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Project Summary

Destruction of Dioxin-Contaminated Solids and Liquids by Mobile Incineration

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The EPA Mobile Incineration System, which consists of a kiln, secondary combustion chamber, air pollution control unit, and separate continuous stack gas analysis capabilities, was rigorously tested in 1982-1983 using PCB-contaminated liquids and other chlorinated organic fluids. Destruction and removal efficiencies of at least 99.9999% were consistently attained at a heat release of 10 GJ/hr.

As a result of these favorable performance data, a project was initiated to evaluate the technical, economic, and administrative feasibility of on-site incineration of dioxin-contaminated materials. During 1984, the system was extensively modified for field use and performance-tested with a variety of uncontaminated soils and other solid wastes at the EPA facility in Edison, NJ.

Based on the results of laboratory and pilot plant studies conducted to establish optimum kiln conditions and the available literature, the EPA system was judged to be more than adequate for detoxifying dioxin-contaminated solids and liquids, and thus could be expected to accomplish a successful dioxin trial burn. Accordingly the system was transported in December 1984 to the Denney Farm site in McDowell, Missouri, which had been selected for the trial burn in the intervening months.

Destruction and removal efficiencies exceeding 99.9999% were achieved for 2,3,7,8-TCDD during a trial burn on dioxin-contaminated liquids and solids conducted in April 1985. The kiln ash and process wastewater byproducts had no detectable dioxins and were in accordance with guidelines identified by EPA's Office of Solid Waste.

A field demonstration on a variety of dioxin-contaminated materials was conducted between July 1985 and February 1986. A total of 0.9 million kg of solids and 81,600 kg of liquids was successfully decontaminated during that time. Operations were suspended on February 6, 1986 pending Superfund reauthorization. When operations resume, the Field Demonstration will be completed and a second trial burn will take place on materials designated by the Resource Conservation and Recovery Act and the Toxic Substances Control Act.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The continued discovery of abandoned hazardous waste sites by Superfund investigations, decreasing availability of landfill sites, and increasing public opposition to toxic and hazardous waste transport have placed increasing pressure on the U.S. Environmental Protection Agency (EPA) to find alternatives for treating and disposing of toxic and hazardous wastes. The treatment and disposal problem is particularly acute in the case of the highly toxic dioxin isomer 2,3,7,8-tetrachlorodibenzodioxin (2,3,7,8-TCDD). In recognition of these difficulties and as a result of preliminary favorable tests of the technology, EPA's "Dioxin Strategy" (November 28, 1983) recommended that high-temperature incineration of dioxin-contaminated materials be evaluated further by the Office of Research and Development (ORD).

The EPA Mobile Incineration System (MIS) was designed and constructed for ORD to provide such treatment at the actual site of dioxin contamination. The system consists of a refractory-lined rotary kiln, a secondary combustion chamber (SCC), and air pollution control equipment mounted on three heavy-duty semi-trailers. Monitoring equipment is carried by a fourth trailer. The ability of the MIS to destroy tetrachloromethane (carbon tetrachloride), dichlorobenzene, trichlorobenzenes, tetrachlorobenzenes, and PCBs while complying with applicable Federal and State regulations for the emissions of HCl and particulate matter was demonstrated during a Liquid Trial Burn conducted between September 1982 and January 1983 at the EPA facility in Edison, NJ.

In March 1984, the ORD Releases Control Branch (RCB) of the Hazardous Waste Engineering Research Laboratory (HWERL), at the request of the EPA Region VII, embarked on a field validation project to evaluate the MIS for on-site treatment and disposal of toxic and hazardous wastes, particularly soils contaminated with 2,3,7,8-TCDD. The purpose of this research was to determine the economic feasibility of the technique and to establish: (1) test burn protocols; (2) health and safety protocol; (3) site specific, risk assessment protocol; (4) an economic model for estimating the cost of treatment per unit of material processes; and (5) national and state permit protocol.

Site Selection and Planning

Agreements were reached in April 1984 to operate the Mobile Incineration System on the Denney Farm near McDowell, MO, where over 90 drums of dioxin-contaminated wastes had been excavated and stored in a diked shelter. A second covered concrete basin on the site contained over 180 m^3 of soil that had become contaminated when the buried drums leaked.

The Denney Farm was chosen in part because the safe removal and destruction of dioxin that contaminated soil, liquids, drums, trash, and chemical solids on the site would demonstrate the versatility of the MIS. Further, the variety of soil types available in the immediate area would demonstrate that incineration could decontaminate dioxin-containing soil found elsewhere in Missouri.

Laboratory and Pilot Studies

These studies, performed concurrently with the Federal and State permitting processes, investigated whether the objective of decontaminating the soil to less than 1 ppb dioxin was feasible given the operating limits of the MIS, and to develop recommended operating conditions for the trial burn and field demonstration.

Soils from two Missouri sites with confirmed dioxin contamination were selected for laboratory treatability testing. The average 2,3,7,8-TCDD concentrations were relatively high in both soils (563 ppb in Denney Farm soils; 338 ppb in Piazza Road soils), enabling investigation of the maximum treatability range. In addition, soils from both sites had wide ranges of pH, conductivity, organic matter content, and particle size distributions.

Three series of treatability tests were conducted. The first determined the optimal kiln residence time and temperature that would produce the target treatment effectiveness of 1 ppb or less of 2,3,7,8-TCDD residue. The second series characterized the effect of soil type (Piazza or Denney), initial soil mositure content, and gas phase composition on treatability under fixed residence time and temperature conditions. The third series included additional treatment conditions to fill in data gaps and also several special tests in which 5-cm "cubes" (to simulate clay lumps) of Piazza Road soil were tested under various conditions.

A linear regression analysis of the treatability data for Denney farm soil allowed prediction of the final 2,3,7,8-TCDD concentrations at different time-temperature conditions as shown in Figure 1 and Table 1. There was no significant correlation between soil treatability and either moisture or atmosphere; soil type had a relatively minor influence.

In the third series of tests, a substant[illegible] lag in achieving the target test tempe[illegible]ature within a cube core was attribut[illegible] largely to the drying process. The eva[illegible]oration rate of the initial 20% moistu[illegible] content from the cube was dependent [illegible] the heat and mass transfer characteri[illegible]tics of the cube and the external g[illegible] temperature, which in the MIS kiln wou[illegible] be higher than 500°C.

The results from the laboratory testi[illegible] demonstrated that the clean-up criteri[illegible] of 1 ppb could be achieved at reasonab[illegible] kiln operating conditions and provid[illegible] part of the information needed to proje[illegible] the specific kiln residence time a[illegible] temperature for various feed rates a[illegible] feed conditions for the MIS.

Modifications to the MIS

Several changes were made in t[illegible] original MIS design, including gene[illegible] modifications affecting the refracto[illegible] the burner controls; the stack g[illegible] monitoring system; the electrical syste[illegible] and the design, specification, procur[illegible]ment, installation, and shakedown of [illegible] solids feed system.

Further design modifications, inclu[illegible]ing a wet electrostatic precipitator, a[illegible] planned.

Site Preparation and Community Relations

After selection of the Denney Farm f[illegible] the MIS demonstration, detailed en[illegible]neering and design were started [illegible] satisfy operating and permitting requi[illegible]ments. The actual incinerator site w[illegible] determined by the physical dimensio[illegible] of the solids feed handling system a[illegible] the location of the contaminated ma[illegible]rials in a prefabricated metal buildi[illegible] Further site contamination was p[illegible]vented by maintaining the incinerator [illegible] an uncontaminated area and the fe[illegible] system in a contaminated area with [illegible] connecting sealed conveyor system.

After several changes in the origi[illegible] design and hot and cold shakedown te[illegible] to ensure reliable operation, the MIS w[illegible] transported to and set up on the Denn[illegible] Farm site in mid-December 1984.

Field Shakedown and Trial Burn

Final preparations, component chec[illegible] and on-site personnel safety traini[illegible] were completed by early January 19[illegible] The incineration system was then start[illegible] up with fuel oil to check its performan[illegible] after transport from New Jerse[illegible]

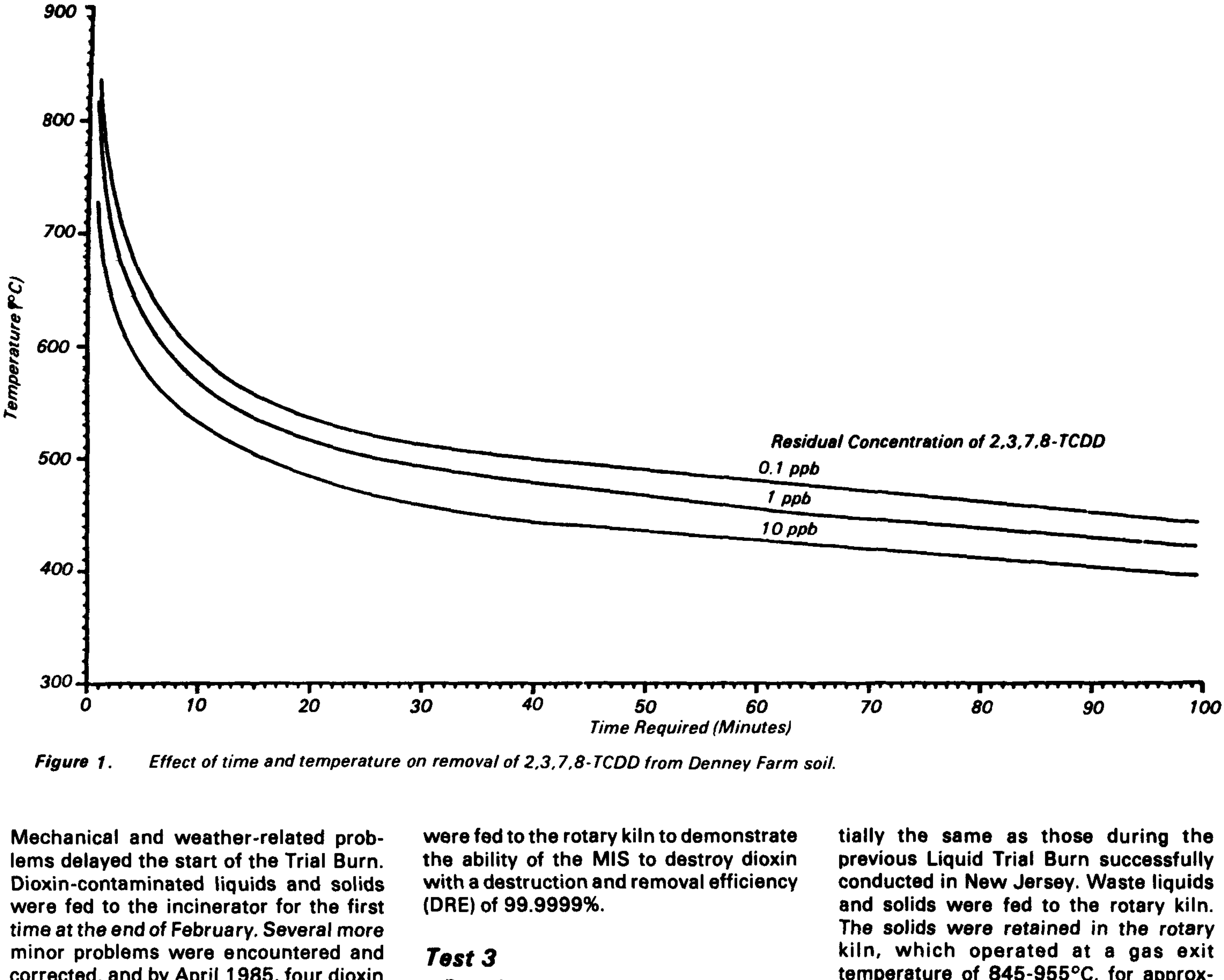

Figure 1. *Effect of time and temperature on removal of 2,3,7,8-TCDD from Denney Farm soil.*

Mechanical and weather-related problems delayed the start of the Trial Burn. Dioxin-contaminated liquids and solids were fed to the incinerator for the first time at the end of February. Several more minor problems were encountered and corrected, and by April 1985, four dioxin trial burn runs had been completed.

Trial Burn Plan

The trial burn program was originally designed to consist of three tests. However, due to the operational problems noted above, Test 1, a burn using a PCB matrix mixed with 5 wt % hexachloroethane to achieve a 5% PCB concentration and liquid tetrachloromethane, was postponed to the end of the field demonstration. The two tests that were performed are described below.

Test 2

2,3,7,8-TCDD (dioxin)-contaminated soil and dioxin-containing waste liquids (primarily trichlorophenol in a solvent mix of methylene chloride and butanol) were fed to the rotary kiln to demonstrate the ability of the MIS to destroy dioxin with a destruction and removal efficiency (DRE) of 99.9999%.

Test 3

Bromine-contaminated industrial chemical sludge was fed to the rotary kiln to demonstrate the ability of the MIS to control bromine/hydrogen bromide emissions while incinerating bromine-contaminated wastes.

The Quality Assurance Project Plan (QAPP) for the Trial Burn ensured that the trial burn data were technically sound and acceptable to regulatory offices. Standard analytical protocols were used whenever possible, but the determination of 2,3,7,8-TCDD in incinerator emissions and by-products required state-of-the-art analyses to demonstrate the required DRE. The samples were analyzed in two laboratories to provide independent verification of test results.

The incinerator operating conditions during the Dioxin Trial Burn were essentially the same as those during the previous Liquid Trial Burn successfully conducted in New Jersey. Waste liquids and solids were fed to the rotary kiln. The solids were retained in the rotary kiln, which operated at a gas exit temperature of 845-955°C, for approximately 30 minutes before being discharged at 750°C into drums. The gases from the combustion of wastes flowed into the SCC where they were heated to 1150-1230°C. The combustion gases in the SCC were mixed with excess oxygen (air) to a control level of 4-7% O_2 and were retained for 2.4-3 sec. The relatively long retention time was due to the operation of the incineration system at low gas flow rates to minimize particulate carryover from the kiln into the SCC, not to a DRE-related requirement.

The combustion gases then passed through three stages of air pollution control equipment to cool, filter, and remove acid gases (by-products from waste combustion) and particulate matter (from the solid wastes processed).

Table 1. Summary of Time-Temperature Effect on Removal of 2,3,7,8-TCDD

Nominal Test Temperature (°C)	Time at Test Temperature[a] (min)	Soil Type[b]	Residual 2,3,7,8-TCDD Concentration (ppb)
429	0	A	377
430	15	A	60
429	30	A	30.8
428	90	A	10.2
429	90	B	2.86
475	0	A	67
478	15	A	8.4
477	30	A	3.7
479	30	A	3.37/3.30[c]
550	0	A	24
550	0	A	27.5
554	15	A	0.16
616	0	A	0.2
616	15	A	ND (0.08)
616	30	A	ND (0.06)
803	30	A	ND (0.02)
808	30	B	ND (0.04)
803	90	A	ND (0.08)

[a]*This time begins when the target test temperature is reached; therefore, zero time is actually six to nine minutes after start of heat-up.*
[b]*A: Denney Farm Soil; B: Reference Soil.*
[c]*Analytical duplicate; separate aliquots of treated soil were analyzed.*

Other process by-product streams (kiln ash, CHEAF mat, and purge water) were collected and analyzed in accordance with delisting guidelines and the Trial Burn Plan. The incinerator performance during the trial burn was actually better than reported since the actual emissions were lower than what is measurable by current sampling and analytical technology. No 2,3,7,8-TCDD was detected in the stack, using state-of-the-art high resolution mass spectrometry. The lowest DRE for 2,3,7,8-TCDD was 99.999973%; the best DRE of 99.99999% during the trial burn occurred in Test 2, Run 4, which had the greatest analytical sensitivity. The results of Test 3 were also satisfactory in that no bromine or chlorine was detected in the stack gas.

In summary, the Trial Burn obtained data, which, when combined with data from the Liquid Trial Burn in Edison, NJ, verified that (1) dioxins and other hazardous organic liquid and solid materials are destroyed by incineration in the EPA MIS to a residual ash concentration of less than 1 ppb, (2) by-product ash, CHEAF media, and water met delisting standards, and (3) the resulting stack emissions do not pose an unacceptable health or safety risk to the surrounding communities.

Field Demonstration

The objective of the field demonstration is to determine the rates at which various types of dioxin-contaminated liquids and solids can be fed into the system and decontaminated. In addition, the demonstration will result in the cleanup of the majority of dioxin-contaminated material in southwestern Missouri. As of February 6, 1986, more than 900,000 kg of solids and 81,600 kg of liquids have been incinerated.

Recommendations

The following recommendations are the result of the experience gained during the design, operation, and maintenance of the MIS Trial Burn and Field Demonstration in Missouri. The recommendations center around the need to prepare for the following circumstances:

- extreme weather conditions
- mechanical failures
- road bed failure due to inadequate site preparation
- unavailability of spare parts

In addition, it is recommended that the permitting process be started as soon as the site is chosen. The delisting protocol required analytical tests on every tank of wastewater and on relatively small quantities of treated soil to confirm that the extracts of the material met RCRA Extraction Procedure (EP) toxicity criteria before discharge or disposal. In retrospect, securing a National Pollution Discharge Elimination System (NPDES) permit may have allowed more efficient site preparations and decreased analytical costs (due to longer analytical turnaround time) since NPDES permits normally require less frequent sampling and reporting of analytical results.

Economic Analysis

The unit cost ($/Mg) of waste material processed by a mobile incinerator strongly depends on its capacity, on-stream factor, and the associated cost. The capacity of the MIS results from a complex interaction between the physical size of its components; the operating conditions necessary to meet the DRE and delisting requirements; and the waste characteristics. The EPA MIS utilizes the largest size components that can be accommodated on semi-trailers. Operating conditions are selected conservatively to process a variety of waste materials and meet the DRE and delisting requirements. For the specific component sizes and operating conditions, the capacity of the MIS was about 450 kg/hr for 8.8 MJ/kg heating value lagoon sludge and about 900 kg/hr for a low heating value soil.

The MIS, being a prototype system, experienced a low (45-55%) on-stream factor during its operation at Missouri. Based on the lessons learned from its operation, a similar mobile system can be expected to demonstrate an on-stream factor of 70%. The costs of an MIS can be grouped into three general categories: capital costs, including all costs that can be amortized over the service life of the system; mobilization/demobilization costs that are associated with the startup and shutdown at a given site and can be amortized while the unit is located (and operated) at a given site; and operating and maintenance costs.

Capital costs include the costs for design and fabrication; development of operating procedures; providing operator training; initial startup and shakedown; application costs for a permit; and trial burn costs for general performance data. Mobilization/demobilization costs include the costs for site preparation and logistics; transportation and system setup; on-site system checkout; site-specific testing for proof-of-performance; and decontamination and demobilization. A review of the operating costs during the 116 days that EI was the operating contractor (October 3, 1985 to February 6, 1986, less the Christmas holiday shutdown of 10 days) showed that the MIS operating is field-labor intensive.

A simplified economic analysis was performed for an incineration system designed and fabricated utilizing all the EPA MIS data and drawings. The actual MIS associated cost factors were used. The capital cost of $5.1 million and mobilization/demobilization costs of $0.9 million were used. Site-specific cost factors such as costs for site preparation and logistics and system transportation were not included.

An on-stream factor of 70% was assumed for this analysis. Operating costs extrapolated from the actual field operation of 116 days were $4.2 million/yr. Based on a 15-year system life with equipment relocation assumed every 2 years, the unit cost of the incineration system was calculated to vary between $750/Mg for low heat content soil to $1500/Mg for lagoon sludge.

The planned modifications to the system will double its capacity, increase the on-stream factor to 80%, increase the capital costs by about 20%, and increrase the mobilization/demobilization and operating costs by about 10%. Therefore, the unit costs for the modified system is expected to be approximately $360/Mg for low heat content soil and $720/Mg for lagoon sludge.

Future Use of the MIS

Further use of the EPA MIS after the field demonstration at Denney Farm will be at the direction of the EPA Office of Solid Waste and Emergency Response.

The intention of future operations of the MIS is to encourage commercialization of on-site cleanup technologies rather than to use the system strictly for cleanup activities. The private sector is likely to build improved, more reliable, larger capacity, lower-cost systems of at least equivalent performance for use in routine cleanup operations.

The full report was submitted in fulfillment of Contract Number 68-03-3255 by Enviresponse, Inc., under the sponsorship of the U.S. Environmental Protection Agency. The report covers a period from February 1984 to February 1986 and work was completed as of April 15, 1987.

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***Frank Freestone** is the EPA Project Officer (see below).*

The complete report, entitled "Destruction of Dioxin-Contaminated Solids and Liquids by Mobile Incineration," (Order No. PB 87-188 512/AS; Cost: $18.95, subject to change) will be available only from:

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