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Project Summary

Pilot-Scale Incineration of Contaminated Soil from the Chemical Insecticide Corporation Superfund Site

A. Siag, D.J. Fournier, Jr., and L.R. Waterland

A detailed test program was performed at the U.S. Environmental Protection Agency's (EPA's) Incineration Research Facility (IRF) to define the incineration characteristics of contaminated soil from the Chemical Insecticide Corporation (CIC) Superfund site in Edison Township, NJ. The soils at the site are highly contaminated with organochlorine pesticides and trace metals. The major metal contaminant, arsenic, is present in site soils at levels up to 8,000 mg/kg. The purpose of these tests was to evaluate the incinerability of these soils in terms of the destruction and removal efficiency (DRE) for organochlorine pesticides (chlordane and p,p'-DDT), the fate of arsenic in terms of the system removal efficiency (RE), and the fate of other contaminant trace metals. Four incineration tests were completed in the IRF rotary kiln incineration system (RKS), which was equipped with a high-efficiency scrubber system, a Calvert Flux Force/Condensation scrubber*. In three of the four tests, soil alone was fed to the kiln of the RKS. In the fourth test, lime was blended with the soil to evaluate whether arsenic RE was affected. All tests were performed at a kiln exit gas temperature of approximately 982°C (1,800°F) and an afterburner exit gas temperature of 1,204°C (2,200°F). The Calvert scrubber was operated at a pressure drop of approximately 12 kPa (50 in. WC).

Incineration under the conditions tested resulted in the elimination of the soil pesticide contaminants. No pesticide contaminants were present in the scrubber exit flue gas with corresponding DREs of at least 99.9916% for p,p'-DDT. Arsenic REs of 99.99% can be achieved with the Calvert scrubber under the conditions tested feeding soil alone. Adding lime to the soil did not measurably improve arsenic RE. Trace metal concentrations in the toxicity characteristic leaching procedure (TCLP) leachates of both untreated soil and kiln ash (treated soil) were significantly below corresponding toxicity characteristic (TC) regulatory levels for all metals except arsenic. Soil leachate arsenic concentrations were 40% to 50% of the regulatory level. Kiln ash leachate arsenic concentrations were near or above arsenic's TC regulatory level. Adding lime to the soil significantly reduced both the soil and the resulting kiln ash TCLP leachate arsenic concentrations. Nominally 70% of the arsenic measured in the incinerator discharges was in the kiln ash in all of the tests in which soil alone was fed; about 30% was in the scrubber liquor. The kiln ash arsenic fraction increased to about 90% in the test in which lime was added to the soil; about 10% was in the scrubber liquor. Scrubber exit flue gas accounted for a negligible fraction of the arsenic discharged in all tests. Particulate levels at the Calvert scrubber exit were nominally 10 to 20 mg/dscm at 7% O_2, well below the hazardous waste incinerator per-

* Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

formance standard of 180 mg/dscm at 7% O_2. Calvert scrubber apparent HCl collection efficiencies were 99.95% or greater, which is above the hazardous waste incinerator performance standard of 99.9%.

Test results suggest that conventional rotary kiln incineration in a unit equipped with a high-efficiency scrubber system such as the Calvert system would be an appropriate treatment technology for site soils: elimination of the contaminant organochlorine pesticides and greater than 99.99-% organic contaminant DREs were achieved; arsenic REs of greater than 99.96% were achieved; and the hazardous waste incinerator particulate and HCl performance standards were easily achieved. The treated soil may be a TC hazardous waste for soils with arsenic concentrations in the range of those of the soil tested. Adding lime to the soil before incineration, however, can significantly reduce the leachability of the kiln ash arsenic in the TCLP test.

This Project Summary was developed by EPA's Risk Reduction Engineering 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

One of the primary missions of the IRF is to support EPA's Regional Offices in evaluating the potential of incineration as a treatment option for contaminated soils at Superfund sites. CIC is a priority site in Edison Township, NJ. EPA Region 2 requested that test burns be conducted at the IRF to support an evaluation of the suitability of incineration as a treatment technology for the contaminated soils at the CIC site. Region 2 was specifically interested in whether flue gas emissions of arsenic could be limited to less than 0.04% of the amount of arsenic in the highly arsenic-contaminated soil fed to the incinerator.

The CIC site was formerly used to manufacture pesticide products. The results of the remedial investigation and feasibility study (RI/FS) show that the soils at the site are highly contaminated by organochlorine pesticides and arsenic. Dioxin (i.e., 2,3,7,8-tetrachlorodibenzo-p-dioxin) has also been found at concentrations up to 1.8 µg/kg (ppb) in some soil samples collected during the RI/FS. Thermal treatment has previously been demonstrated to be an effective means of destroying pesticides, dioxin, and other organic compounds. The finding of high concentrations of arsenic in the soils at the CIC site has raised the question of whether a thermal treatment unit treating soil from the site, and operating under conditions capable of attaining a 99.9999-% DRE for dioxin and a 99.99-% DRE for other organic contaminants, can also reduce arsenic concentrations to acceptable levels in the stack emissions. Therefore, this incineration test program focused on the ability of an incineration system to control the arsenic emissions to levels acceptable to the EPA, while operating at incineration conditions sufficient to destroy dioxin and other organic materials to the prescribed DRE.

The test program was designed to develop the data to support feasibility study (FS) efforts in evaluating incineration as a possible remedial alternative. The specific objectives of the test program were

- To confirm the ability of conventional rotary kiln incineration to destroy organochlorine pesticide contaminants in the soil, as measured by their absence in the treated soil (kiln ash) discharge
- To confirm the ability of a conventional rotary kiln incinerator, with a high-efficiency scrubber, to achieve an arsenic RE of 99.96% under operating conditions associated with a 99.9999% dioxin DRE, where RE is defined as

$$R = 100\ (1 - \frac{\textit{flue gas emission rate}}{\textit{feedrate}}$$

A series of four incineration tests was performed using the IRF's RKS with the Calvert Flux Force/Condensation scrubber for air pollution control. In three of the tests, raw soil alone was packaged into 1.5-gal fiberpacks and fed to the RKS kiln via the system's ram feeder. In the fourth test, raw soil was mixed with lime at a blend ratio of 0.5 kg of lime per 10 kg of soil before being packaged.

Test Program

Test Facility

All tests were performed in the IRF RKS. A process schematic of the RKS is provided in Figure 1. The RKS consists of a rotary kiln primary combustor followed by an afterburner chamber. Downstream of the afterburner, the combustion gas is quenched and then the gas flows through a primary air pollution control system (APCS). A high-efficiency wet scrubber system consisting of the Calvert Flux Force/Condensation scrubber pilot plant was used for these tests. Downstream of the primary APCS, a secondary backup APCS consisting of a carbon bed absorber and a high-efficiency particulate air (HEPA) filter is in place.

The Calvert scrubber system consisted of a condenser/absorber section, a Calvert Collision scrubber, two entrainment separators, a wet electrostatic precipitator (designed to provide the final stage of particulate removal), a caustic injection system, and an induced-draft (ID) fan (Figure 2). The IRF RKS quench chamber and heat exchanger systems were used instead of the quench chamber and cooling tower usually installed with the Calvert pilot unit. The Calvert scrubber liquor was recirculated through the facility heat exchanger for scrubber liquor cooling. The key operating parameter of the scrubber system, pressure drop, was maintained at 12 kPa (50 in. WC), as recommended by Calvert Environmental, the scrubber's vendor. Pressure drop was controlled by a variable-speed drive on the ID fan.

Test Soil Description

The CIC site was formerly used to manufacture a variety of pesticides for commercial and military applications, including a wide range of insecticides, fungicides, rodenticides, and herbicides. One specific product, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), might have contained dioxin as a byproduct. Pesticide manufacturing activities, with associated process-water storage lagoons, and poor housekeeping led to the widespread chemical contamination of this site.

The RI/FS showed that site soils were contaminated with the pesticides p,p'-DDT, p,p'-DDD, p,p'-DDE, α-BHC, γ-BHC, and chlordane; the herbicides 2,4-D, 2,4,5-T, and Silvex; and the trace metals arsenic, cadmium, chromium, lead, and mercury. Arsenic levels as high as 8,000 mg/kg were found. Dioxin was found in some site soil samples at a maximum concentration of 1.8 µg/kg.

Four drums of soil were excavated from the CIC site in February 1991 for this test program. Composite characterization samples were taken for pretest analysis. The results showed that soil with an arsenic content of about 900 mg/kg was available for testing. This same soil was also contaminated with an average of 2 mg/kg of p,p'-DDD; 3 mg/kg of p,p'-DDE; 26 mg/kg of p,p'-DDT; and 9 mg/kg of chlordane.

Before testing, the test soil was packaged into 1.5-gal plastic-bag-lined fiberpack containers for feeding to the RKS via the ram feeder in place on the system. Each fiberpack was filled with 4.5 kg (10 lb)

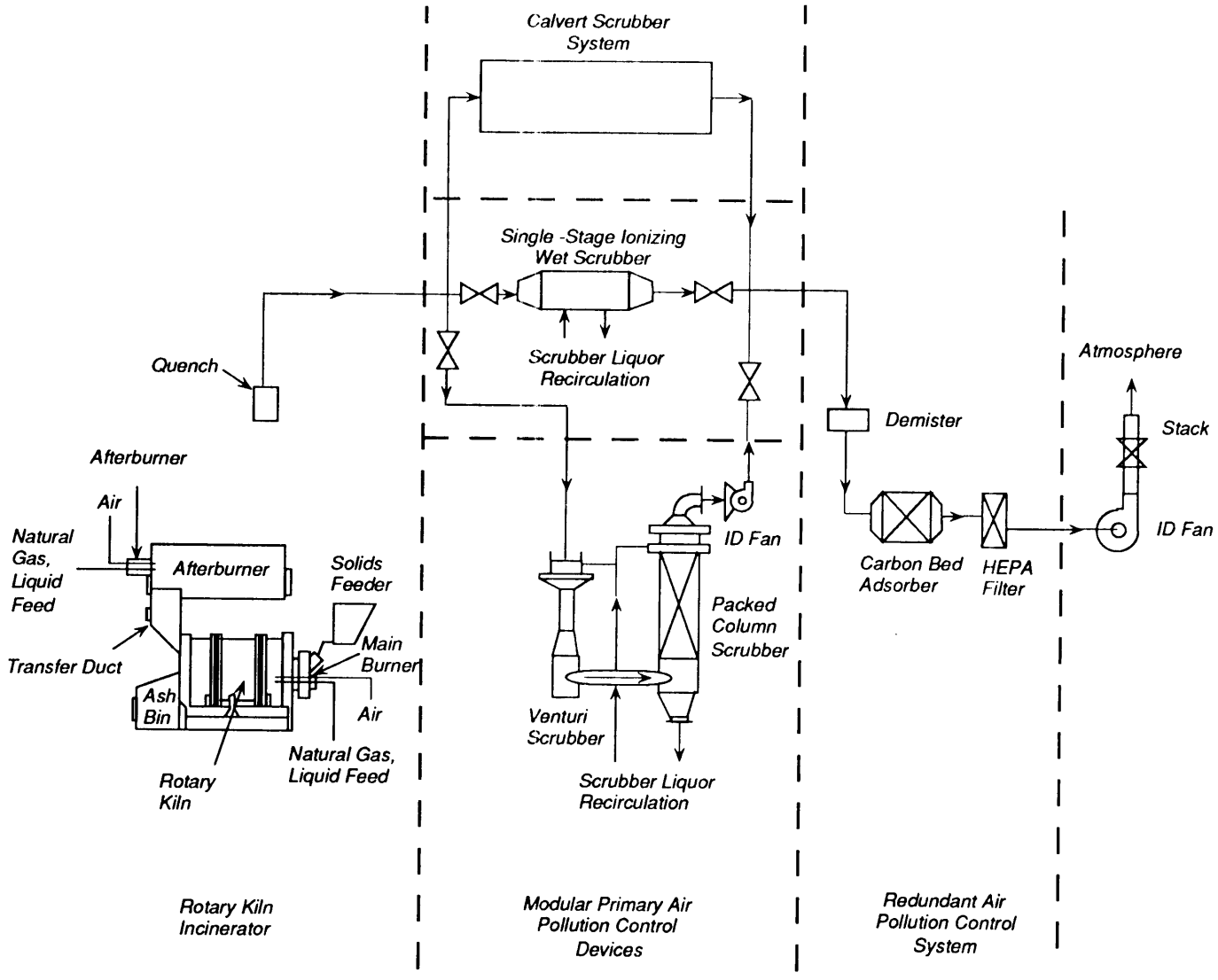


Figure 1. *Schematic of the IRF rotary kiln incineration system.*

of soil, its plastic bag was secured with a wire tie, and then the fiberpack's lid was secured.

Test Conditions

The test series was designed specifically to determine whether incineration can attain a 99.96% RE for arsenic under operating parameters associated with a 99.9999-% dioxin DRE. The kiln chamber, afterburner chamber, and APCS operating parameters were held nominally constant throughout the test program. The target incinerator operating conditions for each test are given in Table 1.

Sampling and Analysis

The scope of the sampling efforts undertaken during this test program is illustrated and the sampling locations are identified in Figure 3. The sampling effort completed during each test consisted of:

- Obtaining a composite sample of the soil feed from each drum before the soil was packaged into the fiberpack containers.

Table 1. *Target Incinerator Test and Operating Conditions*

Kiln exit gas temperature	*982°C (1,800°F)*
Afterburner exit gas temperature	*1,204°C (2,200°F)*
Kiln exit O_2 level	*10%*
Afterburner exit O_2 level	*7.9%*
Kiln solids residence time	*0.5 hr*
Total waste soil feedrate	*55 kg (120 lb)*
Calvert scrubber pressure drop	*12.4 kPa (50 in. WC)*
Scrubber liquor temperature	*66°C (150°F)*
Scrubber liquor blowdown rate	*0 to 2 L/min (0 to 0.5 gpm)*

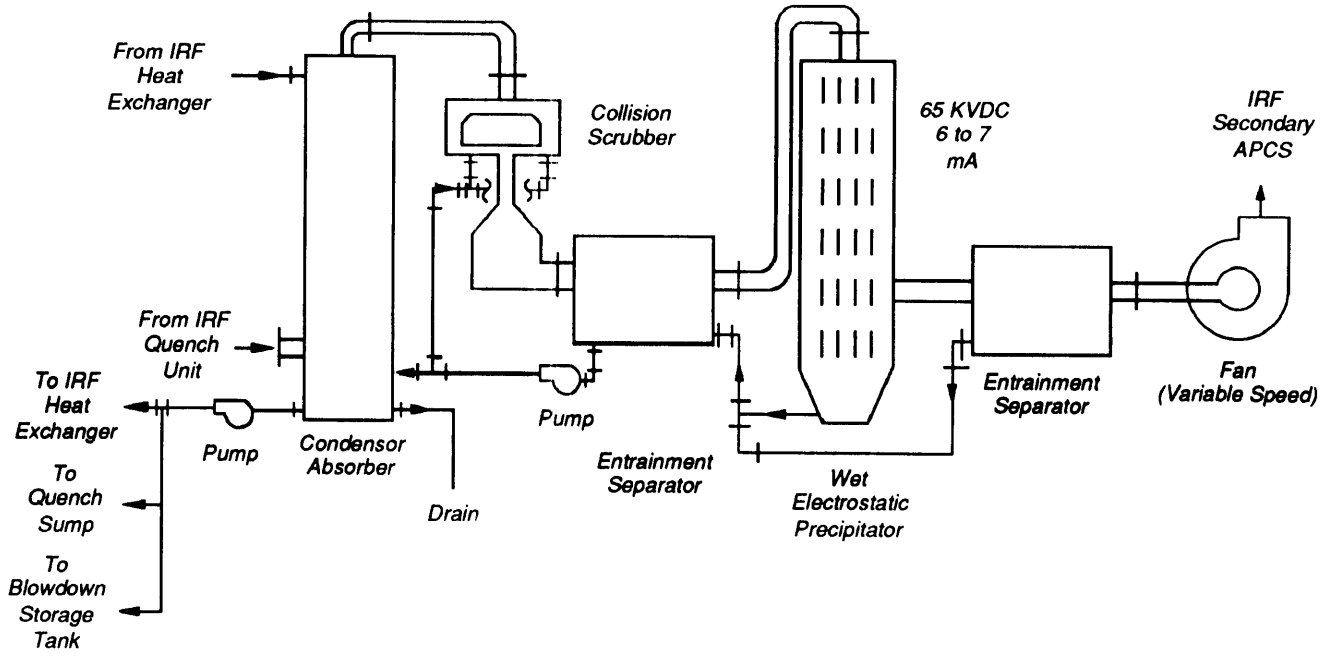


Figure 2. *Schematic of the Calvert scrubber system.*

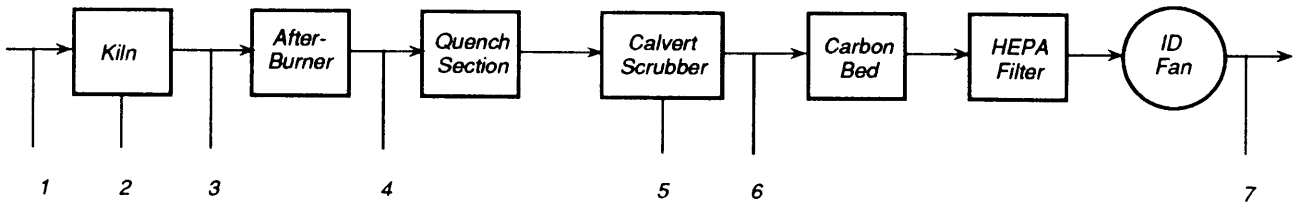
- Collecting a composite sample of the kiln ash.
- Collecting a composite sample of the scrubber liquor.
- Continuously measuring O_2 levels in the kiln exit and afterburner exit flue gases; O_2, CO, CO_2, and NO_x levels at the scrubber exit; and O_2, CO, and CO_2 levels at the stack.
- Sampling flue gas at the scrubber system exit for organochlorine pesticides, arsenic, and particulate and HCl.
- Sampling at the stack downstream of the secondary APCS for arsenic and particulate and HCl.

Aliquots of the soil feed and kiln ash sample for each test were subjected to the TCLP. The soil feed, soil feed TCLP leachate, kiln ash, and scrubber liquor sample for each test was analyzed for organochlorine pesticides and the trace metals arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. The kiln ash TCLP leachate sample for each test was analyzed for the above trace metals. Flue gas sampling train samples were analyzed for this sampled analyte.

Table 2. *Organochlorine Pesticide Analysis Results*

	Concentration					
Sample	*Chlordane*	*α-BHC*	*γ-BHC*	*p,p'-DDE*	*p,p'-DDD*	*p,p'-DDT*
Test 1 (8/6/91)						
Soil feed, mg/kg	*14*	*<2.0*	*<2.0*	*5.5*	*7.3*	*65*
Soil feed TCLP leachate, µg/L	*<10*	*8.3*	*2.3*	*<2.0*	*<2.0*	*<2.0*
Kiln ash, mg/kg	*<0.10*	*<0.02*	*<0.02*	*<0.02*	*<0.02*	*<0.02*
Scrubber liquor, µg/L	*<1.0*	*<0.20*	*<0.20*	*<0.20*	*<0.20*	*<0.02*
Scrubber exit flue gas, µg/dscm	*<0.33*	*<0.066*	*<0.066*	*<0.066*	*<0.066*	*0.10*
Test 2 (8/8/91)						
Soil feed, mg/kg	*17*	*<2.0*	*<2.0*	*6.7*	*7.3*	*92*
Soil feed TCLP leachate, µg/L	*<10*	*4.4*	*<2.0*	*<2.0*	*2.6*	*<2.0*
Kiln ash, mg/kg	*<0.10*	*<0.02*	*<0.02*	*<0.02*	*<0.02*	*<0.02*
Scrubber liquor, µg/L	*<1.0*	*<0.20*	*<0.20*	*<0.20*	*<0.20*	*<0.20*
Scrubber exit flue gas, µg/dscm	*<0.30*	*<0.060*	*<0.060*	*<0.060*	*<0.060*	*<0.060*
Test 3 (8/13/91)						
Soil feed, mg/kg	*<10*	*<2.0*	*<2.0*	*3.4*	*4.3*	*41*
Soil feed TCLP leachate, µg/L	*<10*	*3.6*	*<2.0*	*<2.0*	*<2.0*	*<2.0*
Kiln ash, mg/kg	*<0.10*	*<0.02*	*<0.02*	*<0.02*	*<0.02*	*<0.02*
Scrubber liquor, µg/L	*<1.0*	*<0.20*	*<0.20*	*<0.20*	*<0.20*	*<0.20*
Scrubber exit flue gas, µg/dscm	*<0.31*	*<0.061*	*<0.061*	*<0.061*	*<0.061*	*<0.061*
Test 4 (8/15/91)						
Soil feed, mg/kg	*13*	*<2.0*	*<2.0*	*4.8*	*6.4*	*46*
Soil feed TCLP leachate, µg/L	*<10*	*<2.0*	*<2.0*	*<2.0*	*<2.0*	*<2.0*
Kiln ash, mg/kg	*<0.10*	*<0.02*	*<0.02*	*<0.02*	*<0.02*	*<0.02*
Scrubber liquor, µg/L	*<1.0*	*<0.20*	*<0.20*	*<0.20*	*<0.20*	*<0.20*
Scrubber exit flue gas, µg/dscm	*<0.31*	*<0.062*	*<0.062*	*<0.062*	*<0.062*	*0.077*
TCLP regulatory level, µg/L	*30*	*_a*	*400*	*_*	*_*	*_*

a_ = Has no TCLP regulatory level.



Sampling point	Soil feed	Kiln ash	Calvert scrubber liquor	Continuous flue gas monitoring	Method 0010 (organochlorine pesticides)	Method 108 (arsenic)	Method 5 (particulate and HCl)
1	X						
2		X					
3				X			
4				X			
5			X				
6				X	X	X	X
7				X		X	X

Figure 3. *Sampling matrix.*

Test Results

Results from the test program performed are discussed in the subsections that follow. Test results are grouped by analyte class.

Organochlorine Pesticides Analysis Results

Table 2 summarizes the results of the organochlorine pesticide analyses. The data indicate that the soil feed contained between <10 and 17 mg/kg of chlordane; between 3.4 and 6.7 mg/kg of p,p'-DDE; between 4.3 and 7.3 mg/kg of p,p'-DDD; and between 41 and 92 mg/kg of p,p'-DDT. None of these soil contaminants, however, was found in any of the feed TCLP leachate, kiln ash, or scrubber liquor samples. Low levels of p,p'-DDT were found in the scrubber exit flue gas in two of the four tests, although no other pesticide analyte was found.

Table 3 summarizes the lower bound degree of pesticide decontamination achieved corresponding to the kiln ash practical quantitation limits (PQLs) and identifies the upper bound fraction of the amount of each pesticide introduced in the incinerator feed that could have been present in the kiln ash discharge in each test. The data show that no more than 0.62% of the chlordane, 0.44% of the p,p'-DDE, 0.34% of the p,p'-DDD, or 0.04% of the p,p'-DDT fed to the incinerator could have been discharged in the kiln ash. Thus, the decontamination effectiveness of incineration under the conditions tested was at least 99.38% for chlordane; 99.56%

Table 3. *Organochlorine Pesticide Decontamination Effectiveness*

Parameter	Chlordane	p,p'-DDE	p,p'-DDD	p,p'-DDT
Test 1 (8/6/91)				
Soil feed				
Concentration, mg/kg	*14*	*5.5*	*7.3*	*65*
Amount fed, g	*3.03*	*1.17*	*1.55*	*14.0*
Kiln ash				
Concentration, mg/kg	*< 0. 1*	*< 0.02*	*< 0.02*	*< 0.02*
Amount discharged, mg	*< 16*	*< 3.3*	*< 3.3*	*< 3.3*
Fraction of amount fed, %	*<0.54*	*<0.28*	*<0.21*	*<0.02*
Test 2 (8/8/91)				
Soil feed				
Concentration, mg/kg	*17*	*6.7*	*7.3*	*92*
Amount fed, g	*3.73*	*1.45*	*1.59*	*19.9*
Kiln ash				
Concentration, mg/kg	*< 0. 1*	*< 0.02*	*< 0.02*	*< 0.02*
Amount discharged, mg	*< 17*	*<3.5*	*<3.5*	*<3.5*
Fraction of amount fed, %	*< 0.47*	*< 0.24*	*< 0.22*	*< 0.02*
Test 3 (8/13/91)				
Soil feed				
Concentration, mg/kg	*<10*	*3.4*	*4.3*	*41*
Amount fed, g	*<2.1*	*0.71*	*0.92*	*8.77*
Kiln ash				
Concentration, mg/kg	*< 0. 1*	*< 0.02*	*< 0.02*	*< 0.02*
Amount discharged, mg	*< 16*	*<3.1*	*<3.1*	*<3.1*
Fraction of amount fed, %	*_a*	*< 0.44*	*< 0.34*	*< 0.04*
Test 4 (8/15/91)				
Soil feed				
Concentration, mg/kg	*13*	*4.8*	*6.4*	*46*
Amount fed, g	*2.78*	*1.07*	*1.42*	*10.1*
Kiln ash				
Concentration, mg/kg	*< 0. 1*	*< 0.02*	*< 0.02*	*< 0.02*
Amount discharged, mg	*< 17*	*< 3.4*	*< 3.4*	*< 3.4*
Fraction of amount fed, %	*< 0.62*	*< 0.32*	*< 0.24*	*< 0.03*

a_ = Not applicable because not detected in the feed.

Table 4. Organochlorine Pesticide DREs

Parameter	Chlordane	p,p'-DDE	p,p'-DDD	p,p'-DDT
Test 1 (8/6/91)				
Pesticide feedrate, mg/hr	*791*	*305*	*405*	*3,640*
Scrubber exit flue gas emission rate, µg/hr	*<990*	*<200*	*<200*	*306*
DRE, %	*>99.87*	*>99.934*	*>99.951*	*99.9916*
Test 2 (8/8/91)				
Pesticide feedrate, mg/hr	*951*	*371*	*405*	*5,100*
Scrubber exit flue gas emission rate, µg/hr	*<860*	*<170*	*<170*	*<170*
DRE, %	*>99.910*	*>99.954*	*>99.958*	*>99.9967*
Test 3 (8/13/91)				
Pesticide feedrate, mg/hr	*<540*	*183*	*234*	*2,240*
Scrubber exit flue gas emission rate, µg/hr	*<890*	*<180*	*<180*	*<180*
DRE, %	*_a*	*>99.901*	*>99.923*	*>99.9920*
Test 4 (8/15/91)				
Pesticide feedrate, mg/hr	*712*	*275*	*366*	*2,600*
Scrubber exit flue gas emission rate, µg/hr	*<880*	*<180*	*<180*	*219*
DRE, %	*>99.88*	*>99.935*	*>99.951*	*99.9916*

a_ = Not applicable because not detected in the feed.

for p,p'-DDE; 99.66% for p,p'-DDD; and 99.96% for p,p'-DDT.

Table 4 summarizes the organochlorine pesticide DREs achieved for the tests as measured at the scrubber system exit. For the two tests in which p,p'-DDT was detected in the scrubber exit flue gas (Tests 1 and 4), the DRE achieved was 99.9916%. This exceeds the 99.99-% principal organic hazardous constituent (POHC) DRE requirement in the hazardous waste incinerator performance standard. The lower bound DREs achieved for p,p'-DDT in Tests 2 and 3 based on the flue gas emission stream PQL were also greater than 99.99%. Lower bound DREs based on the flue gas emission stream measurement PQLs were greater than 99.87% for chlordane, 99.901% for p,p'-DDE, and 99.923% for p,p'-DDD. The expectation is that all three of these compounds were destroyed at greater than 99.99% DRE; however, method PQLs were too high to unambiguously establish this when these compounds were present at the lower concentrations in the soil feed. The data in Tables 3 and 4 also show that adding lime to the test soil in Test 4 had no effect on the effectiveness of incineration in decontaminating the soil or on the DREs for the organochlorine pesticide compounds.

Arsenic and Other Trace Metal Distributions

Table 5 summarizes the arsenic concentrations measured and the resulting feedrates and flue gas emission rates for the four tests performed. The arsenic RE achieved for Test 1 at the scrubber exit, 99.89%, was less than the target of 99.96%. This result was obtained on a quick-turnaround laboratory analysis. Based on this result, Test 4 was performed with lime blended with the soil to evaluate whether lime addition affected arsenic RE.

In contrast to the Test 1 experience, the arsenic REs measured at the scrubber exit in Tests 2 and 3 were 99.990% and 99.991%, respectively, greater than the target 99.96%. The authors have no explanation for the order of magnitude higher scrubber exit arsenic emission rate experienced in Test 1 compared to Tests 2 and 3. The 99.991-% scrubber exit arsenic RE in Test 4, in which lime was added to the soil, was comparable to the REs in Tests 2 and 3.

Table 6 summarizes the concentrations of all eight of the test metals in the soil feed and in each of the incinerator discharge streams analyzed. The table also notes the soil feed and kiln ash TCLP leachate metal concentrations for each test, and the TCLP regulatory levels for each TCLP metal determined. Comparing feed soil leachate, kiln ash leachate, and scrubber liquor metals concentrations to the TCLP regulatory levels shows that no regulatory level was exceeded for any metal except arsenic. No feed soil would be an arsenic TC hazardous waste. However, the Test 1 kiln ash was a TC hazardous waste for arsenic, and the Tests 2 and 3 kiln ash leachates contained arsenic levels near the regulatory limit. The arsenic concentrations in TCLP leachates of both the feed soil and the kiln ash for Test 4 were reduced from the levels measured in the other three tests. This suggests that adding lime, as was done in Test 4, renders the arsenic less leachable from both the soil and the resulting kiln ash.

Table 7 summarizes the trace metal distributions among the incinerator discharge streams, expressed as fractions (in percent) of the amount of each metal

Table 5. Arsenic Removal Efficiencies

Parameter	Test 1 (8/6/91)	Test 2 (8/8/91)	Test 3 (8/13/91)	Test 4 (8/15/91)
Soil				
Feedrate, kg/hr	*55.7*	*55.5*	*54.2*	*57.0*
Arsenic concentration, mg/kg	*1,040*	*1,040*	*794*	*803*
Arsenic feedrate, g/hr	*57.9*	*57.7*	*43.0*	*45.8*
Scrubber exit flue gas				
Flowrate, dscm/min	*49.8*	*47.6*	*48.6*	*48.4*
Arsenic concentration, µg/dscm	*22.1*	*2.04*	*1.38*	*1.43*
Arsenic emission rate, mg/hr	*66.0*	*5.82*	*4.02*	*4.15*
RE, %	*99.89*	*99.9899*	*99.9907*	*99.9909*
Stack gas				
Flowrate, dscm/min	*67.4*	*65.2*	*63.6*	*63.2*
Arsenic concentration, µg/dscm	*1.14*	*0.93*	*1.12*	*1.16*
Arsenic emission rate, mg/hr	*4.61*	*3.64*	*4.27*	*4.40*
RE,%	*99.9920*	*99.9937*	*99.9900*	*99.9903*

Table 6. Trace Metals Analysis Results

Sample	As	Ba	Cd	Cr	Pb	Hg	Se	Ag
Test 1 (8/6/91)								
Soil feed, mg/kg	1,040	56	1.7	16	120	10	< 11	< 0.44
Soil feed TCLP leachate, mg/L	2.2	0.89	0.009	<0.007	0.086	<0.002	0.066	<0.005
Kiln ash, mg/kg	653	60	0.50	9.7	74	< 1.0	< 12	< 0.45
Kiln ash TCLP leachate, mg/L	5.8	0.76	0.005	< 0.007	0.28	< 0.002	0.059	< 0.005
Scrubber liquor, mg/L	8.5	0.16	0.054	0.15	0.23	0.007	<0.13	0.01
Test 2 (8/8/91)								
Soil feed, mg/kg	1,040	66	1.1	19	118	5.8	<11	<0.44
Soil feed TCLP leachate, mg/L	2.2	0.57	0.012	<0.007	0.079	<0.002	0.057	<0.005
Kiln ash, mg/kg	619	60	0.42	11	58	< 1.0	16	<0.45
Kiln ash TCLP leachate, mg/L	3.8	0.70	0.005	< 0.007	0.088	< 0.002	0.065	< 0.005
Scrubber liquor, mg/L	12	0.23	0.023	0.089	0.27	<0.002	<0.13	<0.005
Test 3 (8/13/91)								
Soil feed, mg/kg	794	48	0.86	17	104	5.4	<11	<0.43
Soil feed TCLP leachate, mg/L	2.5	0.80	0.012	<0.007	0.083	<0.002	0.063	<0.005
Kiln ash, mg/kg	619	64	0.68	11	61	< 1.0	1.5	<0.46
Kiln ash TCLP leachate, mg/L	4.1	0.78	0.005	<0.007	0.095	<0.002	0.062	<0.005
Scrubber liquor, mg/L	10	0.21	0.017	0.064	0.29	<0.002	0.14	<0.005
Test 4 (8/15/91)								
Soil feed, mg/kg	803	43	0.97	13	86	6.2	15	< 0.48
Soil feed TCLP leachate, mg/L	0.11	0.18	<0.005	<0.007	0.049	<0.002	0.058	<0.005
Kiln ash, mg/kg	1,100	74	0.85	14	83	< 1.0	<11	<0.44
Kiln ash TCLP leachate, mg/L	1.2	0.12	<0.005	<0.007	0.036	<0.002	0.083	<0.005
Scrubber liquor, mg/L	6.0	0.26	0.011	0.057	0.23	<0.002	<0.13	<0.005
TCLP regulatory level, mg/L	5.0	100	1.0	5.0	5.0	0.2	1.0	5.0

fed to the incinerator for each test for all metals analyzed, except arsenic which will be discussed separately. The data in Table 7 show that the kiln ash discharge accounted for most of the barium and lead fed in all tests. The scrubber liquor accounted for about a factor of 10 less (i.e., 10%) of the amount of barium and lead fed than the kiln ash. The kiln ash also accounted for the predominant fraction of chromium fed in all tests, although the scrubber liquor accounted for higher relative fractions of chromium. The behavior of cadmium was apparently inconsistent from test to test. The addition of lime to the soil, as done in Test 4, apparently did not affect metals distributions to kiln ash or scrubber liquor within the variability of the data in Table 7. No mercury was found in any kiln ash or scrubber liquor sample. The "less than" fractions noted in Table 7 correspond to sample analysis PQLs. Most or all of the mercury fed likely escaped the incineration system via the scrubber exit flue gas.

Arsenic distributions are summarized in Table 8 with the addition of the scrubber exit flue gas discharge stream sampled. The data show that the arsenic distributions were quite similar in Tests 1 through 3 in which soil alone was fed. Between 42% and 49% of the arsenic fed was accounted for in the kiln ash (treated soil) discharge. About 20% was collected in the scrubber liquor. With lime added to the soil (Test 4), the scrubber liquor fraction decreased to 13% of the amount fed, and the kiln ash fraction increased to 91% of the amount fed. The scrubber exit flue gas arsenic fraction was low, 0.1% or less, in all four tests.

A clearer picture of the variation in relative arsenic distributions with incinerator operation is possible when the data in Table 8 are normalized by the total mass balance closure achieved. Table 9 sum-

Table 7. Trace Metal Distributions

	Metal distribution, % of metal fed				
Sample	*Ba*	*Cd*	*Cr*	*Pb*	*Hg*
Test 1 (8/6/91)					
Kiln ash	71	20	40	41	<7
Scrubber liquor	6	69	19	4	<1
Total	77	89	59	45	< 8
Test 2 (8/8/91)					
Kiln ash	63	27	42	34	<12
Scrubber liquor	6	36	8	4	<1
Total	69	63	50	38	< 13
Test 3 (8/13/91)					
Kiln ash	84	50	40	37	<12
Scrubber liquor	7	34	7	5	<1
Total	91	84	47	42	< 13
Test 4 (8/15/91)					
Kiln ash	115	59	69	64	<11
Scrubber liquor	10	19	7	5	<1
Total	125	78	76	69	<12

Table 8. *Arsenic Distributions*

Sample	Arsenic distribution, % of arsenic fed			
	Test 1 (8/6/91)	Test 2 (8/8/91)	Test 3 (8/13/91)	Test 4 (8/15/91)
Kiln ash	42	42	49	91
Scrubber liquor	18	19	22	13
Scrubber exit flue gas	0.1	0.01	0.01	0.01
Total	60	61	71	104

Table 9. *Normalized Arsenic Distributions*

Sample	Arsenic distribution, % of arsenic measured			
	Test 1 (8/6/91)	Test 2 (8/8/91)	Test 3 (8/13/91)	Test 4 (8/15/91)
Kiln ash	70.2	68.3	69.3	87.8
Scrubber liquor	29.6	31.7	30.7	12.2
Scrubber exit flue gas	0.17	0.01	0.01	0.01
Total	100	100	100	100
Apparent scrubber collection efficiency	99.44	99.953	99.963	99.937

marizes the test arsenic distribution data in this form. The distribution fractions in Table 9 have been normalized to the total amount of arsenic measured in all the discharge streams analyzed. Thus, these normalized values represent fractions that would have resulted had mass balance closure in each test been 100%. Use of distribution fractions normalized in this manner allows clearer data interpretation because variable mass balance closure is eliminated as a source of test-to-test data variability. In other words, given that variable and less than perfect mass balance closure is invariably experienced, the use of normalized distributions is a best attempt to quantify metal partitioning phenomena.

The normalized distributions in Table 9 clearly show that about 70% of the arsenic accounted for was discharged in the kiln ash, or treated soil, in the three tests feeding soil alone (Tests 1 through 3). About 30% of the arsenic measured was accounted for in the scrubber system liquor. A small fraction of the arsenic measured was accounted for by the scrubber exit flue gas. However, with lime added in Test 4, the kiln ash arsenic fraction increased to 88% and the scrubber liquor arsenic fraction decreased to about 12%. The scrubber exit flue gas arsenic fraction remained negligible. Clearly, the addition of lime to the soil stabilized the arsenic, tending to keep it in the kiln ash.

The apparent arsenic scrubber collection efficiencies for these tests are also given in Table 9, where apparent scrubber collection efficiency is defined as

$$\frac{\text{Scrubber liquor fraction}}{\text{Scrubber liquor fraction} + \text{scrubber exit flue gas fraction}}$$

The data show that the Calvert scrubber system achieved an average of 99.95% arsenic collection in Tests 2 through 4. The apparent collection efficiency in Test 1 was lower at 99.44%. However, the Test 1 result is suspected to be an outlier.

Particulate and HCl Emissions

Flue gas particulate levels measured at the Calvert scrubber exit ranged from 9 to 19 mg/dscm (corrected to 7% O_2). These levels would represent the stack emissions of a typical incinerator equipped with a Calvert scrubber. These levels are substantially below the 180 mg/dscm (at 7% O_2) hazardous waste incinerator performance standard. Apparent scrubber system collection efficiencies calculated using the chlorine feedrates and measured emission rates were 99.95%, or slightly higher, in all tests. These levels exceed the 99-% collection efficiency required by the hazardous waste incineration performance standards.

Conclusions

Test program data confirm that incineration under the conditions tested resulted in the elimination of the soil pesticide contaminants. No pesticide was detected in any kiln ash (treated soil) sample. Based on method PQLs, the decontamination effectiveness demonstrated was at least 99.38% for chlordane, 99.56% for p,p'-DDE, 99.66% for p,p'-DDD, and 99.96% for p,p'-DDT. In addition, pesticide DREs of at least 99.9916% were achieved for p,p'-DDT. None of the other pesticide contaminants was detected in the scrubber exit flue gas, with lower bound DREs, corresponding to method PQLs, ranging from at least 99.87% for chlordane to at least 99.92% for p,p'-DDD.

Arsenic REs of 99.99% were achieved with the Calvert scrubber under the conditions tested feeding soil alone. Adding lime to the soil did not measurably improve arsenic RE.

Trace metal concentrations in TCLP leachates of both untreated soil and kiln ash (treated soil) were significantly below corresponding TC regulatory levels for all metals except arsenic. Soil leachate arsenic concentrations were 40% to 50% of the regulatory level. Kiln ash leachate arsenic concentrations were near or above arsenic's TC regulatory level, suggesting that treated soil could or would be a TC hazardous waste. Adding lime to the soil can significantly lower both the soil and resulting incineration kiln ash leachate arsenic concentrations.

Nominally 70% of the arsenic measured in the incinerator discharge was in the kiln ash of all tests in which soil alone was fed; about 30% was in the scrubber liquor; and a negligible fraction was in the scrubber exit flue gas. In the test in which lime was added to the soil, the kiln ash arsenic fraction increased to about 90%; about 10% was in the scrubber liquor; and a negligible fraction was in the scrubber exit flue gas. The Calvert scrubber apparent arsenic collection efficiency was nominally 99.95% and was not affected by lime addition. Particulate levels at the Calvert scrubber exit were nominally 10 to 20 mg/dscm at 7% O_2, well below the hazardous waste incinerator performance standard of 180 mg/dscm at 7% O_2. Calvert scrubber apparent HCl collection efficiencies were 99.95% or greater, above the

hazardous waste incinerator performance standard of 99%.

In summary, test results suggest that conventional rotary kiln incineration in a unit equipped with a high-efficiency scrubber system, such as the Calvert system tested, would be an appropriate treatment. Elimination of contaminant organochlorine pesticides from the soil and destruction of the contaminant at a DRE of 99.99% were achieved. Arsenic REs of greater than 99.96% were achieved in the system with the Calvert scrubber in normal operation. The hazardous waste incinerator particulate and HCl performance standards were easily achieved.

Incineration treatment of soils with arsenic concentrations in the range of the concentrations of the soil tested may result in the treated soil being a TC hazardous waste. However, adding lime to soil before incineration can significantly reduce the leachability of the kiln ash arsenic in the TCLP test.

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A. Siag, S.J. Fournier, Jr., and L.R. Waterland are with Acurex Environmental Corporation, Jefferson, AR 72079.
***R.C. Thurnau** is the EPA Project Officer (see below). H.O. Wall was the Technical Project Monitor for the test program*
The complete report, entitled "Pilot-Scale Incineration of Contaminated Soil from the Chemical Insecticide Corporation Superfund Site," (Order No. PB93-155968; Cost: $27.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Risk Reduction Engineering Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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