

COST AND PERFORMANCE REPORT

Solidification/Stabilization at the New Bedford Harbor Superfund Site
New Bedford, Massachusetts

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U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

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Summary Information [1,2,4,5,6]

The New Bedford Harbor Superfund Site (NBH) is located along the northwestern shore of Buzzards Bay in New Bedford Massachusetts, approximately 55 miles south of Boston. From the 1940s to 1978, two manufacturing facilities located along the New Bedford Harbor, the Aerovox facility and the Cornell-Dubilier electronics facility, discharged polychlorinated biphenyl (PCB)-contaminated wastewater from industrial operations onto the shoreline and into the harbor. During investigations of the site performed by EPA in the late 1970s, widespread PCB contamination was found in sediments and marine life throughout the 18,000 acres of estuary, harbor, and bay areas. In September 1979, the Massachusetts Department of Public Health (MDPH) closed major fishing areas within the harbor. In August 1982, EPA began a remedial investigation (RI) of the site. Sediments were found to be contaminated with PCBs, polycyclic aromatic hydrocarbons (PAHs), and heavy metals including lead, cadmium, copper, and chromium. The site was listed on the National Priorities List in September 1983.

Figure 1 shows a general layout of the NBH area. The NBH site has been divided into three operable units (OU) - Upper and Lower Harbors (OU1), 5-acre Hot Spot Area (OU2), and the Outer Harbor (OU3). EPA has performed RIs at OU1 and OU2; an RI has not yet been performed at OU3. PCB concentrations in OU1 were found to range from below detection levels to 4,000 mg/kg, while concentrations in the OU2 Hot Spot Area ranged from 4,000 mg/kg to more than 200,000 mg/kg. This report addresses the cleanup of OU2.

The Record of Decision (ROD) for OU2 was signed in April 1990 and specified source control measures that included dredging of PCB contaminated sediments from the Hot Spot area followed by incineration. The ROD specified that dredging would occur at depths of up to four feet to remove sediments with PCB concentrations of 4,000 mg/kg or higher. Dredging of about 15,000 cubic yards (18,000 tons) of sediment from the Hot Spot area was completed in the fall of 1995, with the dredged sediment temporarily stored in a Confined Disposal Facility (CDF) located along the New Bedford shoreline at the end of Sawyer Street. The CDF is a three cell, double-lined (high density polyethylene) holding pond that was planned to be used for staging sediments prior to incineration. However, due to local and congressional opposition to incineration, EPA postponed the incineration component of the Hot Spot remedy to explore alternative treatment technologies. In 1995, EPA issued an Explanation of Significant Difference to address interim storage of the Hot Spot sediments at the CDF. The CDF is covered with a 10-millimeter permalon cover.

EPA evaluated four technologies as possible alternatives to incineration of the Hot Spot sediments - solvent extraction/dechlorination, vitrification, thermal desorption/gas phase chemical reduction, and solidification/stabilization. Pilot-scale testing was performed for the first three technologies and bench-scale testing was performed for solidification/stabilization. Testing was conducted at the 8-acre NBH Sawyer Street location which includes the CDF, a test pad, a water treatment building, and a laboratory (see Figure 2). This report addresses the results of the treatability study of the solidification/stabilization technology, conducted from November 30 to December 4, 1995. Reports about the other technologies tested are available at www.frtr.gov/cost.



According to the EPA RPM, none of the four technologies tested have been implemented for OU2 because of lack of community support for the use of on-site technologies to remediate the Hot Spot sediments. As a result, the ROD for OU2 was amended in April 1999 to specify dewatering of the sediments on-site and transporting them off-site, without further treatment, to a Toxic Substances Control Act (TSCA) permitted landfill.

Figure 1. Site Location Map [1]

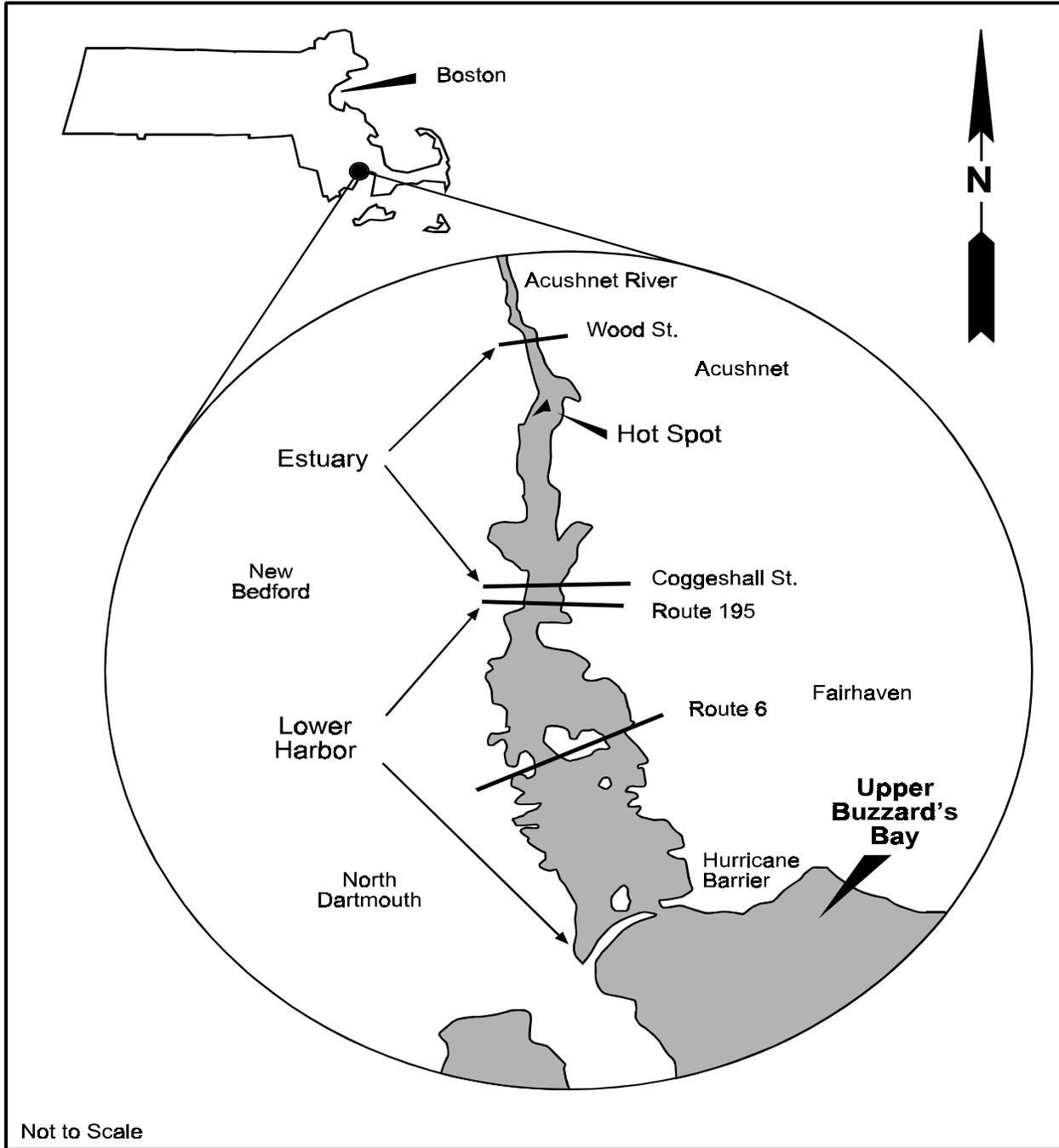
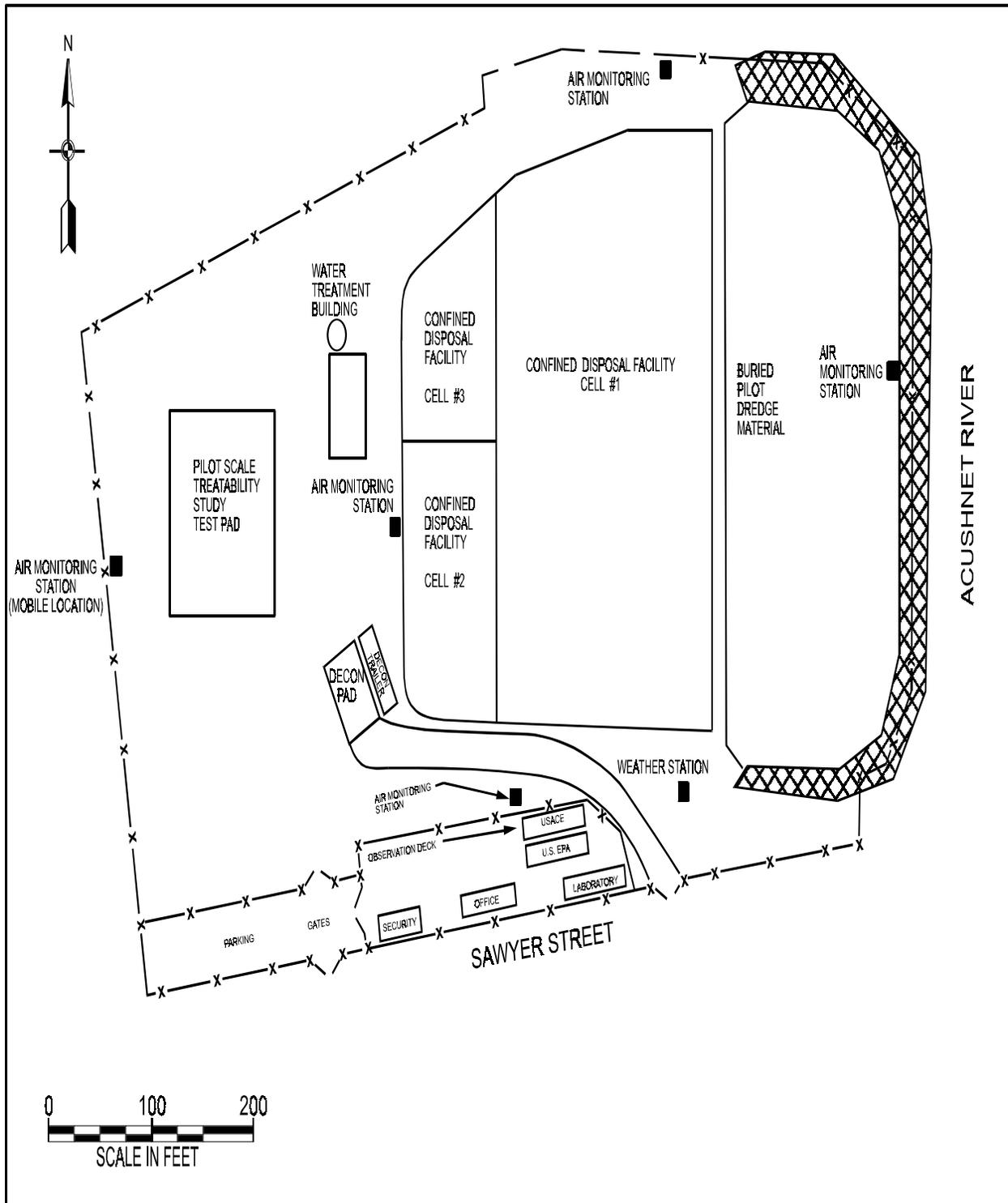


Figure 2. Layout of Confined Disposal Facility and Test Area [1]



Factors That Affected Cost or Performance of Treatment [1,3]

The sediment used in the treatability test was from the Hot Spot area of New Bedford Harbor, which had been dredged in 1995. PCB concentrations in the sediments in the Hot Spot area ranged from 4,000 to more than 200,000 mg/kg.

Matrix Characteristics [1,3]

Listed below are the key matrix characteristics for this technology and the values measured for each based on sediment samples collected in June 1995 from the CDF and from pilot study feed sediments.

Parameter	Value
Soil Classification	Fine sandy silt with some clay-sized particles present
Clay Content and/or Particle Size	50 - 70% of sediment passing a number 200 sieve; sediment contains some small shell fragments (pass through a 1-inch screen)
pH	Not provided
Moisture Content	50% by weight
Total organic carbon	7% (average)
Density	1.2 tons/cubic yard (wet weight)
Oil and Grease	CDF representative sample: 22,000 - 34,000 mg/kg Pilot study feed: 11,700 - 36,900 mg/kg

Treatment Technology Description and Operation [1]

A bench-scale study of solidification and stabilization was conducted to determine whether the technology was viable for treating the Hot Spot sediments and should be considered for further testing. Foster Wheeler conducted the treatability testing of seven solidification/stabilization reagents from Foster Wheeler, MARCOR Environmental (MARCOR), and World Environmental (WORLD). Table 1 presents a brief description of the reagents used in the treatability studies. Detailed information about each reagent is included in the Material Safety Data Sheets in Reference 1.

Treatability testing was performed on November 30 and December 4, 1995, using Hot Spot sediments. Reagents were added, mixed, and cured in accordance with vendor's instructions and were tested in batches, using three different proportions of reagents in the admixtures. Each batch was sampled and analyzed for toxicity characteristic leaching procedure (TCLP) compounds and for compressive strength.

Table 1. Reagents Used in Solidification/Stabilization Bench-Scale Tests [1]

Vendor/Reagent	Description of Reagents
Foster Wheeler	
Portland Cement	Type II Portland cement purchased from a local hardware store
Absorbent Clay	Absorbent clay (oil-dry) commonly used in automotive maintenance to absorb oil spills; purchased from an automotive supply shop
MARCOR	
HWT-27	A sintered material (calcium silicates contained in a crystalline mass that cannot be separated into individual components) that is produced by heating a mixture of substances such as limestone and shale to a high temperature (greater than 1,200°C). The mixture is similar to Portland cement in color and texture.
World	
LPC II	A light gray powder (15% SiO ₂ and 68% CaO), similar to Portland cement. This material is used to stabilize, solidify, and fixate a variety of non-hazardous and hazardous waste.
Clarion SM-399	A complex of montmorillonite clay and quaternary ammonium compound. Clarion SM-399 is specifically designed for dewatering and stabilization of wastes that contain large amounts of organic compounds.
Zonoco-P1	A mixture of some 30 organic and amino acids and other organic compounds, including choline, linolenic acid, tryptophane, and arginine.
OT-P2	A white, milky liquid containing 40% active alkoxysilane emulsified in water. OT-P2 is designed to deposit a reactive hydrophobic silane treatment to inorganic substrates such as glass, mica, or talc. The alkyl silane treatment improves the compatibility of inorganic materials in organic resins, both thermoplastic and thermoset.

Foster Wheeler

The Foster Wheeler solidification/stabilization test used Portland cement alone and mixtures of Portland cement and absorbent clay. Three test batches, 3,000 grams (g) each of sediment, were tested in the following proportions:

Batch No. (Sediment)	Portland Cement	Absorbent Clay	Total Mixing Time
FW1 (3,000 g)	600g (20%)	0	3.5 minutes
FW2 (3,000 g)	600g (20%)	75g (2.5%)	4 minutes
FW3 (3,000 g)	750g (25%)	75g (2.5%)	4 minutes



For each batch, the untreated sediment was first mixed (Hobart mixer) for one minute to ensure that the sediment was uniform. With the mixer running, the Portland cement was then added over a period of about 30 seconds; for Batches #2 and #3, the absorbent clay was added following the Portland cement and mixed for 30 seconds. All three batches were mixed for two additional minutes (final mixing), following the addition of the admixture. After the final mixing was completed, the mixer was turned off and each batch was divided and placed into various containers for curing and testing (six 4-ounce wide mouth glass jars for TCLP analyses and two 2 inch by 4 inch plastic cylindrical molds for analysis of compressive strength). All samples were placed in Ziploc bags and cured for 30 days.

MARCOR

The MARCOR solidification/stabilization test included the HWT-27 reagent, conducted in three batches using mix ratios of 12.5% (M1), 17.5% (M2), and 25% (M3) by weight of the admixture to 2,500 g of sediment. The untreated sediment was first mixed (Hobart mixer) for one minute to ensure that the sediment was uniform. The HWT-27 was mixed with tap water (2 pounds of dry reagent to 2.2 pounds of water) to form a slurry. With the mixer running, the slurry was added to the sediment over a period of 10 seconds, then mixed for an additional two minutes. The total mixing time for all three batches was 3 minutes and 10 seconds. After the final mixing was completed, the mixer was turned off and each batch was divided and placed into various containers for curing and testing (six 4-ounce wide mouth glass jars for TCLP analyses and two 2 inch by 4 inch plastic cylindrical molds for analysis of compressive strength). All samples were air cured for 30 days.

World

The World solidification/stabilization test used mixtures of LPC II, Clarion SM-399, Zonoco P-1, and OT-P2. Three batches of 2,000 grams (g) each of sediment were tested in the following proportions:

Batch No. (Sediment)	LPC II	Clarion SM-399	Zonoco P-1	OT-P2
W1 (2,000g)	360g (18%)	40g (2%)	40g (2%)	0
W2 (2,000g)	360g (18%)	40g (2%)	0	40g (2%)
W3 (2,000g)	300g (15%)	40g (2%)	20g (1%)	0

The untreated sediment was first mixed (Hobart mixer) for one minute to ensure that the sediment was uniform. With the mixer running, the reagents were added one at a time, and mixed thoroughly before the next reagent was added. For Batches #1 and #3, LPC II was added and mixed for 1 minute, followed by Clarion SM-399 and Zonoco P-1, each mixed for 30 seconds. For Batch #2, LPC II was added and mixed for 1 minute, followed by Clarion SM-399 and OT P-2, each mixed for 30 seconds. After all reagents were added, each batch was mixed for a final two minutes, for a total mixing time of 5 minutes for each batch. After the final mixing was completed, the mixer was turned off and each batch was divided and placed into various containers for curing and testing (six 4-ounce wide mouth glass jars for TCLP analyses and two 2 inch by 4 inch plastic cylindrical molds for analysis of compressive strength). All samples were air cured for 30 days.

Performance Information [1]

The objectives of the treatability study included evaluating the effectiveness of solidification/stabilization in terms of ability to reduce the leachability of PCBs, other organics, and heavy metals in the Hot Spot sediments, as measured by the Toxicity Characteristic Leaching Procedure (TCLP), and to evaluate the physical characteristics of the treated material, as measured by compressive strength. For TCLP PCBs, no regulatory limit had been established; therefore, results were used for comparison purposes only. For TCLP semivolatile organic compounds (SVOCs) and TCLP metals with TCLP regulatory limits, these limits were used as the target treatment goal. For TCLP SVOCs and TCLP metals with no regulatory limit, the results were used for comparison purposes only.

Table 2 presents the TCLP results of the treatability study for the Foster Wheeler, MARCOR, and World admixtures for PCBs, SVOCs, and metals, along with data for TCLP constituent concentrations in untreated sediment.

TCLP PCBs

The TCLP PCB concentrations in all batches for the three vendors was found to be higher in the treated sediment than in the untreated sediment, by a factor of two to four times. As shown in Table 2, compared to a concentration of 11 ug/L in the untreated sediment, the TCLP PCB concentration for the Foster Wheeler mixtures ranged from 27 to 35 ug/L in the treated sediment, from 38 to 49 ug/L in the MARCOR mixtures, and from 25 to 43 ug/L in the WORLD mixtures. While the specific reasons for the greater leachability in the treated material could not be determined based on the available data, Foster Wheeler indicated that one possible reason was that the solidification process absorbs some of the oily, organic fraction of the sediment, making the PCBs more mobile in the aqueous phase. Based on these results, solidification/stabilization was determined not to be effective in treating PCBs in the Hot Spot sediments.

TCLP SVOCs

TCLP SVOCs were analyzed to provide additional information about the solidification/stabilization process in terms of treating organics. For the two compounds tested with TCLP regulatory limits (1,4-dichlorobenzene at 7,500 ug/L and 2,4-dinitrotoluene at 130 ug/L), the levels in the treated material were below these limits, with 2,4-dinitrotoluene not detected in any of the batches and 1,4-dichlorobenzene ranging from 82 to 173 ug/L. However, concentrations in the untreated sediment for these compounds were also below the regulatory levels. For three of the SVOCs (phenols, 1,3-dichlorobenzene, and di-n-butylphthalate), concentrations in the treated materials were somewhat higher than in the untreated sediment in several of the mixtures. TCLP concentrations for phenols increased in mixtures from all three vendors, from 2 ug/L in the untreated sediment to as much as 4.7 ug/L in the treated material.

TCLP concentrations for 1,3-dichlorobenzene increased in mixtures from Foster Wheeler from 40 ug/L in the untreated sediment to as much as 48 ug/L in the treated material. TCLP concentrations for di-n-butylphthalate from 2.2 ug/L in untreated sediment to as high as 17 ug/L in mixtures from MARCOR and 3.7 ug/L in mixtures from Foster Wheeler. Similar to the results for PCBs, solidification and stabilization was determined not to appreciably reduce the leachability of SVOCs in the Hot Spot sediments.



Table 2 - Summary of TCLP Results for Solidification/Stabilization (ug/L) [1]

Analyte	TCLP Regulatory Limit	Untreated Sediment Average	FOSTER WHEELER			MARCOR			WORLD		
			FW1	FW2	FW3	M1	M2	M3	W1	W2	W3
PCBs											
Aroclor - 1242	NC	11	27	33	38	47	35	42	40	24	29
Aroclor - 1254	NC	0.22	ND	ND	7.3	1.6	3.0	4.0	2.8	0.8	1.2
Total PCBs	NC	11	27	33	45	49	38	46	43	25	30
SVOCs											
Phenol	NC	2	4.7	3.3	3.0	1	2.7	4.3	1.3	3.0	1.3
1,3-dichlorobenzene	NC	40.25	48	47	36	32	20	22	21	20	28
1,4-dichlorobenzene	7,500	102.5	173	153	88	127	82	94	92	97	122
1,2-dichlorobenzene	NC	1.25	3.0	1.7	4.7	0.33	ND	1.0	ND	ND	ND
N-nitroso-di-n-propylamine	NC	0.75	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-dichlorophenol	NC	13.25	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,4-trichlorobenzene	NC	3.75	4.3	4.0	4.0	3.7	2.3	4.3	3.3	3.7	3.7
4-chloro-3-methylphenol	NC	1.75	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	NC	1.25	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-nitrophenol	NC	2	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-dinitrotoluene	130	0.75	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-butylphthalate	NC	2.25	2.7	3.7	ND	12	17	15	1.0	1.0	1.0
Pyrene	NC	2.25	ND	ND	ND	ND	ND	ND	ND	ND	ND



Table 2 - Summary of TCLP Results (ug/L) for Solidification/Stabilization [1] (continued)

Analyte	TCLP Regulatory Limit	Untreated Sediment Average	FOSTER WHEELER			MARCOR			WORLD		
			FW1	FW2	FW3	M1	M2	M3	W1	W2	W3
Metals											
Arsenic	5,000	54.1	3.0	3.4	3.0	18.3	6.7	8.5	3.4	3.8	10.7
Barium	100,000	618	1,217	1,207	1,760	564	669	534	429	382	328
Cadmium	1,000	147	0.20	0.20	0.20	131	133	34.6	0.20	0.20	0.20
Chromium	5,000	226	18.6	20.6	14.5	207	158	59.2	14.4	13.7	13.9
Copper	NC	161	731	726	820	706	798	688	1,353	1,340	1,497
Lead	5,000	1,630	1.8	3.6	6.0	964	393	67.2	2.9	2.0	7.4
Mercury	200	0.20	0.20	0.20	0.20	0.20	2.6	1.1	0.20	0.20	0.20
Selenium	1,000	12.6	16.9	15.3	10.6	17.1	26.0	19.9	14.9	10.2	10.9
Silver	5,000	0.70	0.70	0.70	0.70	0.70	2.2	1.8	0.70	0.70	0.70
Zinc	NC	18,050	12.7	17.0	60.8	18,307	20,933	10,235	14.2	8.9	16.4

NC - No criteria
ND - Not detected



TCLP Metals

TCLP concentrations in the untreated Hot Spot sediment were below regulatory limits. The highest TCLP metals concentrations in untreated sediment were lead at 1,630 ug/L (compared to a TCLP limit of 5,000 ug/L) and zinc at 18,050 ug/L (no regulatory limit). Other metals detected in the untreated sediment included arsenic, barium, cadmium, chromium, copper, mercury, silver, and selenium. Foster Wheeler identified the metals of concern for the Hot Spot sediments as arsenic, cadmium, chromium, copper, lead, and zinc.

TCLP lead concentrations were reduced in all three solidification/stabilization mixtures from 1,630 ug/L in untreated sediment to a range of 1.8 to 964 ug/L in the treated material. For the other identified metals of concern, the Foster Wheeler and World solidification/stabilization mixtures reduced the TCLP concentrations for arsenic, cadmium, chromium, and zinc. The MARCOR mixture reduced concentrations for arsenic, cadmium, and chromium, but increased concentrations for zinc. Concentrations of copper increased in all three mixtures from 161 ug/L in untreated sediment to a high of 1,497 ug/L in the World mixture, 820 ug/L in the Foster Wheeler mixture, and 798 ug/L in the MARCOR mixture. According to Foster Wheeler, one possible reason for the high copper concentrations may be laboratory error, because the laboratory typically does not include copper in the TCLP analysis. However, Foster Wheeler noted that additional testing of copper would be needed before conclusions could be drawn regarding the reasons for the TCLP results.

For other metals tested, barium concentrations were reduced by the World mixture, but increased in the MARCOR and Foster Wheeler mixtures. No reason for the increase was provided. Concentrations of mercury, selenium, and silver were relatively low in the untreated sediment and were not changed significantly by the three mixtures.

One objective of the treatability study was to examine the effectiveness of Portland cement only (FW1) compared to the other admixtures. The TCLP metals results indicate that Portland cement was as effective as the World and MARCOR mixtures and the Foster Wheeler mixtures of Portland cement and absorbent clay.

Compressive Strength

Table 3 presents the results of the tests of the compressive strength of the admixtures. No performance goal was established for compressive strength for the treatability test. The Foster Wheeler mixtures had the highest compressive strength, ranging from 195 to 270 psi. The MARCOR has the lowest compressive strength, ranging from 45 to 80 psi.

Table 3 - Average Compressive Strength Results (psi) [1]

Foster Wheeler			MARCOR			World		
FW1	FW2	FW3	M1	M2	M3	W1	W2	W3
200	195	270	45	50	80	200	125	160

Overall Performance

Based on the results of the treatability study, Foster Wheeler concluded that solidification/stabilization did not appear to be a viable treatment for the Hot Spot sediments. None of the admixtures tested were effective in reducing TCLP PCB concentrations, and in general, increased leachability, resulting in higher concentrations in the treated material compared to the untreated sediment. Similar results were observed with SVOCs. According to Foster Wheeler, a higher reagent to sediment ratio may decrease leachability of the PCBs, but would result in higher costs to dispose of the larger volume of material that would be generated.

Solidification/stabilization may be appropriate for treating heavy metals in the Hot Spot sediments. The concentrations of metals in the untreated sediment were below TCLP regulatory limits. However, should heavy metals become a concern in the future, Foster Wheeler indicated that solidification/stabilization may be viable for further consideration.

Performance Data Quality [1]

Quality control procedures used for this study included collection of replicate field samples, laboratory quality control measures, including calibrations, blanks, matrix spikes, matrix spike duplicates (duplicate samples for inorganics), internal standard spikes, surrogate spikes, and serial dilutions, and data validation. No deviations in the quality control procedures were noted in the available reference material.

TCLP analyses were performed using EPA Method 1311 and the steel cage procedure (described in detail in Reference 1). However, because data from the steel cage procedure suggested that the samples had been contaminated, the results of the EPA Method 1311 were used for evaluating the performance of the solidification/stabilization treatability tests.

Cost Information

No cost data were available for the treatability study. Foster Wheeler did not develop projected full-scale costs for this application.

Observations and Lessons Learned [1]

None of the solidification/stabilization mixtures tested during the treatability study was effective in stabilizing PCBs or SVOCs in the Hot Spot sediments. In many cases, the contaminant concentrations in the treated material were higher than in the untreated sediment. Specific reasons for the increase in concentrations were not identified, though it is possible that the process increases the mobility of PCBs and other organics in the aqueous phase.

While the concentrations of metals in the untreated sediment were below the regulatory limits, solidification/stabilization generally reduced the TCLP metals concentrations in the treated material, and may be appropriate for treating metals in the Hot Spot sediments.

During the treatability test, two analytical methods were used - EPA Method 1311 and the steel cage method. According to Foster Wheeler, while the results of the steel cage procedure were not significantly different from Method 1311, results for some of the metals data from the steel cage procedure suggested that the samples had been contaminated. Because of this, the Method 1311 results



were used to evaluate performance. However, Foster Wheeler indicated that the steel cage method may provide a more accurate indication of how material behaves when stored in solid form. A detailed description of this procedure as well as the results from this test are included in Attachment G of Reference 1.

Contact Information [1]

EPA RPM:

James M. Brown
U.S. EPA Region 1 (MC HBO)
1 Congress Street, Suite 1100
Boston, MA 02114-2023
Telephone: (617) 918-1308
E-mail: brown.jim@epa.gov

State Contact:

Paul Craffey*
Massachusetts Department of Environmental Protection
Bureau of Waste Site Cleanup
One Winter Street
Boston, MA 02108
Telephone: (617) 292-5591
E-mail: paul.craffey@state.ma.us

EPA Contractor:

Helen Douglas
Foster Wheeler Environmental Corporation
470 Atlantic Avenue
Boston, MA 02210
Telephone: (617) 457-8263
E-mail: helen_douglas@fwc.com

* - Indicates primary contact for this application

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