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# Project Summary

# Evaluation of Hazardous Waste Incineration in an Aggregate Kiln: Florida Solite Corporation

D. R. Day, L. A. Cox, J. A. Peters, and R. E. Mournighan

**Aggregate kiln incineration of chlorinated liquid organic waste was investigated in a one-week program at Florida Solite Company. POHCs (toluene, tetrachloroethylene, methyl ethyl ketone, and methyl isobutyl ketone) were monitored in waste and stack emissions. In addition, stack emissions were monitored for particulate matter, particulate trace metals, HCl, $SO_2$, and $NO_x$. Process samples were collected and analyzed for trace metals and chloride. The destruction and removal efficiency of POHCs and the fate of trace metals and chloride ion in the kiln process were determined.**

**Consistent achievement of greater than 99.99% DRE was demonstrated for each POHC. Emissions of other pollutants ranged as follows: particulates—4.4 to 6.5 kg/hr; HCl—0.008 to 0.034 kg/hr; $SO_2$—72.2 to 99.6 kg/hr; $NO_x$—1.9 to 11.7 kg/hr. Between 60 and 90% of the element chlorine is fed to the kiln from the waste fuel and scrubber influent water, while 95% of the chlorine is discharged from the process as chloride ion in the scrubber effluent water.**

***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

Cofiring of hazardous wastes in high temperature industrial processes is an attractive alternative to hazardous waste incineration. The alternative makes use of the waste's heat content. Many cofiring processes, which include cement and dolomite kilns, glass furnaces, steel furnaces, and some industrial boilers, provide temperatures and residence times similar to those required for incinerators dedicated to incineration of hazardous wastes. In addition to the savings derived from the heat value, the use of existing industrial equipment does not require the capital required if a separate incinerator to process a given amount of hazardous waste is to be built, and it may provide an environmentally acceptable alternative to conventional hazardous waste disposal.

Aggregate kilns, because of their high energy use, are an excellent example of this concept. Such kilns typically operate at temperatures over 1100°C (2000°F), have gas residence times in excess of 1.5 seconds, and have a highly turbulent combustion zone. However, the need exists for data that shows the effect of cofiring hazardous waste on the emissions from the aggregate process.

The sampling and analysis program included evaluation of: (1) the effects of cofiring coal and waste fuel on the destruction and removal efficiency (DRE) of principal organic hazardous constituents (POHCs); (2) the concentrations of particulate matter, $SO_2$, $NO_x$, HCl, and metals in stack emission, and (3) the concentration and fate of metals and chlorine in the process streams.

## Facility and Process Description

The Florida Solite Company operates an aggregate kiln in Green Cove Springs, Florida, which is located approximately 20 miles south of Jacksonville. Annual production of the expanded lightweight inorganic material used as aggregate in a cement mix is approximately $5.45 \times 10^7$ kg (60,000 tons) per year.

This industrial process involves the heating of clay to 1100°C in a horizontal rotary kiln to prepare an expanded lightweight inorganic material used as aggregate in cement mix.

The kiln, with refractory linings, is 2.7m (9 ft) in diameter and 45.7m (150 ft) long. The kiln rotates slowly (90 revolutions per hour), has a gentle slope (6.25 cm/m) to allow material to pass through by gravity. The kiln operates in a counter current flow pattern; i.e., solid materials travel in one direction and hot gases and dust travel in the opposite direction. Clay is fed into the kiln at the upper end at a rate of approximately 12,260 kg/hr (27,000 lb/hr). At the opposite end of the kiln, a mixture of coal and waste fuel is burned at rates of approximately 700 kg/hr (1,540 lb/hr) and 0.87 $m^3$/hr (230 gal/hr), respectively, to provide a heat input of approximately 220 kw (0.74 million Btu/hr). As the clay feed travels down the inclined rotating kiln, it passes through various temperature ranges which cause transformation of the clay into the lightweight aggregate product. The lightweight aggregate is produced at a rate of approximately 9,080 kg/hr (20,000 lb/hr). After heating and transformation in the kiln, the aggregate is graded and large clumps are crushed for sizing. The final product is stored in large piles until sold.

The kiln exhaust gases pass through a pair of mechanical dust collectors, whose dust is recycled into the kiln, then into a horizontal cross-flow water scrubber of fiber-reinforced-plastic (FRP) construction. The series of water sprays cleans the particulate matter and reduces the gas temperature from about 370°C to 70°C (700°F to 160°F) before the gases reach the knockout chamber and fiberglass stack. The scrubber discharge released from the knockout chamber is a mixture of raw steam and water with the entrapped particulate matter. This discharge stream is released to an open ditch which drains to a pond. There is no recycle of the scrubber water.

The fuel used to fire the kiln is an unblended combination of crushed coal and waste organic liquids. The liquid wastes, which are trucked directly from the generators, consist primarily of solvents, alcohols, ethers, still bottoms, and a small fraction of chlorinated hydrocarbons. Any manifested wasteload that contains pesticides, PCBs, acids, caustics, cyanides, sulfides, mercaptans, electroplating wastes, or metal finishing wastes is rejected and returned to the generator. The organic waste mixture makes up from 50% to 100% of the fuel used. During the test period, the waste fuel made up approximately 54% of the total fuel input.

## Experimental Program

The sampling and analytical program was designed to identify the major pollutants from burning waste fuel in an aggregate kiln, quantify their respective emission rates, determine the destruction and removal efficiency (DRE) of the POHCs, and provide information for a mass balance around the process for metals and chlorine. Measured stack pollutants include POHCs (toluene, tetrachloroethylene, methyl ethyl ketone, and methyl isobutyl ketone), particulate matter, particulate trace metals, carbon dioxide, hydrogen chloride, sulfur dioxide, and nitrogen oxides. In addition, the distribution of the metals and the element chlorine were measured in all of the process input and output streams; i.e., the coal feed, waste fuel feed, clay feed, scrubber influent water, aggregate product, and scrubber effluent water. Waste fuel and coal samples were submitted for analyses of sulfur, ash, and Btu content. Waste fuel and scrubber effluent water also were analyzed for principal organics. Table 1 summarizes the overall test program and lists each sampling and analytical method used.

## Results and Discussions

### *Waste Fuel*

A detailed summary of the waste fuel composition for two waste fuel samples collected is shown in Table 2. Tables 3 and 4 show the concentration of each POHC and other properties for the five waste fuel samples (one sample per day, Runs 1-5).

### *POHC Destruction and Removal Efficiencies*

The complex combustion chemistry for organic materials becomes perplexing when a broad range of organic compounds present in a liquid waste are burned. On a weight basis, most of the organic carbon in the waste is oxidized to $CO_2$ in the combustion process, but trace amounts of organic chemicals survive the oxidation process.

The four POHCs were sampled in the exhaust gas by the volatile organic sampling train (VOST) and analyzed by gas chromatography/mass spectrometry (GC/MS). Due to sampling and analysis problems, the number of acceptable VOST runs made each day are as follows: day 1—0 runs; day 2—6 runs; day 3—6 runs; day 4—8 runs; day 5—5 runs. The average and range for DRE is shown in Table 5.

Methyl ethyl ketone was destroyed and removed to at least 99.99% efficiency. Only three runs showed DREs less than 99.999%: Runs 4A, $3A^3$, and $3B^3$. Runs $3A^3$ and $3B^3$ were side-by-side runs (with 3A and 3B) that were split with the EPA QA contractor. Runs $3A^3$ and $3B^3$ do not show good comparison with Runs 3A and 3B for MEK, possibly owing to high blank contamination problems on the QA contractor field blanks. Run $3B^3$ is an outlier and is not considered a significant part of the data. The overall DRE average for MEK for all 5 days was 99.998% ± 0.006% (95% confidence limits).

DREs for methyl isobutyl ketone (MIBK) ranged from 99.986% to ≥99.999%. The 99.986% value was the only DRE less than 99.992%. The overall average for MIBK was 99.998% ± 0.006% (95% confidence limits).

DREs for tetrachloroethylene (Perc) ranged from 99.993% to ≥ 99.999%. Excellent consistency was found for each day of sampling. Split samples on Day 3 (Runs $3A^3$, $3B^3$, and $3D^1$) all showed low relative difference. The overall DRE average for Perc was 99.997% ± 0.004% (95% confidence limits).

DREs toluene ranged from 99.995% to >99.999%. The overall average for toluene was 99.999% ± 0.002% (95% confidence limits), making toluene the easiest POHC to destroy and remove.

### *Stack Samples*

Results for particulates, hydrogen chloride, sulfur dioxide, and nitrogen oxides are summarized in Table 6. The stack rate averaged 652 $m^3$/min (23,320 $ft^3$/min) and the dry stack rate averaged 419 dscm/min (14,780 dscf/min). Particulate emissions of 5.3 kg/hr (11.7 lbs/hr) were less than air permit regulations for this site issued by the Florida Department of Environmental Regulations (DER) of 8.82 kg/hr (19.43 lb/hr). The first $SO_2$ test result had a low value of 270 ppm and is considered an outlier when compared to the remaining seven $SO_2$ test results which ranged 1,030 to 1,470 ppm. The low $NO_x$ value of 40 ppm was expected as it occurred on Day 3 during startup of the kiln.

*Table 1. Summary of Florida Solite Aggregate Kiln Sampling and Analytical Program*

| Parameter | Sampling Method | Analytical Method |
|---|---|---|
| Stack Gas | | |
| • POHCs (tetrachloroethylene, toluene, MEK, MIBK) | Volatile organic sampling train (VOST) | GC/MS, thermal desorption and SIM |
| • Particulate matter | EPA 5 | EPA 5 |
| Metals on particulate | EPA 5 | ICP |
| • Hydrogen chloride | Impinger absorption in 0.5 M NaoAc (back half of EPA 5) | Specific ion electrode |
| • $CO_2$ and $O_2$ | EPA 3 | Fyrite |
| • Nitrogen oxides | EPA 7 | EPA 7 |
| • Sulfur dioxide | EPA 6 | EPA 6 |
| Waste Fuel | | |
| • Principal organics | Grab → composite | GC/MS |
| • Metals | Grab → composite | ICP |
| • Chlorine, sulfur | Grab → composite | XRF |
| • Btu content | Grab → composite | ASTM D240-64 |
| • Ash content | Grab → composite | ASTM D482-IP4 |
| Scrubber Discharge[a] | | |
| • POHCs | Grab → composite | GC/MS |
| • Metals | Grab → composite | ICP |
| • Lead | Grab → composite | AAS |
| • Hexavalent chromium | Grab → composite | APHA312B |
| • Chlorine | Grab → composite | XRF |
| Aggregate Product | | |
| • Metals | Grab → composite | ICP |
| • Chlorine | Grab →composite | XRF |
| Clay Feed | | |
| • Metals | Grab → composite | ICP |
| • Chlorine | Grab→ composite | XRF |
| Coal | | |
| • Metals | Grab → composite | ICP |
| • Chlorine, sulfur | Grab → composite | XRF |
| • Btu and ash content | Grab → composite | ASTM D240-64 |
| Scrubber Influent | | |
| • Metals | Grab → composite | ICP |
| • Chlorine | Grab → composite | XRF |

[a]*The scrubber discharge was split into sludge and supernatant fractions and was analyzed separately where applicable.*

## Conclusions

The results of the program were as follows:

- The aggregate kiln appears to be suitable for destruction of the type of hazardous waste tested in this program. DRE and HCl met the RCRA subpart O incinerator standards.
- Emissions of conventional pollutants were determined and ranged as follows: particulates—4.4 to 6.5 kg/hr; HCl—0.008 to 0.034 kg/hr; $SO_2$—72.2 to 99.6 kg/hr; and $NO_x$—1.9 to 11.7 kg/hr.
- Approximately 60-90% of the element chlorine is fed to the kiln from the waste fuel, while virtually all the element is discharged from the process as chloride in the scrubber effluent water.
- The major percentage of metals is fed to the kiln from the clay feed and waste fuel, while the major percentage of the metals leave the process in the aggregate product and scrubber effluent. Very little is discharged to the air.

**Table 2.** Results of Capillary GC/MS Analysis of Major Components of Waste Fuels Number 1 and Number 4

| Waste Fuel Component | Concentration, wt % Number 1[a] | Number 4[a] |
|---|---|---|
| Ethanol | 1.55 | 1.83 |
| 2-Propanol | 4.55 | 1.97 |
| 1-Butanol | 1.78 | 0.77 |
| Ethyl acetate | 0.68 | 0.72 |
| Methyl ethyl ketone (POHC) | 2.03 | 2.81 |
| Methyl isobutyl ketone (POHC) | 1.52 | 1.12 |
| Toluene (POHC) | 8.40 | 8.06 |
| Tetrachloroethylene (POHC) | 0.19 | 0.07 |
| Ethylbenzene | 1.23 | 2.28 |
| Xylene (isomer No. 1) | 4.47 | 7.89 |
| Styrene | 0.71 | 0.28 |
| Xylene (isomer No. 2) | 1.29 | 2.52 |
| 2-Ethoxyethyl acetate | 2.03 | 1.20 |
| $C_3$-Benzene (isomer No. 1)[b] | 0.47 | 0.33 |
| $C_3$-Benzene (isomer No. 2)[b] | 0.57 | 0.35 |
| $C_{10}$-Alkane (isomer)[c] | 0.83 | 0.76 |
| $C_{11}$-Alkane (isomer)[d] | 0.72 | 0.60 |
| n-Propyl acetate | 1.50 | 1.00 |
| 2-Propanol, 1-(2-methoxy-1-methylethoxy)-isomer No. 1 | 0.46 | 0.14 |
| 2-Propanol, 1-(2-methoxy-1-methylethoxy)-isomer No. 2 | 0.49 | 0.16 |
| 2-Cyclohex 4-1-one, trimethyl (isomer) | 1.28 | 0.54 |

[a]Average of split sample.
[b]Compounds containing three carbons associated with a benzene ring.
[c]Compounds containing ten carbons associated with an alkane.
[d]Compounds containing eleven carbons associated with an alkane.

**Table 3.** POHCs in Waste Fuel

| POHC | Waste fuel concentration, % 1 | 2 | 3 | 4 | 5 | Waste fuel mass rate ($W_{in}$), g/min 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Methyl ethyl ketone | 1.99 | 1.78 | 1.83 | 2.81 | 4.25 | 332 | 390 | 254 | 328 | 564 |
| Methyl isobutyl ketone | 1.53 | 1.70 | 1.41 | 1.12 | 3.90 | 255 | 373 | 195 | 131 | 518 |
| Tetrachloroethylene | 0.19 | 0.19 | 0.17 | 0.06 | 0.03 | 31 | 43 | 24 | 7 | 4 |
| Toluene | 8.38 | 9.27 | 8.21 | 7.99 | 7.54 | 1,397 | 2,033 | 1,137 | 932 | 1,000 |

**Table 4.** Waste Fuel Conditions

| Run number | Chlorine, % | Sulfur, % | PCB ppm | Heat value, Btu/lb | Ash, % | Specific gravity, g/cc | Feed rate, gal/min | Mass rate, g/min |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.08 | 0.41 | ND[a] | 12,550 | 7.74 | 0.966 | 4.56 | 16,670 |
| 2 | 1.08 | 0.41 | 10 | 11,450 | 7.28 | 0.922 | 5.84 | 21,930 |
| 3 | 1.04 | 0.39 | ND | 12,740 | 7.47 | 0.978 | 3.74 | 13,850 |
| 4 | 0.55 | 0.26 | ND | 9,530 | 15.5 | 1.07 | 2.88 | 11,660 |
| 5 | 0.55 | 0.42 | ND | 12,670 | 6.18 | 0.966 | 3.63 | 13,270 |

[a]ND—not detected, detection limit = 0.1 ppm.

*Table 5. Destruction and Removal Efficiencies of POHCs*

| Run number | DRE, % POHC 1 (MEK) | POHC 2 (MIBK) | POHC 3 (Perc) | POHC 4 (Toluene) |
|---|---|---|---|---|
| *Day 2* | | | | |
| *Range* | 99.999 | 99.999 | 99.999 | 99.999 |
| | >99.999 | >99.999 | >99.999 | >99.999 |
| *Average* | 99.999 | 99.999 | 99.999 | 99.999 |
| *Day 3* | | | | |
| *Range* | 99.968 | 99.998 | 99.998 | 99.999 |
| | 99.999 | 99.999 | 99.999 | 99.999 |
| *Average* | 99.992 | 99.999 | 99.999 | 99.999 |
| *Day 4* | | | | |
| *Range* | 99.998 | 99.986 | 99.993 | 99.995 |
| | 99.999 | 99.998 | 99.998 | 99.999 |
| *Average* | 99.999 | 99.995 | 99.997 | 99.998 |
| *Day 5* | | | | |
| *Range* | 99.999 | 99.999 | 99.991 | 99.998 |
| | >99.999 | 99.999 | 99.997 | 99.999 |
| *Average* | 99.999 | 99.999 | 99.995 | 99.999 |
| *Overall Average* | 99.998 | 99.998 | 99.997 | 99.999 |

*Table 6. Average Results for Stack Gas, Particulates, HCl, $SO_2$, and $NO_x$ Emissions*

| Parameter and Unit | Range | Average | Standard Deviation |
|---|---|---|---|
| Stack rate, $m^3/min$ | 623 - 673 | 652 | 19 |
| Stack moisture, % | 21.5 - 28.8 | 26.2 | 3.3 |
| Stack velocity, m/sec | 16.6 - 17.1 | 16.8 | 0.2 |
| Particulates | | | |
| mg/dscm | 163 - 273 | 215 | 48 |
| kg/hr | 4.4 - 6.5 | 5.3 | 1.0 |
| HCl, ppm | 0.15 - 0.68 | 0.46 | 0.22 |
| $SO_2$, ppm | 270 - 1,470 | 1,130 | 380 |
| $NO_x$, ppm | 40 - 227 | 162 | 67 |



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*D. R. Day, L. A. Cox, and J. A. Peters are with Monsanto Research Corporation, Dayton, OH 45407.*
***Robert Morningham** is the EPA Project Officer (see below).*
*The complete report, entitled "Evaluation of Hazardous Waste Incineration in an Aggregate Kiln: Florida Solite Corporation," (Order No. PB 85-189 066/AS; Cost: $13.00, subject to change) will be available only from:*
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