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REMEDIATION OF PCB SOIL CONTAMINATION BY ON-SITE INCINERATION*

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Summary

Throughout the world, sites have been discovered which contain hazardous wastes. To completely destroy the contaminants in the soil, incineration remains the primary option for soils containing organics with high boiling points. This paper deals with operational aspects of the Transportable Incineration System, including specific procedures which were developed during the incineration of PCB-contaminated soils at the Lauder salvage yard in Beardstown, Illinois. Some of the issues treated in this paper include:

- Prescreening of soil to remove oversize materials.
- Process description.
- Treated soil material handling at elevated temperatures.
- Slag formation in the kiln and secondary combustion chamber.
- Development of procedures required for trial burn testing. Some of these procedures may require special system design consideration.

Introduction

Throughout the world, sites are continually being discovered which contain hazardous wastes. At most of these locations, soils have become contaminated prior to or during the cleanup activities. To protect the environment and future generations, cleanup of these contaminated soils is becoming mandatory. While new technologies exist which will mechanically or biologically reduce the levels of contamination in the soils, none currently available can provide reductions which approach total destruction of the contaminant. In order to completely destroy the contaminants in these soils, incineration remains the primary option for soils containing organics with high boiling temperatures.

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For these reasons, the Illinois Environmental Protection Agency (IEPA) has established a program to promote on-site incineration as a means of remediating many of the sites which currently exist in Illinois. This discussion will deal with several major areas which pertain to the promotional effort including the following:

- background,
- permitting,
- process description,
- prescreening of soil to remove oversize materials,
- development of procedures required for demonstration testing,
- results of the demonstration testing conducted on PCB-contaminated soil.

The discussion will stress design criteria and operation. The criteria for transportable incineration systems designed for soils is significantly different from that normally utilized in the industry.

Background

Incineration has been selected as the preferred form of treatment for several sites within the State of Illinois by the Illinois Environmental Protection Agency. Two sites have been remediated, and several others are under consideration for future remedial work. One of the first sites selected and completed for remediation was the Lauder salvage yard located in Beardstown, Illinois. This project was State funded and slated for immediate remediation based upon IEPA's assessment of the risks involved.

When discovered, the abandoned salvage yard contained over 400 transformers, more than 75 capacitors, and assorted non-hazardous debris. Some of the transformers and capacitors were leaking PCB-laden oil. Soil in certain areas was visibly stained with these oils.

During the summer of 1985, electrical equipment, highly contaminated soil, and non-hazardous debris were removed from the site. Following this removal action, an extensive soil sampling program was prepared and implemented. The site was divided into 109 grids of varying sizes averaging 2500 square feet.

TABLE 1

Summary of contamination at the Lauder salvage yard

PCB concentration (ppm by wt.)	Number of grids
<5	87
5 to 50	17
>50	5
Total	109

Survey stakes located grid boundaries and soil samples were collected. The samples were composited to depths of five feet from each grid. In addition, five grids were sampled to a depth of ten feet to further delineate subsurface conditions.

A summary of analytical results is shown on Table 1.

Permitting

Three permits are required for the operation of the transportable incinerator at the Lauder salvage yard. These are as follows:

- United States Environmental Protection Agency National Toxic Substances Control Act Permit for the incineration of PCB's.
- IEPA Division of Land Pollution Control Permit to Develop a Treatment Facility.
- IEPA Division of Air Pollution Control Permit to Construct and Permit to Operate the Facility.

Process description

The transportable incineration system (TIS) described below was designed to incinerate soils contaminated with organic compounds with high boiling temperatures such as polychlorinated biphenyls (PCBs). However, it was also designed to be capable of incinerating fume, hazardous liquids and sludges at rates of up to 33 million BTUs per hour of heat release. The unit is owned and operated by Weston Services, Inc., a subsidiary of Roy F. Weston, Inc.

On 21 October 1988, Weston was granted a national TSCA (Toxic Substances Control Act) Permit for the TIS. The unit was designed and constructed to be employed anywhere in the continental United States. Structural design provides the possibility of siting the TIS in areas of earthquake or hurricane hazard by designing for earthquake zone 4 and 120 mile per hour winds.

System configuration

The TIS is comprised of a $7\frac{1}{2}$ ft diameter, 25 ft long rotary kiln furnace, with a hopper/screw feed system, secondary combustion chamber (afterburner), multi-fuel burners, dry ash handling, exhaust heat recovery, exhaust gas fabric filtration system, operational gas scrubbing (neutralization), an induced draft fan and exhaust stack with an optional air heater for plume suppression. Details of each system component are provided below.

Feed system

The feed system is patterned after one designed by Weston for the U.S. Army Toxic and Hazardous Material Agency for use in feeding explosives-contaminated soil to an incineration system. The feed system consists of a live bottom hopper with screws designed to draw feed material from the bottom of the hopper at a constant rate. Feed rates may be varied from near zero to more than eight tons per hour. The live bottom screws feed an inclined drag conveyor which moves feed material to the twin kiln feed screw conveyors, which are glycol-cooled and fabricated from Inconel for corrosion protection.

Rotary kiln

The kiln is a rugged version of a standard concurrent cylindrical design which provides for retention times of fifteen to ninety minutes. Gas phase operating temperatures can be varied from below 1200 to over 2200°F (650–1200°C), depending upon the characteristics of the specific waste being heated. The system's capacity will be dependent upon the chemical process by which the waste is destroyed. The kiln can physically handle from as much as 10 tons per hour to less than two tons by varying the kiln rotational speed and feed rate to the system. The kiln has a refractory lining of brick capable of withstanding temperatures in excess of 2200°F.

Ash handling

Ash or slag residue from the incineration process falls from the discharge end of the kiln into a cooling screw conveyor where it is sprayed with water and further cooled by indirect heat transfer to the glycol-cooled screw conveyor. The cooled ash is transferred to an inclined stacker belt conveyor which deposits the ash into water-tight steel dumpsters. The containers can be transported or stored until contaminant destruction is confirmed by chemical analysis performed in the on-site laboratory.

Secondary combustion chamber (afterburner)

The secondary combustion chamber (SCC) is an 8 ft 6 in. outer diameter castable lined vertical cylinder. It has the capability of operating at temperatures in excess of 2200°F while maintaining residence times greater than two seconds. The SCC is oriented vertically to avoid slagging failures. A large multi-fuel burner fires in a near vertical position from the bottom of the unit. An auxiliary burner that is continuously operated at low fire by a separate power generator is located adjacent to the afterburner in the SCC. The auxiliary burner automatically increases to high fire upon loss of the afterburner.

Ash or slag dropout from the unit will fall directly into the dry ash handling system at the base of the chamber with the furnace ash discharge. Temperature is controlled by a chamber outlet thermocouple/temperature controller which varies the firing rate of the burner at the base of the SCC.

Quench chamber

To cool the gases existing the SCC, water is atomized into the gas in continuously controlled quantities in the quench chamber. The heat of vaporization of the water cools the gas to about 1000°F (550°C). Quench chamber outlet temperature controls the amount of water injected to maintain a constant exit temperature.

Heat exchanger

Cooling the gas for dust removal in the baghouse is accomplished by the use of an-air-to air heat recovery heat exchanger. The shell and tube heat exchanger cools the flue gas from 1000°F to approximately 350°F. Heat is recovered by the burner combustion air fan.

Fabric filter

The fabric filter is designed to reduce particulate emissions to less than 0.08 grains per dry standard cubic foot of exhaust gas corrected to 12 vol.% carbon dioxide. In reality, the high efficiency teflon coated fiberglass bags used in this system will provide a much cleaner exhaust gas. The baghouse has the capability of adding 33% additional bags. This option is utilized when incinerating extremely fine materials which might have a very high carryout rate from the incinerator. To prevent acid (moisture) condensation in the baghouse, the unit is insulated and heat traced. Special high temperature acid resistant coatings have been used to further resist corrosion.

Scrubber

The TIS is designed with an optional caustic scrubber. In the event that materials are incinerated which produce significant quantities of acid gas such as hydrochloric acid (HCl) or sulfuric acid (H_2SO_4), this option is incorporated. For the destruction of PCBs at Lauder salvage yard the scrubber was required. The crossflow packed tower scrubber employed provides removal of acid gases by neutralization with sodium hydroxide, a basic solution. The exhaust gas is first quenched to its adiabatic saturation temperature in an Inconel quench section before entering the fiberglass reinforced polyester (FRP) scrubber and exiting through the fiberglass exhaust stack.

Exhaust gas system

A stainless steel exhaust, induced draft fan has been provided as the prime gas mover in the system. The induced draft fan is located directly after the baghouse and handles gas at 300–500°F. The gases are blown through the scrubber and out through the stack. In the event that the scrubber is not required, the fan will discharge to a steel exhaust stack.

Plume suppression system

In some cases, it may be advantageous (for public opinion) to eliminate the plume from the scrubber discharge stack. Though not used, the system design

TABLE 2

System operating capabilities

Capacity	2 to 10 t/h TSCA to 7 t/h
Residence time	15 to 90 min
Operating temperatures	
Rotary kiln	up to 2200°F
SCC (afterburner)	up to 2300°F
Gas cleaning capability	
Baghouse emissions:	< 0.08 gr/dscf @ 12 vol.% CO_2
Scrubber:	> 95% removal of H_2SO_4
	> 99% removal of HCL (< 1.8 kg/h HCl at 10 000 ppm PCB).
Maximum heat[a] release capability:	
Kiln:	$23 \cdot 10^6$ BTU/h
SCC:	10^7 BTU/h

[a]1 BTU = 1.054 kJ.

provides for a skid mounted plume suppression air heater to discharge into the exhaust stack immediately above the scrubber exhaust entry point.

Utility systems

All utilities are skid mounted to facilitate rapid mobilization. The system is currently outfitted with a compressor system, fresh water, wastewater filtration and carbon adsorption system and surrogate metering system for demonstration tests.

Operating capacities of the major components of the TIS are summarized in Table 2.

Prescreening of soil to remove oversize materials

In feed material preparation an important consideration is conveyance of the material. Depending on the soil physical characteristics a suitable screening method must be selected. At the Lauder yard site where the soil was sandy, a bar screen followed by a power screen was employed. The screened soil was introduced into the live bottom feed hopper.

With a clay soil such screening would not be practical, therefore, a shredder device would be utilized before the feed hopper. In both cases the objective is to limit the size of the feed to two inches topsize to allow conveyance by the feed screws.

Development of procedures required for demonstration testing

Surrogate feed consideration

In normal incineration process design, the flows are calculated based on assumed feed characteristics. The assumptions for the feed characteristics are based on historic data. System testing is performed on the actual conditions (feed) which normally does not vary greatly from the assumed. When designing an incineration system for PCB destruction, one must consider the surrogate feed which will be introduced for demonstration evaluation and testing.

The surrogate feed characteristics and rates are selected to yield the case scenario for process design. This is due to the fact that PCBs cannot be acquired without being combined with other substances (e.g. trichlorobenzene [TCB] and mineral oil). To feed the required amount of PCB for testing (e.g. one percent, to yield 100 000 ppm PCB-contamination), the other proportional amounts of TCB and mineral oil must be introduced and considered for destruction. Surrogate feed to yield 10 000 ppm PCBs in the feed material may require the addition 15 000 ppm TCBs and 15 000 ppm mineral oil. For this reason it is essential that the surrogate feed be established during the design phase and analyzed in order to incorporate these characteristics into the process design calculations.

Another design consideration relating to the surrogate feed is the storage, metering and actual introduction of the surrogate. Some features which must be included are the installation of holding tanks and pumps on a bermed pad for spill control, use of a metering device which allows visual confirmation of flow, continuous mixing of the surrogate, and totally enclosed introduction of the surrogate to the incineration system.

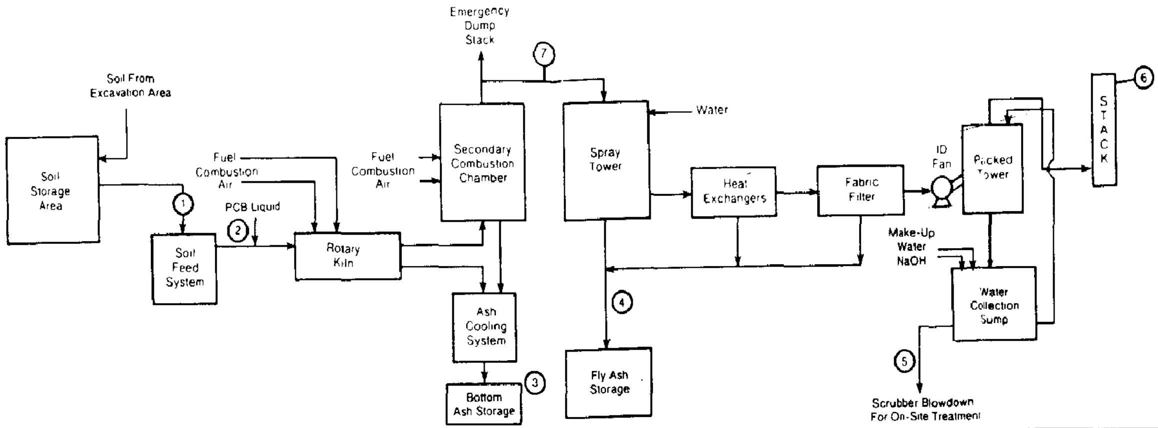
Soils and liquid sampling

Samples of te soils and process streams must be collected for a complete evaluation of the incineration process for demonstration testing purposes. The locations of the sampling points chosen for demonstration testing for the TIS are shown in Fig. 1. A brief description of each of the sampling locations is described below.

Depending upon the nature of the contaminants and the criteria for a successful demonstration, analysis of the samples may be in an on-site or off-site laboratory. For the TIS demonstration tests, all the samples were sent to a CLP certified laboratory. Analysis was performed on each sample matrix for one or all of the following parameters: PCBs, dioxins and furans, chlorides, moisture, pH, suspended solids, volatile and semivolatile organics, particulates, CO_2, O_2, CO, nitrous oxides, and total hydrocarbons.

Feed soil. A sample of contaminated feed soil was collected from each bucket load being dumped into the feed hopper. Discrete samples were composited into a single sample for each test run.

Surrogate feed. The surrogate feed was sampled at the beginning and end of each test run to be sure a consistent mixture was fed to the soil. The surrogate feed rate was confirmed by timing the collection of a one-gallon sample. An



Parameters Sampled/Analyzed	1 Feed Soil	2 PCB Liquid	3 Bottom Ash	4 Fly Ash	5 Scrubber Blowdown	6 Stack Gas	7 SCC Exit	
PCB's	x	x	x	x	x	x		
Dioxins		x		x	x	x		
Furans		x		x	x	x		
Particulates						x		
HCl						x		
Chlorides	x	x	x	x	x			
Volatile Organics						x		
Total Hydrocarbons						x		
Nitrous Oxides						x		
Carbon Dioxide						x	x	
Carbon Monoxide						x	x	
Oxygen						x	x	
Suspended Solids					x			
pH					x			
Mass Flow Rate (Solids)	x							
Volumetric Flow Rate (Liquids)		x						
Volumetric Flow Rate (Gases)						x		
Moisture Content	x					x		

Fig. 1. Location of sampling points.

analytical-surrogate feed sample was prepared from the one-gallon sample. This procedure was repeated at the end of each test run to confirm feed rate and sample consistency.

Treated soil. A sample of the treated soil was collected after it was cooled, prior to its storage in the water-tight ash bins. The samples were collected every five minutes. Discrete samples were composited into a single sample for each test run.

Dust from fabric filter. Dust (or particulate carryout) collected in the fabric filter was sampled every 15 minutes from the screw conveyor carrying the material to the ash collection system. A sample tap and a valve was installed in the bottom of the screw conveyor to draw the sample without disruption to the conveyor. The discrete samples were composited into a single sample for each test run.

Scrubber blowdown. Scrubber blowdown liquor was sampled every 15 minutes from a sample in the blowdown pipeline. The discrete samples were composited into a single sample for each test run.

Stack gas sampling

During normal operation and demonstration testing Continuous Emissions Monitoring (CEM) of the combustion gases is required. Proper probe locations and size must be incorporated into the design. An ideal location for combustion gas sampling is in the exhaust gas stream directly after the secondary chamber where leakage or air infiltration is minimal.

As with any incineration process, the stack, and stack ports must be properly sized and located for system evaluation and testing. For a forced draft incineration process, the stack is normally designed for gas velocities of 3600 ft/min. Four 4 in. diameter testing ports on the same plane should be designed on the stack. It is recommended that the plane be located on a straight run with minimal gas turbulence. A safe approach is to design the straight run to be a minimum of twelve stack-diameters long. The point for the ports are located at eight stack diameters from the last disturbance and four stack diameters from the stack exit.

During demonstration testing, stack sampling was conducted to determine the destruction and removal efficiency (DRE) of PCBs by the incineration process as well as to determine products of incomplete combustion (PICs) and any dioxins and furans that may have been generated during the combustion process.

Results of the demonstration test conducted on PCB-contaminated soil

The incinerator was operated under Demonstration Test conditions on May 18 through May 20, 1988. A stack testing crew was mobilized on site to monitor the stack exhaust gas for PCBs, dioxins, volatile and semivolatile organics.

The incinerator was processing an average of 13 560 lb/hr of soil spiked with PCB oil to an average concentration of 14 740 ppm. Temperature in the kiln was maintained at approximately 1470°F and in the SCC at 2200°F with a soil retention time in the kiln of 30 minutes and gas retention time in the SCC of over 2 seconds.

The incineration achieved 99.9999% DRE of PCBs. The acid-gas scrubber was utilized during this application due to the generation of hydrochloric acid (HCl). Chloride was removed from the exhaust gas to less than 4 lb/hr and particulate was removed to less than 0.08 grains/dry standard cubic feet (dscf) corrected to 12 vol.% carbon dioxide (CO_2). Dioxins, semivolatile organics, and volatile organics were all measured in the less than detectable range or well below performance criteria.

The results for all three tests runs and the operating conditions are summarized in Table 3.

In conclusion, it has been demonstrated that the transportable incinerator system meets all TSCA requirements for PCB destruction by incineration. Also, during the TSCA trial burn demonstration, sufficient RCRA waste was

TABLE 3

Demonstration test results

Parameter	Day		
	18 May 88	19 May 88	20 May 88
Feed soil characteristics			
Soil feed rate (lb/h)	12 718	14 364	13 601
PCB concentration (ppm)	18 843	14 833	10 550
Combustion characteristics			
Kiln temperature (°F)	1488	1469	1461
SCC temperature (°F)	2202	2198	2191
SCC retention time (s)	2.08	2.09	2.11
Stack gas oxygen (%)	13.20	13.80	13.51
Combustion efficiency (%)	100.00	99.994	99.998
PCB removal			
DRE (stack emissions) (%)	99.999989	99.999990	99.999983
Bottom ash (%)	99.9992	99.9995	99.9999
HCL emissions (lb/h)	2.98	2.68	2.66
Particulate emissions @ 12 vol.% CO_2 (gr/dscf)	0.032	0.025	0.040

fed to the system and successfully destroyed to demonstrate compliance with RCRA incineration requirements.

U.S. EPA has issued a National TSCA permit for the TIS. The TIS has been successfully operated, in compliance with TSCA and IEPA regulations to treat over 8500 tons of PCB contaminated soil at the Lauder salvage yard in Beardstown, IL. The PCB levels at the site are now below the cleanup criteria required by IEPA and no longer pose a threat to the ground water. In conclusion, the TIS unit is capable of maintaining compliance with TSCA regulations. The Lauder salvage yard in Beardstown, IL has been remediated, and the TIS is in the process of demobilization. The site may now be used for more prosperous or community-related activities.