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THERMAL DESORPTION TECHNOLOGY COST ESTIMATE

RAYMARK INDUSTRIES, INC., STRATFORD, CONNECTICUT

FINAL REPORT

Prepared for:

U.S. ENVIRONMENTAL PROTECTION AGENCY
RISK REDUCTION ENGINEERING LABORATORY
CINCINNATI, OHIO

Prepared by:

PRC ENVIRONMENTAL MANAGEMENT, INC.

JANUARY 1995

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Cincinnati, OH, 45268

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1.0 INTRODUCTION

This report discusses the regulatory, application, implementation, and cost considerations for applying the thermal desorption technology at the Raymark Industries, Inc. (Raymark), site in Stratford, Connecticut. PRC Environmental Management, Inc. (PRC), prepared this report for the U.S. Environmental Protection Agency (EPA) Risk Reduction Engineering Laboratory under Contract No. 68-C0-0047, Work Assignment No. 0-61, Task 9, Technical Assistance to the Superfund Technical Assistance Response Team at the Raymark Site. The following sections (1) describe the Raymark site; (2) describe the thermal desorption technology, regulatory guidance, technology vendors, applicability, and implementation of the thermal desorption technology at the Raymark site; and (3) present cost estimates for the thermal desorption technology.

2.0 RAYMARK SITE DESCRIPTION

Information concerning the Raymark site was obtained from the thermal desorption treatability study report (Halliburton NUS Corporation 1994). The Raymark site, located in Stratford, Connecticut, was a manufacturing facility for friction materials containing asbestos and nonasbestos materials, inorganics, phenol-formaldehyde resins, and various adhesives. Primary products were gasket material, sheet packing, and friction materials including clutch facings, transmissions plates, and brake linings. As a result of these activities, soils at the site have been contaminated with asbestos, lead, and polychlorinated biphenyls (PCB).

A preliminary estimate of the volume of contaminated soil and waste materials is about 300,000 cubic yards. Soil and waste materials are defined as soils mixed with various manufacturing wastes, including asbestos and other contaminated materials. At least 15 satellite areas have been identified; each area consists of a large number of properties, where Raymark waste is known to have been received and used as fill throughout the Town of Stratford. These areas consist of commercial, residential, and municipal properties. A number of properties within the satellite areas have been designated as a health hazard and are the focus of time-critical removal actions. The excavated waste from these properties is currently being stored at the Raymark facility on a temporary basis until a final cleanup option is selected. Maximum concentrations of contaminants detected in samples of soil and waste materials obtained from the Raymark Industries facility are presented in Attachment 1.

3.0 THERMAL DESORPTION TECHNOLOGY

Several issues must be considered before selecting a thermal desorption technology to remediate a site, including regulatory guidance for implementing a thermal desorption treatment technology, and the performance, limitations, and cost of the technology. Section 3.1 describes regulatory guidance for implementing thermal desorption technologies at Superfund sites; Section 3.2 presents a list of thermal desorption technology vendors; Section 3.3 discusses the applicability of the thermal desorption technology to the Raymark site wastes, including factors that influence thermal treatment, limitations, and performance of the thermal desorption systems; and Section 3.4 describes implementation of a thermal desorption system at the Raymark site.

3.1 DRAFT REGULATORY GUIDANCE FOR IMPLEMENTATION OF A THERMAL DESORPTION TREATMENT TECHNOLOGY

Draft regulatory guidance for implementing a thermal desorption treatment technology at a Superfund site is presented in *Draft Superfund Remedy Implementation Guide: Thermal Desorption Treatment, June 1994* (EPA 1994c). Thermal desorbers are classified under the Resource Conservation and Recovery Act (RCRA) as an incinerator, boiler, furnace, or miscellaneous unit. For ease of reference and consistency with common protocol, this report will refer to RCRA thermal desorption miscellaneous units as thermal desorbers. The draft guide presents the most common operational characteristics associated with thermal desorbers; however, the draft guide does not provide a regulatory distinction regarding whether specific thermal desorbers are incinerators, boilers, furnaces, or other regulated miscellaneous units. Highlight 1 of the implementation guide presents the operational characteristics clearly associated with thermal desorbers, including the thermal desorption chamber, air pollution control devices, and waste residual management. These operational characteristics are discussed below.

- Thermal desorption chamber -- One of the primary regulatory distinctions between a thermal desorber and an incinerator is the degree to which the desorber is direct-flame fired. Thermal desorbers are generally indirectly heated. For example, treatment systems whose primary heat source is conductive heating through the walls of a chamber that contains the waste to be treated are thermal desorbers. In addition, thermal desorbers operate at relatively low temperatures that favor volatilization of contaminants rather than combustion.

- Air pollution control devices -- The volatilized contaminants in the off-gas from the thermal desorber are generally captured via condensation or adsorption. Thermal desorbers typically do not use air pollution control devices that involve direct-flame destruction of the contaminants in the off-gases.

- Waste residual management -- Thermal desorbers are designed to separate contaminants from the waste media, but generally not to destroy the contaminants. Volatilized contaminants are captured in the waste residuals from the air pollution control equipment (APCE), and treatment of the residuals is separate from the thermal desorber.

3.2 THERMAL DESORPTION TECHNOLOGY VENDORS

A large number of thermal desorption systems have been developed to treat hazardous wastes at Superfund sites. PRC identified thermal desorption vendors with treatment systems that may treat wastes contaminated with PCBs. PRC obtained information concerning these vendors from the following sources:

- *Engineering Bulletin: Thermal Desorption Treatment*, EPA/540/S-94/501.
- *Superfund Innovative Technology Evaluation (SITE) Program Technology Profiles, Sixth Edition*, EPA/540/R-93/526.
- *Superfund Remedy Implementation Guide: Thermal Desorption Treatment*, OSWER Publication 9355.08 FS. Draft, June 1994.
- The Vendor Information System for Innovative Treatment Technologies (VISITT), Version 3.0. EPA/542/R-92/001.
- Roy F. Weston, Inc. Low Temperature Thermal Treatment (LT^3) Technology Applications Analysis Report (AAR), EPA/540/AR-92/019. December 1992.
- SITE Demonstration Bulletin: X*TRAX™ Model 200 Thermal Desorption System, EPA/540/MR-93/502. February 1993.
- SoilTech ATP Systems, Inc. Anaerobic Thermal Processor Draft AAR, EPA/540/A. March 1993.
- Canonie Environmental Services Corporation Low Temperature Thermal Aeration (LTTA) Process Draft AAR. January 1994.
- SITE Technology Capsule: Clean Berkshires, Inc., Thermal Desorption System, August 1994.

Table 1 presents information concerning operational characteristics of available thermal desorption systems. When using the VISITT database, PRC identified thermal desorption vendors that indicated that they had treated PCB wastes at bench-, pilot-, or full-scale. As stated in the remedy implementation guide for thermal desorption treatment, the three operational characteristics are to be used as a guide for selecting a thermal desorption treatment system, and each system must be evaluated on a case-by-case basis. Some thermal desorption systems may be altered or modified to address regulatory concerns. For example, the APCE for a thermal desorber may be modified to include cooling and condensing units instead of an afterburner.

3.3 APPLICATION OF THERMAL DESORPTION TECHNOLOGY TO RAYMARK SITE WASTES

This section presents the general applicability of the thermal desorption technology to treat waste types and contaminants at the Raymark site and general implementation considerations for applying thermal desorption technologies to the site. The following sections discuss factors that affect the thermal desorption technology, limitations of thermal desorption, and PCB cleanup performance of thermal desorption technologies.

3.3.1 Factors that Affect Thermal Desorption Treatment

The degree to which a thermal desorption system is able to remove contaminants from wastes and is cost effective depends on certain key characteristics, including the moisture content of the waste, the boiling points of the contaminants, the hydrocarbon content of the waste, and the particle size distribution and soil classification of the waste being treated. These characteristics, which include moisture content, boiling point of contaminants, hydrocarbon content, and particle size distribution, and soil classification, are described below.

3.3.1.1 Moisture Content

In the thermal desorption process, excess moisture is removed at the expense of excess burner fuel and can affect treatment performance. Depending on the specific thermal desorption system being used, the feed material should contain 10 to 20 percent moisture before entering the system. Thermal

TABLE 1

THERMAL DESORPTION TECHNOLOGY VENDORS

Technology Vendor	Technology Name	Heat Source Used for Primary Chamber	Operating Temperature Range	Air Pollution Control Equipment	Management of Condensed Contaminants
Advanced Soil Technologies	Not specified	Exposed burner flame contacts soil	up to 900 °F	Vapors combusted in secondary combustion chamber; particulates removed in baghouse; acid gases removed with wet scrubber; trace hydrocarbons removed with activated carbon bed	None
Ariel Industries, Inc.	Ariel SST Low Temperature Thermal Desorber	Heated compressed air	300 - 1200 °F	Particulates removed from vapor in high efficiency cyclone and volatile organic compound (VOC) scrubber; vapors combusted in secondary combustion chamber; particulates removed from combustion gases in baghouse; acid gases removed in wet scrubber	None
Canonie Environmental Services Corporation	Low Temperature Thermal Aeration (LTTA)	Rotary dryer; concurrent flow of heated air contacts waste	up to 800 °F	Vapors combusted in secondary combustion chamber; particulates removed in cyclones and baghouse; acid gas removed in wet scrubber; trace hydrocarbons removed in activated carbon beds	None
Carson Environmental	Not specified	Two heated paddle augers	up to 450 °F	Vapors oxidized in primary chamber using ozone and hydrogen peroxide as oxidizing agents and ultraviolet light; organic and ozone emissions removed in manganese dioxide resistant heat grid filter	Condensed contaminants treated and disposed of off site
Clean Berkshires, Inc.	Thermal Desorption System (TDS)	Rotary kiln; heated air stream	up to 800 °F	Particulates removed from vapors in cyclone; vapors combusted in secondary combustion chamber; remaining particulates removed from combustion gases in baghouse; acid gases removed in scrubber	None

TABLE 1 (Continued)

THERMAL DESORPTION TECHNOLOGY VENDORS

Technology Vendor	Technology Name	Heat Source Used for Primary Chamber	Operating Temperature Range	Air Pollution Control Equipment	Management of Condensed Contaminants
Clean-Up Technology, Inc.	Not specified	Heated auger with high temperature fluid inside	300 - 700 °F	Vapors destroyed in a thermal or catalytic oxidizer; particulates removed in baghouse; acid gases removed in scrubber	None
Contamination Technologies, Inc.	Low Temperature Thermal Absorber (LTA)	Rotary kiln; exposed flame contacts soil	360 - 900 °F	Particulates removed from vapors in cyclonic scrubber; vapors combusted in afterburner; remaining particulates removed in baghouse; acid gases removed in scrubber	None
Covenant Environmental Technologies, Inc.	Mobile Retort Unit	Indirectly-heated retort chamber	up to 1,500 °F	Particulates removed from vapors in baghouse; vapors condensed; trace hydrocarbons removed in charcoal filter	Condensed contaminants disposed of off site
DBA, Inc.	Not specified	Rotary kiln; heated air stream contacts waste	up to 1,000 °F	Particulates removed in cyclone and baghouse; vapors combusted in secondary combustion chamber	None
ECOVA Corporation	Desorption and Recovery Unit (DRU)	Thermal screws or rotary kiln	850 - 950 °F	Vapors condensed; noncondensed vapors removed in activated carbon bed	Condensed contaminants shipped off site for disposal
Hrubetz Environmental Services, Inc.	Hrubout™	Heated compressed air (for in situ, ex situ, or containerized treatment)	up to 1,200 °F	Vapors destroyed in oxidizer	None
IT Corporation	Not specified	Indirectly fired rotary metal shell	Not specified	Vapors condensed in cooling system or combusted in secondary combustion chamber; particulates removed in baghouse; acid gases removed in wet scrubber	Condensed contaminants disposed of off site

TABLE 1 (Continued)

THERMAL DESORPTION TECHNOLOGY VENDORS

Technology Vendor	Technology Name	Heat Source Used for Primary Chamber	Operating Temperature Range	Air Pollution Control Equipment	Management of Condensed Contaminants
OBG Technical Services, Inc.	Not specified	Exposed flame contacts soil	up to 1,200 °F	Vapors combusted in secondary combustion chamber; particulates removed in baghouse and dust filtration unit; acid gases removed in scrubber	None
Recycling Sciences International, Inc.	Desorption and Vapor Extraction System (DAVES)	Hot gas	200 - 600 °F	Vapors condensed in venturi scrubber, plate washer and mechanical refrigeration; noncondensed vapors removed in activated carbon vessels	Condensed contaminants treated and shipped off site for disposal
Remediation Technologies, Inc.	Thermatek	Holo-flite™ screws containing a heating fluid	500 - 850 °F	Vapors enter condenser; noncondensed vapors removed in activated carbon bed	Condensed contaminants disposed of off site
Roy F. Weston, Inc.	Low Temperature Thermal Treatment (LT^{3})	Hollow-flight screw conveyor with high temperature oil circulating inside	300 - 560 °F	Particulates removed from vapors in baghouse; vapors condensed; trace hydrocarbons removed in carbon adsorption system	Condensed contaminants treated and disposed of off site
RUST Remedial Services, Inc.	X*TRAX™	Indirectly-fired rotary dryer	500 - 1,100 °F	Particulates removed from vapor in eductor scrubber; vapors removed in air-cooled and glycol/water-cooled condensers; particulates and remaining hydrocarbons removed in high efficiency particulate air filter and carbon adsorption system	Condensed contaminants disposed of off site
Seaview Thermal Systems, Inc.	HT-6 Thermal Distillation	Indirectly heated rotary desorber	up to 2,200 °F	Vapors enter water-cooled condenser; non-condensed vapors removed by series of scrubbers and separators; remaining vapor is compressed, dried, and refrigerated to recover liquid petroleum gas	Condensed contaminants disposed of off site

TABLE 1 (Continued)

THERMAL DESORPTION TECHNOLOGY VENDORS

Technology Vendor	Technology Name	Heat Source Used for Primary Chamber	Operating Temperature Range	Air Pollution Control Equipment	Management of Condensed Contaminants
Separation and Recovery Systems, Inc.	Sarex MX-2000/2500	Heated hollow auger	MX-2000: 212 - 600 °F MX-2500: 600 - 1,200 °F	Particulates removed; vapors condensed into separate phases of water and hydrocarbons; remaining hydrocarbons removed in activated carbon unit	Condensed organics disposed of off site
Soil Purification, Inc./Astec	LTTD with Heat Recovery	Paddles heated by internally circulating hot oil	up to 500 °F	Particulates removed from vapors in multi-tube cyclonic separator; vapors combusted in afterburner; particulates removed from combustion gas in heat exchanger, baghouse, induced draft fan; acid gases removed with scrubber	None
SoilTech ATP Systems, Inc.	Anaerobic Thermal Processor (ATP)	Indirectly heated rotary kiln with four internal zones: preheat, retort, combustion, and cooling zones	Preheat: 400 - 600 °F Retort: 900 - 1,200 °F	Preheat and retort vapors condensed in water-cooled condensers; residual vapors combusted in combustion zone; particulates removed from combustion gases in cyclone and baghouse; acid gases removed in scrubber; trace hydrocarbons removed in activated carbon bed	Condensed contaminants separated in three-phase separator; oil phase stored and shipped off site
Thermotech Systems Corporation	Tandem SRU Model 1420	Two rotary dryers directly heated by hot air	1,200 - 1,400 °F	Particulates removed from vapors in cyclone; vapors combusted in secondary combustion chamber; particulates from combustion gas removed in baghouse	None
Texarome, Inc.	Mobile Solid Waste Desorption	Countercurrent, superheated steam	up to 900 °F	Vapors condensed in quench	Condensed vapor and moisture treated with boiler chemicals and recycled as boiler feedwater
Western Research Institute	Thermal Treatment Using Screw Reactors	Heated screws	1,100 - 1,200 °F	Vapors combusted in secondary combustion chamber; acid gases removed in dry or wet scrubber	None

TABLE 1 (Continued)

THERMAL DESORPTION TECHNOLOGY VENDORS

Technology Vendor	Technology Name	Heat Source Used for Primary Chamber	Operating Temperature Range	Air Pollution Control Equipment	Management of Condensed Contaminants
Westinghouse Remediation Services, Inc.	Low Temperature Thermal Stripping System (LTTS)	Infrared glow bars	up to 1,400 °F	Vapors condensed in scrubber	Contaminants disposed of off site

desorption technologies can treat wastes that contain more than 20 percent moisture; however, pretreating wastes that contain more than 20 percent moisture improves process economics. Pretreatment methods include filter presses, air drying, blending with dryer materials, and mixing with treated fines.

Samples collected from the Raymark site for treatability testing ranged from 4.1 to 47 percent moisture. In general, the moisture content increased as the depth of the sample increased. Controlled air drying and blending should be considered to reduce the moisture content of the Raymark wastes. Site wastes may contain significant levels of volatile organic compounds (VOC); therefore VOC emissions may hamper air drying and blending. Site wastes also contain high levels of asbestos and metals, and air drying and blending may result in significant and potentially harmful inorganic emissions to the air. All drying and blending operations should be conducted in a controlled environment.

3.3.1.2 Boiling Point of Contaminants

For effective desorption of contaminants from soil, a thermal desorption system should be operated at temperatures exceeding the boiling points of the contaminants in the soil. PCBs are the primary organic contaminants of concern at the Raymark site. Commercial PCBs were produced by collecting boiling point fractions during distillation of chlorinated biphenyl mixtures.

Table 2 presents the molecular weight, boiling point range, vapor pressure, and vaporization rate for various Aroclors. In general, the boiling point range increases and the vapor pressure and vaporization rate decrease with increasing molecular weight. Therefore, it is expected that more highly chlorinated Aroclors would be more difficult to remove from a waste than less chlorinated Aroclors. Similarly, more chlorinated isomer groups such as octachlorinated biphenyls are expected to be harder to remove than less chlorinated isomer groups such as trichlorinated biphenyls. The principal Aroclors detected at the Raymark site were Aroclor 1262 and 1268. Therefore, a thermal desorption system should be operated at temperatures exceeding about 850 °F to effectively remove PCBs from site soils.

TABLE 2

PHYSICAL AND CHEMICAL PROPERTIES OF AROCLORS

Type of Aroclor	Molecular Weight	Boiling Point Range (°F)	Vapor Pressure (25 °C, mm[b] Hg[c])	Vaporization Rate[a] (mg[d]/cm^{2}[e]/hour)
Aroclor 1221	200.7	527 - 608	6.7×10^{-3}	1.7
Aroclor 1232	232.2	554 - 617	4.1×10^{-4}	0.87
Aroclor 1016	257.9	617 - 673	4.0×10^{-4}	NA[f]
Aroclor 1242	266.5	617 - 691	4.1×10^{-4}	0.34
Aroclor 1248	299.5	644 - 707	5.0×10^{-4}	0.15
Aroclor 1254	328.4	689 - 734	7.7×10^{-5}	0.053
Aroclor 1260	375.7	725 - 788	4.1×10^{-5}	0.009
Aroclor 1262	NA	734 - 797	NA	0.013
Aroclor 1268	NA	815 - 842	NA	NA

Notes:

a	Exposure at 100 °C for 12 hours; surface area = 12.3 square centimeters (cm^2)
b	Millimeter
c	Mercury
d	Milligrams
e	Square centimeters
f	Data not available (NA)

Source: Alford-Stevens 1986

3.3.1.3 Hydrocarbon Content

Contaminated sites typically contain "hot spots" where soil contamination levels are much higher than surrounding areas. The hot spot soils have elevated heat values and can cause fluctuations in the system temperature if not combined with cleaner material. In order to achieve uniform feed material characteristics, excavated material containing high levels of organic or oily waste typically must be blended before being fed to the primary desorption chamber. Different systems have allowable maximum feed concentration ranging from 3 to 25 percent hydrocarbons by weight. Sampling and analysis of the blended material for contaminant concentration and moisture content is typically performed to ensure uniform feed material.

For a given volume of contaminated soil, a specific volume of gases will be created from vaporized moisture, volatilized contaminants, and products of combustion from the primary chamber burners. The concentration of the volatilized contaminants in the gas stream will determine the lower explosive limit (LEL) of the gas. This is a limiting factor associated with low temperature thermal treatment systems and directly relates to processing rates at specific contaminant levels. In practice, vapor concentrations should be limited to 25 percent of the LEL. Higher levels of organics may be allowed in the desorption unit if oxygen is maintained at low levels in the system. For example, a nitrogen purge gas is used in the RUST X*TRAX™ system to maintain low concentrations of oxygen in the desorption. In general, the Raymark site does not contain high concentrations of hydrocarbons; therefore, hydrocarbon content should not hamper thermal desorption treatment. However, care should be taken to blend hot spot soils to lower the hydrocarbon content fed to the thermal desorber.

3.3.1.4 Particle Size Distribution and Soil Classification

Care must be taken to properly prepare the contaminated soil for treatment. For optimum treatment, consistency of the feed should be as uniform as possible. Preparation of soils may be needed to ensure that the material is properly sized. By screening or grinding, particles can be reduced to a uniform size of less than 0.5 to 2.5 inches, depending on the requirement of the system used. Large clumps should not be fed into the thermal desorption system because some contaminants could remain in the soil due to inefficient heat transfer in the soil particle.

Soils with high silt and clay content, that is greater than 20 to 30 percent, or gummy solids may reduce the process throughput and increase treatment costs. Heavy clays may need to be processed in a mixer with other materials such as dry sand to achieve a semi-flowable solid. In addition, contaminants tend to be adsorbed onto smaller soil particles because such particles have a larger surface area with more active sites available for contaminant sorption and chemical and physical bonding. Because fine-grained soils, such as clayey soil, have more active sorption sites, they are typically more difficult to treat than are coarser soil and sediment that contain an equal concentration of contaminants.

Soil boring samples collected at the Raymark site for treatability testing indicate that site soils vary significantly. Sample descriptions indicate that site soils contain fine to coarse sand, clay, straw, and fibrous matter. In addition, some samples were moist or oily. Some soil blending may be necessary to improve soil transport through the thermal desorption system.

3.3.2 Limitations of Thermal Desorbers

Thermal desorption technology is not effective for the removal of nonvolatile inorganic contaminants, such as metal wastes, with the exception of mercury, which has a boiling point of 674 °F. Studies indicate that metals in the leachate from the Toxicity Characteristic Leaching Procedure (TCLP) generally do not increase in concentration after treatment. Though nonvolatile inorganic contaminants such as metals are not removed, they do not inhibit the process when treating organic contaminants.

Samples collected at the Raymark site contain high levels of metals, including lead at concentrations up to 5.7 percent and copper up to 6.8 percent. The Raymark site also contains high levels of asbestos. Because of their elevated boiling points, these compounds will not be vaporized in a thermal desorber. Therefore, the contaminants will remain in the treated solids discharged from the thermal desorption system. Because of the inhalation hazards associated with air-borne asbestos, extreme care must be taken when quenching and handling the treated solids. Lead has a relatively low (621 °F) melting point. Therefore, if the Raymark wastes contain high levels of lead, the lead may melt and agglomerate during soil quenching or may foul the inside of the thermal desorber.

Materials that are difficult to treat include tars and substances that form tars at low temperatures and at relatively short exposure times. The technology is most effective on matrixes that are nonadsorptive and of low porosity. Sands are easily treated because contaminants are easily desorbed from the surface. Materials that are difficult to treat include humus, organic decay products, wood, and industrial adsorbents.

3.3.3 PCB Cleanup Performance

EPA has specified a PCB performance standard of 2 milligrams per kilogram (mg/kg) for evaluating the applicability of thermal desorbers at the Raymark site. A number of thermal desorption technologies have demonstrated during full- and pilot-scale applications that this PCB performance standard can be met. The results of full-scale applications of thermal desorbers at PCB-contaminated sites are discussed below. In addition, Table 3 summarizes full- and pilot-scale performance data in the technical resources specified in Section 3.2.

To date only three vendors have used thermal desorption technology for full-scale remediation of PCB-contaminated Superfund sites: SoilTech ATP Systems, Inc. (SoilTech); RUST Remedial Services, Inc. (RUST); and Westinghouse Remediation Services, Inc. (WRS). The SoilTech anaerobic thermal processor (ATP) system was used at the Wide Beach Development site in Brant, New York and at the Waukegan Harbor Superfund site in Waukegan, Illinois. In May 1991, the SoilTech ATP treated 104 tons of soil at the Superfund Innovative Technology Evaluation (SITE) demonstration performed at the Wide Beach Development site. The average total PCB concentrations were reduced from 28.2 mg/kg to 0.043 mg/kg, a 99.8 percent removal efficiency. The test indicated that an average of 23.1 micrograms per dry standard cubic meter (μg/dscm) of PCBs was discharged from the stack to the atmosphere. During the Wide Beach Development site remediation, the ATP treated 42,000 tons of soil containing 10 to 100 mg/kg PCBs. The treated soil PCB concentrations were less than 2 mg/kg.

Approximately 253 tons of soil was treated during the SoilTech ATP SITE demonstration at the Waukegan Harbor Superfund site in June 1992. The average PCB concentration was reduced from 9,761 mg/kg in the feed soil to 2.0 mg/kg in the treated solids, a 99.8 percent average removal efficiency. An average of 0.84 μg/dscm was emitted to the atmosphere from the ATP stack, resulting in a 99.999987 percent destruction and removal efficiency (DRE).

TABLE 3

PERFORMANCE DATA FOR THERMAL DESORPTION TECHNOLOGIES

Vendor	Waste Source	Medium	Application Type	Untreated PCB Concentration	Treated PCB Concentration	Information Source
IT Corporation	PCBs from transformer reclamation	Soil	Pilot-scale	50 to 45,000 mg/kg	<2 mg/kg	EPA 1994e
	PCB transformer spill	Soil	Pilot-scale	37.5 mg/kg	<2 mg/kg	EPA 1994e
Recycling Sciences International, Inc. (RSI)	River and harbor sediment	Sediment	Pilot-scale	8.6 to 206 mg/kg	1.9 mg/kg	EPA 1990
	Inorganic manufacturing	Soil	Toxic Substances Control Act (TSCA) research and development	No information available	No information available	EPA 1994e
Remediation Technologies, Inc.	Multiple industrial uses	Natural sediment	Field demonstration	14.8 mg/kg[a]	<0.6 mg/kg	EPA 1994e
RUST Remedial Services, Inc.	Solvent recycling and organic waste disposal facility	Soil	SITE demonstration (full-scale)	181 to 515 mg/kg	<1 mg/kg	EPA 1993a
			Full-scale	25 to 13,000 mg/kg	2 to 8 mg/kg	EPA 1994e
Seaview Thermal Systems, Inc.	Petroleum refining and reuse	Sludge	Pilot-scale	190 mg/kg	<0.1 mg/kg	EPA 1994e
	No information available	Sludge	Pilot-scale	3.9 mg/kg	<0.1 mg/kg	Seaview Thermal Systems, Inc. Product Literature

TABLE 3 (Continued)

PERFORMANCE DATA FOR THERMAL DESORPTION TECHNOLOGIES

Vendor	Waste Source	Medium	Application Type	Untreated PCB Concentration	Treated PCB Concentration	Information Source
SoilTech ATP Systems, Inc.	Dust control using oil contaminated with polychlorinated biphenyls (PCB)	Soil	SITE demonstration (full-scale)	28.2 mg/kg	0.043 mg/kg	EPA 1993b (in review)
			Full-scale cleanup	10 to 100 mg/kg	<2 mg/kg	EPA 1994e
	Industrial operations	Soil and natural sediment	SITE demonstration (full-scale)	9,761 mg/kg	2 mg/kg	EPA 1993b (in review)
			Full-scale cleanup	6,700 to 23,000 mg/kg	<2 mg/kg	EPA 1994e
Westinghouse Remediation Services, Inc.	Industrial landfills	Soil	Full-scale cleanup	1 to 20 mg/kg	<2.5 mg/kg	WRS 1994

Note:

a Milligram per kilogram

During the Waukegan Harbor site remediation, the ATP treated about 12,800 tons of soil containing 6,700 to 23,000 mg/kg PCBs. The treated soil PCB concentrations were less than 2 mg/kg. The SoilTech ATP has been used to clean up two additional Superfund sites contaminated with VOCs, semivolatile organic compounds (SVOC), and pesticides.

The RUST X*TRAX™ system SITE demonstration was performed in May 1992 at the Re-Solve, Inc. Superfund site in North Dartmouth, Massachusetts. Approximately 215 tons of PCB-contaminated soil was treated. The average PCB concentration in the feed soil was 247 mg/kg; while average PCB concentration in the treated soil was 0.13 mg/kg, a 99.95 percent removal efficiency. PCBs were not detected in the stack gas samples. During the Re-Solve site remediation, the X*TRAX™ system treated over 50,000 tons of soil containing 25 to 13,000 mg/kg PCBs. The treated soil PCB concentrations ranged from 2 to 8 mg/kg.

The WRS low-temperature thermal stripping (LTTS) system was selected to clean up the Acme Solvents Reclaiming, Inc. (Acme) site in Rockford, Illinois. The site is contaminated with VOCs, phthalates, and PCBs. A proof-of-process (POP) test was conducted in March and April 1994. Approximately 210 tons of contaminated soil was treated during 10 test runs. The contaminated soil contained up to 20 mg/kg of PCBs, and the treated soil contained less than 2.5 mg/kg of PCBs. The vent gas contained less than 1.8 μg/dscm of PCBs. During the Acme site remediation, the WRS LTTS treated about 6,000 tons of soil and achieved average treated soil PCB concentration of 0.6 mg/kg.

3.4 IMPLEMENTATION OF THERMAL DESORPTION TECHNOLOGY AT THE RAYMARK SITE

Implementation considerations for thermal desorption systems include requirements for mobilization, utilities, services, supplies, waste pretreatment, and waste posttreatment. These considerations are discussed below.

3.4.1 Mobilization Requirements

Mobilization factors include site area, site preparation, and site access. These factors are described in the following sections.

3.4.1.1 Site Area

Thermal desorption systems typically require a relatively level area ranging from about 5,000 square feet (for the Weston LT^3 system) to 23,000 square feet (for the SoilTech ATP system). Additional area is also required for office space and on-site laboratory work. Additional space is needed for pretreatment and posttreatment of soil.

3.4.1.2 Site Preparation

Thermal desorption systems require placement of gravel or a concrete pad area and supports such as steel plates, wood, or concrete blocks, to support trailers to prevent equipment from leaning or sliding in soft soil.

3.4.1.3 Site Access

Site access requirements for thermal desorption systems are minimal. Most thermal desorption systems are mobile or transportable. The site must be accessible by tractor trailer trucks of standard size and weight. The roadbed must be able to support vehicles that may deliver the primary desorption chamber, tanks, APCE, and other equipment required for system operation.

3.4.2 Utilities

Thermal desorption systems typically require electricity, fuel, water for cooling and quenching treated soil and for fire protection. In addition, thermal desorption systems may require compressed nitrogen for purging the primary desorption chamber (for example, the RUST X*TRAX™ system) or for manometers to monitor the oil levels in the condensing units of the vapor recovery system (for example, the SoilTech ATP system). Technology vendors should be contacted for specific utility requirements.

3.4.3 Services and Supplies

A number of services and supplies are required for use of a thermal desorption technology. Operation of many systems require maintenance supplies and services such as welding supplies and tools, personal protective equipment (PPE), and leased equipment (such as front-end loaders). An adequate supply of spare parts (such as pumps, flow meters, and piping) should also be available from an on-site supply or from a nearby industrial supply center. For hollow-auger heating systems, additional heating fluid should be kept on site to replenish minor losses in the heating system.

3.4.4 Waste Pretreatment

Pretreatment requirements typically include size separation and may also include moisture content reduction. Size separation typically includes removing large debris from excavated wastes and screening to remove oversized (greater than 0.5- to 2.5-inch diameter) material. Oversized material may be crushed and treated in the thermal desorption system or disposed of off site. Extreme care must be taken when screening soil at the Raymark site to ensure that VOCs, asbestos, and metals are not emitted during screening operations.

Several methods can be used to reduce soil moisture. Blending is one option; however, soil blending may be difficult if large amounts of clay or very wet material is blended. Air drying, preferably enclosed in a tent, may be used to allow soil to dry at the Raymark site. Adequate space must be available on site to allow air drying. Pretreatment for soil moisture reduction should only be considered if air emissions can be adequately controlled; otherwise, moisture will be removed in the thermal desorption system at the expense of additional fuel costs.

3.4.5 Waste Posttreatment

Posttreatment requirements include treated soil quenching, treatment of inorganics, disposal of treated soil, and treatment residue disposal. The treated soil is very dry; therefore, soil quenching is needed to reduce emissions of dust contaminated with inorganics. Treated soil moisture may be used as quench water, or an off-site source of quench water may be provided. Soil quenching should be conducted in an enclosed conveyor at the Raymark site to reduce asbestos and metals emissions.

Treated soil from the Raymark site is expected to contain high levels of metals and asbestos. Wastes containing inorganics must be treated to immobilize the inorganics before final disposal. Treatment typically involves stabilization or solidification of the treated solids because these contaminants will not be affected by thermal desorption. The treated soil may be backfilled on site or disposed of off site in a solid or hazardous waste landfill in accordance with applicable or relevant and appropriate regulations.

Thermal desorption systems generate significant treatment residues that require off-site treatment. The majority of these residues are oils or condensed organics generated by the cooling and condensing units of the thermal desorption system. The oils and condensed organics must be treated and disposed of off site, usually in an approved incinerator. Other solid waste streams, such as cyclone and baghouse fines, are typically blended with the feed material to reduce the moisture content of the feed material and to retreat the fines. If the fines meet cleanup goals, they are typically disposed of with the treated soil.

4.0 COST ESTIMATE

This section presents a cost analysis for using a low temperature thermal desorption treatment technology to treat soils contaminated with PCBs. Empirical cost data can be obtained for numerous technologies. Cost data for this analysis, however, has been primarily compiled from economic data available for the X*TRAX™ thermal desorption treatment technology. The X*TRAX™ system was selected for this cost analysis because it clearly satisfies the operational characteristics described in the thermal desorber guidance, has been operated at full scale, and cost data is available in 1994 dollars. Costs have been placed into cost categories and are considered to be order-of-magnitude estimates, with an accuracy between minus 30 percent and positive 50 percent. Costs have been calculated for three contaminated soil volume scenarios: 50,000; 150,000; and 300,000 cubic yards (yd^3).

Table 4 presents the total costs associated with each treatment volume scenario, rounded to the nearest thousandth dollar. The table also presents the costs per yd^3 and per ton of treated soil. The cost estimate presented in Table 4 is specific to the Raymark site. Table 5 presents cost ranges provided by thermal desorption vendors included in the VISITT 3.0 database. The costs presented in Table 5 are not specific to the Raymark site, and represent estimated costs for a variety of applications of the thermal desorption technology. Numerous factors may influence the cost of applying the thermal desorption technology at a site, such as waste type, contaminant types and concentrations, moisture content of the waste, regulatory and permitting requirements, and volume of waste to be treated. Therefore, although the costs presented in Table 4 are within the range of costs in Table 5, costs in Table 5 can not be used for developing site-specific cost estimates without first considering site-specific factors.

4.1 COST ESTIMATE APPROACH AND ASSUMPTIONS

Cost data has been primarily compiled from an economic analysis conducted on the X*TRAX™ thermal desorption treatment technology to treat PCB-contaminated soil. The X*TRAX™ treatment system offers the following advantages over other thermal desorption treatment technologies: (1) it most accurately matches the definition of a low temperature treatment system used in this report, (2) it has been demonstrated to effectively treat PCB-contaminated soils at a Superfund site, (3) recent cost data (in 1994 dollars) is available from a draft Applications Analysis Report (in preparation), and (4) its cost data are within the order-of-magnitude estimate required for this analysis. X*TRAX™ data, where applicable, has been adjusted to correspond with the assumptions made in this analysis.

Annual operation and maintenance (O&M) costs include all variable costs associated with operating the treatment system and remediation activities conducted on an annual basis and are presented in costs per yd^3. This analysis specifically estimates the following costs: siting, capital equipment, labor, supplies, utilities, residuals and oversized material treatment and disposal, sampling and analyses, and maintenance.

TABLE 4

COSTS ASSOCIATED WITH THERMAL DESORPTION TREATMENT TECHNOLOGY[a]

Cost Categories	Total Treatment Costs[b]		
	Cubic Yards of Soil to Treat		
	50,000	150,000	300,000
Siting[c]	$125,000	$125,000	$125,000
Capital Equipment[c,d]	3,387,000	8,078,000	15,114,000
Labor[d]	3,558,000	10,672,000	21,341,000
Supplies[d]	368,000	1,103,000	2,205,000
Utilities[d]	1,050,000	3,150,000	6,300,000
Residuals and Oversized Material Disposal[d]	1,148,000	3,443,000	6,885,000
Sampling and Analyses[d]	186,000	563,000	1,125,000
Maintenance[d]	117,000	352,000	704,000
Total Costs	**$9,939,000**	**$27,486,000**	**$53,799,000**
Cost per Cubic Yard Treated	$198.78	$183.24	$179.33
Cost per Ton Treated[e]	132.52	122.16	119.55

Notes:

[a] Costs have been compiled from an economic analysis conducted on the X*TRAX™ thermal desorption treatment technology.

[b] Total costs for treating the soil volume indicated. 50,000 cubic yards will take about 1.7 years to treat completely; 150,000 cubic yards will take about 5.1 years; and 300,000 cubic yards will take about 10.2 years.

[c] Fixed cost.

[d] Variable cost (see text).

[e] One cubic yard of soil is about 1.5 tons.

TABLE 5

COST RANGES FOR THERMAL DESORPTION TECHNOLOGIES

Technology Vendor	Technology Name	Estimated Price Range
Advanced Soil Technologies	Not specified	$35 to $150 per ton
Ariel Industries, Inc.	Ariel SST Low Temperature Thermal Desorber	$65 to $200 per ton
Clean-Up Technology, Inc.	Not specified	$20 to $100 per ton
Contamination Technologies, Inc.	LTA	$50 to $150 per ton
Covenant Environmental Technologies, Inc.	Mobile Retort Unit	$100 to $800 per ton
DBA, Inc.	Not specified	$50 to $80 per ton
ECOVA Corporation	DRU	$200 to $500 per ton
Hrubetz Environmental Services, Inc.	Hrubout™	$25 to $125 per cubic yard
OBG Technical Services, Inc.	Not specified	$50 to $100 per ton
Recycling Science International, Inc.	DAVES	$61 to $89 per ton
Remediation Technologies, Inc.	Thermatek	$100 to $600 per ton
Roy F. Weston, Inc.	LT^3	$100 to $150 per ton
RUST Remedial Services, Inc.	X*TRAX™	$125 to $225 per ton
Seaview Thermal Systems	HT-6 Thermal Distillation	$50 to $400 per ton
Separation and Recovery Systems, Inc.	Sarex MX-1500 and MX-2000/2500	$50 to $150 per ton
Soil Purification, Inc./Astec	LTTD with Heat Recovery	$25 to $75 per ton
SoilTech ATP Systems, Inc.	ATP	$120 to $400 per ton
Texarome, Inc.	Mobile Solid Waste Desorption	$200 to $1,000 per ton
Thermotech Systems Corp.	Tandem SRU Model 1420	$15 to $30 per ton
Westinghouse Remediation Services, Inc.	Infrared Thermal Desorption Unit	$150 to $300 per ton

Assumptions about the site and treatment activities and equipment include the following:

- Utilities such as electricity and telephone exist overhead at the site
- Adequate roads and infrastructure exist at the site
- The treatment system will operate 19 hours per day, 7 days per week
- The feed rate of untreated soil will be 82 yd^3 per day, or 2,460 yd^3 per month
- All primary treatment and support equipment and treatment supplies can be purchased or rented from sources located within 150 miles of the site
- Contaminated soil has already been excavated from its source and is staged in a pile on a bermed concrete pad
- Labor overhead and insurance costs are accounted for in fully-loaded labor rates used in this analysis
- All equipment will be operated by treatment system personnel who have received the 40-hour health and safety training
- No annual cost adjustments for inflation are presented for the 150,00-yd^3 and 300,000-yd^3 scenarios, each of which will take over 3 years to complete

Assumptions about the soil conditions and treatment parameters used in this cost analysis:

- Soil moisture content is about 10 percent; this assumption was used for the Halliburton NUS Corporation cost estimate in the treatability study (Halliburton NUS Corporation 1994)
- One cubic yard of untreated soil is about 1.5 tons of loose soil
- The only pretreatment needed for the soil will be to screen for oversized material
- Oversized material comprises 2 percent of the feed soil

4.2 COST ESTIMATE FOR THERMAL DESORPTION TECHNOLOGY AT THE RAYMARK SITE

Cost data for this analysis have been assigned to the following categories: (1) siting, (2) capital equipment, (3) labor, (4) supplies, (5) utilities, (6) residuals and oversized material treatment and disposal, (7) sampling and analyses, and (8) maintenance. Costs in these categories include profit but do not include contingency. Each cost category is discussed below.

4.2.1 Siting

Siting costs include the costs of design, utility hookup, and permitting. This analysis assumes an area will be leveled and a compacted gravel base will be installed for siting the treatment equipment. A bermed concrete soil staging area is assumed to already exist on site. This concrete pad is bermed to prevent contaminated soil from migrating from the pad during inclement weather. Based on the X*TRAX™ analysis, siting costs are estimated to be $125,000.

4.2.2 Capital Equipment

Capital equipment costs include the variable cost of primary treatment equipment and support equipment, and the one-time costs of mobilization and demobilization of all equipment. Primary treatment equipment consists of the thermal desorption technology and all peripheral equipment associated with it such as tanks, piping, and valves. Support equipment includes one front-end loader to transport untreated feed soil, one front-end loader to backfill treated soil on site, one system control trailer, one office trailer, and two portable toilets. Based on the X*TRAX™ analysis, the cost for this estimate will be about $115,400 per month.

Mobilization costs include transporting all primary and support equipment to the site, and initial startup and shakedown activities. Transportation costs are based on transporting the treatment equipment in trailers over 150 miles of highway. A small crane is assumed to be needed to assemble the treatment equipment upon arrival at the site. The total cost includes all necessary labor, which is assumed to require 15 8-hour days. Based on the X*TRAX™ analysis, mobilization is estimated to cost $136,000.

Initial startup and shakedown costs include all activities required to make the treatment system fully operational. Startup is estimated to take 1 week and shakedown will take about 2 weeks. Based on the X*TRAX™ analysis, this cost is estimated to be $360,000.

Demobilization costs include final decontamination of reusable equipment, transportation to return reusable equipment, and proper disposal of nonreusable equipment. The total cost includes all necessary labor, which is assumed to require 10 8-hour days. Based on the X*TRAX™ analysis, demobilization costs are estimated to be $681,000.

4.2.3 Labor

Labor costs include all labor needed to operate and maintain primary treatment equipment and all support equipment. For this analysis, labor hours are calculated from the time staged soil is fed into the treatment system to the time it leaves the treatment system and is verified clean of PCBs. Costs for lodging, meals, and transportation for personnel are included in the hourly rates used in the X*TRAX™ analysis. The labor costs for excavation, staging, and backfilling are not presented in this cost analysis.

This analysis presents the exact labor costs used in the X*TRAX™ analysis, which used labor rates for the northeastern United States. A total of 18 people will operate and maintain the treatment system. Four additional personnel will collect samples and maintain the site. Four people will be required for project management. All personnel are assumed to work at a rate that is compatible with treating 82 yd^3 per day.

Based on the X*TRAX™ analysis, total labor costs are estimated to be $175,000 per month. Labor costs per yd^3 of treated soil will decrease as the feed rate increases. Cost figures presented in Table 4 assume no wage adjustments during the treatment periods for the 150,000-yd^3 scenario and the 300,000-yd^3 scenario, which will take 5.1 and 10.2 years, respectively.

4.2.4 Supplies

This analysis presents the exact costs for supplies used in the X*TRAX™ analysis. In that analysis, supplies included PPE, replacement filters and activated carbon for off gas treatment, calibration gases for air monitoring equipment, and diesel fuel for heavy equipment. Based on the X*TRAX™ analysis, this cost is estimated to be $7.35 per yd^3 of treated soil.

This analysis assumes supplies are consumed at constant rates during the entire treatment period for each treatment volume scenario. In addition, no annual inflation cost adjustments have been made.

4.2.5 Utilities

Among thermal desorption technologies, power requirements and energy types vary greatly. For example, the X*TRAX™ treatment system primarily can run on natural gas or propane gas, but the costs were presented for propane gas. The LT^3 technology consumes natural gas and electricity. X*TRAX™ consumes electricity and water to a lesser extent, and the water was not even obtained from a local utility but rather from an on-site groundwater treatment plant. Further, feed soils with a 15 percent soil moisture content or higher will not require supplemental water sources. In addition, utility and fuel costs will vary from region to region based on local rates.

This variability makes it difficult to provide a credible utility cost estimate even for the general terms used in this analysis. As a result, actual utility costs will vary greatly depending on the technology used. This analysis presents the propane gas, electrical, and water utility costs used in the X*TRAX™ analysis, which was about $21 per yd^3 of treated soil.

4.2.6 Residuals and Oversized Material Treatment and Disposal

Waste residuals from the X*TRAX™ treatment system considered for disposal in this analysis include condensed organic liquids, spent filters, activated carbon, and PPE. Based on the X*TRAX™ analysis, this cost is estimated to be about $10.35 per yd^3 of treated soil.

Oversized material comprises 2 percent of soil volume. As a result, about 60 pounds of oversized material is generated for every yd^3 of feed soil. Oversized material is assumed to be hazardous and will require proper disposal. Based on the cost analysis for the LT^3 treatment system, the cost of disposal, including storage containers, transportation, and any associated labor is estimated to be about $12.60 per yd^3 of treated soil. Total residuals and oversized material treatment and disposal costs will be about $22.95 per yd^3 of treated soil.

4.2.7 Sampling and Analyses

This analysis assumes that samples will be routinely collected for PCB analysis at the following frequencies: one sample of untreated feed soil per week; one sample of treated soil per day; one sample of condensed organic liquids per month; and one sample of condensed aqueous liquids per week. Based on the X*TRAX™ analysis, total analytical costs are estimated to be \$3.75 per yd^3 of soil treated.

4.2.8 Maintenance

Maintenance costs are assumed to be about 5 percent of primary treatment and support equipment costs. For this analysis, this cost is estimated to be \$5,770 per month.

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ATTACHMENT 1

MAXIMUM CONCENTRATIONS DETECTED IN SOIL-WASTE MATERIALS RAYMARK INDUSTRIES, INC. SITE, STRATFORD, CONNECTICUT

(Three pages)

ATTACHMENT 1

MAXIMUM CONCENTRATIONS DETECTED IN SOIL-WASTE MATERIALS RAYMARK INDUSTRIES, INC., SITE, STRATFORD, CONNECTICUT

CONSTITUENT	MAXIMUM CONCENTRATION	DETECTION LIMIT	DEPTH (feet)
VOCs (μg/kg)			
SW846-3550/8240			
● Acetone	3,893	100	8 to 10
● Benzene	80.4	5	8 to 10
● 2-Butanone	28,046	100	8 to 9
● Carbon Disulfide	209	100	7 to 8
● Chlorobenzene	141,379	5	8 to 9
● 1,2 -Dichlorobenzene	195	5	8 to 9
● 1,4-Dichlorobenzene	138.0	5	8 to 9
● 1,1-Dichloroethane	2,287	5	8 to 9
● 1,2-Dichloroethane	35	5	8 to 9
● 1,1-Dichloroethene	148.6	5	15 to 17
● trans-1,2-Dichloroethene	202	5	8 to 10
● Ethylbenzene	22,644	5	8 to 9
● 2-Hexanone	109.6	50	8 to 10
● 4-Methyl-2-Pentanone	1,399	50	4 to 6
● Styrene	367	5	0 to 2
● Tetrachloroethene	20.2	5	45 to 47
● Toluene	2,569,620	5	4 to 6
● 1,1,1-Trichloroethane	116.7	5	20 to 22
● 1,1,2-Trichloroethane	544	5	48 to 50
● Trichloroethene	2,196	5	41 to 43
● Vinyl Chloride	514	10	8 to 10
● Xylenes	113,908	5	8 to 9
SVOCs/BNA (μg/kg)			
SW846-3550/8270			
● Acenaphtene	12.6	4.4	0 to 8
● Acenaphtelene	10.4	4.4	0 to 8
● Anthracene	36.5	4.4	0 to 8
● Benzo(a)anthracene	61.7	4.4	0 to 8
● Benzo(b)fluoranthene	35.1	4.4	0 to 8
● Benzo(k)fluoranthene	47.6	4.4	0 to 8
● Benzo(g,h,i)perylene	10.8	4.4	0 to 8
● Benzo(a)pyrene	26.1	4.4	0 to 8
● Bis(2-ethylhexyl)phtalate	27.4	3.6	0 to 10
● Butyl benzyl phtalate	16.9	3.6	0 to 10
● Chrysene	54.0	4.4	0 to 8
● Dibenzofuran	11.1	4.4	0 to 8
● Di-n-butylphtalate	36.6	5.4	6 to 11
● 2,4-Dimethylphenol	19.3	1.2	2 to 12
● Fluoranthene	170.4	4.4	0 to 8
● Fluorene	32.4	4.4	0 to 8
● Indeno(1,2,3-cd)pyrene	9.4	4.4	0 to 8
● Isophorone	33.6	3.8	92 to 102
● 2-Metylnaphtalene	6.2	4.4	0 to 8
● 2-Methylphenol (o-cresol)	3.2	1.2	2 to 12
● 3-Methylphenol (m-cresol)	55.9	1.2	2 to 12
● 4-Nitrophenol	0.5	0.4	34 to 38
● Naphtalene	5.3	4.4	0 to 8
● Phenantrene	154.3	4.4	0 to 8
● Pyrene	139.6	4.4	0 to 8

ATTACHMENT 1 (Continued)

MAXIMUM CONCENTRATIONS DETECTED IN SOIL-WASTE MATERIALS RAYMARK INDUSTRIES, INC., SITE, STRATFORD, CONNECTICUT

CONSTITUENT	MAXIMUM CONCENTRATION	DETECTION LIMIT	DEPTH (feet)
Chlorinated Herbicides (µg/kg)			
SW846-3550/8150			
● 2,4-Dichlorophenylacetic Acid	398	NR	2 to 12
● 2,4-D	670	NR	6 to 11
● Dinoseb	100	NR	2 to 12
● 2,4,5-T	1,020	NR	8 to 11
● 2,4,5-TP (Silvex)	1,700	NR	38 to 48
Pesticides (µg/kg)			
SW846-3550/8140			
● Triphenylphosphate	203	NR	0 to 8
● Diallate	540	NR	0 to 8
● Dimethoate	125	NR	38 to 44
● Disulfoton	1,000	NR	0 to 8
● Famphur	180	NR	0 to 8
● Methyl Parathion	680	NR	0 to 10
● Parathion	125	NR	38 to 44
● Phorate	340	NR	2 to 12
● Pronamide	780	NR	7 to 15
● Sulfotep	125	NR	38 to 44
● Thiazin	118	NR	52 to 62
Sulfides (mg/kg)			
SW846-3550/9030	250	37	12 to 22
Cyanides (mg/kg)			
SW846-3550/9012	8.3	NR	0 to 8
PCBs (mg/kg)			
SW846-3550/8080			
Aroclor 1268	190	0.1	0 to 10
Dioxins (µg/kg)			
SW846-3550/8280			
TEF	7.2162	N/A	0 to 10
Asbestos (% by weight)			
EPA Analytical Method NR			
Chrysotile	40-45	N/A	0 to 10
Cellulose	30-35	N/A	15 to 18.5
Matrix	99-100	N/A	10 to 15
Synthetic	1-2	N/A	12 to 22

ATTACHMENT 1 (Continued)

MAXIMUM CONCENTRATIONS DETECTED IN SOIL-WASTE MATERIALS
RAYMARK INDUSTRIES, INC., SITE, STRATFORD, CONNECTICUT

CONSTITUENTS	MAXIMUM CONCENTRATION	DETECTION LIMIT	DEPTH (feet)
Metals (µg/kg) SW846-6010/7471			
• Antimony	30,182	1,000	6 to 11
• Arsenic	130,208	200	0 to 8
• Barium	2,314,400	400	7 to 15
• Beryllium	8,400	500	0 to 4
• Cadmium	10,364	500	6 to 11
• Chromium	316,949	1,000	0 to 10
• Cobalt	87,100	5,000	0 to 4
• Copper	67,966,101	NR	0 to 10
• Lead	57,230,769	NR	2 to 11.5
• Mercury	1,017	100	0 to 10
• Nickel	774,576	4,000	1 to 10
• Selenium	6,780	NR	0.5 to 2
• Silver	67,470	1,000	0 to 10
• Thallium	781	500	10 to 18
• Tin	229,730	4,000	0 to 8
• Vanadium	103,000	NR	0 to 4
• Zinc	13,175,675	NR	0 to 8

NOTES:

E:	Estimated Value
N/A:	Not Applicable
ND:	Not Detected
NR:	Not Recorded

Source: Halliburton NUS Corporation. 1994 "Draft Treatability Study Report for Bench-Scale Low Temperature Thermal Desorption, Remedial Investigation, Raymark Industries, Inc. Site, Stratford, Connecticut." June.