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NARPM Presents...In Situ Sediment Remediation Using Benthic Waterjet Amendment Placement

Delivered: November 16, 2011, 1:00 PM - 3:00 PM, EST (18:00-20:00 GMT)

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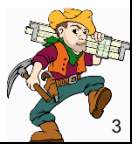
In-Situ Sediment Remediation Using Benthic Waterjet Amendment Placement

Joel G. Burken
Missouri University of Science &Technology

NARPM Presents
November 16, 2011



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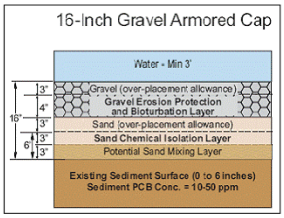
Introduction

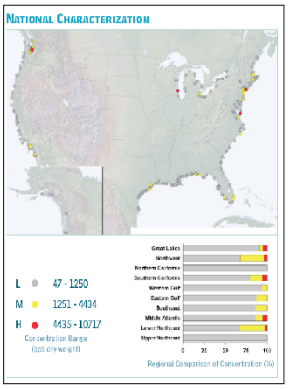
- Polycyclic Aromatic Hydrocarbons (PAHs) in sediments
- Current solution is dredging or capping



Fox River Cleanup Capping design (foxrivercleanup.com)

Dredging: (strategic-sediment-solutions.com)

- New approach uses activated carbon to reduce bioavailability of PAHs in sediment (Ghosh et al)



NOAA National Status and Trends: Mussel Watch Program

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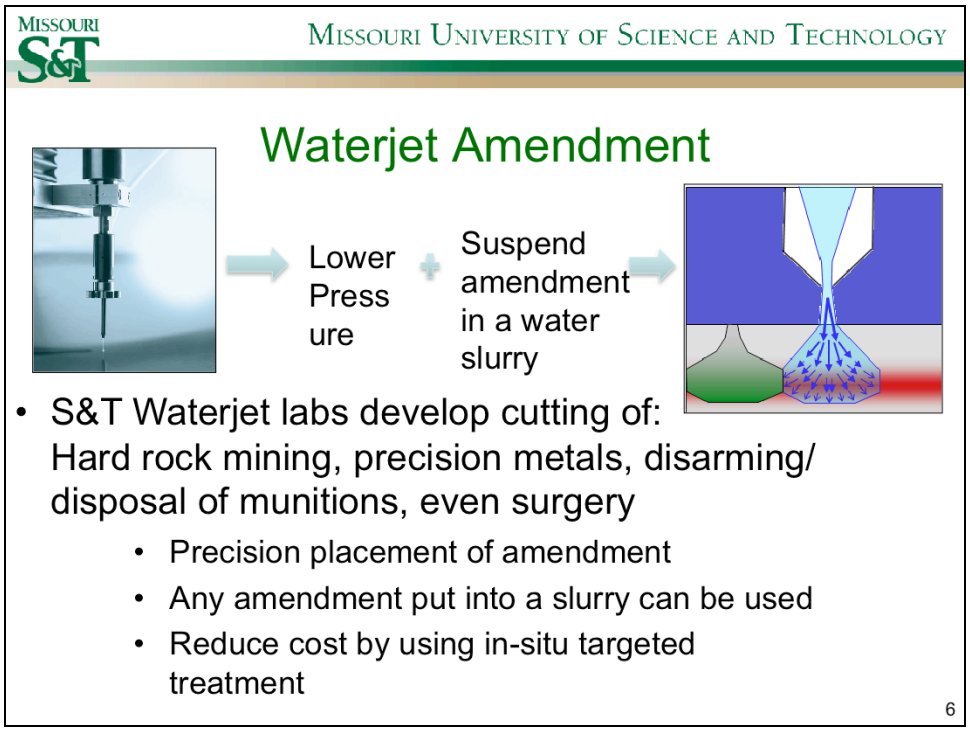
PAHs- highly persistent, toxic and tend to accumulate into sediments due to low solubility in water.

Dredging - problems associated with dredging are the resuspension of contaminated sediments, exposing contaminated sediment beneath, the high cost of dredging, and what to with the contaminated sediment once it has been dredged

Capping - difficult to lay precisely on river beds, may change river bottom, may be difficult for the covered benthic organisms to repopulate the cap.

Research has shown that toxicity in contaminated sediments can be reduced with AC amendment between 1 and 3% w/w.



Traditionally waterjets are used in cutting material, cleaning pipes and material and in mining.

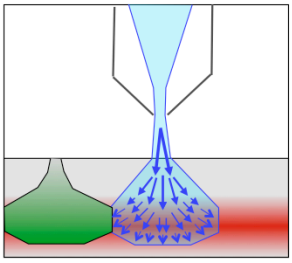
We wanted to use the waterjets to place a treatment amendment into contaminated sediment

By lowering the pressure and suspending an amendment in a slurry and running that through a waterjet we thought that it would be possible to place treatment amendments precisely and in the correct concentration for treatment

Offers a variety of amendments such as Liquid amendments, AC, and zero-valent iron

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



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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.

Pulsed Injection: Liquid amendment

Pulsed Injection: Liquid amendment

Pulsed Injection: Liquid amendment

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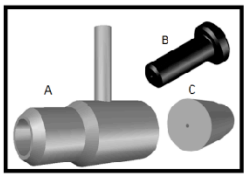
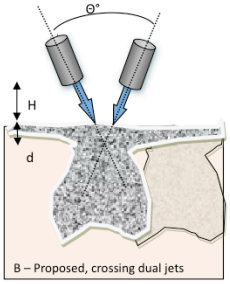
Pulsed Injection: Liquid amendment

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



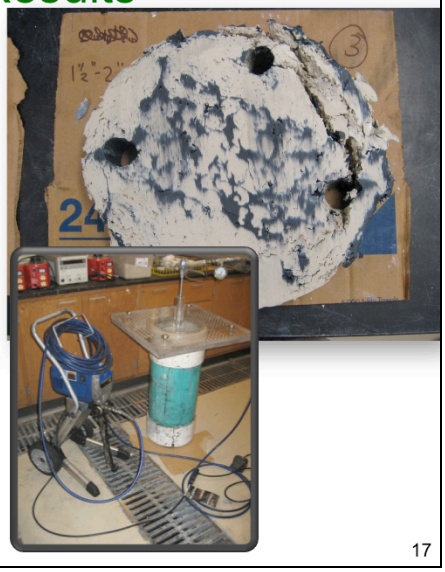


Positive Displacement Methods Characteristics

- Burst Injection at 2500 psi stabilizing at 700 psi for 5 to 7 seconds
- 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]

Injection Results

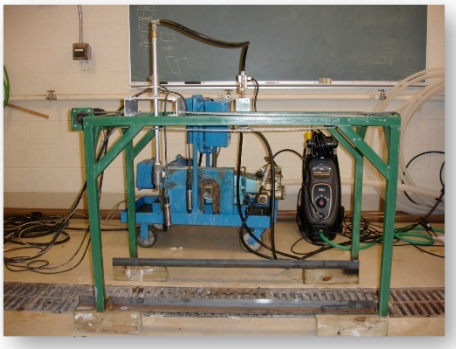
- Achieved 3.4% carbon at depths of 20 cm and less
- In consolidated media individual injections were still distinguishable

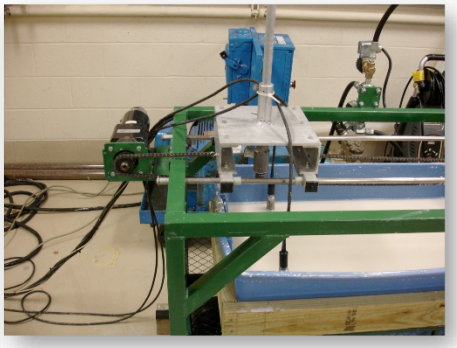


Redell, C.*, Elmore, A.C., Burken, J., Stringer, R. (2011)**Waterjet injection of powdered activated carbon for sediment remediation** *J. of Soils and Sediments* 11, (6), 1115-1124, DOI: 10.1007/s11368-011-0392

Constant Flow Slurry Injections

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





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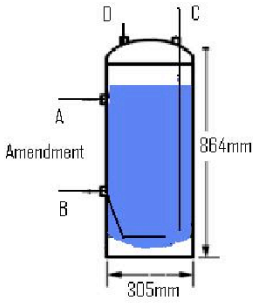
Continuous Slurry Systems

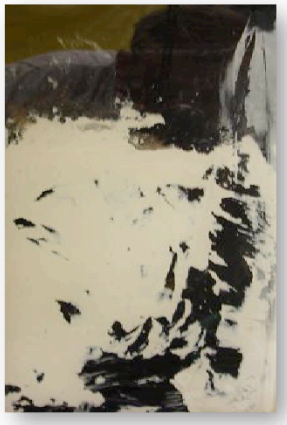
- Pressure chamber mixed pneumatically
- Up to 35% PAC in solution.
- 120 PSI, did not reach targeted depth of delivery, more pressure needed.. Pneumatic Danger.



- Progressive cavity pump.
- 15% slurry
- 8 gpm max, up to 1200 PSI

Single Nozzle, continuous flow

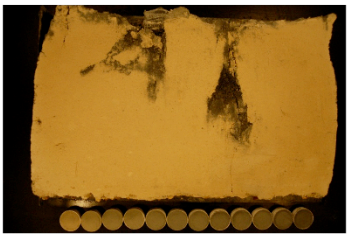
PAC injected into Kaolin

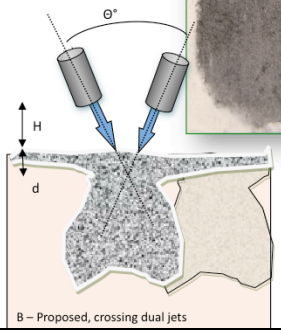


PAC injected to a depth of 12 inches consolidated sediment

Dual Nozzle injections

20% Carbon slurry
Pressure 175 psi, Q 5.4 gpm,
Nozzles: Dia is .015" , Θ = 15°fan
Injection depth 30 cm
Width of 18 cm, Neck is 10 cm





B – Proposed, crossing dual jets

Injections can be done through caps

- Cap can be penetrated, and while resuspension occurs, amendment is also deposited.

In-situ placement

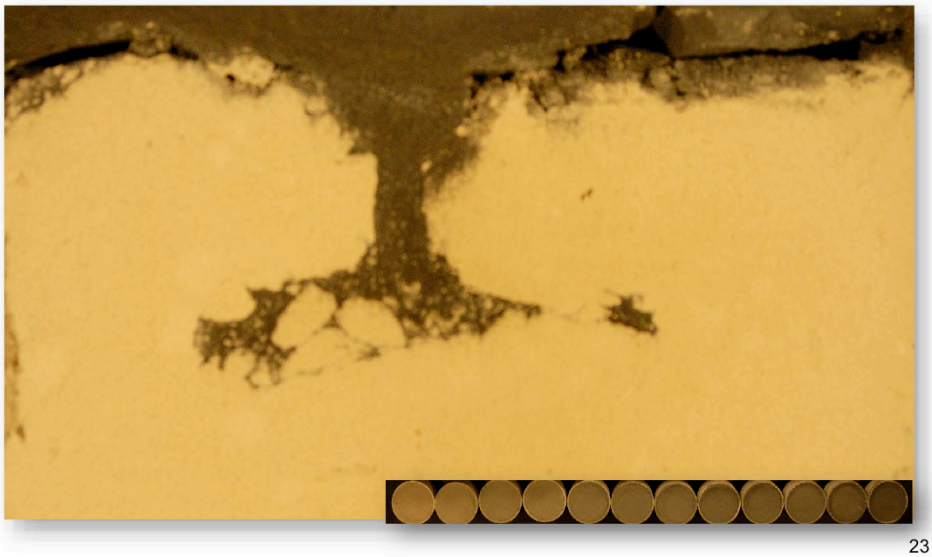
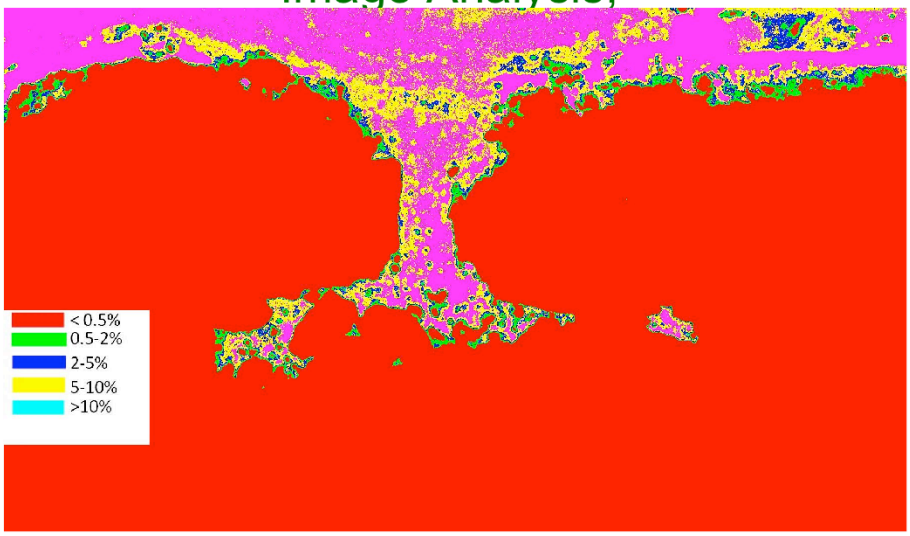


Image Analysis,



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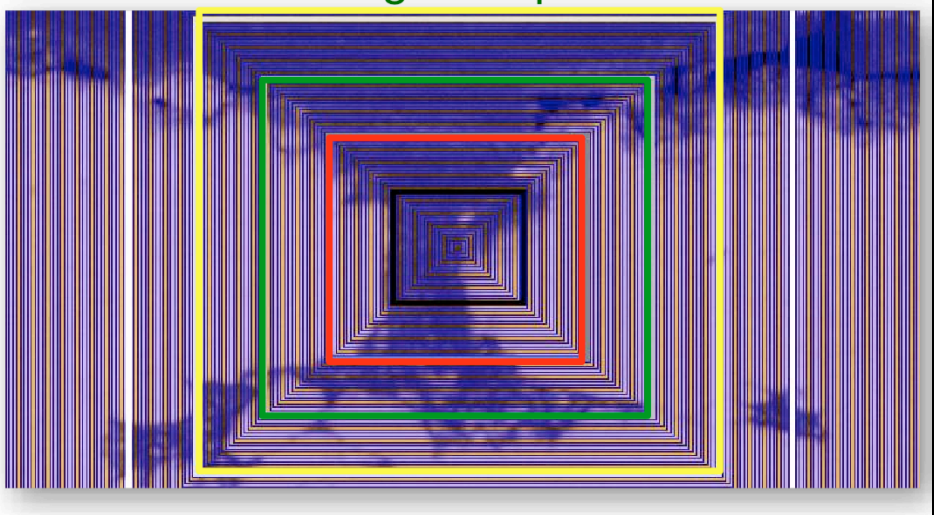
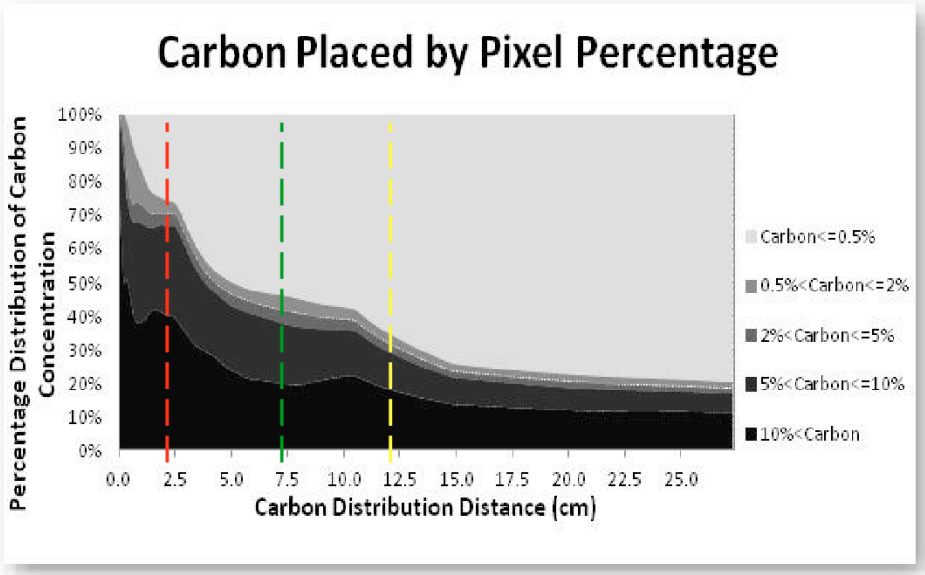
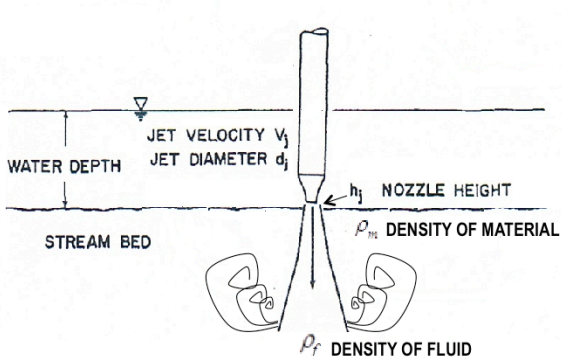
Determining PAC placement




Carbon Placed by Pixel Percentage
Percentage Distribution of Carbon Concentration
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
Carbon Distribution Distance (cm)
Carbon<=0.5%
0.5%<Carbon<=2%
2%<Carbon<=5%
5%<Carbon<=10%
10%<Carbon

Hydraulic Schematic



Modified from Mih et al 1983

Hydraulic Modeling Analysis

- Energy Equation
  $E = \rho g Q (\eta + \frac{\alpha}{2g} * \frac{Q^2}{A^2})$
  - ρ= pressure
  - g= gravity
  - Q= flow
  - η = constant
- Momentum of Jet flux
  $M_j = \pi/4 * P_f * V_o * d^2$
  - P_f= dynamic viscosity of fluid
  - D= diameter of jet
  - V_o = velocity of jet a the nozzle

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Bioavailability Impacts

- Evaluate AC placement impacts in contaminated soil using *in-situ* Solid Phase Micro Extraction(SPME) with PDMS
  - Custom SPME fiber, 100 µm, with 33 µm PDMS coating
  - Large log(K_{pdms}) values (3.2-5.2)
  - Equilibrium method
  - Multiple measurements
  - No destructive sampling, no sed extraction,

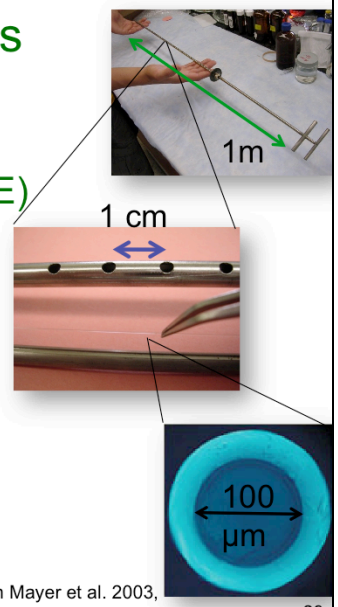
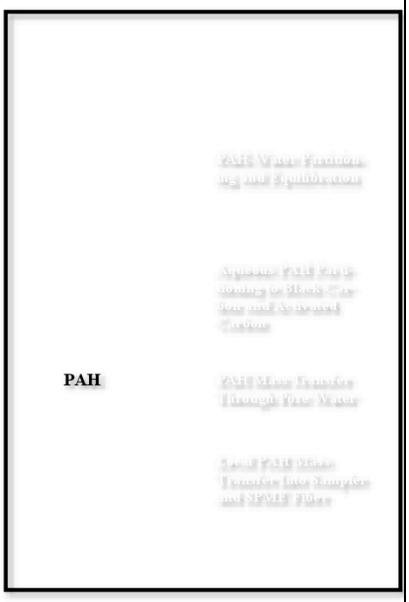


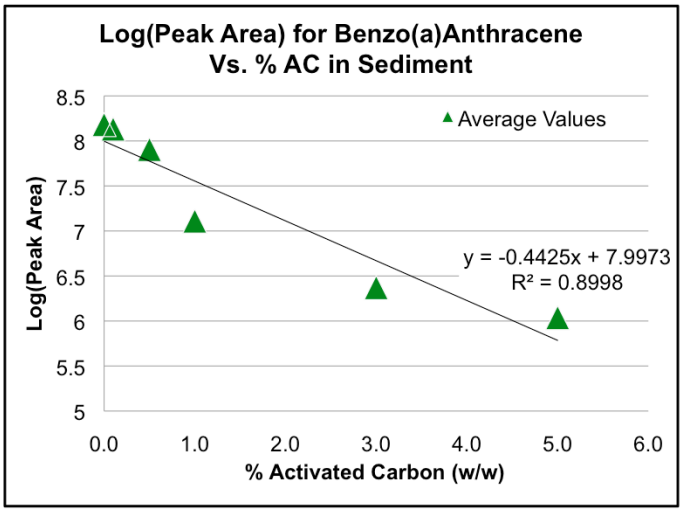
Photo from Mayer et al. 2003, Equilibrium Sampling Devices, E S&T.

Sediment PAH Profiling

- Measure PAH concentrations at different depths
  - Long SPME fibers (0.6 m)
  - PAHs partition into SPME
  - Each SPME fiber section shows local PAH pore water concentration



Target PAC concentrations



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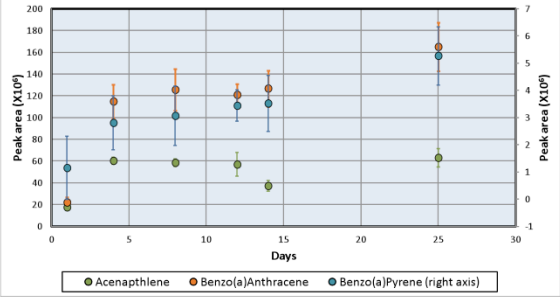
SPME Contaminated Sediment Experiments

- SPME Equilibration
  - Equilibrate in quiescent sediment
  - Relative std. dev. of low Kow PAHs range rom 20 to 25% while high Kow PAHs range from 43 to 106%



Avg. Relative Standard Deviation	
Benzo(ghi)perylene	79%
Dibenzo(a,h)anthracene	106%
Benzo(a)pyrene	77%
Benzo(k)fluoranthene	89%
Benzo(b)fluoranthene	60%
Chrysene	43%
Benzo(a)Anthracene	32%
Pyrene	19%
Fluoranthene	33%
Anthracene	23%
Phenanthrene	34%
Fluorene	30%
Naphthalene	47%

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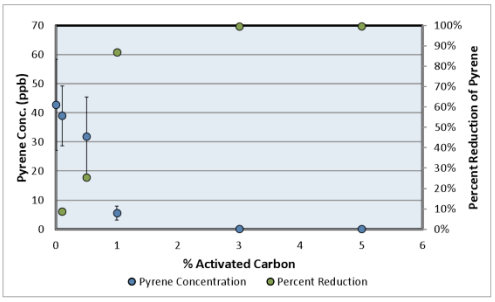
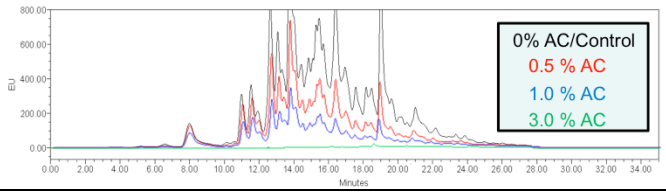
SPME Contaminated Sediment Experiments

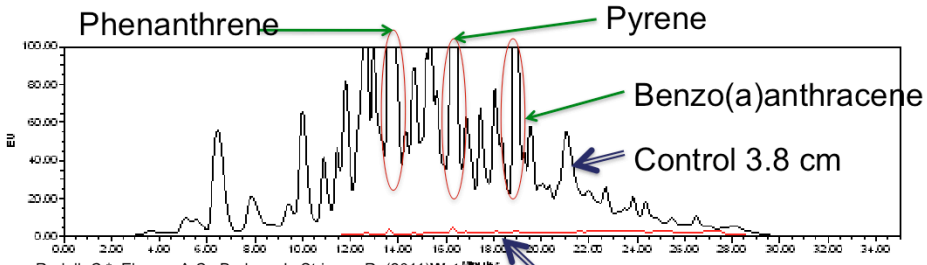
- AC Dosing
  - 200 ml jars
  - Hand mixed PAC
  - 7 day equilibration
  - Significant removal seen at 1% AC addition





Single Injection Experiment

- 2 minute injection of 20% w/w AC solution in PAH contaminated sediment
- SPME samplers placed 3.8 and 7.6 cm from center
- Over 90% PAH removal found in 3.8 cm sample
- No change found in 7.6 cm sample



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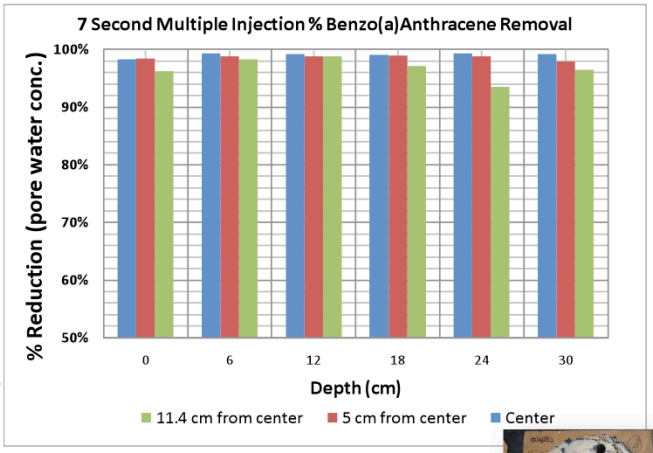
Pulsed Water Jet Injections Experiment

- Multiple short duration injections.
- 2.54 cm spacing
- Greater than 90% reduction in bioavailability throughout



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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)

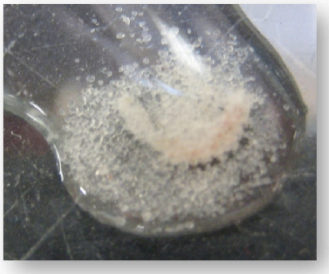
Harper, G., Elmore, A.C., Redell, C., Risley, G., Burken, J. (2011). **Physical impact of waterjet-based remediation on benthic organisms**. *Remediation,* 21(4), 107–118.

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



C. Tentan found alive after being sieved from sand after the experiment. 37

The flowrate is 0.38 gallons per minute or 1.44 L/minute
Nozzle Diameter is 13/1000 inch
Transverse Speed was about 1 m/s.

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

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

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

Harper, G., Elmore, A.C., Redell, C., Risley, G., Burken, J. (2011). **Physical impact of waterjet-based remediation on benthic organisms**. *Remediation,* 21(4), 107–118.

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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

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

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Questions?

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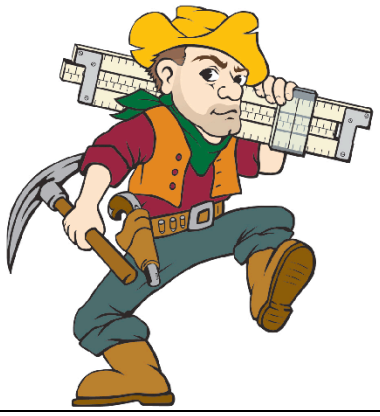

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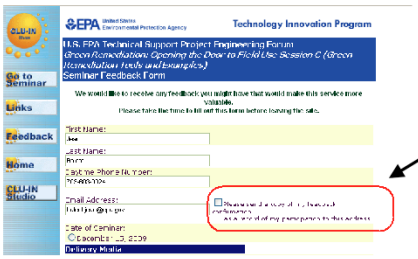
- Please complete the **Feedback Form** to help ensure events like this are offered in the future



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