Bioaccumulation Control Demonstration at Ashtabula Open Water Placement Site

Engineer Research and Development Center

P.R. Schroeder, M.G. Channell, C.E. Ruiz, B.W. McComas, and C.C. Carrillo

INTRODUCTION

Sediments in the urban harbors often exhibit elevated levels of polychlorinated biphenyls (PCBs) bioaccumulation, limiting their suitability for beneficial use or placement in aquatic sites. Hydrophobic organic contaminants of concern are typically strongly bound to the organic fraction of fine-grained sediment. Amendment of dredged material in the bioactive zone with activated carbon has the potential to provide bioaccumulation control, permitting expanded use of aquatic placement where confined disposal facility (CDF) capacity is being exhausted.

Activated carbon has been applied directly to sediment only about a dozen times, mostly in small pilot demonstrations (Patmont et al. 2015). Only a few of these applications were larger than our current demonstration and half of the applications were much smaller. None of these applications used techniques representative of common dredging operations; however, their goal like ours was to remediate contaminated sediment by reducing contaminant exposure and limiting bioaccumulation.

Objectives

The purpose of this demonstration is to determine the efficacy of mixing activated carbon (both powdered and granular) within the barge using conventional dredging equipment, the potential loss of activated carbon (powdered and granular) during conventional placement through 15 meters (50 feet) of water and during the long term after placement, the extent of replacement of the bioactive zone with activated carbon amended dredged material, and the long-term reduction in PCB bioavailability and bioaccumulation in the bioactive zone of the demonstration site.

Figure 1. Conventional dredging operation

Figure 2. Dump scow

Approach

In August 2015, fine-grained sediment from the Ashtabula, Ohio Harbor on Lake Erie was mechanically dredged and placed in an 1150-cu m (1500-cy) eight-compartmented bottom dump scow (Figure 2). The dump scow sampled to characterize its physical, chemical and bioaccumulative characteristics. Then, the dredged material was amended with powdered activated carbon (PAC) and granular activated carbon (GAC) (Figure 3). The activated carbon and dredged material were blended using a 7.6-cu m (10-cy) clamshell bucket to mix the material in the barge (Figure 4). The amended material was discharged over the dredged material mound to create a treated bioactive zone..

Figure 3. Activated carbon addition

Figure 4. Mixing in activated carbon

Twenty-five surface grab samples were collected at the placement site using a 10-liter Petersen grab dredge that collected approximately a 10-cm (4-inch) deep sample over an area of 930 sq cm (a square foot). Roughly the top half of the samples contained activated carbon and were analyzed for grain size distribution, solids content, organic content, labile organic matter, refractory organic matter, PAC content and GAC content. Organic and activated carbon contents were analyzed gravimetrically by incremental combustion and sieving.

In July 2016, an additional twenty-five surface grab samples were collected at the placement site to compare their physical, chemical and bioaccumulative characteristics with the initial conditions and to determine potential loss of activated carbon.

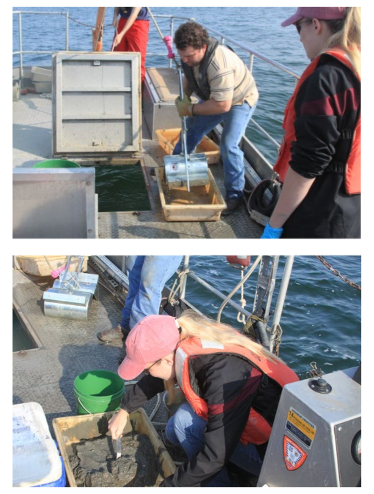

Figure 5. Grab sampling

Results

Characterization

The unamended dredged material had 2.8% organic matter. The amended dredged material sampled from the barge contained 3.7% activated carbon, 2.2% GAC and 1.5% PAC. The activated carbon concentrations in the barge were normally distributed and ranged from 1.5% to 6.6% with a coefficient of variation (CV) of 0.32. The surface grab samples from about the top five centimeters (two inches) of the placement site showed that the GAC content was largely unchanged while the PAC content was only 0.5% despite being 1.5% in the barge. The results suggests that both mixing with the surface of the mound and loss of PAC during descent and collapse of the amended discharge from the eight bins of the dump scow. The detailed results are given in Table 1. Initial PCBs bioaccumulation data is given in Table 2.

Table 1. Surficial activated carbon content at placement site.

SAMPLE	PAC Content	GAC Content	Total AC Content*	Thickness of Amended Dredged Material	
				cm	inches
P1	0.39%	0.27%	0.56%	10	4
P2	0.99%	1.31%	2.17%	5	2
P3	0.64%	1.27%	1.62%	10	4
P4	0.65%	3.39%	4.14%	5	2
P5	0.60%	1.45%	2.05%	6.3	2.5
P6	0.44%	2.78%	2.86%	5	2
P7	0.01%	0.91%	0.91%	5	2
P8	0.21%	2.22%	2.51%	3.8	1.5
P9	0.31%	1.55%	1.97%	7.6	3
P10	0.14%	1.48%	1.69%	2.5	1
P11	0.30%	1.45%	1.76%	3.8	1.5
P12	0.39%	1.84%	2.23%	3.8	1.5
P13	0.14%	0.88%	1.09%	2.5	1
P14	0.30%	4.23%	4.05%	7.6	3
P15	0.34%	2.61%	2.80%	2.5	1
P16	0.44%	4.86%	5.12%	2.5	1
P17	0.41%	2.28%	2.60%	10	4
P18	0.86%	2.92%	3.77%	2.5	1
P19	0.26%	3.18%	3.16%	5	2
P20	0.70%	2.51%	2.88%	2.5	1
P21	0.61%	3.24%	3.67%	5	2
P22	0.42%	2.98%	3.40%	2.5	1
P23	0.63%	2.91%	3.33%	3.8	1.5
P24	0.88%	3.02%	3.64%	6.3	2.5
P25	0.68%	2.67%	3.19%	5	2
Average	0.47%	2.33%	2.69%	5	2.0
Maximum	0.99%	4.86%	5.12%	10	4.0
Median	0.42%	2.51%	2.80%	5	2.0
Minimum	0.01%	0.27%	0.56%	2.5	1.0
Std. Dev.	0.25%	1.09%	1.10%	2.5	1.0
CV	52.9%	46.7%	41.0%	48.4%	

* Average of total measurement and sum of sieved results.

Table 2. Bioaccumulation results for unamended dredged material.

Sample	Tissue %Lipids	Tissue Total PCBs (ug/kg)	Tissue Total PCBs (lipid normalized)
Barge1	0.444	32.5	7.32
Barge 2	0.433	43.2	9.98
Barge 3	0.461	36.6	7.94
Barge 4	0.631	40.9	6.48
Barge 5	0.394	52.4	13.30
Barge 1-5 Composite	0.403	50.0	12.41

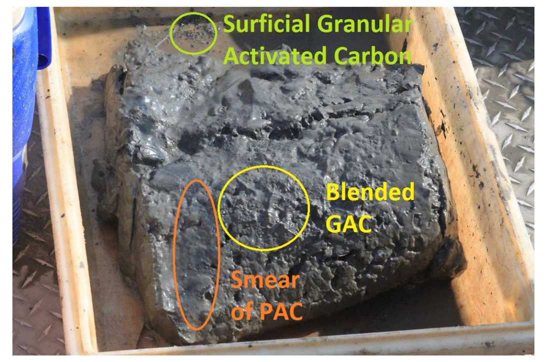

Figure 6. Surface grab sample from placement site

Results (continued)

1-Year Results

Table 3 shows the characteristics of the top 10 cm (4 inches) of the placement mound about one year after placing a thin amended surface layer (approximately 5 cm or 2 inches). The 25 grab samples were divided into three composites based on their activated carbon content. Bioaccumulation reductions ranged from 52 to 75 percent in the first year. AC within the bioactive zone did not appear to be lost but may have decrease due to mixing within the sampling depth. Higher bioaccumulation reductions may have been achieved in the upper portion of the sampling because the AC may have not been well-mixed throughout the sampling depth in the field. The effectiveness of the GAC appears limited in the first year due to non-equilibrium conditions from diffusion limitations.

Table 3. Bioactive Zone (10-cm depth) Characteristics

Sample	%GAC	%PAC	%AC	Effective %AC*	Percent Reduction in PCBs Concentration in Lipids after 1 year
No AC**	0	0	0	0	0
Low AC	0.20	0.24	0.44	0.26	52
Med AC	0.67	0.19	0.87	0.28	56
High AC	0.89	0.31	1.20	0.42	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.

SUMMARY AND CONCLUSIONS

- Activated carbon can be applied for bioaccumulation control using conventional dredging equipment. Good coverage of the dredged mound was achieved.
- GAC appears to be less effective in the short term due to the diffusion kinetics in a low mixing environment.
- Losses of PAC during descent and collapse of the amended discharge were much greater than expected. However, the losses would still provide benefits to the project.

Point of contact: Paul.R.Schroeder@usace.army.mil, 601-634-3709

Acknowledgements: This work was funded by the USACE Buffalo District and the USACE Engineering with Nature initiative of the Dredging Operations and Environmental Research (DOER) Program at the U.S. Army Engineer Research and Development Center.