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BENCH- AND PILOT-SCALE THERMAL DESORPTION TREATABILITY STUDIES ON PESTICIDE-CONTAMINATED SOILS FROM ROCKY MOUNTAIN ARSENAL*

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ABSTRACT

Thermal desorption is being considered as a potential remediation technology for pesticide-contaminated soils at the Rocky Mountain Arsenal (RMA) in Denver, Colorado. From 1988 through 1992, numerous laboratory- and bench-scale indirect-heated thermal desorption (IHTD) treatability studies have been performed on various soil medium groups from the arsenal. RMA has contracted Argonne National Laboratory to conduct a pilot-scale direct-fired thermal desorption (DFTD) treatability study on pesticide-contaminated RMA soil. The purpose of this treatability study is to evaluate the overall effectiveness of the DFTD technology on contaminated RMA soils and to provide data upon which future conceptual design assumptions and cost estimates for a full-scale system can be made. The equipment used in the DFTD treatability study is of large enough scale to provide good full-scale design parameters and operating conditions. The study will also provide valuable emissions and materials-handling data. Specifically this program will determine if DFTD can achieve reductions in soil contamination below the RMA preliminary remediation goals (PRGs), define system operating conditions for achieving the PRGs, and determine the fate of arsenic and other hazardous metals at these operating conditions.

This paper intends to compare existing data from a bench-scale IHTD treatability study using equipment operated in the batch mode to new data from a pilot-scale DFTD operated in a parallel-flow continuous mode. Delays due to materials-handling problems and permit issues have delayed the start of the pilot-scale DFTD testing. The first pilot-scale test is scheduled for the first week in January 1995. The available data will be presented March 9, 1995, at the Seventh Annual Gulf Coast Environmental Conference in Houston, Texas.

INTRODUCTION

Thermal desorption (TD) is a maturing technology for the remediation of contaminated soil. The United States Environmental Protection Agency (EPA) reported that TD was selected for use at 32 Superfund sites from 1985 through fiscal year 1992 (1). TD has been used to remove pesticides, polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs). There is an even larger market for TD in nonregulated cleanups (petroleum-hydrocarbon-contaminated soils). A survey reports that in 1993 125 companies with 180 thermal desorption units treated 5.85 million metric tons of soil (2).

Superfund soil remediation projects frequently cost tens of millions of dollars. Because of the cost and potential risk, major concerns are how much testing is necessary and at what scale to accurately forecast full-scale TD performance and cost. In addition to the question of scale, one must consider the type of thermal desorption system used for the testing. There are two basic types of thermal desorbers: direct-fired thermal desorbers (DFTDs) and indirect-heated thermal desorbers (IHTDs). Questions regarding performance and application of bench- and pilot-scale TD experiments remain. Can data from one type of system be used to predict the performance of the other? What testing scale and mode is appropriate (such as batch versus continuous or parallel flow versus countercurrent flow)?

In this paper, we intend to compare existing data from a bench-scale IHTD operated in the batch mode to new data from a pilot-scale DFTD operated in a parallel-flow continuous mode. The DFTD is of large enough scale to provide good full-scale design parameters and operating conditions, as well as provide valuable emissions data. The soil for both testing programs is from the Rocky Mountain Arsenal (RMA) near Denver, Colorado.

However, delays due to materials-handling problems and permit issues have significantly delayed the start of the DFTD testing. The available DFTD treatability data will be presented March 9, 1995, at the Seventh Annual Gulf Coast Environmental Conference in Houston, Texas.

THERMAL DESORBER TYPES

TDs can be separated into two basic types: direct-fired and indirect heated. The majority of the existing thermal desorbers are of the direct-fired rotary-kiln type. For most applications, these desorbers thermally destroy the off-gas in an afterburner. As mentioned earlier, most of the 180 existing TD units have processed petroleum-contaminated soil and were not operated under Resource Conservation and Recovery Act (RCRA) regulations. This paper will discuss only thermal desorbers capable of being permitted under RCRA.

A DFTD is very similar in design and operation to those of a RCRA incinerator. Temperature in the kiln is the major operating difference. The off-gas from an incinerator will typically be in the temperature range of 700 to 1,000°C and the ash 500 to 750°C. A DFTD, operated in the parallel-flow mode, will typically have exit gas temperatures of 300 to 650°C, and the treated soil will exit at between 300 and 550°C. Since the gas temperature in a DFTD is considerably lower than that in an incinerator, refractory lining of the kiln is not used in most DFTDs. The absence of the refractory lining allows a much lighter kiln for transport and one that requires less set-up time and maintenance. The burner nozzle may protrude into the kiln or be backed out so that only a small portion (or none) of the flame is in the kiln. In a DFTD, the carrier (sweep) gas will be air, along with the products of combustion from the burner. The amount of oxygen in the carrier gas can be adjusted only over a limited range, since there must be sufficient oxygen for proper burner operation. A DFTD with an afterburner most likely will have feed limitations based on the metals concentration of the feed soil and the type of air-pollution-control equipment used. These limitations may or may not restrict the maximum feed rate to the DFTD. Significant levels of arsenic, cadmium, and chromium, such as found in several of the soil media areas at RMA, could restrict feed rates, depending on system design. Mercury could also be a problem if it is present at high enough levels.

An IHTD has the heat source separated from the contaminated medium by a metal wall. For laboratory-scale testing, electric resistance heating is frequently used. At the bench- and pilot-scales, electric or fossil-fueled burners are the most common heat sources. Fossil-fueled burners, electric resistance heating, microwave heating, and heat-transfer fluids have been used at the pilot- and full-scales. The bench-scale IHTD testing reported in this paper was performed by International Technology (IT) Corporation using their rotary thermal apparatus (RTA), which is electrically heated. The solids-exit-temperature capability for a full-scale IHTD is similar to that of a DFTD, but the temperature can be more closely controlled in a multiple-burner IHTD. The exit-gas temperature in an IHTD will typically be in the 125 to 425°C range, which is considerably lower than that from a DFTD. The exit-gas temperature is important if the off-gas is to be chilled to condense the volatilized organics and water. In an IHTD, the composition of the sweep gas can be controlled. Many systems use nitrogen and can maintain oxygen levels below 1%. The sweep gas used in the RTA tests was a mixture of air and nitrogen, resulting in 5% oxygen in the sweep gas. This concentration was chosen to approximate the oxygen level in a DFTD. An IHTD using an off-gas condensing system would most likely not have any waste-feed-metals limitations, with the possible exception of mercury.

ROCKY MOUNTAIN ARSENAL

The Rocky Mountain Arsenal is located eight miles northeast of Denver, Colorado, and immediately to the west of Commerce City. The site occupies approximately 17,800 acres or 27.8 mi^2. The U.S. Army used RMA facilities to produce and destroy munitions from 1942 through 1970. Chemical warfare agents and incendiary and explosive munitions were manufactured, assembled, stored, tested, and destroyed at RMA. In 1947, the Army leased excess RMA facilities to a private company for the manufacture of pesticides. In 1952, a second company assumed the lease and continued to manufacture pesticides and herbicides until 1982. A third private company also leased facilities at the RMA from 1946 to 1948 for the production of chlorobenzene and dichlorodiphenyltrichloroethane (DDT). There are no current production activities at RMA.

Production of military agent, munitions, and agricultural chemical products occurred at the North and South Plants manufacturing facilities. Liquid wastes generated by the manufacturing processes were discharged into Basin A (unlined), Basin F (asphalt-lined), and other unlined basins at the site. Spills, leaks, and other releases from the past production and disposal activities noted above have resulted in soil and groundwater contamination of various RMA areas.

The Army began the remedial investigation/feasibility study (RI/FS) process at the RMA in 1984 to define the nature and extent of contamination and to evaluate strategies for cleanup. RI/FS activities are being conducted by various subcontractors under specific task order assignments issued by the Army.

The soil medium groups at RMA are contaminated with a wide variety of organic and metallic contaminants. These contaminants include: volatile halogenated organics, volatile hydrocarbons, volatile aromatic organics, organosulfur compounds, organophosphorus compounds, dibromochloropropane, fluoroacetic acid, polynuclear aromatic hydrocarbons (PAH), semivolatile halogenated organics, and organochlorine pesticides (OCP). RMA soils have also been found to contain heavy metals, including arsenic (As), mercury (Hg), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), and zinc (Zn).

Soil Used in Bench-Scale Testing

Soil samples collected for the bench-scale IHTD testing represented three soil medium groups:

1. Mixed Basins
2. Mixed South Plants, and
3. Mixed Undifferentiated.

The Mixed Basins soils, in general, refer to Basins A, B, C, D, E, F, and Little Basin F. For the treatability testing program, soils were collected from Basins A, D, and F.

The South Plants area includes 27 RI action sites. The Mixed South Plants soils for this testing program were collected from three of these sites: two from the central manufacturing and associated areas and one from the salt storage pad.

Mixed Undifferentiated soils are found in 40 RI action sites, most of which are associated with spills and storage areas. Samples for the treatability testing program were collected from six of these sites: open trenches (Eastern Study Area), drainage ditches (North Central Study Area), Sand Creek Lateral, ammunition demolition/chemical sump (North Plants Study Area), East Landfill (Western Study Area), and motor pool area .

Soils Used in Pilot-Scale Testing

Soil samples for the current pilot-scale DFTD testing were collected from three soil-medium groups:

1. Basin F,
2. Basin A, and
3. South Plants.

Ten tons of soil have each been collected from the South Plants Central Processing Area and the Basin A areas. The soils were excavated from the actual sites and containerized in 55-gal plastic drums. Prior to beginning the test runs, each test soil will be emptied from the drums, screened to remove rocks and debris larger than 1/2-in. diameter, and mixed and blended to increase homogeneity. If required, the soil may be air dried to reduce moisture to the range where the soil is readily feedable with the 2-1/2-in. screw auger feed system.

The drummed Basin F soil consists of a dark-brown sandy clay soil having a 14% moisture content. The soil in the drums was originally collected in 1988 during the Basin F Interim Response Action (IRA) and stored in an on-site warehouse. The Basin F IRA was performed to drain and store the approximately 11 million gallons of Basin F liquid and to excavate and contain in an on-site landfill approximately 500,000 cubic yards of sediment from the bottom of Basin F. Approximately 300,000 cubic yards of contaminated soil remain at the site of the former Basin F, and this area is the specific site that is being considered for thermal desorption. Fifty drums, containing a total of 14 tons of soil, were selected for testing after visual inspection and sampling of the drums.

The drummed South Plants soil consists of a brown clayey sand having 13% moisture content. Because of the heterogeneous nature of the contamination throughout the South Plants area, soil was excavated from two different sites within South Plants; these two soils will be blended together to create a composite sample. The bulk of the South Plants soils was excavated from a site containing high concentrations of chlorinated pesticides, and the remaining soil was obtained from a site containing high concentrations of arsenic. The excavation and drumming of the soil was performed in January 1994.

The drummed Basin A soil was excavated directly from a site in Basin A that had been found to have the highest levels of contaminants. This site was near the lowest point in the basin, and although the basin is now dry, the soil there was of a higher moisture content than the other two soils. The drummed Basin A soil is a light-brown sandy clay having an average moisture content of 30%. This soil will require air drying and/or blending with dry soil to lower the overall moisture content and improve feed handling characteristics.

RMA Soil Remediation Goals

The preliminary remediation goals (PRGs) were originally identified in the development and screening of alternatives (DSA) phase of the feasibility study. Further revisions to the PRGs were made during the detailed analysis of alternatives (DAA) as more information on the site characteristics and the performance of alternatives became available. The PRGs are chemical-specific remediation and treatment criteria that address all 27 contaminants of concern (COC). The list is presented in Table 1.

INDIRECT HEATED BENCH-SCALE TESTING

In 1989 Shell Development Company (SDC) conducted a laboratory-scale treatability study to examine the thermal desorption of contaminants from RMA soils. Testing was conducted at SDC's Westhollow Research Center in Houston, Texas, using static tray and tube (vertical and horizontal) test apparatus. The treatability study showed that organochlorine pesticides (OCPs) present in RMA Basin soils at total concentration levels of several hundred to several thousand parts per million (ppm) were reduced to less than 50 parts per billion (ppb) at temperatures as low as 250°C (3). The ability to thermally desorb non-OCP contaminants was also indirectly addressed in the study by demonstrating treatment conditions (i.e., temperature and residence time) that produced soils free of all compounds above a preselected value.

In addition to the laboratory-scale studies conducted at the Westhollow Research Center, Morrison-Knudsen Engineering Corporation, under contact to SDC, conducted a bench-scale thermal desorption treatability study in 1990 using RMA Basin F sediments. This bench-scale testing was conducted at IT's Technology Development laboratory in Knoxville, Tennessee, using an RTA (4). The study showed that OCPs present in RMA Basin F sediments at a total concentration of approximately 800 ppm were reduced to below their detection limits (32 ppb or less) at temperatures of 300, 450, and 650°C.

On the basis of the laboratory- and bench-scale data collected by SDC and the thermal desorption data available in the literature, Roy F. Weston, Inc. (Weston) prepared a bench-scale treatability study plan to further investigate thermal desorption treatment of RMA soils (5). The purpose of the study was to perform a series of bench-scale thermal desorption tests using the RTA to provide the data necessary to support the FS evaluation of remedial alternatives involving thermal desorption. FS data needs addressed in Weston's treatability test plan included direct examination of the removal of all RMA COC that are expected to be present at concentrations above remediation goals from the Mixed Basins, Mixed South Plants, and Mixed Undifferentiated soil-medium groups; the effect of thermal treatment on the leachability of metals and the geotechnical (i.e., structural) properties of the soil; and the characterization of desorber off-gas with respect to evaluating alternative off-gas treatment systems. Our paper will focus on comparing the efficacy of two types of thermal desorbers, tested at two different scales, in removing pesticides from RMA soil.

The data presented in this section are from the 1992 Weston report (6). Bench-scale thermal desorption tests were performed using the externally heated RTA illustrated in Figure 1. The rotating-tube portion of the RTA is 5 in. in diameter and 12 in. in length and is fabricated from Incoloy to resist corrosion during high-temperature tests. The cylinder rotates at 5 rpm and is externally heated by a custom-made electric furnace. The chain-driven tube is suspended at both ends by brass rollers and sealed by graphite ridding rings at the two "distribution boxes" located on either side of the unit. Sweep gas is passed through the distribution box shown on the right side of Figure 1. The sweep gas was prepared by mixing nitrogen and air in a ratio of 3:1 (i.e., 75% of the mixed gas is nitrogen and the remainder is air). This gas mixture results in an oxygen concentration of approximately 5% by weight. This oxygen concentration is similar to that in combustion gas (generated from fuel-oil or natural-gas burners) used for heating soils in full-scale thermal desorption units.

The heatup rate and operating temperature of the furnace are controlled by an automatic temperature controller. The temperatures of the soil bed and the gas in the rotating cylinder are measured with two Type K thermocouples that are calibrated against an NIST-traceable standard. The soil-bed cylinder gas, furnace, and off-gas system temperatures are continuously recorded on a multipoint recorder.

RTA off-gas (sweep gas plus desorbed phase) is removed from the cylinder by an induced-draft air pump. The off-gas flow is controlled to maintain a slight negative pressure in the cylinder. A manual air-pump bypass valve is used to control the vacuum inside the cylinder. The flow rates of the sweep gas and the off-gas are measured by rotameters located on the RTA gas inlet and outlet lines, respectively. The concentration of oxygen in the RTA cylinder gas is continuously measured with a galvanic cell.

A total of 22 tests were performed on the three soil groups. The Mixed Basins and Mixed South Plants soils were the most extensively tested, with ten tests and nine tests performed, respectively. Soil-bed temperatures ranged from 200 to 400°C; time at temperature, from 5 to 20 min; and sweep gas flow, from 1 to 3 L/min. Data from Weston's study for the Mixed Undifferentiated soil group is not included in this report, since no similar soil will be tested in the pilot-scale DFTD. All but two of the tests were conducted with a sweep-gas flow of 1 L/min, and only the tests at this gas flow will be used for comparison. The time at temperature value of 10 min was chosen for comparison purposes for the following reasons. The total residence time in the DFTD tests will range from 25-35 min, which requires a time at temperature of less than 25 min. In reviewing the data, it was difficult to see any significant removal-rate increase at 20 min when compared to 10 min at the same temperature. Since there were only two test runs at 5 min, a time at temperature of 10 min was selected. The bench-scale temperatures selected for comparison were the low, high, and midpoint for each series that met the other criteria.

The bench-scale test results are shown in Tables 2. From Table 2, we see that at 400°C all of the pesticides in the Mixed South Plants soil have been reduced to below their respective detection levels. At 300°C and 350°C there was some DDE remaining, but the level was below the PRG, although the DDE level was close to the PRG at 300°C. This result suggests that 350°C may be a good baseline value for the DFTD testing. The only other organic in the feed above the PRG value was DBCP, which was effectively removed at 300°C. Both benzene and toluene appeared to increase in concentration, but the levels of these two organics are considerably below their respective PRG values. As expected, there was no evidence of significant metals removal at any temperature, except for mercury. The mercury was removed even at the lowest temperature. The slightly alkaline feed soil was reduced in pH to near neutrality at all temperatures.

Similar results were obtained with the Mixed Basin soils at somewhat lower temperatures, as shown in Table 3. At 250°C, there was still detectable aldrin and DDE, with the aldrin level only slightly below the PRG. At 300°C, the aldrin level was nondetectable, and the DDE level was almost one order of magnitude below the PRG. At 350°C, all pesticides were below their detection limits. For pesticide removal, it appears that 300°C will be sufficient. Again, both benzene and toluene levels appeared to increase in concentration, but they are still considerably below their respective PRG values. The metals behaved as expected, with no evidence of volatilization except for mercury. Increasing the temperature continued to improve the removal efficiency for mercury. The TCLP limit for mercury is 0.2 mg/L, which allows a total constituent value of approximately 4.0 mg/kg because of the twenty to one dilution in the TCLP test. This would require a temperature of 300°C on the basis of this test. The pH of the alkaline soil was slightly reduced at all temperatures.

DIRECT-FIRED PILOT-SCALE TESTING

Rocky Mountain Arsenal has contracted with ANL to conduct a pilot-scale DFTD treatability study on pesticide-contaminated RMA soil. The purpose of this treatability study is to evaluate the overall effectiveness of the DFTD technology on contaminated RMA soils and to provide data upon which future conceptual design assumptions and cost estimates for a full-scale system can be made. Specifically, this program will determine if DFTD can achieve reductions in soil contamination below the PRGs for RMA, define system operating conditions for achieving the PRGs, and determine the fate of arsenic and other hazardous metals at these operating conditions. If proven to be a feasible technology, DFTD will provide RMA with a mechanism for cleaning up selected areas on-site and will provide the Army with valuable information about a technology that may be used at other contaminated facilities. Argonne will design the study, supervise the test runs, analyze the data produced, and produce a comprehensive evaluation of the technology.

The testing is being performed at the EPA's Incineration Research Facility (IRF) in Jefferson, Arkansas, which is operated by Acurex Environmental Corp. The rotary kiln system (RKS) at the IRF consists of a 3-ft diameter, 7-ft long, refractory-lined rotary kiln, with a 2.0-MM Btu/h burner mounted at the feed end of the kiln. Off-gas is treated by a 1.5-MM Btu/h afterburner; a primary air-pollution-control system, consisting of a quench, an ionizing wet scrubber, and a fabric-filter baghouse; and a secondary air-pollution-control system, consisting of an activated-carbon bed and an HEPA filter. For this pilot-scale study, the RKS has been equipped with a 2-1/2 in. screw-auger and hopper system that is capable of continuously feeding RMA soils at rates up to 900 lb/h. The rotary kiln is also equipped with seven thermocouples to measure soil-bed temperature at approximately 1-ft intervals along the axis of the kiln. A schematic of the RKS at the IRF appears in Figure 2.

The biggest challenge of the project to date has been the development of a system to continuously feed the soil into the RKS at the desired feed rates of 500 lb/h and 750 lb/h. Acurex has acquired an Arcison BDF-2 screw-conveying system, consisting of a 2-1/2 in. diameter screw auger, dual agitator bars, and a 24 cubic foot feed hopper. The screw auger is powered through a 60:1 gear reducer by a 2-hp electric motor. After screening and blending, the South Plants soil was readily fed through the screw feeder at rates up to 900 lb/h at the as-received moisture content of 13%. Basin F soils, on the other hand, is a much more cohesive soil; at 14% moisture, it was compacted by the screw feeder into firm chunks approximately 1-in. diameter × 3-in. length. Although the Basin F soil was conveyed by the screw feeder at rates of 900 lb/h, the compaction of the soil into chunks was determined to be unacceptable, as the chunks may tend to form solidified bricks in the kiln, trapping contaminants within them.

Upon further laboratory testing, it was determined that at approximately 8% moisture content, the Basin F soil will feed without the formation of the undesirable chunks. Air drying of the Basin F soil is being considered to decrease the moisture content to the 8% range. No work has been done yet on screw-feeder testing of the Basin A soil. When the Basin A soil was drummed, it contained approximately 30% moisture. After storage and shipping, a liquid layer of 1-3 in. has formed on the soil surface. Even after decanting the free liquid, the remaining soil is a cohesive paste that is difficult to screen and will not feed using the current screw feeder. The amount of moisture content in the soils (13% for South Plants and 8% for Basin F) that allowed a feedable soil in the screw-feeder system may be different because of a difference in grain size distributions and in the clay content of the two soils. Preliminary geotechnical analysis of grain size and Atterberg limits did not clarify the reasons for the different behavior of the soils. A detailed geotechnical analysis is currently being performed on both soils.

Metals feed-rate limitations have also been a major issue. The current operating permit that the IRF has with the State of Arkansas limits the soil feed rate for the South Plants and Basin A soils to well below the feed rates desired in this study. The feed limitations are controlled by risk-based emission rates for arsenic, beryllium, cadmium, and chromium. IRF, however, was able to demonstrate compliance with the risk-based emission rates due to the recent installation of a fabric-filter baghouse, and they obtained a waiver for the higher feed rates required by our study. This issue is mentioned as a cautionary note when conducting pilot-scale thermal-desorption treatability studies on RCRA-regulated soils that contain elevated metals contamination.

The planned DFTD test conditions are given in Table 4. The original design was to treat all three soil types at each of the four conditions; however, due to the materials-handling problems mentioned previously, there may be a reduction in project scope. Most likely, all four conditions will not be utilized for the Basin A soil. In the baseline test (Test A), the soil will heated to 360°C, which is just above the minimum value determined for the Mixed South Plants soil from the bench-scale testing. By heating to 360°C, the soil will be at or above 350°C for 5-15 min. Due to the design of the IRF kiln, fill volume is limited to approximately 6%. It was decided to keep the fill volume approximately constant for all tests to eliminate one variable. The potential variables then were solids temperature, residence time, and feed rate. Temperature is of primary concern, and tests will be conducted at the baseline value of 360°C, at 440°C (Test B), and at a temperature to be determined (Test D). At the 440°C temperature, all of the pesticide contaminants should be reduced to below their detection level. Since fill volume is being held constant, the increased feed rate test(Test C) will also have a shortened residence time. The to-be-determined temperature (Test D) will most likely be 275°C, unless the early data indicate that a higher temperature is required.

Preliminary pesticide, VOC, and metals analysis results for the DFTD test soils are presented in Table 5. These values are from samples taken before mixing, blending, and drying (if required). With the exception of DDE and DDT, all of the pesticides are present at levels well above their respective PRGs in at least two of the three soil samples.

The pesticide concentrations for the soil groups for both the bench-scale IHTD tests and the pilot-scale DFTD tests are listed in Table 6. With the exception of chlordane and endrin, the pesticide concentrations are of the same order of magnitude for the Mixed Basins (IHTD) soil and the Basin F (DFTD) soil. The Mixed South Plants IHTD data and South Plants DFTD data are also quite similar, with the exception of dieldrin. The soil groups are similar enough that valid comparisons should be able to be drawn when the study is completed and all data have been analyzed.

CONCLUSIONS AND DISCUSSION

Conclusions cannot be drawn before completing the experiment. However, some discussion is in order. Materials-handling, metals-feed limitations, and permitting issues have delayed starting the treatability tests far beyond any planned project schedule contingency, in spite of the excellent cooperation and support from the IRF staff and the State of Arkansas. The first test is scheduled for January 5, 1995. Preliminary data should be available for the March 1995 conference. The data presented will focus on comparing the pesticide removal efficiencies of a bench-scale IHTD with a pilot-scale DFTD operated at similar residence times and temperatures.

Will there be significant effects due to mixing of the soil, difference in sweep gas composition, different heating rates, partial combustion in the kiln, or some other factor? Considerable treatability testing time and costs savings can be realized if the bench-scale IHTD can be used to accurately predict the performance of a pilot- or full-scale DFTD. Any unexpected results will be highlighted.

For anyone considering thermal desorption as an on-site remedy, the permitting issues must considered. The EPA has drafted a document titled *Superfund Remedy Implementation Guide: Thermal Desorption Treatment*, which has been or will soon be released. Since the document is still in draft form, it cannot be cited, but the message is clear. The current guidance philosophy is that some thermal desorbers will be permitted under RCRA as Miscellaneous Units and others will require permitting as incinerators. It is anticipated that the guidance document will suggest that DFTDs with afterburners will require permitting as incinerators, while IHTDs that use carbon adsorption or off-gas-condensing systems may be permitted as Miscellaneous Units. Requiring a thermal desorber to be permitted as an incinerator will affect project cost, as a trial burn will be required. Calling a system a thermal desorber but requiring it to be permitted as an incinerator may not be well-accepted by the public. Public acceptance of hazardous waste incinerators is currently very low. All of these factors must be considered when evaluating technologies for a remedy selection.

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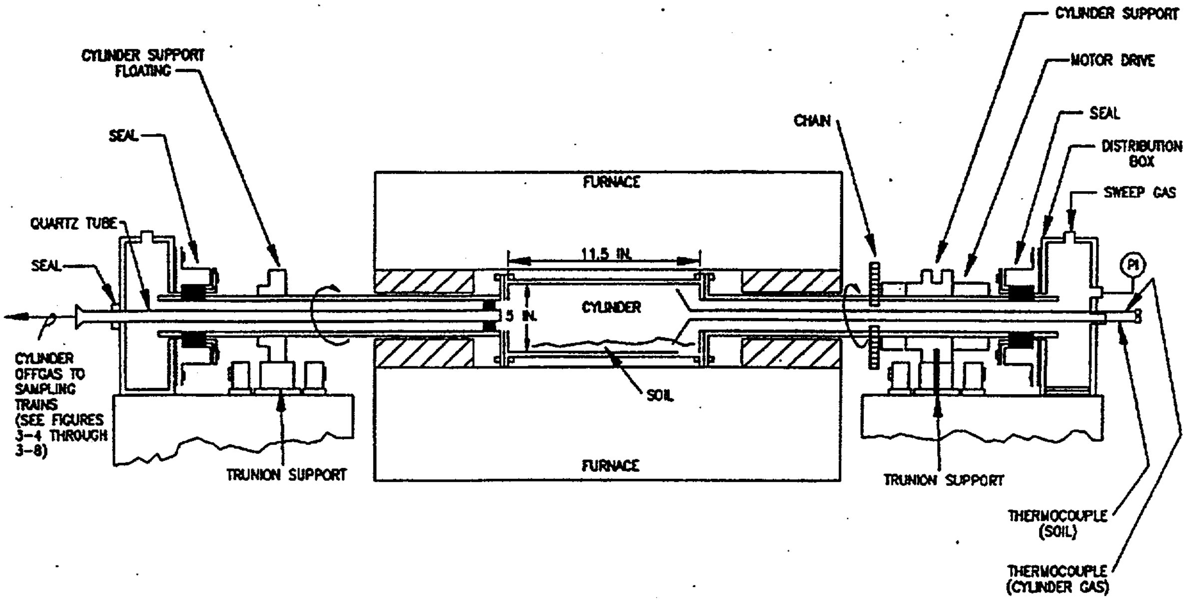
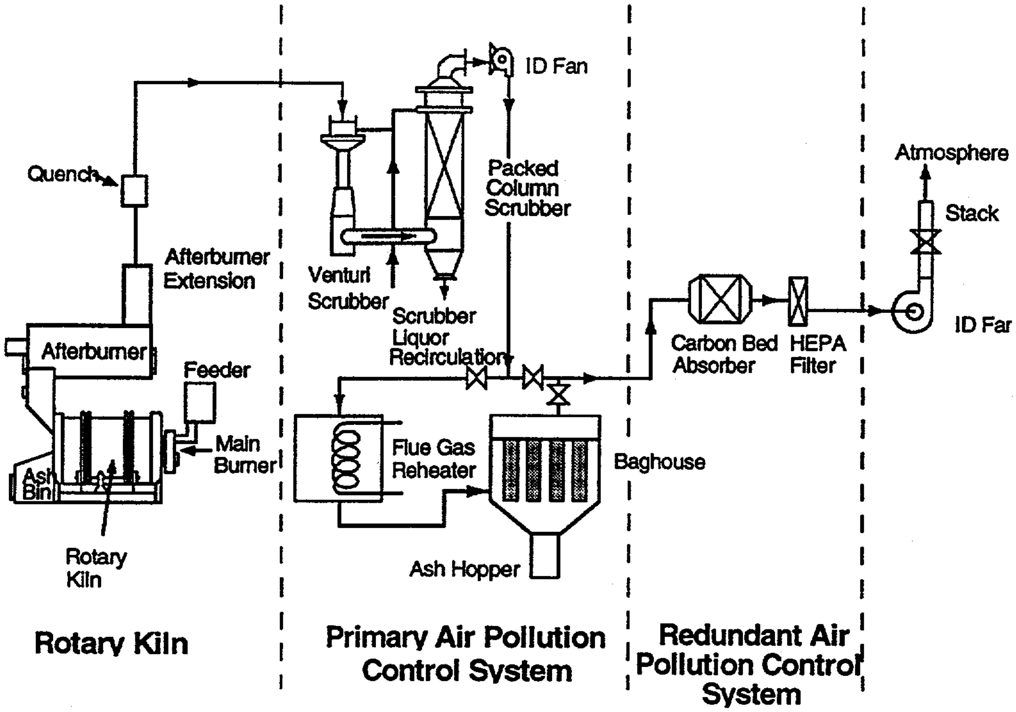
FIGURE 1



SOURCE: MODIFIED FROM FINAL REPORT FOR MK ENVIRONMENTAL SERVICES (THERMAL DESORPTION STUDIES), INTERNATIONAL TECHNOLOGY CORPORATION, 29 AUGUST 1990.

FIGURE 2



ID Fan
Quench
Packed
Column
Scrubber
Atmosphere
Stack
Afterburner
Extension
Venturi
Scrubber
Scrubber
Liquor
Recirculation
ID Far
Afterburner
Feeder
Carbon Bed
Absorber
HEPA
Filter
Main
Burner
Flue Gas
Reheater
Baghouse
Ash
Bin
Rotary
Kiln
Ash Hopper
Rotary Kiln
Primary Air Pollution
Control System
Redundant Air
Pollution Control
System

TABLE 1

Preliminary Remediation Goals for RMA Soils

Contaminant of Concern	Goal (ppm)[a]
Aldrin	0.72
Benzene	10
Carbon Tetrachloride	2.3
Chlordane	3.7
Chloroacetic Acid	77
Chlorobenzene	850
Chloroform	48
DDE	13
DDT	14
DBCP	0.2
1,2-Dichloroethane	3.2
1,1-Dichloroethylene	0.52
DCPD	3,700
Dieldrin	0.41
Endrin	230
HCCPD	1,100
Isodrin	52
1,1,2,2-Tetrachloroethane	1.5
Methylene Chloride	35
Tetrachloroethylene	5.4
Toluene	7,700
Trichloroethylene	28
Arsenic	4.2
Cadmium	50
Chromium	7.5
Lead	2,200
Mercury	570

[a] PRGs are based on a Biological Worker reasonable maximum exposure at a 10^{-6} risk level.

Source: *Proposed Detailed Analysis of Alternatives Report*, Version 3.0-Soils DAA, DAAA-05-92-D-0002, EBASCO, December 1994.

TABLE 2

Bench-Scale RTA Results for Mixed South Plants Soil

Test Name	Feed Soil	MSP-1	MSP-3	MSP-6	PRGs
Temperature (C)	NA	300	350	400	NA
Time at Temp.(min)	NA	10	10	10	NA
Gas Flow Rate(l/min)	NA	1	1	1	NA
	Concentration (mg/kg)				
PESTICIDES					
Aldrin	665	<0.08	0.098	<0.08	0.72
Chlordane	11.05	<0.08	<0.08	<0.08	3.7
4,4-DDE	3.35	0.96	0.13	<0.16	13
4,4-DDT	36	<0.16	<0.16	<0.16	14
Dieldrin	41	<0.16	<0.16	<0.16	0.41
Endrin	<305	<0.16	<0.16	<0.16	230
Isodrin	34.5	<0.08	<0.08	<0.08	52
SEMI-VOLATILE ORGANICS					
HCCPD	<2.165	<3.2	<3.3	<1.6	1,100
VOLATILE ORGANICS					
Benzene	<0.016	0.017	0.009	0.026	10
Toluene	<0.01	0.014	0.007	0.011	7,700
DBCP	0.625	<0.05	<0.05	<0.05	0.2
DCPD	<1.11	<0.05	<0.05	<0.05	3,700
METALS					
Arsenic	920	787	532	1,070	4.2
Cadmium	16	15.7	9.0	22.1	50
Chromium	56	45.3	43.1	67.8	7.5
Lead	508	443	394	602	2,200
Mercury	1.4	0.003	<0.02	<0.02	570
pH	9.00	7.50	7.52	7.86	NA

TABLE 3

Bench-Scale RTA Results for Mixed Basins Soil

Test Name	Feed Soil	MB-2	MB-6	MB-10	PRGs
Temperature (C)	NA	250	300	350	NA
Time at Temp.(min)	NA	10	10	10	NA
Gas Flow Rate(l/min)	NA	1	1	1	NA
	Concentration (mg/kg)				
PESTICIDES					
Aldrin	160	0.34	<0.08	<0.08	0.72
Chlordane	36.5	<0.08	<0.08	<0.08	3.7
4,4-DDE	4.25	0.36	0.15	<0.016	13
4,4-DDT	2.2	<0.016	<0.016	<0.016	14
Dieldrin	130	<0.016	<0.016	<0.016	0.41
Endrin	<72	<0.016	<0.016	<0.016	230
Isodrin	140	<0.08	<0.08	<0.08	52
SEMI-VOLATILE ORGANICS					
HCCPD	<3.9	<0.66	<0.33	<0.03	1,100
VOLATILE ORGANICS					
Benzene	<0.006	0.17	0.31	0.34	10
Toluene	0.003	0.021	0.041	0.035	7,700
DBCP	<0.012	<0.05	<0.05	<0.05	0.2
DCPD	0.054	<0.05	<0.05	<0.05	3,700
METALS					
Arsenic	139	116	141	127	4.2
Cadmium	3.2	2.7	4.7	3.9	50
Chromium	23	20.4	31.2	33.8	7.5
Lead	29	29.2	33	29.9	2,200
Mercury	164	70	3.8	0.89	570
pH	11.76	11.07	11.02	10.96	NA

TABLE 4

DESCRIPTION OF DFTD TEST CONDITIONS FOR RMA SOIL

Test ID	Test Name	Feed Rate (lb/hr)	Feed Rate (kg/hr)	Resi- dence Time(min)	Fill Vol. (%)	Desired Exit Soil Temp(C)	Predicted Exit Gas Temp(C)
A	Baseline	230	500	35	5.5	360	440
B	High Temperature	230	500	35	5.5	440	520
C	Low Residence Time/High Feed Rate	340	750	25	5.8	360	525
D	TBD (Low Temp,Other or Dupl.)	230	500	35	5.5	275??	????

TBD = To Be Determined

TABLE 5

Preliminary Feed Soil Analytical for Pilot-Scale DFTD Testing

	Basin A	Basin F	South Plants	PRGs
	Concentration (mg/kg)			
PESTICIDES				
Aldrin	<0.01	575	840	0.72
Chlordane	160	<10	100	3.7
4,4-DDE	<10	5	<10	13
4,4-DDT	<10	<10	<10	14
Dieldrin	700	320	1,800	0.41
Endrin	30	380	210	230
Isodrin	<10	110	60	52
VOLATILE ORGANICS				
Benzene	<0.025	<0.025	<0.025	10
Toluene	<0.025	<0.025	<0.025	7,700
DBCP	<10	<10	<10	0.2
DCPD	<0.025	4.0	2.0	3,700
METALS				
Arsenic	160	35	240	4.2
Cadmium	<0.5	40	<0.5	50
Chromium	13	130	15	7.5
Lead	35	15	43	2,200
Mercury	3.9	25	3.8	570

TABLE 6

Comparison of Pesticide Contamination for IHTD and DFTD Tests

PESTICIDES	Basin A (DFTD)	Mixed Basins (IHTD)	Basin F (DFTD)	Mixed S. Plants (IHTD)	South Plants (DFTD)
	Concentration (mg/kg)				
Aldrin	<0.01	160	575	665	840
Chlordane	160	36.5	<10	11	100
4,4-DDE	<10	4.25	5	3.35	<10
4,4-DDT	<10	2.2	<10	36	<10
Dieldrin	700	130	320	41	1,800
Endrin	30	<72	380	<305	210
Isodrin	<10	140	110	34.5	60