OPEN WATER PLACEMENT DEMONSTRATION OF AMENDED DREDGED MATERIAL FOR BIOACCUMULATION CONTROL

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ABSTRACT

The U.S. Army Corps of Engineers (USACE) Buffalo District and Research and Development Center (ERDC) performed a demonstration of open water placement of dredged material amended with activated carbon in Ashtabula Harbor, Ohio and at the Ashtabula Lake Erie Dredged Material Placement Area as a control measure for bioaccumulation of polychlorinated biphenyls (PCBs). The goals of the pilot project are three fold: 1) demonstrate effectiveness of activated carbon in managing PCB bioaccumulation from dredged material placed in open water (Lake Erie), 2) demonstrate that implementation can be performed within the normal dredging operation as an additional activity, and 3) verify presence of both powder and granular activated carbon (PAC and GAC) throughout the bioactive zone of dredged material mound.

PCB bioaccumulation will be characterized prior to and following placement of amended dredged material. In addition the activated carbon dosage requirements are being verified in the laboratory along with corresponding measurements of both pore water concentrations and bioaccumulation reduction. The demonstration site will be sampled during the summer 2016 and bioaccumulation reduction will be assessed and compared to laboratory results. In addition, activated carbon content is being measured from barge prior to placement, from samples of the bioactive zone of dredged material mound collected shortly after placement and approximately a year after placement.

Keywords: Dredged material management, treatment, activated carbon, PCBs, effectiveness verification.

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). Additionally, activated carbon has been applied in caps at contaminated sediment sites at about a dozen sites, also mostly in small field 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. All of the applications were intended to remediate in situ contaminated sediment by reducing contaminant exposure/flux and limiting bioaccumulation. None of the applications used a technique similar to our method of applying activated carbon except two applications in Norway that applied carbon as a blended cover with clean dredged clay; however, the carbon was placed as pumped slurry from a hopper dredge with a tremie (Cornelissen et al. 2012 and Eek et al. 2012). Carbon has been applied directly to the surface of the sediment without mixing in test plots at Grasse River,

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and Upper Canal Creek near Aberdeen, MD (USEPA 2013) while activated carbon within a delivery system such as SediMite® and AquaGate™ have been applied at about a dozen sites (Patmont et al. 2015). Prior to this study, an application of activated carbon in a conventional mechanical dredging operation has never been demonstrated in a navigation dredging project.

The United States Army Corp of Engineers (USACE) Buffalo District partnered with the Engineering with Nature (EWN) Program and the Dredging Operations and Environmental Research (DOER) Program of the U.S. Army Engineer Research and Development Center (ERDC) Environmental Laboratory (EL) to perform the first large scale demonstration of bioaccumulation control using activated carbon at an open water placement site. The U.S. Army Corps of Engineers (USACE) initiative EWN is providing an achievable path to more sustainable projects. The EWN approach seeks to intentionally align natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaborative processes. Science, engineering and field-scale projects within the EWN initiative demonstrate the following elements: 1) science and engineering to produce operational efficiencies supporting sustainable delivery of project benefits; 2) natural processes to maximum benefit, thereby reducing demands on limited resources, minimizing the environmental footprint of projects, and enhancing the quality of project benefits; 3) approaches that will broaden and extend the base of benefits provided by projects to include substantiated economic, social, and environmental benefits; and 4) science-based collaborative processes to organize and focus interests, stakeholders, and partners to reduce social friction, resistance, and project delays while producing more broadly acceptable projects.

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. The long-term effect on bioaccumulation as well as the mixing, spreading and losses during spreading will be used to evaluate the dosage screening protocols and volume requirements for amended dredged material to adequately treat the bioactive zone.

STUDY APPROACH

In early 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 as shown in Figure 1. The dump scow was initially filled with dredged material to the effective top of the compartment walls and sampled to characterize its physical, chemical and bioaccumulative characteristics. The scow was discharged at a specified location in the placement site through 15 m (50 ft) of water. The process was repeated four times until a shallow mound of dredged material was created that was up to 0.76 m (2.5 ft) thick and up to 90 m (300 ft) in diameter. The day after placement of the fourth barge of dredged material, one dump scow of dredged material was amended with powdered activated carbon (PAC) and granular activated carbon (GAC) as shown in Figure 2. 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 as shown in Figure 3. The amended dredged material was discharged from the surface at the same location as the dredged material to cover the mound of dredged material with amended dredged material to serve as substrate for the bioactive zone. Additional GAC was dispersed across the surface of the amended dredged material in the scow to determine whether it would remain with the discharge and provide additional surface coverage of the disposal mound, providing an additional rapid method of applying activated carbon for bioaccumulation control.

The unamended dredged material was characterized for physical, chemical and bioaccumulative properties and its variability. Physical characterization included grain size distribution, solids content, organic content, labile organic matter, refractory organic matter and Atterberg limits to assess liquidity index, plasticity index, and toughness index. Chemical characterization included bulk sediment PCB congener analysis, and total organic carbon (TOC). Bioaccumulative properties for PCBs were characterized using 28-day tests with *Lumbriculus variegates*. The amended dredged material was additionally characterized for PAC and GAC content. Forty samples of unamended dredged material were collected from the barges to determine the variability in grain size distribution, solids content, organic content, labile organic matter, and refractory organic matter of the material being placed. Five composite unamended dredged material samples, one from each barge, was collected for chemical characterization, bioaccumulative properties and Atterberg limits to determine their respective variability.

Figure 1. Dump scow for open water placement of dredged material.

Figure 2. Activated carbon addition.

Figure 3. Mixing the activated carbon into the dredged material.

Nearly three weeks after placement of the amended dredged material, 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). Samples were collected at the center of the placement site and at radii of 12, 24 and 36 m (40, 80 and 120 ft) on eight equally spaced spokes from the center as shown in Figure 4. Figure 5 shows examples of the hydrographic surveys of the disposal site collected before and after the placement demonstration by personnel from the USACE Buffalo District. The hydrographic surveys show that the dredged material was placed in the disposal area with an average depth of 30 to 45 cm (1 to 1.5 feet) of material once all five barges were unloaded; the thickness of the mound along the center transect is not very uniform and suggests significant cratering upon impact. This corresponds to a 120-m (400-ft) diameter mound of dredged material at the in-barge density. The hydrographic surveys indicate that dredged material was spread over an approximately 120-m (400-ft) diameter area within the placement area, supporting the observation that the dredged material did not measurably entrain any water during placement. Roughly the top half of the sample was collected to physically characterize the anticipated bioactive zone for grain size distribution, solids content, organic content, labile organic matter, refractory organic matter, PAC content and GAC content. The samples are being used to evaluate water entrainment during descent and spreading, extent of spreading, extent of mixing with dredged material mound, and loss of carbon during placement. The samples are being stored at 10°C for possible bioaccumulation testing after a year of aging to effect a reduction in bioavailability.

Additional sampling of the bioactive zone of the placement site is scheduled for July 2016 to characterize the PAC and GAC content and assess for potential losses of both forms of activated carbon by bioturbation, resuspension and erosion, as well as potential reductions by deposition. The samples will also be used to characterize the bioaccumulation in the bio active zone and to evaluate the reduction in bioaccumulation achieved by amendment with activated carbon.

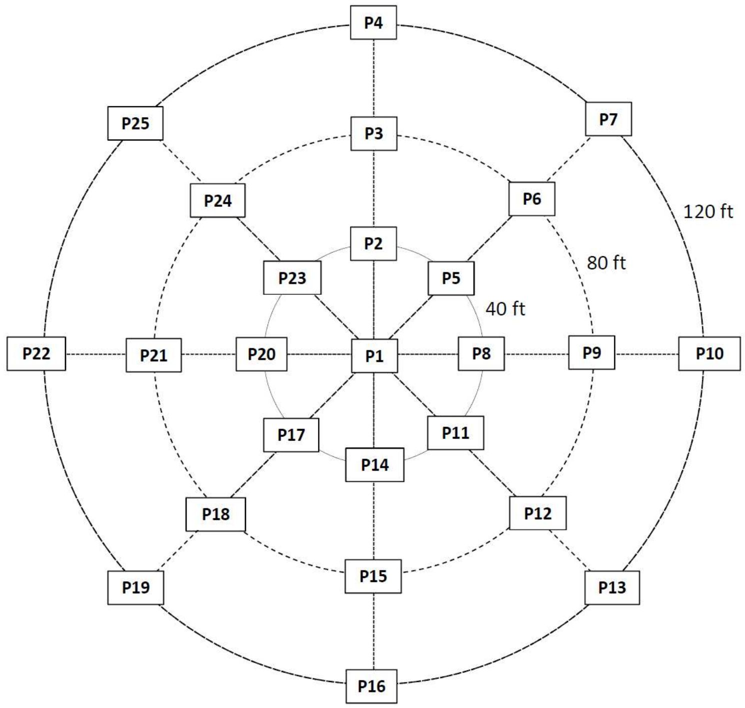

Figure 4. Sample locations for surface grab samples at placement site.

RESULTS

Only early results of the demonstration are presently available, describing the initial conditions. The dredged material is classified as CL (lean clay of low plasticity by the Unified Soil Classification System), having a liquid limit (LL) of 37, plastic limit (PL) of 22 and plasticity index (PI) of 15. The dredged material had an engineering water content ranging from 65 to 67% and a solids content of 60%. The liquidity index ranged from 2.7 to 3.0 and the toughness index ranged from 1 to 1.3. The amended dredged material had an engineering water content of 60%, a solids content of 62%, a liquidity index of 2.4 and a toughness index of 2.1. The amended dredged material in the barge prior to discharge had an average dry bulk density of 0.934 g/cc while the placement site surface grab samples had an average dry bulk density of 0.947 g/cc, indicating that no water was entrained in the dredged material during descent and spreading.

The unamended dredged material in the first four barge load had 2.5% organic matter of which 0.5% was associated with soft labile organic matter and 2% was associated hard refractory organic matter. The TOC was about 1.3% of which 1.0% represents refractory carbon which dominates the availability of organic contaminants such as PCBs. The dredged material in the fifth barge load prior to being amended with activated carbon had 2.8% organic matter of which 0.8% was associated with soft labile organic matter and 2% was associated hard refractory organic matter. The TOC was about 1.5% of which 1.0% represents refractory carbon.

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 GAC concentration ranged from 0.8% to 4.0% while the PAC concentration ranged from 0.6% to 2.6%. Approximately a third of the PAC was lost during addition and mixing as fugitive dust. Both the PAC and GAC were added dry from suspended super sacks as shown in Figure 2. Additionally, the overall concentration of GAC in the barge was increased by 0.3% by spreading four super sacks of GAC across the surface of the amended dredged material prior to discharging the amended dredged material at the placement site.

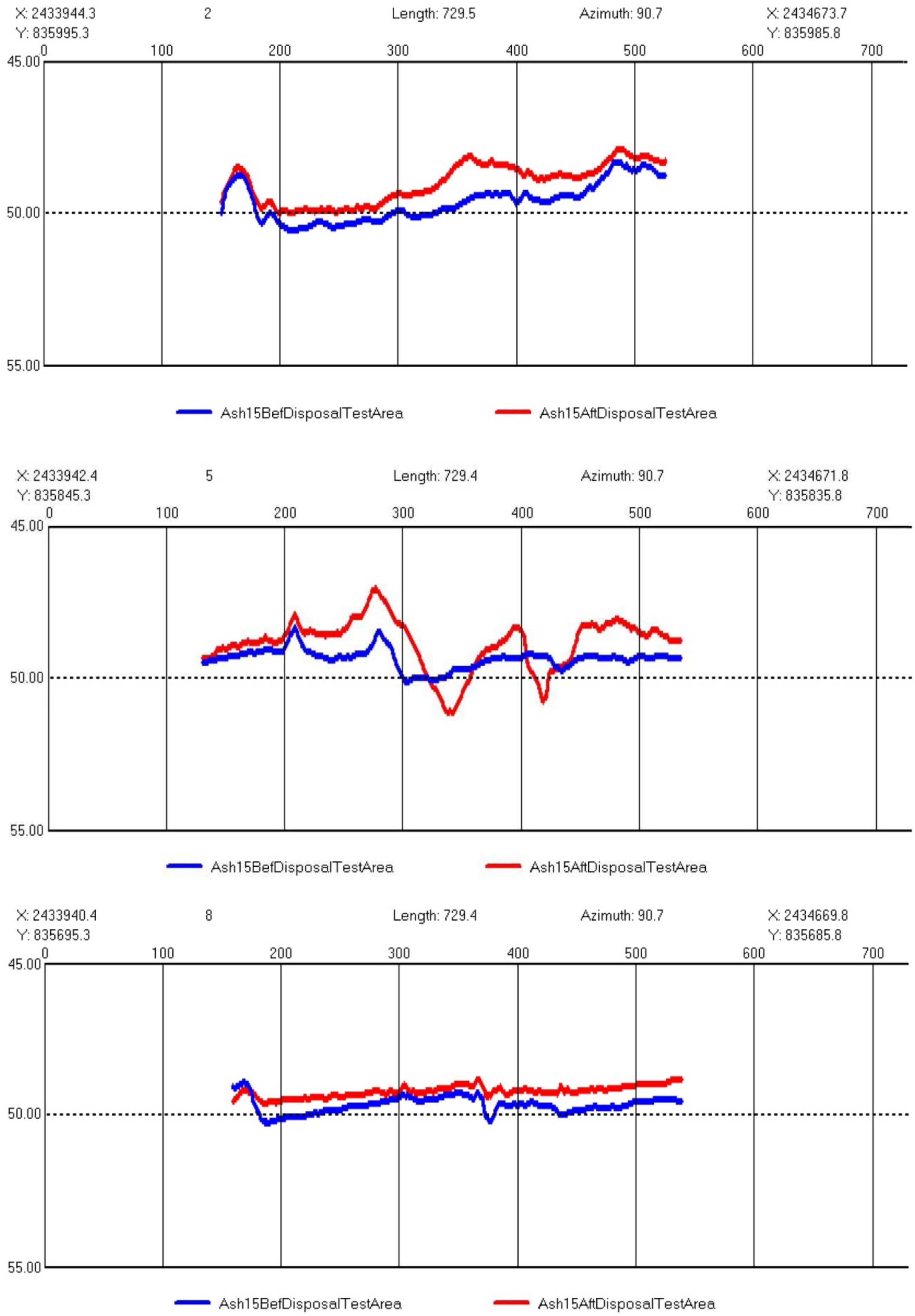

Figure 5. Hydrographic survey E-W transects of Ashtabula demo site before and after placement (top transect – 150 ft north of mound center, middle transect – mound center, bottom transect – 150 ft south of mound center) showing water depth in ft along the transects which show their length and positioning in ft.

The CV's were 0.35 and 0.34 for the GAC concentration and PAC concentration, respectively, showing that GAC and PAC mixed similarly with the dredged material. The results showed that the activated carbon concentration was not very uniform despite about six hours of mixing with a clamshell dredge bucket. However, the CVs were characteristic of a moderately well mixed system since the concentrations were normally distributed. If poorly mixed, the CV would be greater than 0.6 and the concentrations would not be normally distributed. If very well mixed, the CV would be less than 0.1.

The surface grab samples from about the top five centimeters (two inches) of the placement site showed a lower concentration of activated carbon than the amended dredged material samples from the barge, particularly for the PAC. The activated carbon contents of the individual samples are reported in Table 1. The average activated carbon concentration was 2.7%, 1% lower than present in the amended dredged material in the barge. The average GAC concentration was 2.2%, the same GAC concentration as in the barge, but the average PAC concentration was 0.5%, a full 1% lower than in the barge. The AC concentration ranged from 0.6% to 5.1% with a CV of 0.41. The GAC concentration ranged from 0.3% to 4.8% with a CV of 0.49, while the PAC concentration ranged from 0.0% to 1.1% with a CV of 0.53.

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.

The concentration of PAC in the surface grab samples at the placement site was only a third of the PAC concentration in the amended dredged material while the concentration of GAC was the virtually the same as in the amended dredged material. The low concentration of PAC most likely resulted from limited spreading of the amended dredged material which formed a cover much thinner than the four-inch grab, diluting the amended dredged material with dredged material mound. The spreading was much less than desired due to its cohesiveness, toughness, shear strength and low liquidity. The PAC is not believed to have been lost during descent and spreading because no water was entrained in the surficial dredged material. The GAC concentration was largely unchanged despite the dilution because the surface loading of GAC in the barge was able to spread freely and enrich the surface of the cover. Figure 6 shows a grab sample from the placement site with the various activated carbon components.

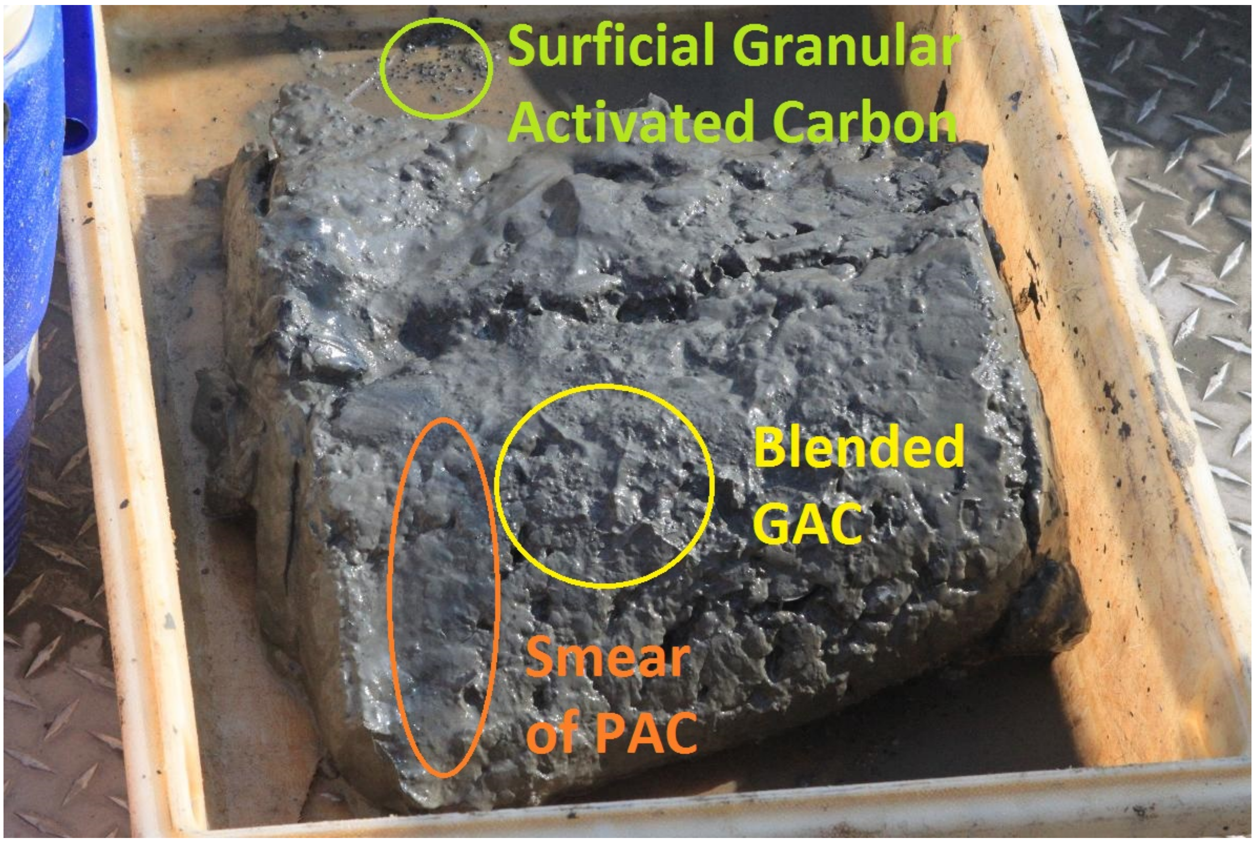

Figure 6. Surface grab sample from placement site showing activated carbon.

Chemical characterization of each barge of unamended dredged material was performed to establish baseline conditions for the study. Table 2 below presents the data for total PCBs for each of the 4 unamended barges of dredged material that was placed at the disposal site and the dredged material that was placed in barge 5 prior to amendment of carbon.

Table 2. Total PCBs from the unamended dredged material barge composites.

Barge	Total PCBs (ug/kg)
1	45.5
2	70.2
3	40.7
4	42.2
5	12.7

Bioaccumulative properties for PCBs were characterized using 28-day tests with *Lumbriculus variegates*. Table 3 presents the results of bioaccumulative test of the unamended dredged material to provide a baseline for the study for PCB congeners and percent tissue lipids.

Table 3. Bioaccumulation results for unamended dredged material.

Sample	% Tissue Lipids	Tissue Total PCBs (ug/kg)	Tissue Total PCBs (lipid normalized) (mg/kg)
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

A second round of surface grab samples will be collected from the placement site in July 2016 to determine the reduction in bioaccumulation resulting from the treatment.

CONCLUSIONS

USACE Buffalo District and USAERDC successfully placed an activated carbon amended cover on a dredged material mound at an open water placement site using a conventional mechanical dredging operation. The physical characteristics, organic matter and organic carbon of the dredged material have been quantified. The activated carbon contents of the amended dredged material and the surface of the cover at the placement site have been measured. The mechanical dredging operation was able to able to mix the activated carbon into the dredged material fairly well. The placement operation was also able to achieve a fairly good coverage that is believed to be sufficient to achieve the desired bioaccumulation reduction. The surficial loading of GAC in the barge is believed to have provided the desired spreading of activated carbon despite the limited liquidity of the dredged material.

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CITATION

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