B-024, in: A.K. Bullard and E.A. Stern (Conference Chairs), *Remediation of Contaminated Sediments—2013.*
Seventh International Conference on Remediation of Contaminated Sediments (Dallas, TX; February 4–7, 2013).
ISBN 978-0-9819730-6-7, ©2013 Battelle Memorial Institute, Columbus, OH. **www.battelle.org/sedimentscon**.

Installing an Activated-Carbon Sediment Amendment at the Puget Sound Naval Shipyard and Intermediate Maintenance Facility, Bremerton, WA

R. K. Johnston (johnston@spawar.navy.mil), V. J. Kirtay, D. B. Chadwick, G.H. Rosen, and J. M. Guerrero (Space and Naval Warfare Systems Center Pacific, San Diego, CA)
J. Collins and C. Ortega (AquaBlok Ltd, Toledo, Ohio)
R. Webb and R. May (Dalton Olmsted & Fuglevand, Inc., Poulsbo, WA)
J. Germano, D. Browning, and E. Beaver (Germano & Associates, Inc., Bellevue, WA)
M. Wicklein, J. Pittz, and D.E. Leisle[1] (Naval Facilities Engineering Command Northwest, Bangor, WA)
L. Doyle and L. Hsu (Puget Sound Naval Shipyard & Intermediate Maintenance Facility, Bremerton, WA)

ABSTRACT: A demonstration project for Pier 7 at the Puget Sound Naval Shipyard & Intermediate Maintenance Facility (PSNS&IMF) located in Sinclair Inlet, Puget Sound, WA is evaluating and validating the placement, stability and performance of activated carbon to treat contaminated sediments in an active harbor setting. During a fender pile replacement project for Pier 7 at the shipyard in 2010, legacy contamination was identified adjacent to the pier. In October 2012, the contaminated area was amended with powdered activated carbon (PAC) using the AquaGate+PAC™ composite aggregate system to improve delivery, physical stability, and decrease the bioavailability of polychlorinated biphenyls (PCBs) and other contaminants in the 190 × 115 ft (58 × 35 m) target area of which about half of the area was located under the pier. The amendment was applied from a tug-operated, moored barge that contained the staged AquaGate+PAC™ product packaged in 119 individual 2400 lb (1000 kg) fabric bags, a backhoe loader that moved each bag to a hopper feeder, and a truck-mounted conveyor belt-type (telebelt) broadcast conveyor system. Successful placement required uniformly placing about 2 to 3 inches of the product over the target area. The broadcast application obtained a rapid, relatively uniform placement of about 143 tons (130 metric tons) of product over the target area. The equipment was able to place the material both in the open access berthing area and under the dock by accessing the under dock areas between existing pilings during low tide. Pre- and post-placement monitoring is being conducted to document physical, geochemical, and biological conditions with diver-assisted sampling using the sediment ecotoxicity assessment (SEA) ring protocol, the sediment profile imaging (SPI) camera, benthic infauna sampling, and geochemical analysis.

INTRODUCTION

Successfully demonstrating the delivery, placement, and effectiveness of in-situ treatment materials in active harbors has the potential to reduce costs, shorten recovery times, and provide more effective alternatives to traditional methods of remediation for a wide range of sites with contaminated sediment. Although in-situ treatment is described

[1] Current affiliation Port of Portland, Portland, OR

in Environmental Protection Agency (EPA) guidance for remediating contaminated sediment sites (US EPA 2010), large scale demonstrations, implementation, and acceptance are generally lacking (Ghosh et al., 2011). Traditional sediment remedies usually involve removal by dredging or isolation by capping. However, removal actions may cause increased mobility and bioavailability of the contaminants, physical capping may not be practical in active harbors and navigable waterways, and dredging and capping may cause more harm than good (Ghosh et al., 2011). Significant challenges for amendment placement in active harbors include security access, scheduling, deep water placement, working near and under waterfront structures, complex bathymetry and dredge cuts in berthing areas, strong and variable tidal currents, and possible disturbance from ship movement and other harbor activities.

The purpose of this study was to conduct a full scale (0.5 acre) amendment application at an active deep-water harbor location adjacent to Pier 7 at the Puget Sound Naval Shipyard & Intermediated Maintenance Facility (PSNS&IMF, Figure 1). Amending contaminated sediments with a chemical sorbent is designed to enhance ecosystem recovery by sequestering the contaminants thereby reducing uptake by sediment dwelling organisms and lessening the flux into the overlying water column. Recently, activated carbon has shown promising results at the pilot scale for reducing bioavailability of hydrophobic contaminants such as polychlorinated biphenyls (PCBs, Ghosh et al., 2011; McLeod et al., 2007; Millward et al., 2005; Sun and Ghosh, 2008), polycyclic aromatic hydrocarbons (PAHs, Cornelissen et al., 2006), mercury (Hg) and methylmercury (MeHg, Ghosh et al., 2011; Kim et al. 2011), dioxins (Fagervold et al., 2010), and other contaminants (Tomaszewski et al., 2007). However, most applications have used granulated activated carbon which is not well suited for use in deep water due to its low density and difficulty in applying the amendment to the seafloor at depth.

FIGURE 1. Location of Pier 7 at PSNS&IMF in Sinclair Inlet near Bremerton, WA.

Site Description. Pier 7 is located inside the Controlled Industrial Area (CIA) of the shipyard and is part of the Bremerton Naval Complex (BNC) which includes Naval Base Kitsap Bremerton and PSNS&IMF. The industrial waterfront consists of an armored shoreline with dry docks, quay walls, and several large piers. Site characteristics for Pier 7 are shown in Table 1. Vessel traffic ranges from small recreational and commercial fishing vessels to occasional larger tug and Navy ship traffic, and regularly scheduled Washington State ferries arriving and leaving the Bremerton Ferry Terminal. Wind action in Sinclair Inlet generally creates a wave height range of 0.5 to 2.5 ft (0.15 – 0.76 m). Maximum wave heights are generated with winds from the SW (Wang and Richter 1999).

TABLE 1. Pier 7 site characteristics.

Tide [1]	Mean Range	Diurnal Range
	2.44 m	3.58 m
Bottom Depth [2]	Avg	Range
	12.5 m	10.7 -15.5 m
Temperature [3]	14.5 C	9.7 - 21.7 C
Salinty [3]	29.3 PSU	28.3 - 30.3 PSU
Current Speed [4]	Avg	Upper Bound
	2.5 cm/s	40 cm/s
Sediment Texture [5]		
Type	Sandy Mud/Muddy Sand	
	phi	mm
Mean	4.35	0.05
	Avg	Range
Gravel %	0.0	0 - 0
Sand %	45.2	20.5 - 75.7
Mud %	54.8	24.3 - 79.5
TOC % [6]	3.1	2.6 - 3.5

[1] NOAA 2012 [5] McLaren 2011
[2] NOAA 1990 [6] URS 2012
[3] Albertson et al., 1993
[4] Wang and Richter 1999

The sediments in the nearshore area of the BNC have been designated as Operable Unit B Marine (OU B Marine) under the Comprehensive Environmental Response and Liability Act (CERCLA) response action for cleanup. A Record of Decision (ROD) for OU B Marine was signed in June 2000 (U.S. Navy, Ecology, and USEPA, 2000). A component of the ROD required dredging contaminated marine sediments within OU B Marine and disposing them in a confined aquatic disposal pit created within inner Sinclair Inlet. The remedy also included monitored natural attenuation, which relies on natural sediment recovery processes to gradually cover any residual contamination with cleaner sedimentary deposits. The objective of the remedy was to reduce sediment-bound PCB exposure to benthic infauna to protect tribal consumption of fish and shellfish. Cleanup goals for PCBs were defined for area-weighted average sediment concentrations and English sole fish tissue concentrations (U.S. Navy, Ecology, and USEPA 2000). Subsequent reviews identified that Hg was also a contaminant of concern for tribal consumption of fish and shellfish (NAVFAC NW 2012). During a fender pile replacement project for Pier 7 in 2010, elevated PCBs, Hg, and other contaminants were found adjacent to Pier 7 (NAVFAC NW 2012). Based on these findings, the Navy submitted a proposal to the Environmental Security Technology Certification Program (ESTCP) to conduct a full-scale sediment amendment demonstration project at the site using activated carbon (Chadwick et al., 2011). The proposal was selected for funding in Fiscal Year 2011, and following a successful laboratory go/no-go evaluation (Kirtay et al., 2012), the field demonstration was initiated in August 2012 as a remedial action under the CERCLA ROD for OU B Marine.

MATERIALS AND METHODS

Sediment Survey. A diver assisted sediment survey was conducted around Pier 7 to more thoroughly delineate the nature and extent of contamination at the site. Ten transects perpendicular to the pier were established with 4 in (10 cm) surface cores taken about every 50 ft (15 m) in the berthing area and every 30 ft (9 m) under the pier and avoiding the recently disturbed area 15 ft (4.5 m) on either side of the fender pilings (see Figure 3). Rapid Sediment Characterization (RSC, Kirtay et al., 2001) methods were used to rapidly screen the samples using a portable X-ray Fluorescence (XRF) detector for metals (Cu, Zn, and Pb) and Enzyme Linked Immuno-Sorbent Assays (ELISA) for PCBs (as Aroclor 1254, RaPID™ Assay, Strategic Diagnostics Inc., Newark, DL) and PAHs (as total PAHS, EPA Method 4035). A subset (20%) of the samples was used for confirmation analysis using more expensive analytical techniques including inductively coupled plasma mass spectroscopy (ICP-MS) for metals and gas chromatography/mass spectroscopy (GC/MS) for organics (Guerrero et al., 2011). A split of each sample was also submitted for laboratory analysis for total Hg using cold vapor atomic absorption and grain size distribution (McLaren, 2011).

Pre-placement Sampling. The effectiveness of the amendment will be evaluated on the basis of reduced bioaccumulation of PCBs and Hg in benthic organisms and the reduction in porewater concentrations of contaminants measured using diffusive gradients in thin-film (DGT) passive samplers (SSC Pacific, 2012). The pre-placement monitoring was conducted from July 31 to August 14, 2012. The monitoring consisted of diver-assisted placement of Sediment Ecotoxicty Assessment (SEA) Rings (Rosen et al., 2011) at 10 locations for 14 days, sediment core sampling from the SEA Ring sites and at an additional 4 reference locations outside the placement area, and about 50 sediment profile image (SPI) sites located within an area that encompassed the amendment target area (Figure 2A). The SEA Ring (Figure 2B) consists of benthic chambers to measure PCB and Hg uptake by clams *(Macoma nasuta*), worms (*Neanthes arenaceodentata*), and DGT passive samplers; assess toxicity to amphipods (*Eohaustorius estuaries*); and collect samples to characterize the physical, geochemical, and biological conditions of the site (Rosen et al. 2012). The SPI camera is an optical coring device that images a cross-section of the upper 8 in (20 cm) of the seafloor (Germano et al. 2011). Two SPI systems were used, a frame-mounted system deployed by crane for imaging the sediment surface in the open-water berthing area and a hand held system deployed by divers for imaging the under pier area. On October 30-31, 2012, one week following placement, another set of SPI images was taken to verify the amendment thickness and the area treated. Follow-on monitoring is planned that will repeat the SEA Ring deployments, SPI camera monitoring, and sampling for infauna, total organic carbon (TOC), and black carbon for January 2013 (3 months, sampling for TOC and black carbon, only), April 2013 (6 months), April 2014 (18 months), and September 2015 (36 months, SSC Pacific 2012).

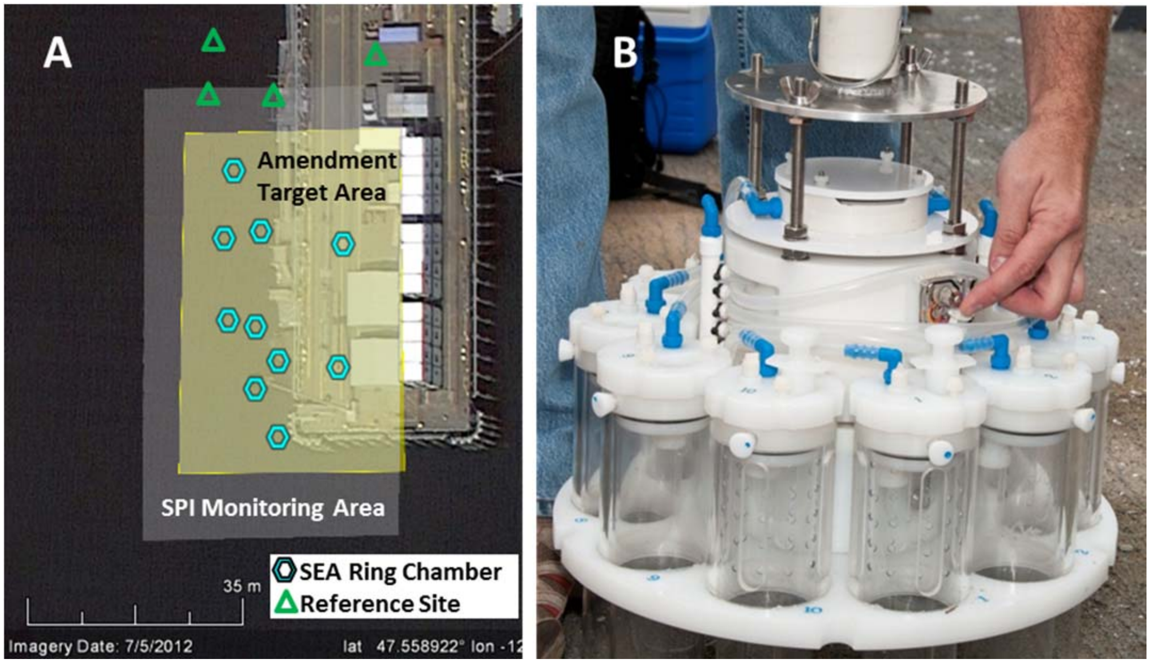


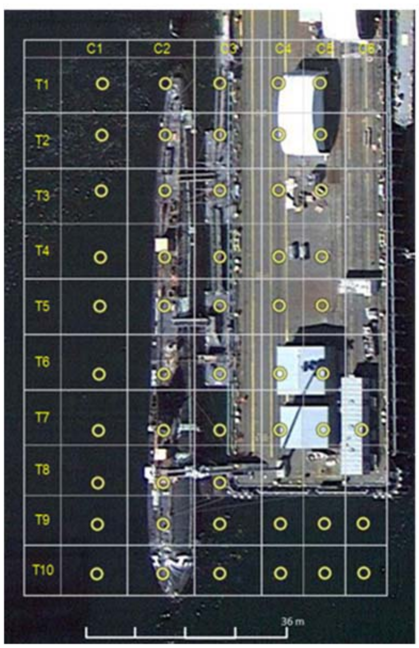
FIGURE 2. (A) South end of Pier 7 and the location of SEA Ring deployments, amendment target area, and SPI camera monitoring area. (B) SEA Ring device.

Amendment. AquaGate+PAC™ (AquaBlok Ltd, Toledo, OH) is made of composite particles manufactured with a crushed stone core coated with a combination of bentonite-based clay and PAC. The formulation used for this project was 2% to 5% (by weight) PAC, 5-10% clay (calcium bentonite) and 85% aggregate (60 – 96 mm), with a dry bulk density of 85 – 90 lbs/ft^3 (1.36 –1.44 g/cm^3). After placement on the sea floor, the PAC is designed to separate from the aggregate core and become incorporated into bottom sediment. The product was manufactured in Toledo, OH and transported to the Port of Tacoma, WA in seven truck-hauled containers containing the product packaged in water resistant, 2,400 lb (1095 kg), "Super Sacks" (bulk bags), where the material was staged on a barge for transport to the shipyard. Because, the product is sensitive to water, care was taken to protect the material from water damage at all times.

Dive Support. Dive support for the project was provided by the PSNS&IMF Dive Locker. The divers were equipped with SuperLite® 17 helmets (Kirby Morgan Dive Systems, Inc., Santa Maria, CA) and 7 mm neoprene wet suits with surface supplied air and warm water through an umbilical tether system from the dive boat. The dive team consisted of two divers, two tether handlers, a dive supervisor and backup, standby divers. The divers were in constant communication with the dive supervisor and scientific team with audio communications and an underwater video camera (UWS-3200, Outland Technology, Slidell, LA) with a light emitting diode that was either attached to the diver's helmet or hand held. The video was displayed on a monitor onboard the dive boat and the video and audio from the divers were recorded with a digital video recording device. The direct communication with the divers was very valuable to the scientific team, as the divers were able to communicate information about sea floor conditions and provide feedback on equipment performance and sampling conditions.

RESULTS AND DISCUSSION

Site Characterization. Within 36 hr of sampling, the screening data were used to identify the location of elevated PCB contamination. The results showed an isolated area of elevated contamination for PCBs and patchy locations of elevated total Hg (Figure 3). Bulk sediment samples were collected from cell (T6, C3) for the laboratory go/no-go evaluation study (Kirtay et al. 2012). Washington State Sediment Quality Criteria (SQC) and Maximum Cleanup Levels (MCL) (WAC 173-204) were exceeded by the maximum concentrations of PCBs, Hg, Cu, and Zn, while only Hg exceeded the sediment standards based on the ninetieth percentile (90% of geomean) of the geometric mean (geomean, Table 2). Sediment texture ranged from sandy mud to muddy sand with an average size of 4.35 ϕ (0.05 mm) and average TOC content of 3.1% (Table 1).



PCB_{RSC} ng/g

	C1	C2	C3	C4	C5	C6
T1	234	192	91	46	152	
T2	176	151	28	261	58	
T3	170	96	285	74	48	
T4	341	140	113	133	11	
T5	111	594	159	150	74	
T6	243	262	6650	305	439	
T7	224	261	129	655	193	105
T8	227	129	163			
T9	74	74	73	84	80	
T10	161	24	126	92	134	115

Hg ug/g

	C1	C2	C3	C4	C5	C6
T1		0.64	0.40	0.24	0.62	
T2	0.52	0.20		0.70	0.17	
T3	0.43	0.11	0.73	0.19		
T4	1.19	0.29	0.45	0.57	0.21	
T5	0.21	0.83	0.69	0.44	0.49	
T6	0.56	0.49	0.90	0.36	0.60	
T7	0.33	0.85	0.14	0.69	0.34	0.26
T8	0.12	0.17	0.28			
T9	0.32	0.35	0.17	0.06	0.18	0.20
T10	0.67	0.06	0.44	0.81	0.92	1.00

FIGURE 3. Sediment sampling transects at Pier 7 and the results for PCBs and Hg.

TABLE 2. Results from sediment transects at Pier 7 and comparison to sediment standards. The RSC results were converted using regressions from the confirmation analysis using ICP/MS for metals and GC/MS for organics (Guerrero et al., 2011).

$PCBs = 0.8344 \times PCB_{RSC} \quad R^2 = 0.811$ $\qquad Cu = 1.46 \times Cu_{RSC} \quad R^2 = 0.850$

$PAHs = 0.1810 \times PAH_{RSC} \quad R^2 = 0.923$ $\qquad Zn = 1.40 \times Zn_{RSC} \quad R^2 = 0.815$

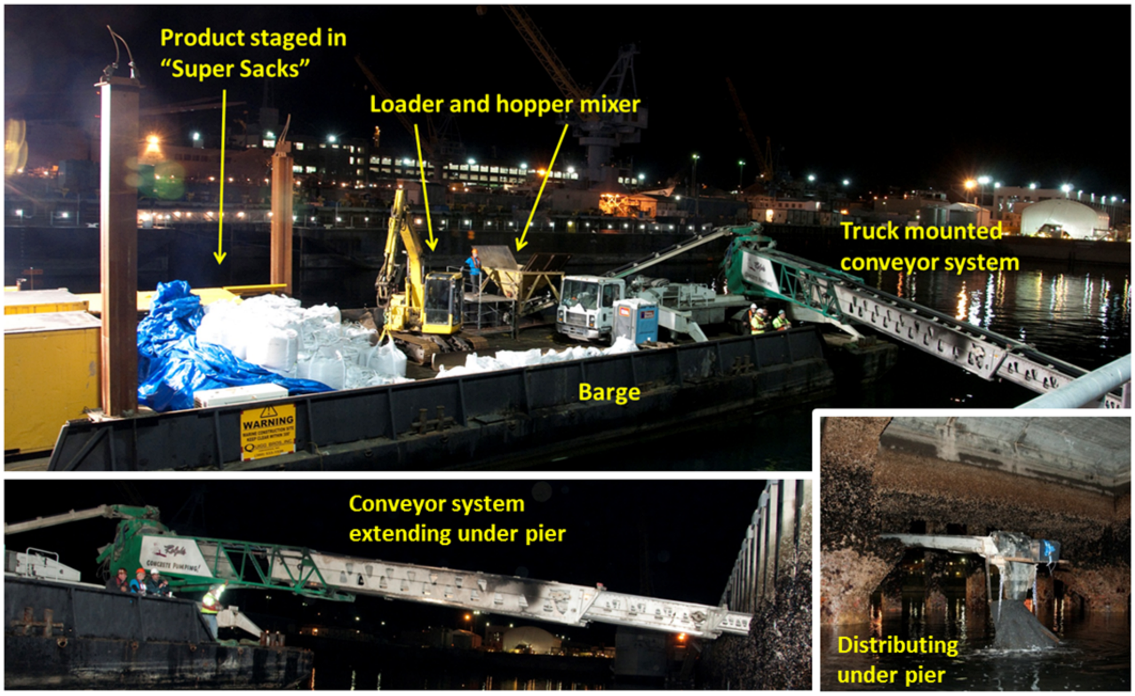
$Pb = 1.04 \times Pb_{RSC} \quad R^2 = 0.810$

	PCBs ng/g	PAHs ug/g	Cu ug/g	Zn ug/g	Pb ug/g	Hg ug/g
Detect Limit	44.7	0.18	70.1	60.7	39.7	0.005
min	4.6	0.18	70.1	60.7	39.7	0.058
max	5549.1	4.58	3659.1	1182.7	431.6	1.189
average	241.1	1.32	176.2	273.2	83.5	0.445
standard dev.	773.1	0.75	507.6	188.1	61.7	0.278
geomean	101.5	1.12	100.9	230.7	73.1	0.356
90% of geomean	288.8	2.09	199.6	396.5	114.8	0.738
median	112.1	1.38	70.1	228.0	61.0	0.402
WA SQC	**372.0 ***	**41.23 ***	**390.0**	**410.0**	**450.0**	**0.410**
WA MCL	**2015.0 ***	**188.48 ***	**8390.0**	**960.0**	**530.0**	**0.590**

* Assuming average TOC = 3.1%

Product Placement. On October 15, 2012, the tug *Margaret Mary* and barge *Aberdeen* arrived onsite at Pier 7. Amendment placement commenced at 20:00 on October 16 and the contractor worked 12 hr shifts through the nights of October 16-17 to take advantage of the favorable tides and weather. The product was placed in both open berthing and under pier areas from the tug-operated, moored barge that contained the staged product packaged in the "Super Sacks," a backhoe loader that moved each bag to a hopper feeder, and a truck-mounted conveyor belt-type (telebelt) broadcast conveyor system (Figure 4). The broadcast application obtained a rapid, relatively uniform placement of about 143 tons (130 metric tons) of product over the target area. The equipment was able to place the product both in the open access berthing area and under the pier by accessing the under pier areas between existing pilings during low tide. Most of the placement occurred at night to accommodate the tidal conditions. Measurements of the amendment thickness were made by placing a 5 gallon bucket on the seafloor next to the pier and capturing the product as the conveyor distributed the product along the pier. A layer of about 2 – 4 in (5 – 10 cm) of the product was captured in the bucket from the single pass used to distribute the product. Once the barge was moored in the desired position, distribution of the product occurred relatively quickly, resulting in cycle-time of about 3 min/sack to distribute the product.

On the morning of October 19, 2012, the PSNS&IMF Divers were on site to observe placement of the final two sacks during daylight hours. Diver observations of product delivery showed that the small pebbles were resistant to the current velocities and sank slowly to the bottom settling on the existing bottom substrate, without any untoward impact to sea life on the bottom, such as sea anemones, sea stars, crabs, and flat fish. No turbidity plumes associated with the placement were observed. Diver surveys, sediment cores, and SPI camera monitoring of the placement area conducted on October 30-31, 2012, showed that the PAC covering had released from the aggregate, as the light-colored aggregate was plainly visible on the seafloor (Figure 5). Initial observations indicated that the amendment was placed effectively over the target area; however variation in thickness was observed and there was



some overspray or drift of the amendment slightly beyond the edge of the target area.

FIGURE 4. Product placement.

FIGURE 5. Seafloor at base of Pier 7 following amendment placement.

Detailed analysis of the cores and SPI results is currently underway (Kirtay et al. 2013). Because of the nature of the demonstration project, the costs incurred (Table 3) may not necessarily reflect the production-scale placement unit cost which could be reduced by minimizing the fixed price for installation while maximizing the area treated.

Table 3. Cost for monitoring and placement.

Monitoring (per event)				
Field Work	$	97,000		
Dive Support	$	27,000		
Laboratory Analysis	$	59,000		
Reporting	$	40,000		
	$	223,000		
Placement			cost/ton	
Product (140 tons)	$	56,000	$	400
Shipment	$	42,000	$	300
Staging/Delivery	$	140,000	$	1,000
Verification	$	16,000	$	114
	$	254,000	$	1,814
Placement Unit Cost				
Area Treated		0.502	acre	
Placement Cost/ft²	$	11.62		
Placement Cost/m²	$	125.13		

CONCLUSIONS

Overcoming the challenges associated with installing the amendment under operational shipyard conditions included long range planning and coordination to obtain the outages and security clearances required to perform the work at Pier 7 within the CIA, contracting the necessary expertise and equipment, leveraging resources with other funded projects, and engaging with stakeholders to garner understanding and acceptance of the project's goals and objectives. The demonstration project at Pier 7 is being conducted to demonstrate and validate placement, stability, and performance of reactive amendments for treating contaminated sediments in an area with elevated PCB and Hg contamination. Because the PAC and the clay mineral associated with the aggregate may also sorb Hg and MeHg complexes, thereby reducing mercury bioavailability, a subset of the data collected to meet biological and chemical performance objectives for this project will also include measurement of Hg and MeHg endpoints (SSC Pacific 2012). Successful amendment application will require measurable reductions in the bioavailability of the target contaminants (PCBs and Hg/MeHg), the lack of toxicity or impact to the benthic community at the site, and achieve long term stability at a reasonable cost.

ACKNOWLEDGMENTS

Funding for this work was provided by the Environmental Security Technology Certification Program (ESTCP), the Navy's Environmental Sustainability Development to Integration Program (NESDI), Naval Facilities Engineering Command Northwest, and PSNS&IMF. The authors thank the following for significant contributions to the success of the project: PSNS&IMF Dive Locker and Photo Lab; Naval Base Kitsap Port Ops; Brad Helland - Hart Crowser Inc.; Skip Simpson and crew of tug MARGARET MARY and barge ABERDEEN - Quigg Bros Inc.; and Dr. Jason Conder - ENVIRON International, Corp. Mention of trade names and products are for information purposes only and do not constitute an endorsement for use. Approved for public release; distribution is unlimited.

REFERENCES

Albertson, S. L., J. Newton, L. Eisner, C. Janzen, and S. Bell. *1993. —1992 Sinclair Dyes Inlet Seasonal Monitoring Report*. Final Report 95345, Washington Department of Ecology, Olympia, WA.

Chadwick, D.B 2011. *Demonstration of In Situ Treatment with Reactive Amendments for Contaminated Sediments in Active DoD Harbors ER-201131*. Fact Sheet, ESTCP, Washington, DC.

Chadwick, D.B, V.J. Kirtay, V. Magar, J. Condor, R. Luthy, J. Germano, J. Collins, and R. Webb. 2011. *Demonstration of In Situ Treatment with Reactive Amendments for Contaminated Sediments in Active DOD Harbors*. Poster presented at The Partners in Environmental Technology Symposium and Workshop, Nov. 29 – Dec. 01 2011, Washington, DC.

Cornelissen, G., G.D. Breedveld, A.M.P. Oen, K. Næs, A. Ruus. 2006. "Bioaccumulation of native PAHs from sediment by a polychaete and a gastropod: Freely dissolved concentrations and activated carbon amendment." *Environ. Toxicol. Chem*., 25: 2349–2355.

Fagervold, S.K., Y. Chai, J. Davis, M. Wilken, U. Ghosh. 2010. "Bioaccumulation of polychlorinated dibenzo-p-dioxins/dibenzofurans in *E. fetida* from floodplain soils and the effect of activated carbon amendment." *Environ. Sci. Technol*. 44: 5546-52.

Germano, J.D., D.C. Rhoads, R.M. Valente, D.A. Carey, and M. Solan. 2011. "The use of Sediment Profile Imaging (SPI) for environmental impact assessments and monitoring studies - lessons learned from the past four decades." *Oceanography and Marine Biology: An Annual Review* 49: 247-310

Ghosh, U., R.G. Luthy, G. Cornelissen, D. Werner, and C.A. Menzie. 2011. "In-situ Sorbent Amendments: A New Direction in Contaminated Sediment Management." *Environ. Sci. Technol*., 45 (4): 1163–1168.

Guerrero, J., B. Beckwith, J.M. Brandenberger, R.K Johnston, J.M. Leather, and D. Leisle, 2011. *An Integrated Screening Methodology for Concise Site Decision Making and Chemical Characterization*. Poster presented at the Society of Environmental Toxicology and Chemistry 32nd Annual Meeting, Nov. 13-17, 2011, Boston, MA.

Kim, E., A.L. Seyfferth., S. Fendorf, R.G. Luthy. 2011. "Immobilization of Hg(II) in water with polysulfide-rubber (PSR) polymer-coated activated carbon." *Water Research*, 45: 453–460

Kirtay, V.J., S.E. Apitz, D. Lapota and J.M. Leather. 2001. *Rapid Sediment Characterization Tools for Ecological Risk Assessments*, EPA Tech Trends No. 40, EPA Solid Waste and Emergency Response, EPA 542-N-01-001.

Kirtay, V.J., D.B. Chadwick, G. Rosen, E. Arias, and J. Germano, 2012. *Reactive Amendments Treatability Study*, Technical Report, January 2012. Space and Naval Warfare Systems Center Pacific, Code 71750, San Diego, CA.

Kirtay, V.J., Chadwick, D.B., R.K Johnston, G. Rosen, J. Guerrero, J. Condor, M. McMeechan, M. Wicklein, J. Pittz, J. Germano, J. Collins, and R. Webb. 2013. *Demonstration of In Situ Treatment with Reactive Amendments for Contaminated Sediments in Active DOD Harbors*. Poster presented at the Seventh International Conference on Remediation of Contaminated Sediments, Feb. 4-7, 2013, Dallas, TX.

McLaren, P., 2011. *An assessment of nearshore sediments of the Bremerton waterfront: Their grain-size distributions, changes over time and transport pathways*. Final Report, December 19, 2011, SedTrend Analysis Ltd., Brentwood Bay, BC, Canada.

McLeod, P. B., M.J. van den Heuvel-Greve, S.N. Luoma, R.G. Luthy, R. G., 2007. "Biological uptake of polychlorinated biphenyls by *Macoma balthica* from sediment amended with activated carbon." *Environ. Toxicol. Chem*. 26: 980–987.

Millward, R.N., T.S. Bridges, U. Ghosh, R.G. Luthy, J.R. Zimmerman. 2005. "Addition of activated carbon to sediments to reduce PCB bioaccumulation by the polychaete, *Neanthes arenaceodentata*, and the amphipod, *Leptocheirus plumulosus*." *Environ. Sci. Technol*., 39: 2880–2887.

NAVFAC NW 2012. *Third 5-Year Review for the Bremerton Naval Complex*. Naval Facilities Engineering Command Northwest, Bangor, WA.

NOAA 2011. *Sinclair Inlet Chart 18452*, Rev. 2011, scale 1:10000, US Department of Commerce, Washington, DC.

NOAA 2012. Tide prediction web site. http://tidesandcurrents.noaa.gov/

Rosen, G., 2011. *Demonstration and Commercialization of the Sediment Ecosystem Assessment Protocol (SEAP) ER-201130*. Fact Sheet, ESTCP, Washington, DC.

Rosen, G., D.B. Chadwick, G.A. Burton, C. Stransky, H. Bailey, M.S. Greenberg, and J. Radford. 2012. *Preliminary Evaluation of a New Tool for Assessment of In Situ Biological Exposure and Effects in Aquatic Environments*. Presentation at the Society of Environmental Toxicology and Chemistry, European Annual Meeting, May 20-25, 2012, Berlin, Germany.

SSC Pacific (Space and Naval Warfare Systems Command Pacific). 2012. *Demonstration of In Situ Treatment with Reactive Amendments for Contaminated Sediments in Active DoD Harbors Project ER-201131: Demonstration Plan for Pier 7 at PSNS&IMF*. April 10, 2012. ESTCP, Washington, DC.

Sun, X., U. Ghosh. 2008. "The effect of activated carbon on partitioning, desorption, and biouptake of native PCBs in four freshwater sediments." *Environ. Toxicol. Chem.*, 27: 2287–2295

Tomaszewski, J.T., D. Werner, R.G. Luthy. 2007. "Activated carbon amendment as a treatment for residual DDT in sediment from a superfund site in San Francisco Bay, Richmond, California, USA." *Environ. Toxicol. Chem.*, 26: 2143–2150.

U.S. Navy, Ecology, and USEPA 2000. *Record of Decision for Operable Unit B Marine, Bremerton Naval Complex, Bremerton, WA*. June 13, 2000

URS 2012. 2012 *Operable Unit B Marine Monitoring Plan, Bremerton Naval Complex, Bremerton, WA*. Naval Facilities Engineering Command Northwest, Bangor, WA.

U.S. EPA 2010. *Superfund Cleanup Policies and Guidance*. U.S. Environmental Protection Agency, Office of Superfund, Washington, DC.

Wang, P.F and K.E. Richter 1999. *A Hydrodynamic Modeling Study Using CH3D for Sinclair Inlet*, Draft Report. Space and Naval Warfare Systems Center, San Diego, CA, November 3, 1999.