Treatment – Expanding Dredged Material Management Alternatives

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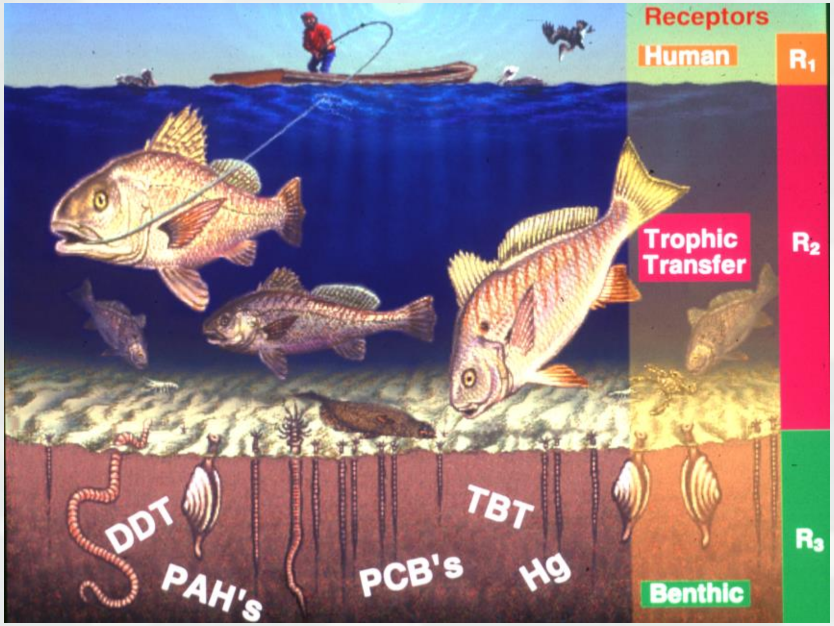
Problem

- Historic contamination poses ecological and human health concerns from potential bioaccumulation of contaminants placed dredged material placed in an aquatic environment for disposal or beneficial use
- Limiting placement alternatives and increasing costs
- Upland CDFs are filling up
- Need for cost-effective, implementable bioaccumulation control technology



Objectives

- Evaluate the dosage screening protocols and volume requirements for amended dredged material to adequately treat the bioactive zone
- Examine the performance of low activated carbon dosages suitable for controlling widespread low-level contamination using laboratory testing
- Place amended dredged material at a field demonstration site to reduce bioaccumulation using conventional placement methods
- Determine the long-term reduction in PCB bioavailability and bioaccumulation in the bioactive zone of the field demonstration site
- Determine the effects of AC on benthos

Sediments Tested

Sediment	PCBs Conc. µg/kg	% Organic Matter			% Clay	% Silt	% Sand	% Solids
		Total	Soft	Refractory				
Ashtabula Harbor	43.7	3.4	0.8	2.6	21	69	10	60.7
Cleveland Harbor	110	4.1	1.6	2.5	20	69	11	58.6
Buffalo River	184	4.3	1.8	2.5	24	63	13	48.1

Unamended Bioaccumulation Results

Bioaccumulative properties for PCBs were characterized using 28-day tests with *Lumbriculus variegates*.

Sediment	% lipids	Total PCBs Conc. in Tissues (ng/g)	Lipid Normalized PCBs Conc. (µg/g)	Bioavailability, µg PCBs / g Lipid per µg PCBs / g OM (Refractory)
Ashtabula Harbor	0.49	41.1	8.40	6.5 (5.0)
Cleveland Harbor	2.19	129	5.87	2.2 (1.3)
Buffalo River	2.10	702	33.2	7.7 (4.4)

Laboratory Testing

- Mixed 6 gallons of sediment plus PAC at target dosage in 20-gallon stainless steel barrel
- Rolled at 10 rpm for a minimum of 7 weeks
- Performed 28-day bioaccumulation testing using *Lumbriculus variegates*

PAC Amended Bioaccumulation Results

Sediment	Treatment	% Lipids	Total PCBs Conc. in Tissues (ng/g)	Lipid Normalized PCBs Conc. (µg/g)	Reduction in Lipid Normalized Bioaccumulation
Ashtabula Harbor	3% PAC static	1.3	6.39	0.52	93.8%
	0.3 % PAC rolled	1.5	8.24	0.55	93.4%
	0.06% PAC rolled	1.5	17.8	1.21	85.6%
Cleveland Harbor	0.3 % PAC rolled	1.3	27.2	2.14	63.6%
	0.1% PAC rolled	1.7	32.5	1.97	66.4%
Buffalo River	0.3% PAC rolled	1.4	103	7.54	77.3%
	0.1% PAC rolled	1.6	130	7.91	76.2%

Target Lipid Normalized PCBs Conc. of 2 µg/g.
Reductions of 65 to 85%.

Treatment Effectiveness by Homolog

- Comparison of the homolog distributions in the tissues from the bioaccumulation testing of original unamended sediments and the sediments amended with 0.3% PAC dosages showed that activated carbon was effective in sequestering all of the dominant homologs in the Ashtabula and Cleveland sediments.
- The greatest reductions were for the tetra-PCBs and penta-PCBs.
- Similarly, penta-PCBs and less chlorinated PCB homologs were effectively sequestered by the PAC in the Buffalo River sediment, but the reductions in hexa-PCBs and hepta-PCBs were well below the overall reduction.
- The more chlorinated homologs were poorly sequestered, likely due to their low solubility.

Low Dosage Performance

- Typical activated carbon dosages that have applied at contaminated sediment sites range from 3 to 6% on a dry wt basis to achieve bioavailability reductions of 95% to 98%.
- These results show that dosages of about 0.1% can achieve reductions of about 75%, which may be sufficient for low level widespread contamination.
- The reduction for a given PAC dosage is a factor of the sediment's organic matter composition, and the composition/distribution and bioavailability of the PCBs. Reductions increase with bioavailability and decrease with higher chlorinated PCB homologs.

Ashtabula Field Demonstration

- Placed four barges of unamended mechanically dredged material at a point in the open water placement site in 50 ft of water (about 6000 cy to form a 1-ft thick mound); and sampled the barges to characterize the unamended dredged material in August 2015.

Approach

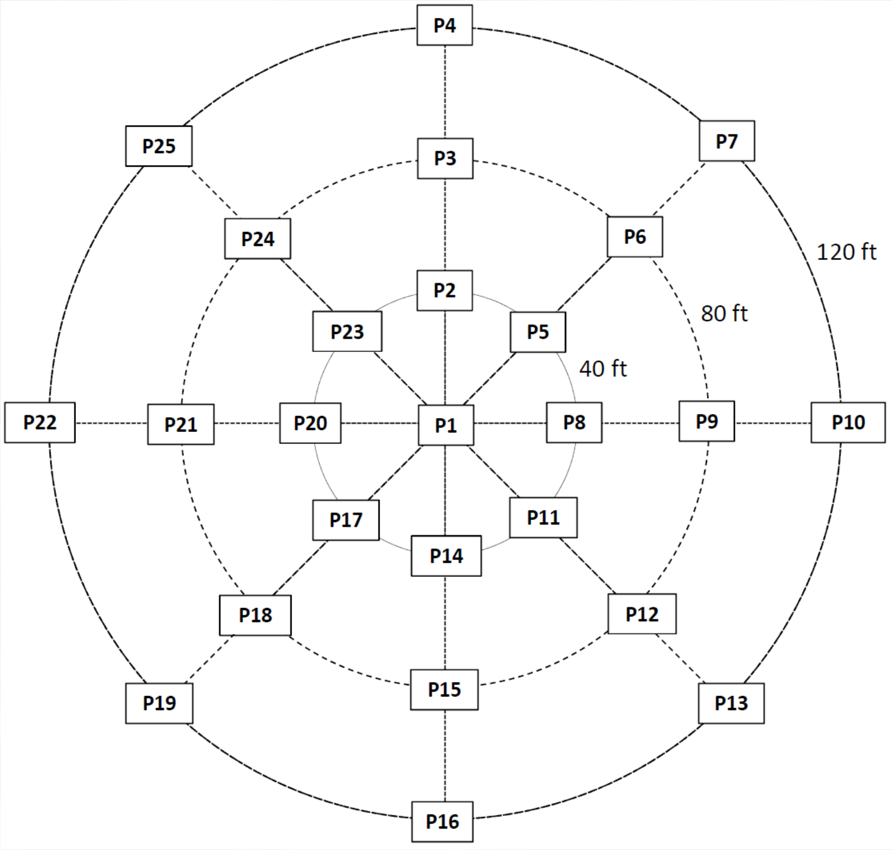
- Mixed both PAC and GAC in two layers of dredged material in the dump scow using a small conventional dredge bucket; and sampled the amended dredged material from each hopper of the dump scow to characterize the activated carbon distribution.

Carbon Addition

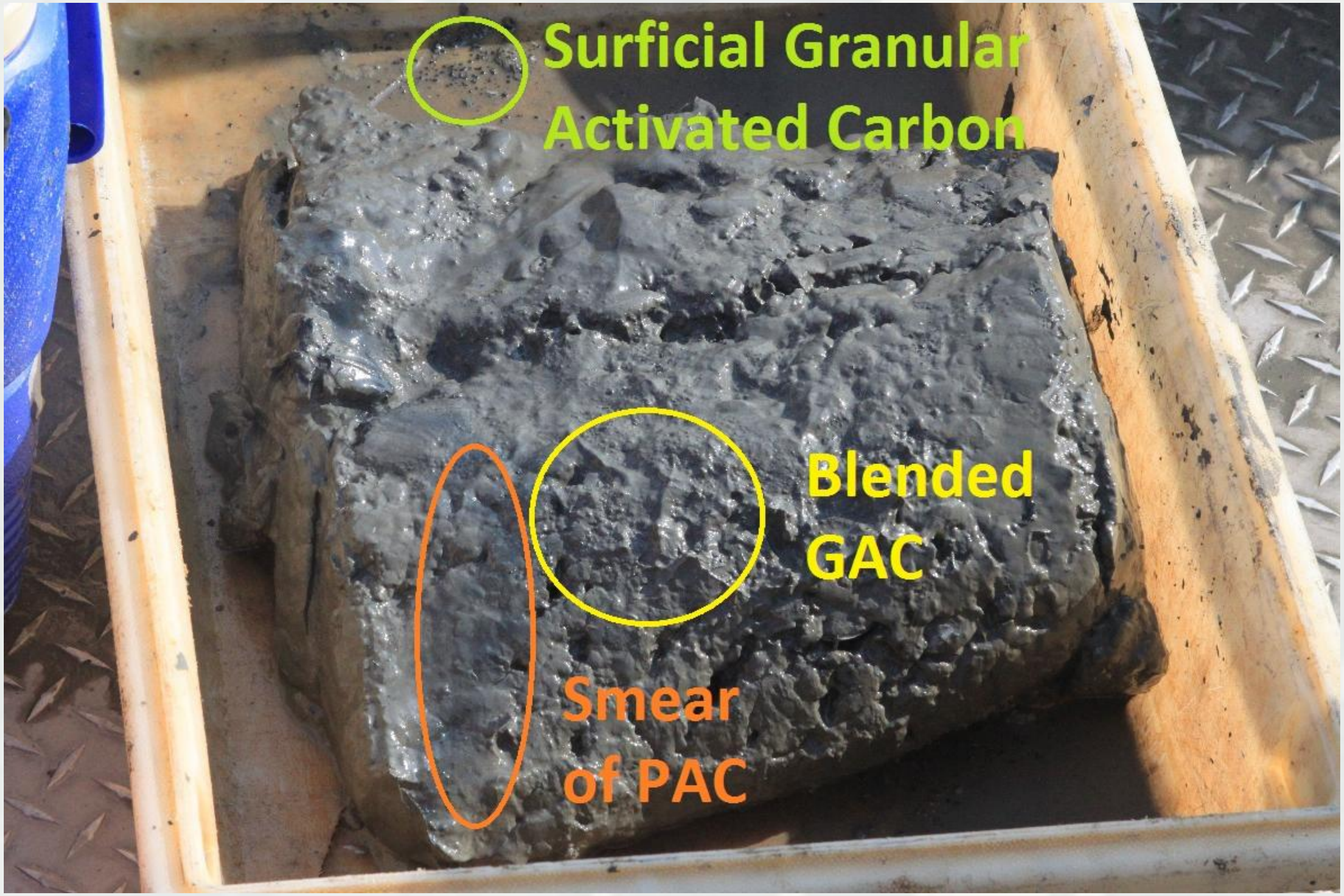
Mixing

Approach

- Dispersed GAC on the surface of the amended dredged material in the dump scow.
- Bottom dumped the amended dredged material on the placement mound.
- Sampled the top four inches of the placement mound to characterize the activated carbon distribution three weeks after placement at end of August 2015.



Placement Site Sample



1-Year Bioaccumulation Reductions

Sample	% GAC	% PAC	%AC	Effective % AC	Percent reduction in PCB concentrations in lipids after 1 year
No AC	0	0	0	0	0
Low AC	0.40	0.48	0.88	0.52	52
Medium AC	1.34	0.38	1.74	0.56	56
High AC	1.78	0.62	2.40	0.84	75

*Assuming GAC is about 10% as effective as PAC in the short-term due to distance between AC particles in the dredged material.

** TOC is 1.4% comprised of 0.4% carbon from soft labile organics and 1.0% carbon from hard refractory carbon.

3-Year Bioaccumulation Reductions

Sample	% GAC	% PAC	%AC	Effective % AC	Percent reduction in PCB concentrations in lipids after 3 years
No AC	0	0	0	0	0
Low AC	0.09	0.29	0.38	0.31	61
Medium AC	0.3	0.43	0.73	0.49	67
High AC	0.99	0.68	1.67	0.88	79

*Assuming GAC is about 10% as effective as PAC in the short-term due to distance between AC particles in the dredged material.

** TOC is 1.4% comprised of 0.4% carbon from soft labile organics and 1.0% carbon from hard refractory carbon.

Impacts on Benthos

- The abundance, richness, Shannon diversity, pollution tolerance and the relative abundance of tubificid worms were computed for each benthic sample (ten unamended and ten amended).
- The abundance (number of organisms) was greater, but not statistically significant ($p=0.059$), in the unamended samples compared to the AC-amended samples. GAC appeared to impact the abundance of pollution tolerant tubificid worms.
- The percent community composition of tubificids was statistically significantly larger ($p=0.011$) in unamended sediment, showing a less balanced community structure in the unamended sediment than in the amended sediment.

Impacts on Benthos

- The average pollution tolerance scores of the organisms in the unamended sediment were significantly greater ($p=0.011$) than that of organisms in the amended sediment.

- While the richness (number of genera) of the two sets of sediments were not statistically different, the diversity of organisms in the amended sediment was statistically greater, about 50% greater on average, using a 1-tailed t-test ($p=0.033$), due to more balance in the number of organisms in each genus, indicating a healthier community structure.

Conclusions

- These results show that PAC dosages of about 0.3% (and perhaps as low as 0.1%) can achieve reductions of about 75% in both laboratory and field applications, which may be sufficient for treating low level widespread contamination.
- Dredged material treatment is a viable option for placement marginally unsuitable dredged material in aquatic placement/ beneficial use settings rather than placement in CDFs.
- Benthos diversity improved slightly and included some less pollution tolerant species.
- PAC needs to be applied only to the bioactive zone to achieve the bioaccumulation reduction benefits.
- Bioaccumulation reductions are greatest in the tri-, tetra- and penta-chlorinated PCB homologs.

Acknowledgements

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- Additional on-going support is being provided by the USACE Engineering with Nature (EWN) Program and the Dredging Operations and Environmental Research (DOER) Program

Past Applications of Activated Carbon in Sediments

- Activated carbon has been applied directly to sediment only about a dozen times, mostly in small pilot demonstrations, but not applied to dredged material for placement in the aquatic environment.
- Additionally, activated carbon has been applied in caps at contaminated sediment sites at about a dozen sites, also mostly in small field demonstrations.
- All of the applications were intended to remediate in situ contaminated sediment, not dredged material , by reducing contaminant exposure/flux and limiting bioaccumulation.

Dredged Material Characteristics

- Classified as CL (lean clay of low plasticity)
- Liquid Limit of 37, Plastic Limit of 22 and Plasticity Index of 15
- Engineering water content ranging from 65 to 67%
- Solids content of 60%
- Liquidity Index ranged from 2.7 to 3.0
- Toughness Index ranged from 1 to 1.3
- Amended dredged material: 0.934 g/cc dry bulk density in barge
  0.947 g/cc dry bulk density at site