COST AND PERFORMANCE REPORT

Thermal Desorption/Gas Phase Chemical Reduction at the
New Bedford Harbor Superfund Site
New Bedford, Massachusetts

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

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Summary Information [1,2,3,4,5,7]

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 (GPCR process), 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 pilot-scale study of the thermal desorption/ chemical reduction technology, conducted from November 18, 1996 to November 25, 1996. 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 Layout [1]

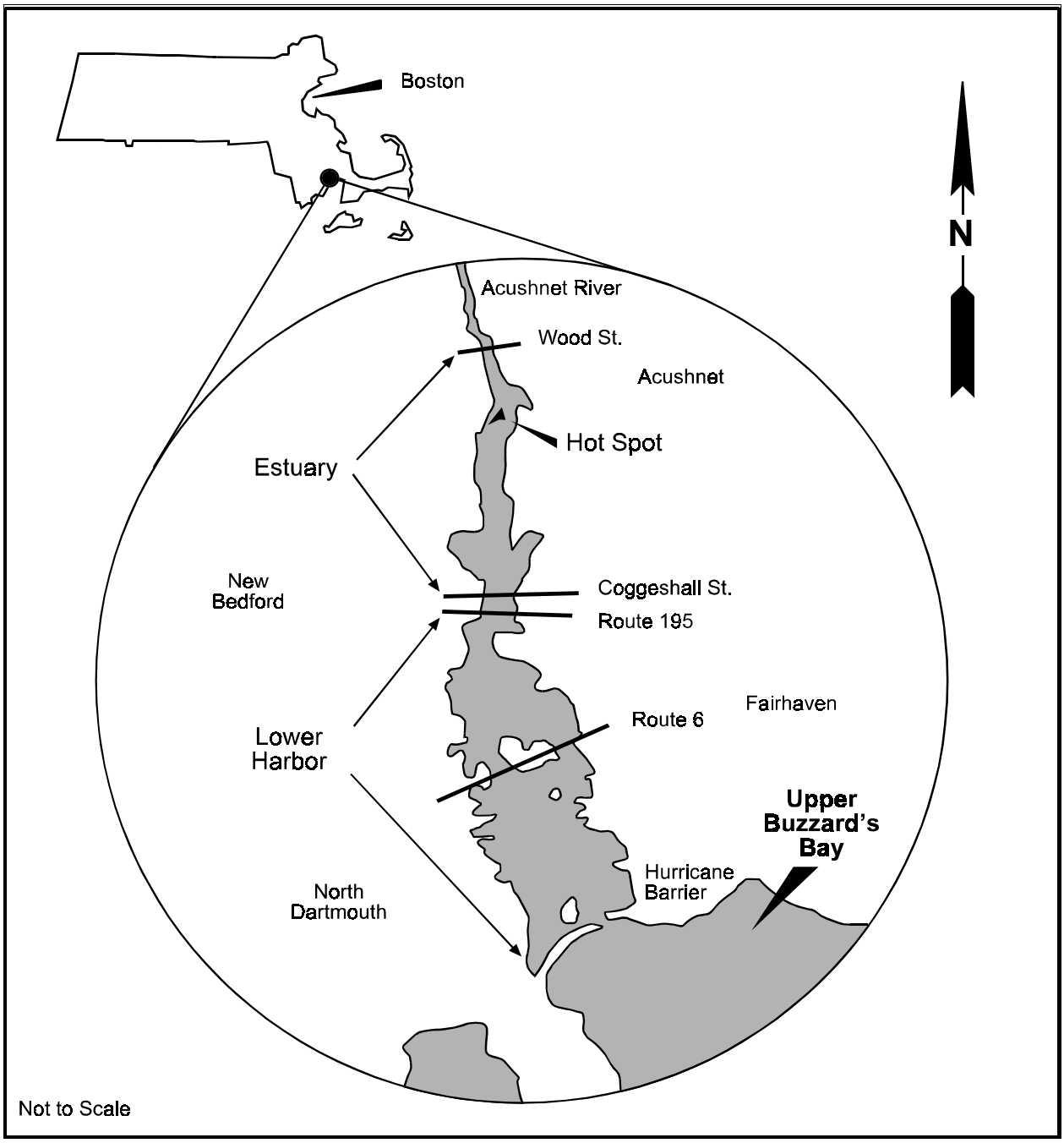
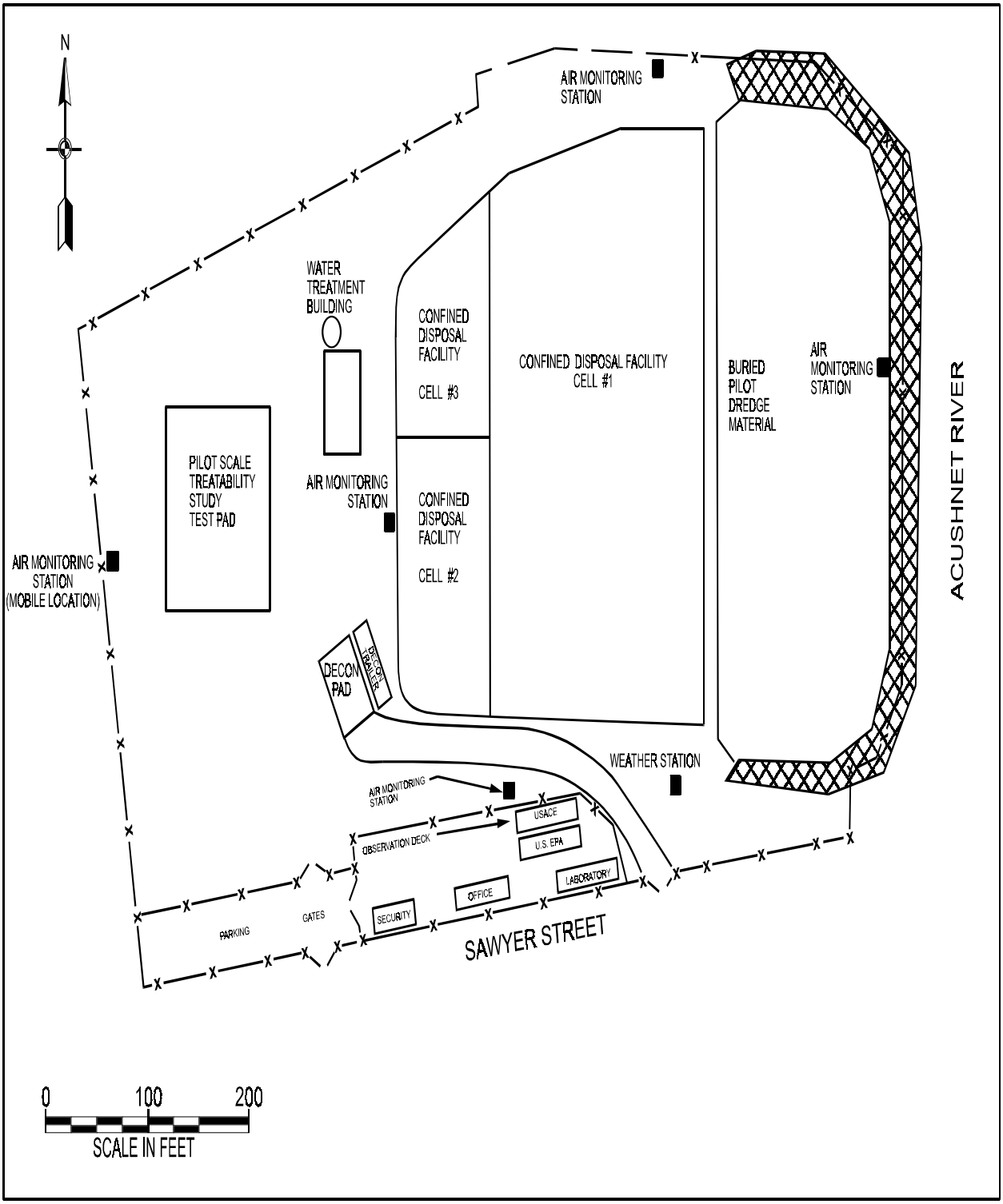


Figure 2. Layout of Confined Disposal Facility and Test Area [1]



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

The sediment used in the pilot-scale demonstration 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

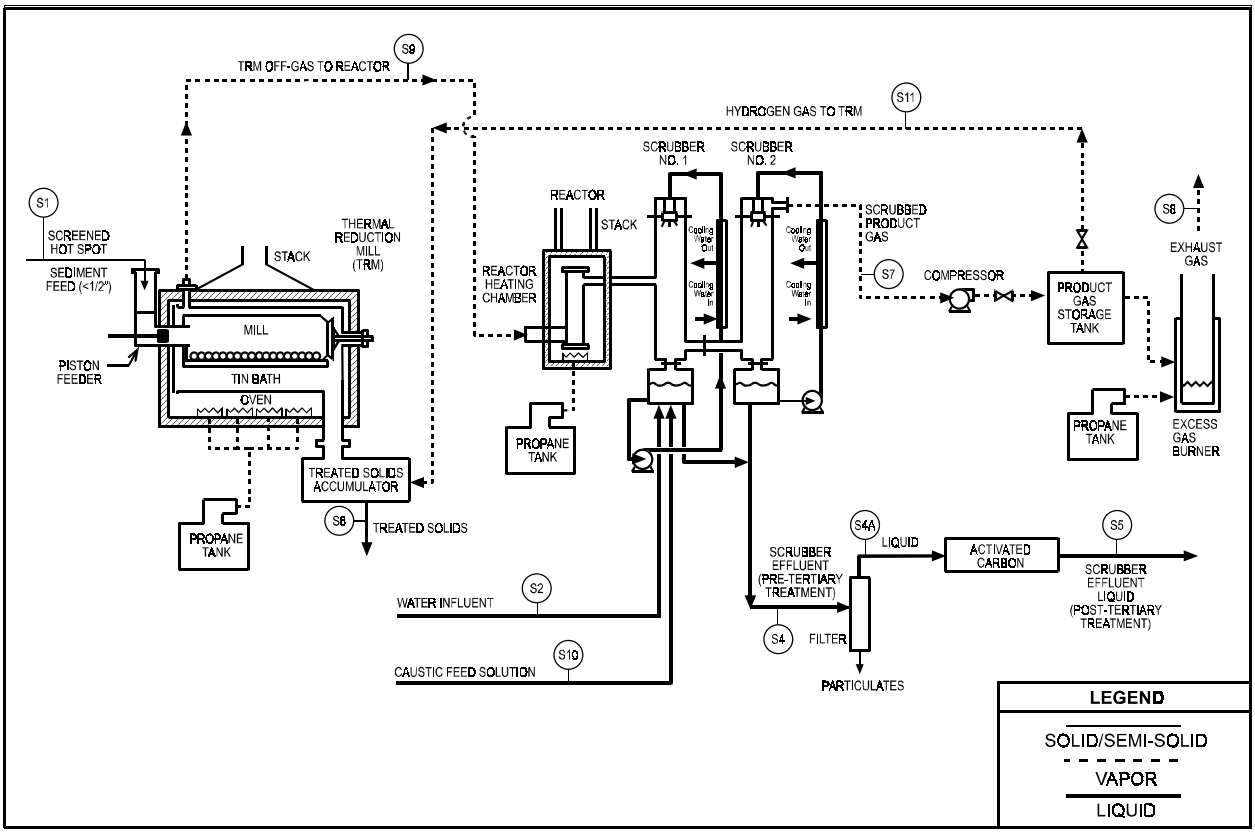
Treatment Technology Description [1,6]

SAIC and Eco Logic conducted a pilot-scale test of Eco Logic's GPCR process (thermal desorption followed by gas phase chemical reduction) on Hot Spot sediments. SAIC and Eco Logic formed a teaming partnership for the project; the technology and equipment belong to Eco Logic.

According to Eco Logic, the GPCR process tested on the Hot Spot sediments and shown in Figure 3 consisted of three basic components, each with distinct functions: the front-end system where contaminants are desorbed and rendered into a form suitable for destruction in the GPCR reactor (a thermal reduction mill or TRM was used for the pilot test); the GPCR reactor which uses hydrogen to reduce contaminants; and the gas scrubbing and compression system.

Hot Spot sediments were first screened to remove oversize material (greater than 1/2 inch). The screened sediments were then fed into the TRM . The TRM operated with indirect heat, using a molten tin bath (heated by propane) to transfer heat to the sediments. Because of the absence of free oxygen and the presence of a highly reducing atmosphere within the process, the potential for the formation of dioxins and furans was minimized. Organic compounds and steam were volatilized from the sediment and removed from the TRM using hydrogen sweep gas and this off-gas (hydrogen sweep gas, water, and desorbed contaminants) was vented to the GPCR reactor.

Figure 3 - Thermal Desorption/Chemical Destruction Process [1]



The GPCR reactor was operated in a hydrogen atmosphere at a minimum temperature of 900°C. As the gas passed through the reactor (typical residence time of 4 to 10 seconds), the organics were reduced to methane and hydrochloric acid. The gas exiting the GPCR was sent through a two-stage caustic scrubbing system to remove water, hydrochloric acid, and fine particulates. The scrubbed gas was then compressed and stored before being burned in the Excess Gas Burner to destroy methane and other residual organics prior to release to the atmosphere. Effluent from the scrubber was passed through a filter and activated carbon, then sent to post-tertiary treatment.

Operation [1,6]

The pilot-scale test involved three acclimation runs to provide preliminary data for optimizing process conditions and three performance verification runs to evaluate the process. The acclimation runs focused on the operation of the TRM and included variations in the waste feed rate, mill speed, and sweep gas flow rate.

The schedule for the pilot test of the GPCR process is presented below. The test program was originally planned for seven days, with two acclimation runs and five performance runs. However, operational difficulties, described in this section, extended the acclimation testing, and ultimately shortened the test program to six days. After the first two acclimation runs (A1 and A2), operating conditions were held constant. Operating conditions for run A3 and the three performance runs (P1 to P3) are summarized in Table 1.

Date	Test Day	Run Number	Test Description
11/18/96	1	A1	Acclimation/Optimization runs
11/19/96	2	A2	Acclimation/Optimization runs
11/20/96	3	A3	see note
11/23/96	4	P1	Verification/Performance runs
11/24/96	5	P2	Verification/Performance runs
11/25/96	6	P3	Verification/Performance runs
Note: Run A3 was intended as an acclimation/optimization run but was later used in conjunction with performance data to provide a larger data set for evaluating overall process performance.			

Table 1 - SAIC/Eco Logic Test Program Operating Conditions [1]

Parameter	Run No.			
	A3	P1	P2	P3
Date	11/20/96	11/23/96	11/24/96	11/25/96
Total Test Duration (min)	290	305	360	485
Waste Solids (kg):				
Input waste (wet solids)	9.7	10.3	11.3	17.3
Recovered solids (dry solids)	4.4	2.1	3.0	4.1
Scrubber water volume (L)				
Pre-run	70	70	70	70
Post-run	76	76	77	80
System Temp (°C)				
TRM - molten tin	627	636	629	639
GPCR Reactor flame	786	829	783	823
GPCR Reactor exit	912	916	939	910
Scrubber Stage 1	28	26	27	29
Scrubber Stage 2	15	14	13	15
Product gas	10	10	6.6	13
Flare inlet	574	613	738	741
Flare outlet	669	714	835	848

Table 1 - SAIC/EcoLogic Test Program Operating Conditions [1] (continued)

Parameter	Run No.			
	A3	P1	P2	P3
Product Gas Concentration (%)				
Carbon monoxide	1.39	1.98	1.66	1.66
Methane	2.12	0.47	0.39	0.34
Hydrogen	97.9	98.1	97.4	98.4
Oxygen	0.0	0.0	0.0	0.0

Screened sediment was loaded into the TRM feed hopper in batches, then fed through the piston feed system into the TRM at a rate of 2 kg per hour. The TRM was operated in a hydrogen atmosphere, with tin bath temperatures ranging from 627°C to 639°C. Treated sediment was weighed and sampled.

The GPCR reactor was operated under a slight positive pressure, at temperatures ranging from 910°C to 939°C. The hydrogen content was maintained at levels above 97%. According to Eco Logic, the minimum concentration of hydrogen required to ensure a complete reaction is 55%. In addition, Eco Logic indicated that the higher concentration was used for the pilot test to ensure adequate gas flow through the entire system and to allow collection of gas samples after the scrubber, and that the presence of the excess hydrogen did not affect performance.

Following the final performance run (P3), the TRM was dismantled and inspected. It was determined that, during the P3 run, the treated sediment auger had separated from the drive mechanism, resulting in treated sediment accumulating in the auger, possibly restricting gas flow through the system and limiting the desorption rate in the TRM.

Performance Information [1,6]

The objectives of the pilot study included evaluating the effectiveness of thermal desorption/gas phase chemical reduction in treating PCBs and heavy metals in the Hot Spot sediments, identifying potential environmental or engineering constraints related to the use of the technology to remediate sediments, and evaluating scale-up to full-scale operation. The target treatment goal for PCBs was 50 mg/kg, based on the TSCA disposal requirements for PCB-contaminated dredged soil. The target treatment goal for metals were the Toxicity Characteristic Leaching Procedure (TCLP) criteria. In addition, Federal and State air regulations required air monitoring for on-site technologies that have the potential to generate polychlorinated dibenzo-p-dioxins (dioxin or PCDD) and dibenzofurans (furans or PCDF), reported as total PCDD/PDCF and as toxicity equivalent quotient (TEQ), calculated based on EPA toxicity equivalent factors.

Data from runs A3, P1, P2, and P3 were used to evaluate the performance of the GPCR process. Acclimation run A3 was not initially intended to be used for performance evaluation purposes. However, because of operating difficulties, described above, that occurred during run P3, a decision was made to include the data from A3 (operated under the same conditions as the performance runs) to provide a larger data set.

Sampling locations are presented in Figure 3 and are shown in parentheses in the discussion below. For example, (S1) is the sample location for the feed sediment.

TRM Performance

Table 2 presents the concentrations of total PCB, total dioxin and furans, and the TEQ for dioxin and furan in the feed sediment (S1) and the treated sediment (S6). Table 2 also includes the TCLP results for PCBs and metals in the feed sediment (S1) and the treated sediment (S6). Table 3 presents the PCB data by run and the calculated desorption efficiency for PCBs. The data in these tables are the averages for the available data from the four runs.

Table 2 - TRM Performance Data [1]

Analyte	Feed Sediment Average (S1)	Treated Sediment Average (S6)
Total PCBs (mg/kg)	5,700	52
Dioxin and Furan (TEQ) (pg/g)	1,775	34
Dioxin and Furan (total) (pg/g)	29,750	2,100
1,4 - dichlorobenzene (mg/kg)	19	0.4
Total PAHs (mg/kg)	16	1.2
Chloride (mg/kg)	17,500	7,525
TCLP Results (ug/L)		
PCBs	27	0.6
Arsenic	22.5	ND
Barium	350	637
Cadmium	18	31
Chromium	21.5	11
Copper	50.5	2,450
Lead	470	840
Mercury	ND	ND
Selenium	13	13
Silver	ND	ND
Zinc	8,250	4,100

ND - Not Detected

Table 3 - PCB Data for the TRM By Run [1]

Parameter	A3	P1	P2	P3
PCBs in Untreated Sediment (mg/kg)	6,400	4,700	5,000	6,700
PCBs in Treated Sediment (mg/kg)	31	77	28	72
Desorption Efficiency of PCBs (%)*	99.52	98.36	99.44	98.93

* PCB concentration in untreated sediment minus PCB concentration in treated sediment divided by the PCB concentration in the untreated sediment; the result was multiplied by 100.

The concentration of PCBs in the treated sediment from the TRM ranged from 28 to 77 mg/kg, with an average of 52 mg/kg. The PCB desorption efficiency ranged from 98.36 to 99.52%, with an average of 99.06%. The PCB concentrations in treated sediment were higher than Eco Logic expected, and may be attributed to the treated sediment accumulating in the auger, as observed for run P3, which could possibly restrict gas flow through the system and limit the desorption rate in the TRM. In addition, when the sediment feed tube became plugged, untreated sediment would “squirt” into the TRM rather than feeding smoothly, and the effective residence time of the sediment in the TRM was reduced.

The average concentration of dioxins and furans (total) and dioxins and furans (TEQ) in the treated sediment was 2,100 pg/g (parts per trillion) and 34 pg/g, respectively. Treatment in the TRM reduced total dioxin and furan concentrations by an average of 93%, and TEQ dioxin and furan concentrations by 98%.

Table 4 presents data on the mass of PCBs and dioxins and furans that was used to examine the potential for generation of dioxins and furans during the thermal desorption component of the process. The mass of contaminants in the “input” sediment was calculated by subtracting the mass of contaminants in the feed sediment (S1) from the mass of contaminants in the treated sediments (S6). The mass of contaminants in the input sediment was then compared to the mass of contaminants in the TRM off-gas (S9). As shown in Table 4, the total mass of PCBs decreased during each run, while the mass of total dioxin/furan increased during runs P2 and P3. According to Foster Wheeler, the high variability of the results for the TRM off-gas (S9) indicted that the samples were not isokinetic (flow representative) and therefore could not be used to draw definitive conclusions. Eco Logic indicated that, due to the reducing hydrogen atmosphere (the absence of free oxygen) and the difficulties in obtaining a representative (isokinetic) sample during the pilot study, additional testing would be needed to fully evaluate the potential for dioxin/furan formation by the TRM.

As presented in Table 2, data on Toxicity Characteristic Leaching Procedure (TCLP) metals concentrations in the treated sediment were below regulatory levels for all metals. However, a comparison of metals concentrations in the feed sediment (S1) and treated sediment (S6) showed increases in concentrations of barium, cadmium, copper, lead, and zinc. According to Eco Logic, the increase indicates the thermal desorption process increased the leachability of these heavy metals. TCLP concentrations of arsenic, chromium, and zinc decreased. According to Eco Logic, these metals may have volatilized during the thermal desorption process or become fixed to the treated soils, and therefore, less leachable.

Table 4 - Mass from Input Sediment (S1-S6) to TRM Off-Gas (S9)* [1]

	A3		P2		P3	
Parameter	**Input Sediment (S1-S6)**	**TRM Off-gas (S9)**	**Input Sediment (S1-S6)**	**TRM Off-gas (S9)**	**Input Sediment (S1-S6)**	**TRM Off-gas (S9)**
Total PCBs (mg)	25,000	1,100	23,000	7,300	46,000	19,000
Total Dioxin/ furan (ng)	120,000	13,000	120,000	240,000	190,000	800,000
Dioxin TEQ (ng)	6,500	270	7,600	5,100	12,000	15,000

* Mass data were not provided for run P1

Chemical Reduction Reactor Performance

Sampling limitations with the pilot scale unit (location of some of the sample ports) precluded the collection of isokinetic (flow representative) samples of the untreated TRM off-gas input to the reactor (S9) and the product gas (treated gas exiting the reactor/scrubber system) (S7). Therefore, conclusive results regarding the destruction efficiency of the unit could not be reported. However, samples taken downstream from the exhaust gas exiting the excess gas burner (S8) were isokinetic and, along with the other available data, were used for a summary analysis of the reactor performance.

Table 5 summarizes data on the average vent gas concentrations of PCBs, dioxins and furans, and other selected parameters. Samples were collected from the TRM off-gas, the treated product gas, and the exhaust gas (treated off-gas exiting the excess gas burner).

Table 5 - Summary of Selected Parameters Measured in Vent Gas [1,6]

Parameter	TRM Off-Gas (S9)	Product Gas (S7)	Exhaust Gas (S8)
Total PCBs (ug/dsm^3)	546,667	1.2	0.11
Dioxin (TEQ) (pg/dsm^3)	408,333	1.9	0.10
Dioxin/furan (Total) (pg/dsm^3)	21,400,000	189	26
Total PAHs (ug/dsm^3)	105,667	53,000	5.3
Benzene (ug/dsm^3)	Not Available	Not Available	9.6
Particulate (mg/dsm^3)	5,700	37	6.68
Chloride (ug/dsm^3)	4,900	51	Not Detected
HCL (ug/dsm^3)	570,000	71	19

The PCB destruction efficiency was determined by comparing the total mass of PCBs in the input sediment (feed sediment S1 minus treated sediment S6) with the mass of PCBs in the exhaust gas from the excess gas burner (S8). As shown in Table 6, the destruction efficiency for PCBs ranged from 99.99972% to 100%. The destruction efficiency for dioxins and furans (total and TEQ) was calculated using the same method described above for PCBs, and reported as an average (data were not provided by each of the four runs). The average destruction efficiency for total dioxins and furans was 99.9923 and 99.99959, respectively.

Table 6 - PCB Destruction Efficiency by Run [1]

Parameter	A3	P1	P2	P3
Total mass of PCBs in Input Sediment (mg)	25,000	19,000	23,000	46,000
Total mass of PCBs in exhaust gas (mg)	0	0.026	0.0023	0.13
Destruction Efficiency of PCBs (%)	100	99.99986	99.99999	99.99972

Performance Data Quality [1]

Samples were analyzed using EPA methods or analytical methods similar to those used by an EPA Contract Laboratory Program (CLP) laboratory. In general, the data were used in the evaluation process as the data were found to be consistent and comparable to historical data and analyses typically performed under the EPA CLP program. PCDD and PCDF were analyzed for total isomers and 2,3,7,8-substituted congeners. TEQs were calculated for each 2,3,7,8-substituted congeners based on EPA toxicity equivalent factors. EPA Method 1311 was used to analyze TCLP metals.

A comprehensive quality control (QC) program was used during the testing, including field and laboratory duplicates, performance evaluation samples, and data validation. The results of the QC program indicated that, overall, analytical results were comparable and accurate for the purpose of assessing process performance as part of an engineering evaluation. While some QC results exceeded established criteria, resulting in some data being considered as “estimated”, the data do not pose a significant concern for the purposes of the engineering evaluation.

Cost Information [1]

The pilot-scale testing of thermal desorption followed by gas phase chemical reduction for the Hot Spot sediments from the New Bedford Harbor Superfund Site was conducted by EPA under an Alternative Remedial Contracting Strategy (ARCS) contract. Foster Wheeler served as the prime contractor, providing overall management and technical oversight of the testing and preparing the evaluation report (Reference 1) and projected cost estimates for full-scale projects, with input from the vendors.

Table 7 presents the projected cost for full-scale thermal desorption followed by gas phase chemical reduction to treat Hot Spot sediments developed by Foster Wheeler using input from EcoLogic. As shown in Table 7, the total projected cost is $11,114,000, including $5,865,000 in capital costs and $5,249,000 in O&M costs. The project unit cost for full-scale treatment, based on 18,000 tons of Hot Spot sediment, is $617 per ton.

The projected costs assumed treatment of a total of 18,000 tons of Hot Spot sediments with a unit weight of 1.2 tons per cubic yard. The on-line capacity was assumed to be 42 tons per day based on a 60% on-line factor used by Foster Wheeler (assuming a design capacity of 56 tons per day). According to Foster Wheeler, the on-line factor used was relatively low, reflecting the problems that Eco Logic experienced with the TRM during the pilot scale testing which resulted in significant downtime for the unit and the unit operating at only 40% of the design capacity.

Table 7 - Projected Costs for Full-Scale Thermal Desorption/ Gas-Phase Chemical Reduction of Hot Spot Sediments [1]

Item	Total Cost (1997$)
Capital costs	
Mobilization	1,810,000
Demobilization	675,000
Equipment (allocated capital cost)*	3,000,000
Commissioning (system startup and testing)	290,000
Permitting**	100,000
Operation and maintenance	
Labor (salaries, travel, accommodations)	2,583,000
Materials:	
Chemicals/oils (caustic, hydrogen, nitrogen, carbon dioxide, boiler chemicals, calibration gases, wash oil, compressor and other oils)	288,000
Filters (bag and cartridge filters)	96,000
GAC	36,000
Utilities and fuel	
Electricity, natural gas, diesel fuel	1,447,000
Sewer and water	18,000
Equipment rental	215,000
Other	
Personal protective equipment	287,000
Maintenance	179,000
Miscellaneous parts and supplies	90,000
Other technology-specific costs	0
Cost per ton of sediment (18,000 tons)	$617/ton
Total cost	**$11,114,000**

* Eco Logic typically amortizes the $10,400,000 cost for their treatment units over a five year period (260 weeks). Using a total project duration of 75 weeks (61 weeks for treatment and 14 weeks for mobilization, commissioning, and demobilization) for treating the 18,000 tons of Hot Spot sediment, the capital cost allocated by Foster Wheeler is $3,000,000.

** Permitting costs directly applicable to the treatment process, including use of associated reagents and the process gases. Includes federal, state, and local permits.

According to Eco Logic, the company is no longer pursuing the development of a full-scale TRM, but has teamed with Torftech Inc. (Canada) to provide an integrated solution for the treatment of contaminated soil, sediment, and sludge. Eco Logic stated that this combination provides separation of contaminants from granular solids such as soil, sediment, and sludge using Torftech's TORBED® reactor system coupled with Eco Logic's GPCR process for the destruction of contaminants.

Observations and Lessons Learned [1]

The thermal desorption component of Eco Logic's GPCR process (TRM) had a PCB desorption efficiency ranging from 98.36 to 99.52%, with an average of 99.06%. The concentration of PCBs in the treated soil from the TRM ranged from 28 to 77 mg/kg, with an average of 52 mg/kg. The TRM reduced total dioxin and furan concentrations by an average of 93%, and TEQ dioxin and furan concentrations by 98%. The GPCR reactor achieved PCB destruction efficiencies ranging from 99.99972% to 100%.

The TRM did not perform as well as expected, with PCB concentrations in treated sediment being higher than anticipated. According to Eco Logic, these results may be attributed to the treated sediment accumulating in the feed auger, possibly restricting gas flow through the system and limiting the desorption rate in the TRM. In addition, when the sediment feed tube became plugged, untreated sediment would "squirt" into the TRM rather than feeding smoothly, and the effective residence time of the sediment in the TRM was reduced.

The pilot-scale TRM unit did not allow for the collection of isokinetic (flow representative) gas samples. Therefore, the results of the pilot study can be used for a summary assessment of performance, but additional data would be needed to draw definitive conclusions regarding dioxin and furan production and the concentrations of contaminants downstream of the TRM.

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Acknowledgments

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