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Application of thermal desorption technologies to hazardous waste sites

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Abstract

Thermal desorption is a separation process frequently used to remediate many Superfund sites. Thermal desorption technologies are recommended and used because of (1) the wide range of organic contaminants effectively treated, (2) availability and mobility of commercial systems, and (3) the public acceptance of the treatment approach. Thermal desorption is applicable to many organic wastes and generally not used for treating inorganics and metals. Commercial systems are now in operation remediating Superfund sites, and more are under construction. The public has shown a preference for this technology over incineration because, as a separation process, it seems less likely to create dioxins and other oxidation products. The US EPA SITE program has evaluated the major thermal desorption vendors to answer several questions about the technology; what is the treatment effectiveness, are there products of incomplete combustion, and what are the air emissions?

1. Introduction

Five Superfund innovative technology evaluation (SITE) program field demonstrations have been performed on four thermal desorption processes. Table 1 lists the TD vendors, site locations and contaminants for the successfully completed remediations and SITE demonstrations.

These SITE field demonstrations were designed to answer three questions about thermal desorption: (1) what is the treatment effectiveness for non-volatile organics, (2) are there products of incomplete combustion, e.g., dioxins/furans, and (3) what are the air emissions? These questions are raised because the thermal desorption operating temperatures may not be above some compound boiling points and recovery, i.e., non-destructive, air pollution control systems are used to collect the volatilized organics. To understand the questions, a brief description of the major TD treatment system and the air emission control systems follow.

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Table 1
US EPA SITE demonstrations

Vendor name	Site location	Site contaminant
SoilTech ATP	Wide Beach Development Brant, NY	PCBs
SoilTech ATP	Outboard Marine Corp Waukegan, IL	PCBs
Rust Engineering X*TRAX	Re-solve site, North Dartmouth, MA	PCBs
Canonie Environ. LTTA	Pesticide site West Phoenix, AZ	DDT, DDD, DDE, toxaphene
Roy F. Weston LTTT	Anderson Devel. Corp Adrian, MI	4,4'-methylene bis (2-chloroaniline) (MBOCA)

2. Vendor designs

There are two major design approaches for thermal desorption processes: rotary dryer and screw auger. To show the differences in vendor systems, below are descriptions of the four TD systems.

*2.1. Rust Engineering (formerly Chemical Waste Management) – X*TRAX*

The X*TRAX system is an indirectly heated rotary dryer capable of treating up to 250 t/day of soil and sediments. Propane or natural gas is used to heat the dryer shell to temperatures between 300 and 900 °F [1]. A nitrogen sweep stream carries the volatilized water and organics to gas treatment. There the water and most organics are collected by condensation, refrigeration and finally carbon adsorption. After being reheated, the nitrogen is reused. Use of the nitrogen avoids explosion hazards. The liquid water and organics are separated, and the water used to control the dusting of the treated solids. The system is transportable. Fig. 1 shows all the stream flows.

2.2. SoilTech, Inc. – ATP

The anaerobic thermal processor (ATP) system is a four-zone double-shell rotary dryer capable of treating up to 25 t/h of soil and sediments. Solids are fed to the inside shell [2, 3]. The first (preheat) zone of this shell volatilizes the water and VOCs at low temperatures (400–650 °F). At temperatures of 900–1150 °F, the organics are volatilized and cracked (pyrolysis) in the second (retort) zone. From the second zone the solids drop into the third (combustion) zone where the soils move in the opposite direction in the outer shell, helping to heat the inside shell. In this annulus between the two shells, propane or natural gas are fired to heat the inside shell and to remove any carbon residues in the solids. Combustion gases are treated by a cyclone, baghouse, caustic scrubber and finally carbon adsorption. Then the hot soils move through the

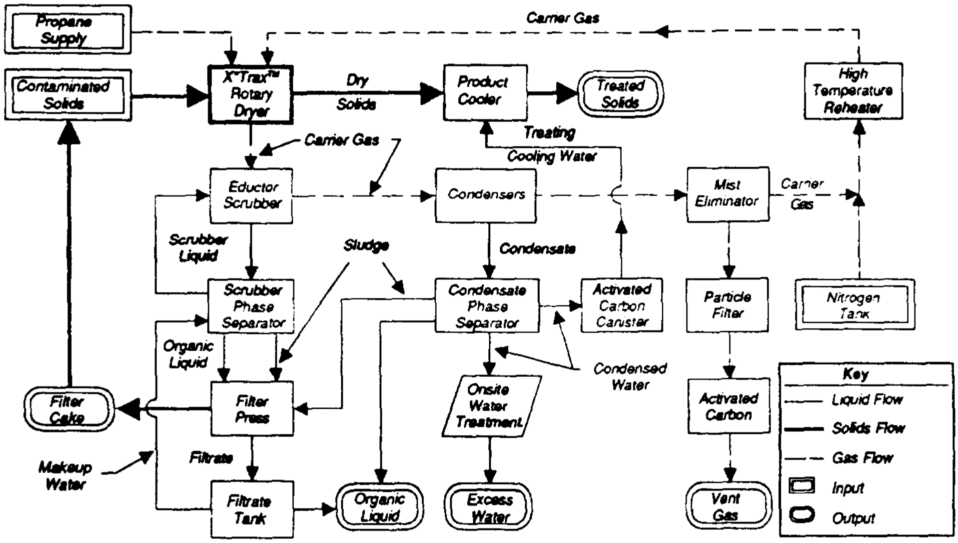

Fig. 1. Diagram of X*TRAX system.

fourth (cooling) zone heating the preheat zone. Gases from both zones are treated by condensation and the liquids stored. The non-condensable gases are used as a fuel in the combustion zone.

There is an option with the SoilTech ATP system to use a dechlorination process as an integral part of the process. The alkaline polyethylene glycol (APEG) dechlorination process was used with the ATP system to remediate the Wide Beach, NY site.

2.3. Roy F. Weston, Inc. – LT^3

The low temperature thermal treatment (LT^3) system uses two banks of four heated screws to treat up to 20 t/h of contaminated soils and sediments [4]. Heat transfer oil is heated by propane combustion and pumped through the screws and shell to heat the solids to temperatures up to 600 °F. The combustion gases from heating the heat transfer oil are used to sweep the volatilized water and organics to the gas treatment system. Fig. 2 details all the soil, liquid and gas flows.

2.4. Canonie Environmental – LTTA

The low temperature thermal aeration (LTTA) system is a direct-heated rotary dryer capable of treating up to 50 t/h of solids [5]. Natural gas or propane are burnt in a plenum. The hot gases then enter the rotary kiln, heating the soil and volatilizing the organics. The off-gases are then treated by two cyclones, a baghouse, a wet venturi scrubber and two vapor-phase carbon (GAC) beds. The condensed water and

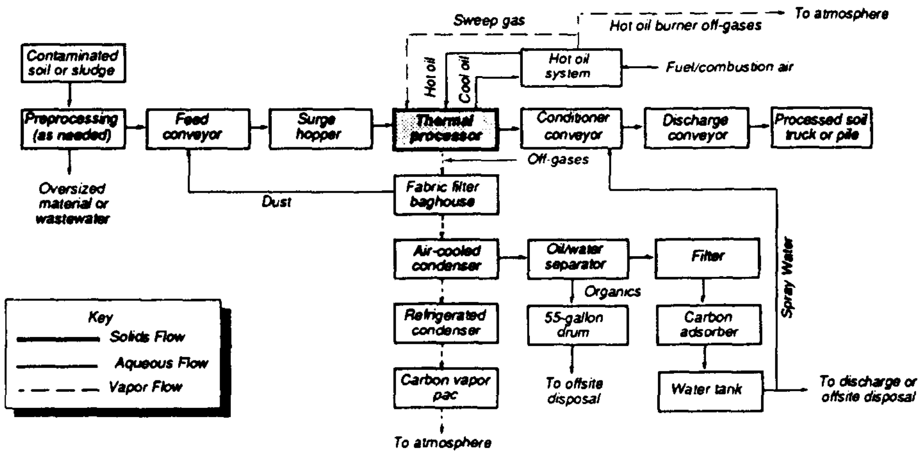

Fig. 2. Diagram of LT³ system.

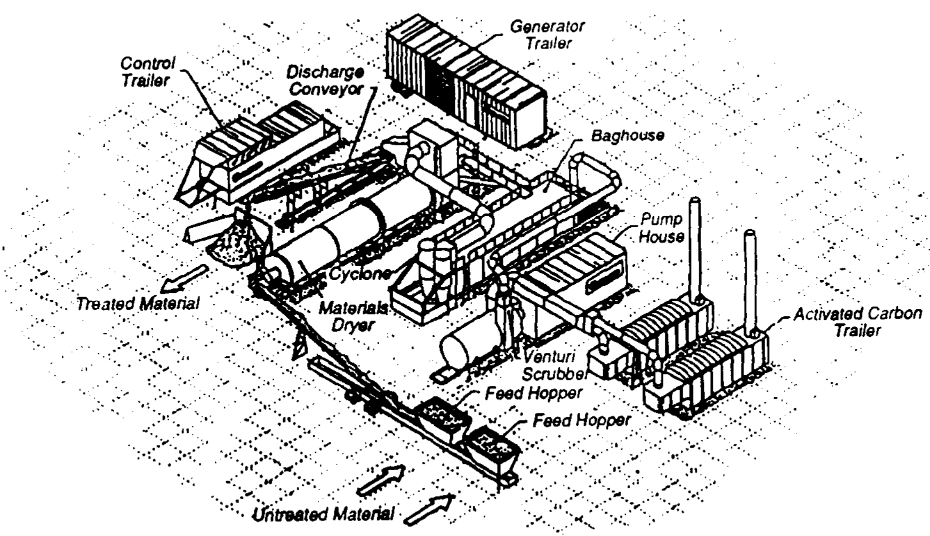

Fig. 3. LTTA soil processing equipment layout.

organics are treated by a liquid-phase carbon bed. Fig. 3 shows an equipment layout for the LTTA system.

3. Treatment effectiveness

Thermal desorption has been proven effective in treating contaminated soils, sludges and filter cakes. Chemical contaminants for which bench-scale through

Table 2
Thermal desorption SITE demonstration results

Vendor/site	Contaminant	Concentration	
		Feed (mg/kg)	Product (mg/kg)
SoilTech Wide Beach, NY	PCBs	28.2	0.043
SoilTech Waukegan, IL	PCBs	9761	2
Rust Engineering Re-solve, MA	PCBs	25	0.25
Roy F. Weston ADC, Adrian, MI	MBOCA	43.6–860	3–9.6
Canonie Environ. West Phoenix, AZ	DDT/DDD/DDE,	26.2	0.678
	toxaphene,	18.3	< 0.017
	SVOCs	7.1	4.5

full-scale treatment data exist include volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs), and even higher boiling point compounds such as PCBs and dioxins. Table 2 shows the treatment results from the five SITE demonstrations [6, 7]. There are pilot-scale data showing that dioxins and furans in the soil can be removed, but higher temperatures (1000 °F) are needed to be fully effective.

4. Products of incomplete combustion

Under certain operating conditions, products of incomplete combustion (PICs) can be formed in thermal desorption systems. In most cases, however, properly operated TD systems do not form PICs. During the five SITE demonstrations, formation of dioxins and furans was used as one measure for PIC formation. In four instances no dioxin or furans were formed during the demonstration (remediation); in the other, dioxins/furans were formed. It is felt the formation of dioxins during this demonstration was due to the presence of chemical precursors (MBOCA), alkaline pH, high concentrations of free chloride and the elevated treatment temperatures (> 500°F) needed to cope with the high soil moisture levels (40%). In another instance, dioxins were formed during the proof-of-process testing required for final approval to remediate the site. After the process operations were modified and sodium bicarbonate was added to act as a scavenger of free chloride, the system easily met the 30 ng/m^3 (total dioxin/furans) requirement.

Other PIC compounds were analyzed for in the treated soils and residuals, and in some cases were found. Like dioxins and furans, these compounds were primarily found in the residuals collected in the air pollution control system, and not in the soil.

Table 3
SITE demonstration air emission data

Vendor/site	Compound	Air concentration	Air emissions
Canonie Environ.	VOCs	11 200 mg/m^3	0.42 lb/h
West Phoenix, AZ	DDT/DDD/DDE	1.99	
	Toxaphene	< 0.90	
	SVOCs	1 180	
	Particulate		0.16
	Chloride[a]	168	0.0092
	Dioxin/furan	0.0865	
Roy F. Weston	MBOCA	ND[b]	
ADC, Adrian, MI	TNMHC	11 ppmv	
	Particulate	0.434 mg/m^3	0.0092 lb/h
	Chloride	0.028 mg/m^3	0.00006
	Dioxin/furans	ND	
Rust Engineering	PCBs	ND	
Re-solve, MA	TNMHC		0.4 g/d
	VOCs	171 mg/m^3	
	SVOCs	140 mg/m^3	
	Particulate	ND	
	Dioxins/furans (TCDD equivalent)	9.6×10^{-2} ng/m^3	
SoilTech	PCBs	23.1 μg/m^3	
Wide Beach, NY	SVOCs	NA[c]	
	Particulate	828 mg/m^3	
	Dioxins/furans	9.52 ng/m^3	
SoilTech	PCBs	0.84 μg/m^3	
Waukegan, IL	SVOCs	8.52 μg/m^3	
	Particulate	3.89 mg/m^3	
	Dioxins/furans	0.079 μg/m^3	

[a] Chloride was used as indicator for compound of interest.
[b] ND: non-detect.
[c] NA: not analyzed.

It should be noted that many hazardous waste sites with chlorinated aromatic compounds will have dioxins and furans. The thermal desorption systems will tend to remove these compounds from the soils and sediments, and concentrate them in the air pollution control residuals.

5. Thermal desorption air emissions

All TD systems have extensive air pollution control (APC) systems. Because thermal desorption systems are separation and not destruction processes, there usually are measurable quantities of contaminants in the air emissions. The indirect heated TD systems (Roy F. Weston and Rust Engineering) have very low gas flow and small quantity of air emissions. The direct heated systems (Canonie and SoilTech) have similar air emissions to combustion sources. Table 3 presents the air emission data from the five SITE demonstrations.

Although destruction and removal efficiency (DRE) is not appropriate to thermal desorption systems, calculations were made for several demonstrations. SoilTech for Waukegan, IL and Wide Beach, NY had DREs of 99.999995 and 99.77, respectively; showing the improvement in the APC system between the two remediations.

6. Summary and conclusions

Five SITE demonstrations were performed in an effort to answer three questions about thermal desorption systems. First, the demonstration results found thermal desorption to be very effective on PCBs and pesticides, besides the usual VOCs and SVOCs. Second, products of incomplete combustion are possible, but can be avoided. Finally, measurable air emissions will be detected. The air emissions varied from very acceptable (indirect heated systems) to acceptable.

References

[1] Demonstration bulletin, X*TRAX Model 200 Thermal Desorption System, Chemical Waste Management, Inc., US Environmental Protection Agency, EPA/540/MR-93-502, February 1993.

[2] Demonstration bulletin, AOSTRA-SoilTech Anaerobic Thermal Processor: Wide Beach Development Site, US Environmental Protection Agency, EPA/540/MR-92/008, March 1992.

[3] Demonstration bulletin, SoilTech Anaerobic Thermal Processor: Outboard Marine Corporation Site, US Environmental Protection Agency, EPA/540/MR-92/078, November 1992.

[4] Applications Analysis Report, Low Temperature Thermal Treatment (LT3) Technology, Roy F. Weston, US Environmental Protection Agency, SPA/540/AR-92/019, December 1992.

[5] Demonstration bulletin, Low Temperature Thermal Aeration (LTTA) Process; Canonie Environmental Services, Inc., US Environmental Protection Agency, EPA/540/MR-93/504, March 1993.

[6] Draft Applications Analysis Report, SoilTech ATP Systems, Inc., Anaerobic Thermal Processor, Site Demonstrations at the Wide Beach Development Site, Brant, New York and Waukegan Harbor Superfund Site, Waukegan, Illinois, US Environmental Protection Agency, March 1993.

[7] Draft Applications Analysis Report, Canonie Environmental Services Corp., Low Temperature Thermal Aeration (LTTA) Process, US Environmental Protection Agency, March 1993.