction over 3 years: 80% in BG sites and 95% for Mixed Tiller sites

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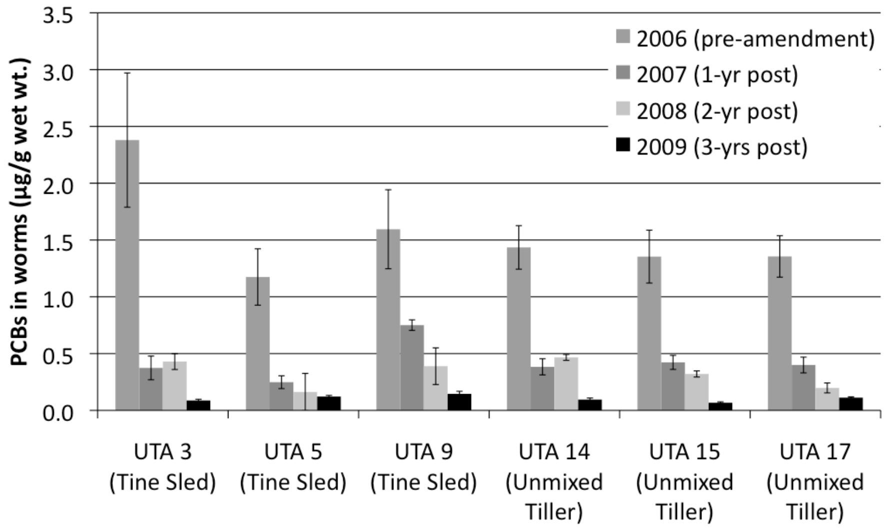
PCB IN L. VARIEGATUS EX-SITU EXPOSURE (CONT.)



- % reduction over 3 years: 93% for Tine sled and Unmixed Tiller sites
- AC continues to be effective in reducing PCB bioaccumulation over 3 years in all 3 treatment areas

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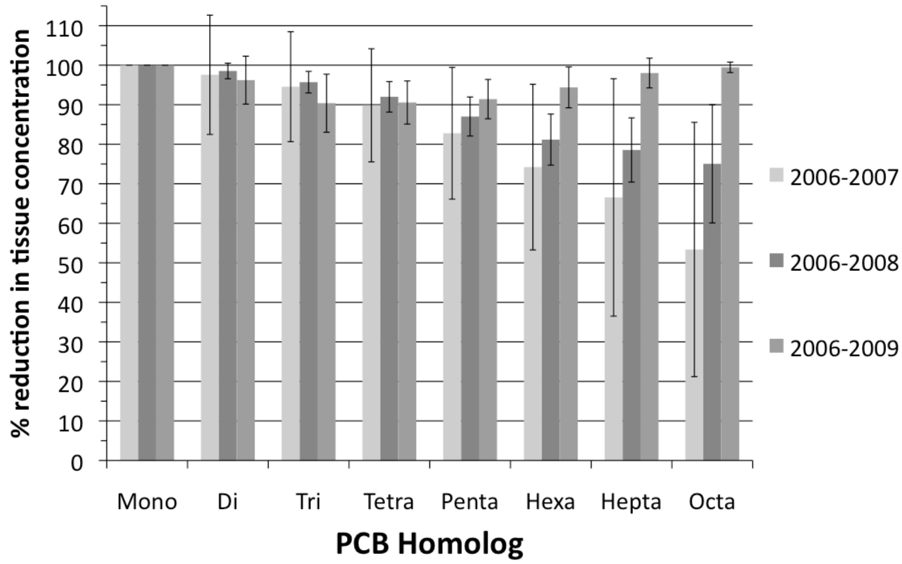
PERCENT REDUCTION IN PCB UPTAKE IN-SITU



% reduction in the higher chlorinated congeners better with time for both treated and background sites

31
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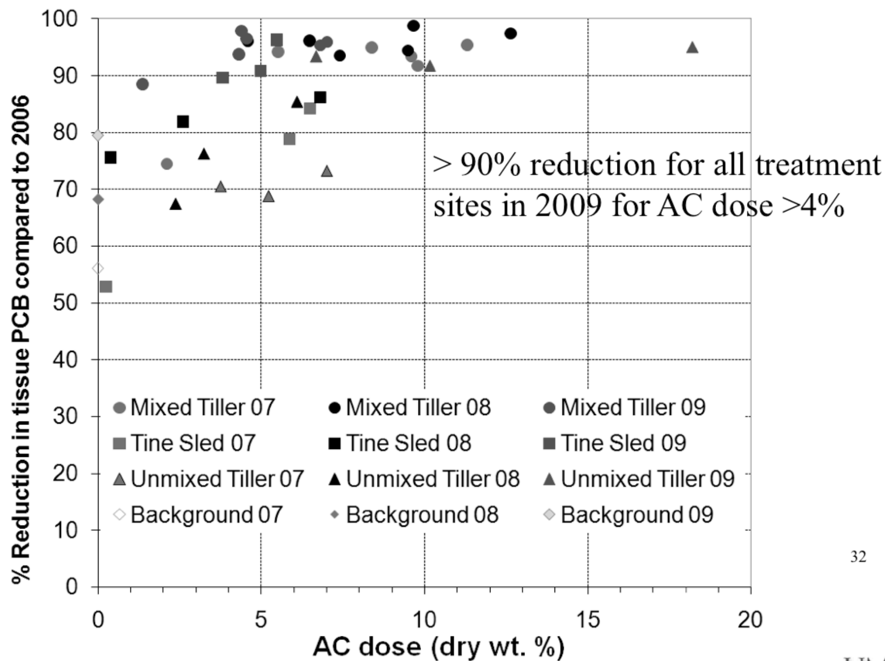
% REDUCTION IN WORMS VS. AC DOSE



32

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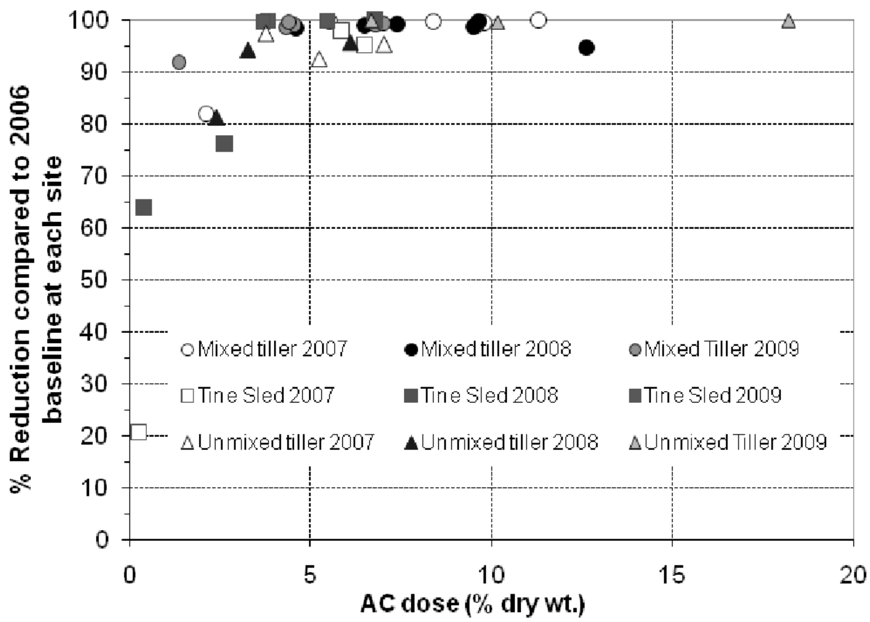
AQUEOUS EQUILIBRIUM REDUCTION VS. AC DOSE



33

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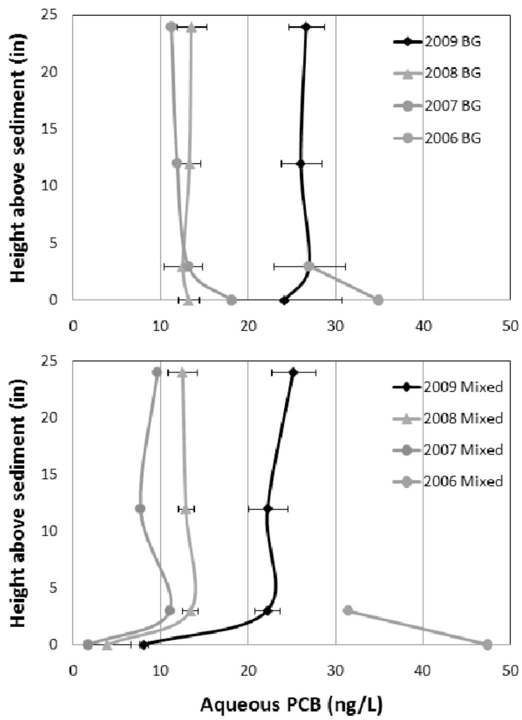

PCB IN WATER BASED ON IN-SITU PASSIVE SAMPLERS

Reduced aqueous PCB on sediment surface at AC treated sites compared to overlying wa

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KEY LEARNINGS FROM PILOT-SCALE STUDIES:

1. AC can be applied to sediment in a large scale
2. AC remains in place 3 years after placement
3. Reductions in porewater PCB levels & desorption
4. Reductions in tissue PCB levels
5. Over time, the AC-amended sediment is covered with new sediment deposit
6. No major changes to benthic community due to amendment

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THE BIG PICTURE:

5% AC by dry wt in top 4” = 6 lb/sq. yd. = **30,000 lb/acre**
(equivalent to 2 mm sedimentation)

100 acre site: 3M lb of AC (<1% of US annual production of AC)

Material cost at $1/lb cost of AC = **$30,000/acre**
Application cost will depend on the method utilized

Promising considerations:

- Application of small increments over multiple years to incorporate into annually deposited sediments
- Use of activated biochars from agricultural residue can provide additional opportunity for carbon sequestration
- Low-impact delivery methods

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LIST OF PUBLICATIONS ON IN-SITU AMENDMENTS

1. Bioaccumulation of polychlorinated dibenzo-p-dioxins/dibenzofurans in *E. foetida* from floodplain soils and the effect of activated carbon amendment. Sonja K. Fagervold, Yunzhou Chai, John W. Davis, Michael Wilken, and Upal Ghosh. ***Environ. Sci. Technol***. 2010, 44, 5546-5552.
2. Modeling the mass transfer of hydrophobic organic pollutants in briefly and continuously mixed sediment after amendment with activated carbon. Hale, S.E.; Werner, D. ***Environ. Sci. Technol***. 2010, 44, 3381-3387.
3. Evaluation of sorbent amendments for in situ remediation of metal contaminated sediments. Seokjoon Kwon, Jeff Thomas, Brian E. Reed, Laura Levine, Victor S. Magar, and Upal Ghosh. In press, ***Environ. Toxicol. Chem***., 2010.
4. Polychlorinated biphenyl sorption and availability in field-contaminated sediments. Werner, D; Hale, S.E.; Kwon, S.; Ghosh, U.; Luthy, R.G. Environ. Sci. Technol. 2010, 44, 2809-2815.
5. Quantification of activated carbon contents in soils and sediments using chemothermal and wet oxidation methods. Braendli, Rahel; Bergsli, Anders; Ghosh, Upal; Hartnik, Thomas; Breedveld, Gijsbert; Cornelissen, Gerard. ***Environmental Pollution.*** 157, 3465-3470, 2009.
6. Field application of activated carbon amendment for in-situ stabilization of polychlorinated biphenyls in marine sediment. Cho, Y., Ghosh, U., Kennedy, A. J., Grossman, A., Ray, G.; Tomaszewski, J. E., Smithenry, D., Bridges, T. S., Luthy, R. G. ***Environ. Sci. Technol***. 43, 3815-3823, 2009.
7. Modeling PCB Mass Transfer and Bioaccumulation in a Freshwater Oligochaete before and after Amendment of Sediment with Activated Carbon. Sun, X.; Werner, D.; Ghosh, U. ***Environ. Sci. Technol***., 43, 1115-1121, 2009.
8. Measurement of Activated Carbon and Other Black Carbons in Sediments. Adam Grossman, and Upal Ghosh. ***Chemosphere,*** 75, 469-475, 2009.
9. The effect of activated carbon on partitioning, desorption, and biouptake of native PCBs in four freshwater sediments. X. Sun and U. Ghosh. ***Environ. Toxicol. Chem***. 27, 2287-2295. 2008.
10. The Stability of Marine Sediments at a Tidal Basin in San Francisco Bay Amended with Activated Carbon for the Sequestration of Organic Contaminants. John R. Zimmerman, Philip J. Dacunto, Jeremy D. Bricker, Craig Jones, Robert L. Street, and Richard G. Luthy. ***Water Research***; 42(15) pp 4133-4145; 2008.
11. Biodynamic Modeling of PCB Uptake by Macoma balthica and Corbicula fluminea from Sediment Amended with Activated Carbon, " Pamela B. McLeod, Samuel N. Luoma and Richard G. Luthy. ***Environ Sci. & Technol***; 42(2) pp 484 - 490; 2008.
12. PCB Bioavailability Control in *Lumbriculus variegatus* Through Different Modes of Activated Carbon Addition to Sediments. X. Sun and U. Ghosh. ***Environ. Sci. Technol***. 41, 4774-4780, 2007.
13. Activated Carbon Amendment as a Treatment for Residual DDT in Sediment from a Superfund Site in San Francisco Bay, Richmond, California, USA, Jeanne Tomaszewski and Richard G. Luthy, ***Environmental Toxicology & Chemistry***, vol. 26, pp 2143-2150, 2007.
14. Field methods for amending marine sediment with activated carbon and assessing treatment effectiveness. Y-M. Cho, D.W. Smithenry, U. Ghosh, A.J. Kennedy, R.N. Milward, T.S. Bridges, R.G. Luthy. ***Marine Environment Research***. 64, 541–555, 2007.
15. Biological Uptake of Polychlorinated Biphenyls by Macoma balthica from Sediment Amended with Activated Carbon, Pamela B. McLeod, Martine J. van den Heuvel-Greve, Samuel N. Luoma, and Richard G. Luthy, **Environmental Toxicology & *Chemistry***, vol. 26, no. 5 pp. 980-987, 2007.
16. Modeling Polychlorinated Biphenyl Mass Transfer after Amendment of Contaminated Sediment with Activated Carbon. D. Werner, U. Ghosh, and R. G. Luthy. ***Environ. Sci. Technol***. 40, 4211-4218. 2006.
17. Addition of Activated Carbon to Sediments to Reduce PCB Bioaccumulation by a Polychaete (Neanthes arenaceodentata) and an Amphipod (Leptocheirus plumulosus). R.N. Millward, T.S. Bridges, U. Ghosh, J.R. Zimmerman, R.G. Luthy. ***Environ Sci. Technol***. 39, 2880-2887, 2005.
18. The Effects of Dose and Particle Size on Activated Carbon Treatment to Sequester Polychlorinated Biphenyls and Polycyclic Aromatic Hydrocarbons in Marine Sediments. J.R. Zimmerman, D. Werner, U. Ghosh, R.N. Millward, T.S. Bridges, R.G. Luthy. ***Environ. Toxicol. Chem***. 24, 1594-1601, 2005.
19. Response to comment on: "Addition of carbon sorbents to reduce PCB and PAH bioavailability in marine sediments. Physicochemical tests. J.R. Zimmerman, U. Ghosh, R.G. Luthy, R.N. Millward, T.S. Bridges. J.R. Zimmerman, U. Ghosh, R.G. Luthy, R.N. Millward, T.S. Bridges. ***Environ Sci. & Technol***, 39, 1199-1200, 2005.
20. The Sequestration of PCBs in Lake Hartwell Sediment with Activated Carbon, David Werner, Christopher P. Higgins, and Richard G. Luthy, ***Water Research***, vol. 39, pp. 2105-2113, 2005.
21. Effects of Particulate Carbonaceous Matter on the Bioavailability of Benzo[a]pyrene and 2,2',5,5' Tetrachlorobiphenyl to the Clam, Macoma balthica. McLeod, P.M., M.J. van den Heuvel-Greve, R.M. Allen-King, S.N. Luoma, and R.G. Luthy,. ***Environ. Sci. & Technol***., vol. 38(17), pp. 4549-4556. 2004
22. Addition of carbon sorbents to reduce PCB and PAH bioavailability in marine sediments. Physicochemical tests. J.R. Zimmerman, U. Ghosh, R.G. Luthy, R.N. Millward, T.S. Bridges. ***Environ Sci. & Technol***, 38, 5458-5664, 2004.

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38

UMBC

Contaminated Sediments: New Tools and Approaches for *In Situ* Remediation Using Amendments

Joel G Burken, Professor & Assoc Chair
Missouri University of Science and Technology

39

Coauthors and support

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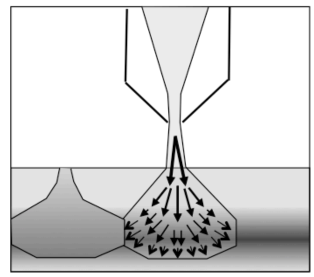
  Program officer: Heather Henry

40

Background – Waterjet Amendment



- Controlled placement of remediation amendments into sediments :
  - Liquid
  - Activated Carbon
  - Fe^0 - ZVI
  - Reductions in contaminant resuspension vs. other methods
- Reductions in benthic mortality vs. other methods

41

Preliminary work summary

- Liquid/aqueous amendments can be injected to depth with Pulsed injections.
- Solid amendments were Troublesome
  - Concentration limitations
  - Plugging, the stop-start stalls and packs amendment
  - Damage to equipment
- Testing into Surrogate sediments
  - Minimal surface disturbance.
  - Minimal resuspension was observed.

42

Pulsed Injection: Liquid amendment

43

Pulsed Injection: Liquid amendment

44

Pulsed Injection: Liquid amendment

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Pulsed Injection: Liquid amendment

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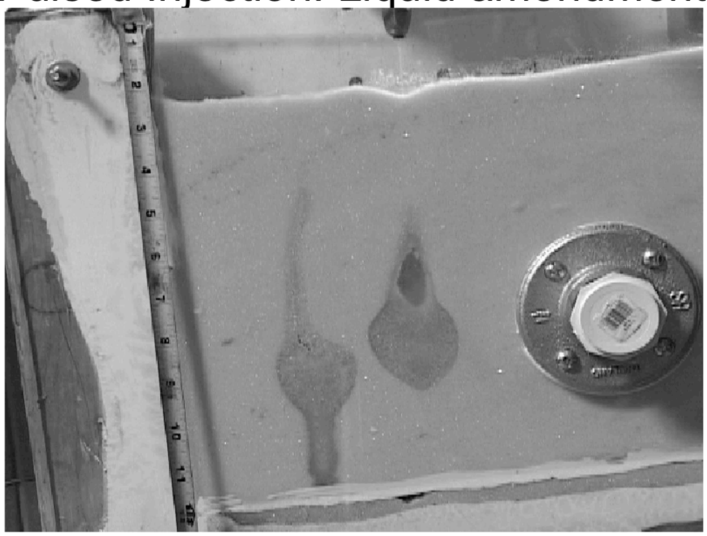
Pulsed Injection: Liquid amendment

47

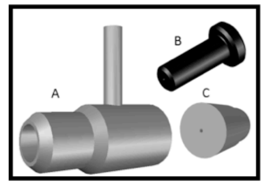
Pulsed Injection: Liquid amendment

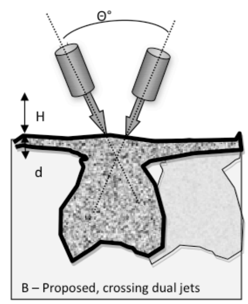


48

Granular Amendment Delivery Method 1

- Pneumatic amendment delivery Amendment and water meet at the nozzle.
- Single Pulse 'blast' using a pressure dissipation method
- Constant flow single nozzle
- Constant flow dual nozzle

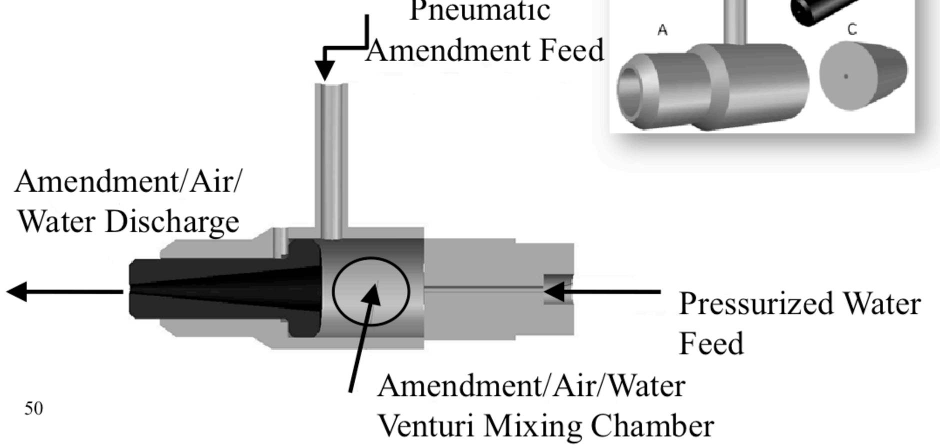




49

Pneumatic delivery: Nozzle Design

- Independently pressurized air and water feeds



50

Test nozzle created that eliminated issues found in prototype testing.

Composed of three components: solid aluminum mixing chamber, carbide or steel discharge (collimating) nozzle, aluminum water injection nozzle

Solid aluminum construction.

Adjustable mixing chamber.

Interchangeable discharge nozzles.

Pneumatic Performance – Concentration Tests

Pump (psi)	% Fe in Discharge
700	33.0
1,000	54.7
1,500	46.8
1,500	46.5
Using Atomet28 from QMP while maintaining pressure vessel and nozzle conditions.	

Pump (psi)	% PAC in Discharge
200	47
300	16
700	16
1,000	10
Using WPH powdered activated carbon from Calgon Carbon Corporation while maintaining pressure vessel and nozzle conditions.	

51

Iron captured in filter bag and water captured in filter bag containment vessel.

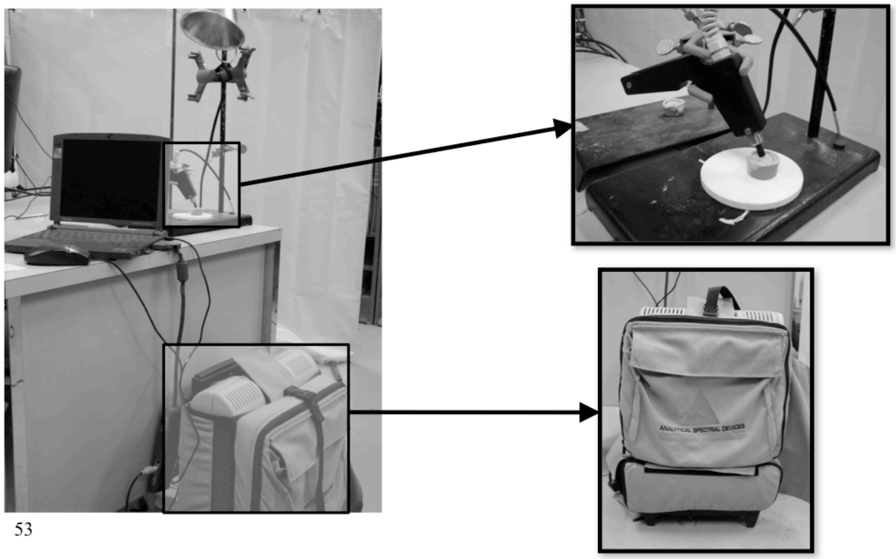
PAC Quantification Methods – Spectroradiometer

- Spectroradiometer – measures reflectance of light off of a sample vs. the wavelength emitted from the light source

- Differentiates between different concentrations of carbon within kaolinite clay due to highly contrasting color

52

Quantification Methods – Spectroradiometer



Spectroradiometer setup

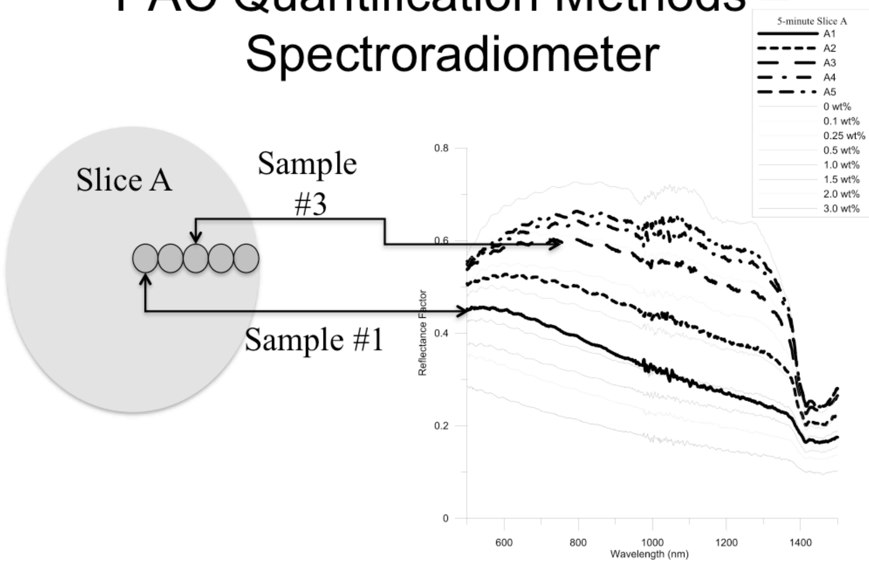
DC light source

Fiber optic bundle

Spectroradiometer

Laptop for data recording

PAC Quantification Methods – Spectroradiometer

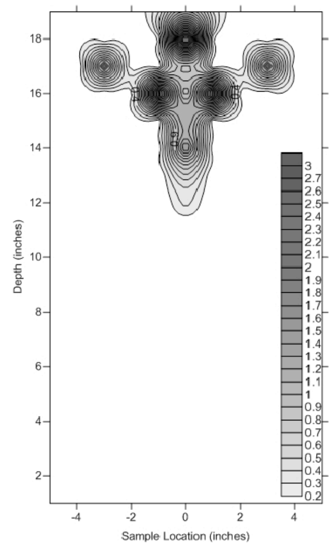


54

PAC Concentration Distribution

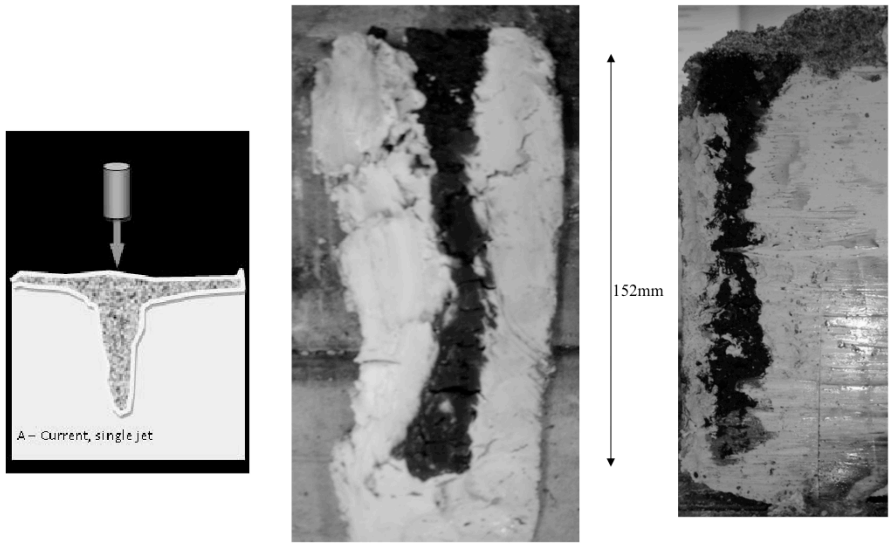
Spectroradiometer data

- 5-minute injection duration at 500 PSI
- Depth ~ 8 inches
- Pocket formation



55

Injection Profiles

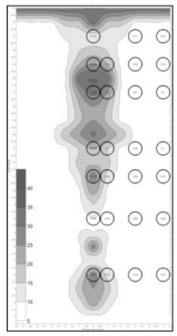


56

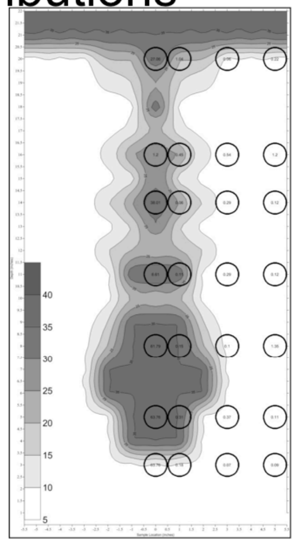
Iron Concentration Distributions

- Depth ~ 20 inches
  - 2.5 times PAC injection depth
- Pocket/Vein distribution: Likely due to the air escape from the pneumatic delivery of amendment
- Pneumatics caused high resuspension

57



30 second injection



1 minute injection

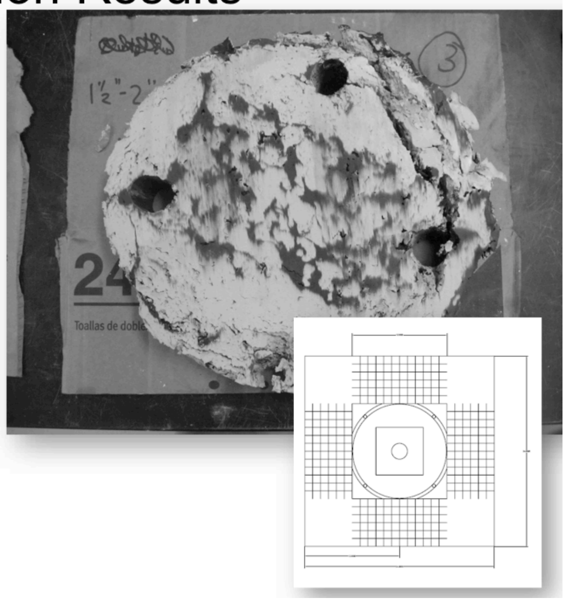
Positive Displacement Methods Characteristics

- Graco Tradeworks 170, 5/8 hp DC
- Flow Rate: 210 mL/ 7 second shot
- Straight Nozzle, 0.023”diameter
- Carbon Slurry: 15% carbon by weight
- Test bed: Fully saturated Kaolinite
- 54 shots taken on 1" increment. [9 shots horizontally] and [6 shots vertically]
- Burst Injection at 2500 psi stabilizing at 700 psi for 5 seconds

58

Injection Results

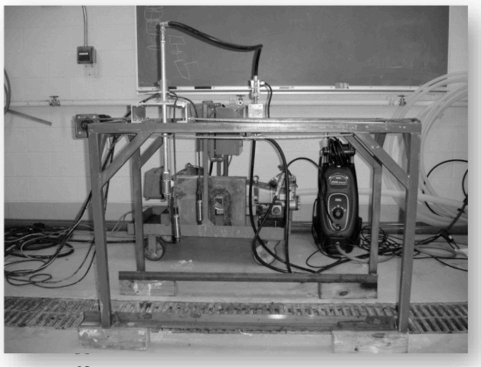
- Achieved 3.4% carbon at depths of 20 cm and less
- In consolidated media individual injections were still distinguishable

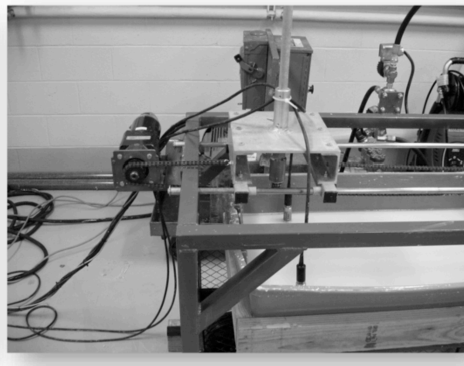


59

Constant Flow Slurry Injections

- Testing platform developed to repeat testing
- Control flow, traverse speed, lance location
- Capture video, turbidity, P, Q

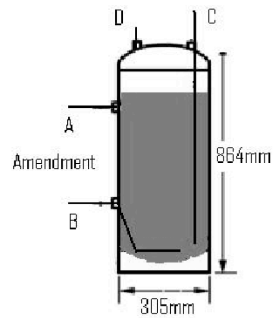




60

Continuous Slurry Systems

- Pressure chamber mixed pneumatically
- Up to 35% PAC in solution.
- 120 PSI, did not reach targeted depth of delivery, more pressure needed.. Pneumatic Danger.



- Progressive cavity pump.
- Hydracell Model D10 Pump
- 8 gpm max, up to 1200 PSI

61

Single Nozzle, continuous flow

PAC injected into Kaolin

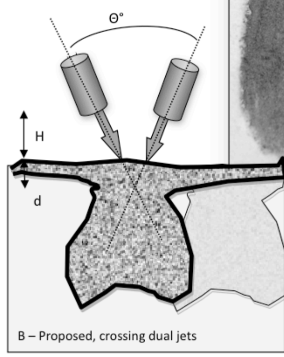
PAC injected to a depth of 12 inches consolidated sediment

62

Dual Nozzle injections

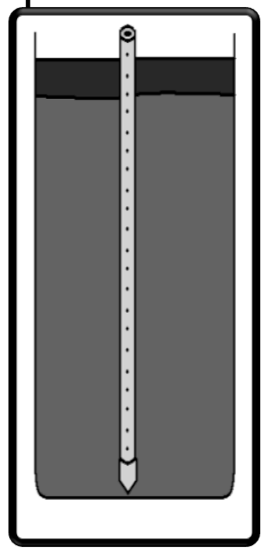
20% Carbon slurry
Pressure 175 psi, Q 5.4 gpm,
Dia is .015”
Nozzles 15° fanjet, 0.015”inch Θ = 15°

Injection depth 30 cm
Width of 18 cm
Neck is 10 cm



63

Measuring bioavailability impacts



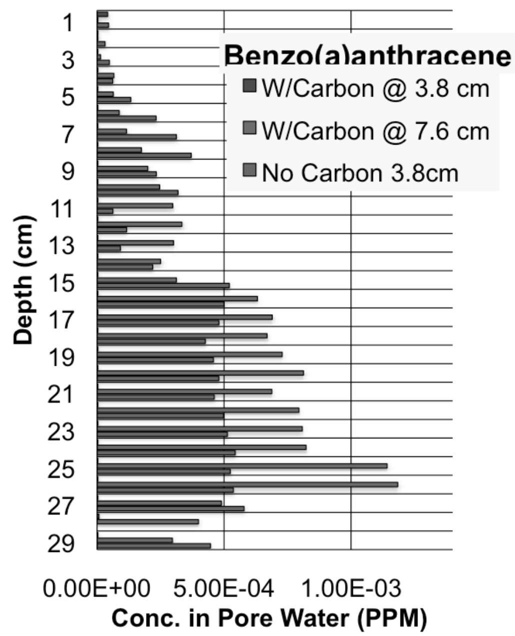
- SPME fibers to assess bioavailability. (Polymicro Tech.)
  - 1 mm fused silica core
  - 30 µm PDMS coating
- Equilibrate > 7 days
- 1 cm sections of SPME fiber into 0.5 ml of acetonitrile (ACN)
  HPLC Analysis via fluorescence

64

Bioavailability in Contaminated sediments

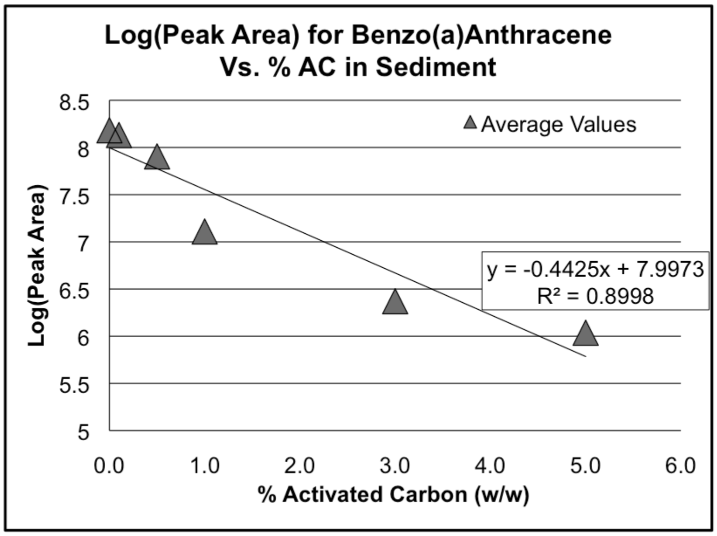
20% w/w solution of PAC
2 minute injection into of PAH contaminated sediment.
SPME samplers placed at 3.6 and 7.8 cm from center of shot

Bioavailability tested after 10 days



65

Target PAC concentrations



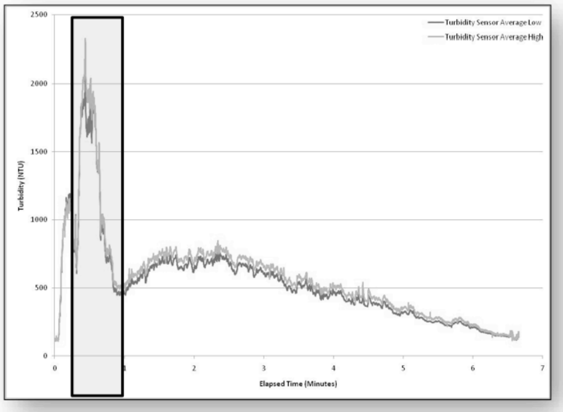
66

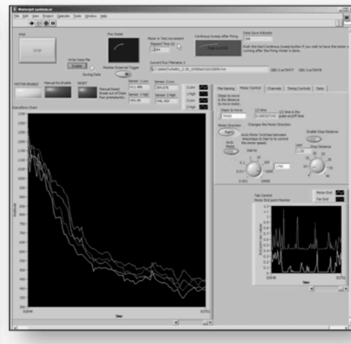
Objectives on Operations

- Minimize Resuspension
- Placement under a cap
- Evaluate benthic impacts

67

Turbidity spike

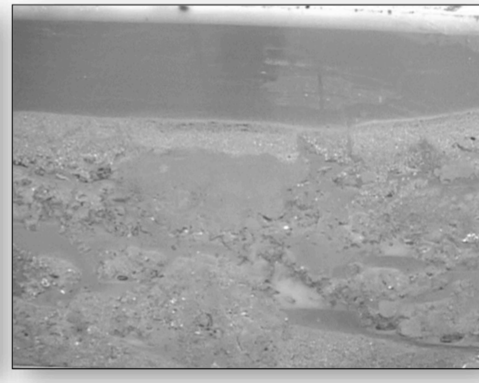




Turbidity spike was higher than hoped due to the pneumatic feed. Minimal water overburden in sediment (only 8 cm)

68

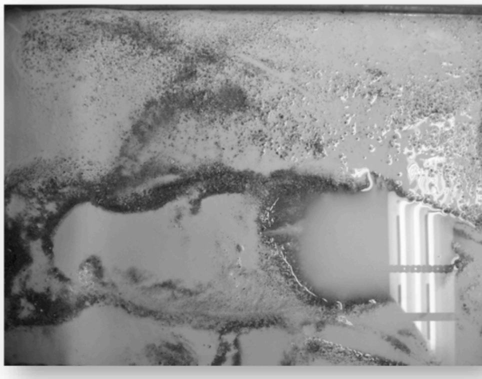
Sediment and cap, before and after



Cap was disturbed, but still observed.

69 Amendment was not evenly distributed in consolidated sediment

Sediment Redeposition on Cap



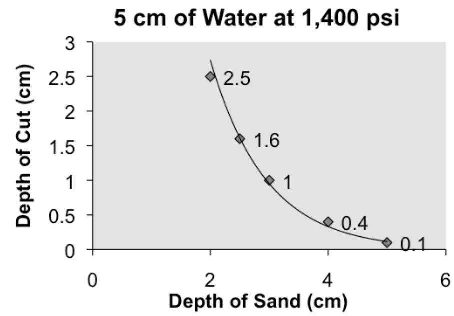
- Injection to capped surrogate sediment (Clay)
- Some sediment was suspended to the water column, but cap was still continuous.
- Sediment deposition was on order of 1mm to 7 mm

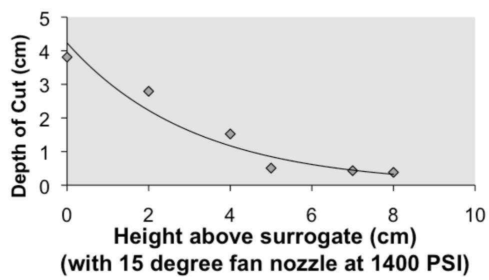
Benthic Damage testing

- Tested acute damage to Mussels
- Tests were developed to use polystyrene surrogates and not live test subjects
- Penetration depth into dense polystyrene recorded
- Direct impacts on invertebreates viability tested after direct jetting to sediment best (no amendments)

71

- Little to no direct damage to mussels at up to 1400 PSI
- Damage directly injecting to only 5 cm depth (energy dispersed)
- Surface disturbance of <15% expected, But sediment will be redeposited to the surface…..
  WITH the amendment





72

Direct impacts to invertebrates

OBJECTIVES: Determine the impacts of waterjets to *Hyalella azteca* and *Chironomus tentans*

Experiments

- A waterjet passed over the test bed at a maximum pressure of 800 PSI
- Organisms forced into water column were decanted immediately; the sand sieved for organisms
- Viability by microscopy

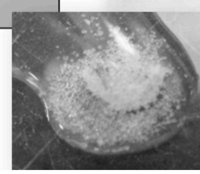
73

C. Tentan found alive after being sieved from sand after the experiment.

Hyalella azteca	Decanted		In sand	
30 & 20	A	D	A	D
Post Injection	21	2	6	0
1.5 hours later	21	2	6	0
Post Injection	15	1	4	0
1.5 hours later	10	6	4	0

http://www.ipm.ucdavis.edu/WATER/

Chironomus tentans	Decanted		In sand	
20 & 10	A	D	A	D
Post Injection	9	4	2	2
Post Injection	2		8	



74

Summary

- Amendment can be delivered via a variety of methods, each with challenges & benefits
- Slurries to 35% carbon can be delivered with pneumatic systems. Positive displacement pumps 15 – 20%
- Short-pulsed injections closely spaced result in distribution to 20 cm
- Dual nozzle, continuous injections can reach to 30 cm, minimizing disturbance

75

Summary

- Resuspension was substantial and penetration was limited with pneumatic amendment feed.
- Impacts to benthic organisms were minimal
  - No impact to mussels to 1400 PSI
  - Less than 20 % mortality to invertibrates
  - Disturbance of <15% of surface
  - Amendment deposition with resuspended sediments likely limits bioavailability

76

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77

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