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Evaluation of Hazardous Waste Incineration in Cement Kilns at San Juan Cement Company

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Cement kiln incineration of chlorinated liquid organic wastes was investigated in a 5-month demonstration program at San Juan Cement Company in Puerto Rico. Chlorinated monocarbon compounds (POHC's) were monitored in the waste and emissions, and the fate of added chlorine in cement production was determined. Seven levels of percent chlorine in the waste were burned at ten different waste feed rates. Extensive sampling and analysis was conducted to look for the potential presence of polychlorinated dibenzodioxins (PCDD's) and polychlorinated dibenzofurans (PCDF's).

The destruction and removal efficiencies (DRE) of the POHC's ranged from 91.043 percent to 99.997 percent, with only 6 percent of the DRE's greater than 99.99 percent. Poor DRE results were attributed to the absence of waste atomization and the difficult incinerability of chlorinated monocarbon compounds. It was found that about 82 percent of the input chlorine appeared in the cement clinker. The amount of chlorine appearing in the baghouse dust varied from 5 percent to 26 percent of total chlorine input. The total absorption of the HCl formed averaged 99.7 percent in seven tests. PCDD's and PCDF's were not produced at detectable levels when the cement plant was operating normally.

This Project Summary was developed by EPA's Industrial Environmental 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

A number of cement plants have been used to test cofiring of hazardous wastes, and the data from these tests appeared to indicate that properly operated cement kilns could destroy many organic chemical wastes. However, the data were not sufficiently extensive to allow a determination of minimally acceptable operating conditions and maximum waste firing rates for attaining the requirements of incinerators and were insufficient to permit a determination of the fate of heavy metals in such systems. The tests at the Marquette Cement facility, sponsored by the U.S. Environmental Protection Agency (USEPA) helped to resolve some of the issues associated with the fate of heavy metals and provided data on conventional pollutant emissions, but questions about the degree of destruction and removal efficiency remained unanswered.

To obtain additional data, the USEPA's Industrial Environmental Research Laboratory-Cincinnati, in cooperation with USEPA's Region II and the Puerto Rican Environmental Quality Board, conducted a comprehensive experimental program at San Juan Cement, in Dorado, Puerto Rico, from October 1981 to February 1982 to evaluate the ability of the cement kiln to destroy hazardous waste containing chlorinated compounds such as methylene chloride (CH_2Cl_2), chloroform ($CHCl_3$), and carbon tetrachloride (CCl_4); to determine the effects of firing wastes on the emissions of conventional pollutants such as particulate, CO, NO_x and SO_x; and to evaluate the ability of the process to consume the HCl generated by incineration of chlorinated compounds and measure emissions of HCl in the stack gas.

Other objectives of the tests were to determine if chlorinated dibenzofurans and dibenzodioxins are produced while burning chlorinated compounds, determine the fate of heavy metals, and identify products of incomplete combus-

tion and other residual organic compounds.

Facility and Process Description

San Juan Cement Company has operated a cement plant in Barrio Espinosa in Dorado, Puerto Rico, since 1970. The plant is located about 27 km west of San Juan and is dedicated to the manufacture of Portland cement. Its annual production averages 4.082×10^8 kg (450,000 tons) per year, it employs 350 workers, and it is the second largest cement plant in Puerto Rico.

At San Juan Cement, kiln #2 is 137 m (450 feet) long with an outer shell diameter of 3.05 m (10 ft) and 0.305 m (12 inch) thick walls The kiln rotates 75 times per hour and has a gentle slope to allow material to pass through by gravity. In cement kilns, solid materials travel in one direction and hot gases plus dust emissions travel in the opposite direction. A slurry of 30-40% water (typically 35-39%) and finely crushed rock is fed into the kiln at the upper end. At the opposite end of the kiln is an intense oil fire; at San Juan Cement kiln #2, No. 6 fuel oil is burned at about 1.51×10^{-3} m^3/s (24 gpm), a heat input of approximately 62×10^6 watts (212 million Btu/hr). As the raw material passes slowly through the kiln, it first dries, then, at a temperature of 550°C (1,020°F), calcination starts (CO_2 is liberated from the calcium carbonate in the slurry feed), and finally it approaches the hot burning zone of the kiln. In the burning zone, 1,500°C (2,700°F) temperatures calcine and fuse the raw materials creating a complex calcium silicate alumino-ferrite mineral substance called "clinker," which is discharged from the lower end of the kiln and cooled by large fans in the clinker cooler [1]. The clinker production rate at San Juan Cement ranged from 28-33 metric tons/hr (31-36 ton/hr). The addition of about 6% gypsum to milled clinker completes the process in the production of Portland cement. Exhaust gases from kiln #2 pass through a baghouse where entrained particulate matter is removed. The cleaned exhaust gases are then released to the atmosphere through a single stack.

Experimental Design

The sampling and analytical program was designed to identify all major pollutants from the burning of the hazardous wastes available for this program and to quantify their respective emission rates, investigate the chlorine material balance of the cement process, determine burning rate limits as related to product acceptability and refractory lining integrity, and determine the destruction and removal efficiencies (DRE) of the principal organic hazardous constituents (POHC's) in the waste fuels. The POHC's chosen for this program were the three chlorinated compounds known to be present in the waste fuel mixture:

(1) Methylene chloride (dichloromethane), CH_2Cl_2 higher heating value (HHV) = 3058 Btu/lb
(2) Chloroform (trichloromethane), $CHCl_3$ HHV = 1349 Btu/lb
(3) Carbon tetrachloride (tetrachloromethane), CCl_4 HHV = 432 Btu/lb

Emission measurements included particulate matter, carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_x), hydrogen chloride (HCl), total gaseous hydrocarbons (THC), total chlorinated hydrocarbons, methylene chloride (CH_2Cl_2), chloroform ($CHCl_3$), carbon tetrachloride (CCl_4), trace metals in particulate matter, organics, with special attention given to dioxins, and furans in the baghouse fly ash Chlorine content of the baghouse fly ash and cement clinker was also monitored. The waste fuels and fuel oil used to fire the cement kiln were analyzed for principal organics, trace metals, ash, chlorine, nitrogen, and sulfur content.

Table 1 summarizes the test matrix of the demonstration program wherein the waste feed rate to the kiln and the chlorine content of the waste were varied. Table 2 summarizes the overall test program and shows each collection method and analytical method. A Quality Assurance Project Plan was prepared and reviewed prior to the program. A full description of the QA/QC results involving replicates, splits, blanks, spikes, and reference standards is provided in the final report

Results and Discussion

A detailed summary of the waste fuel composition of each of the six waste shipments used in the tests is given in Table 3. A seventh waste batch composed of a mixture of shipments 4 and 6 was burned and tested.

Five baseline tests (no waste fuel burned) were carried out to determine stack emissions when waste fuel was not being burned. Four of the baseline testing days involved EPA Method 5 testing, whereas the fifth test was a SASS run. The SASS was used to identify PICS and quantify dioxins and dibenzofurans. NO_x, SO_2, TSP, total hydrocarbons, and HCl were measured repeatedly during the program to determine the difference in emissions between baseline operation (no hazardous waste fed to the kiln) and waste fuel burns.

When waste fuel was burned, ten comprehensive tests on the seven waste fuel batches were completed. These included SASS runs on waste batches 3, 4, and 6; and EPA Method 5 runs on seven waste fuel burn tests. An additional fourteen tests were conducted with only POHC and CO monitoring

Table 4 presents the comparisons for particulate NO_x, SO_2, total hydrocarbon, and HCl emissions using the t-test to determine statistically significant difference.

Carbon Monoxide Emissions

High carbon monoxide emissions can be an indicator of inefficient combustion in the cement kiln. During stable kiln combustion, CO emission levels stayed below 10 ppm. However, any process fluctuation or change in kiln variables caused a momentary excursion in CO emissions to levels often greater than 1,000 ppm (0.1%), even during baseline testing.

During start-up of the waste fuel burn, stack CO concentration often changes in the transient period after the waste is turned on. From 0800 hours to 0905 hours, the kiln was not burning waste fuel and CO emission levels hovered at 0-40 ppm, indicative of stable kiln operation. As the waste fuel was introduced, the CO levels rose rapidly beyond 1,000 ppm for approximately 20 min and then returned to levels below 100 ppm as the kiln operation stabilized.

POHC Destruction and Removal Efficiency

Destruction and removal efficiency (DRE) for an incineration/air pollution control system is defined by the following equation:

$$DRE = \frac{W_{in} - W_{out}}{W_{in}} (100\%)$$

where DRE = destruction and removal efficiency, %
W_{in} = mass feed rate of the principal organic hazardous constituent(s) to the incinerator
W_{out} = mass emission rate of the principal organic hazardous constituent(s) to the atmosphere (as measured in the stack prior to discharge).

Concentrations of the POHC's were measured during baseline testing (days

Table 1. *Test Matrix of Waste Feed Rate and Chlorine Content*

Approximate waste feed rate to kiln, m^3/s (gpm)	Percent chlorine in waste, wt %						
	6.5	10.1	18.7	21.4	22.9	32.0	35.1
8.39×10^{-5} (1.33)		x					
9.46×10^{-5} (1 50)	x		x				
1.10×10^{-4} (1.75)			x				x
1.26×10^{-4} (2.00)		x		x			
1.89×10^{-4} (3.00)						x	
2.21×10^{-4} (3.50)		x		x			x
2.71×10^{-4} (4 30)				x			
3.15×10^{-4} (5.00)					x	x	
3.47×10^{-4} (5.50)		x					
3.79×10^{-4} (6.00)		x					

x = Conditions tested.

when no waste fuel was burned) in order to give background or normal concentrations of the POHC's in the exhaust gas. The average background level was then subtracted from the results obtained during a waste fuel burn to arrive at the contribution attributable to the waste burn.

The average DRE for each test run for the POHC's is presented in Table 5. Methylene chloride was destroyed to at least 99.0% efficiency, with the only exceptions being the two tests with waste batch #5, which contained only 1.4% methylene chloride. In general, the lower the mass feed rate of a POHC, the lower the DRE.

Table 2. *San Juan Cement Company Waste Fuel Demonstration Burn Sampling and Analytical Program*

Parameter measured	Sampling method	Analytical method
Stack Samples		
Particulate matter	EPA Method 5	EPA Method 5
Metals on particulate	EPA Method 5	ICAP
Organics on particulate	EPA Method 5	Extractions and GC/MS for principal organics, dioxins, and furans
Opacity	EPA Method 9	EPA Method 9 (on site)
Sulfur dioxide	EPA Method 6	EPA Method 6
Nitrogen oxides	EPA Method 7	EPA Method 7
Carbon monoxide	EPA Method 10	NDIR continuous analyzer
CO_2 and O_2	Integrated bag sample	EPA Method 3 (on site)
Hydrogen chloride	Impinger train	Specific ion electrode
Total gaseous hydrocarbons	Direct to analyzer	Continuous FID
Total chlorinated hydrocarbons	Integrated bag samples	GC/EC (on site)
Three chlorinated species (POHCs)	Integrated bag samples	GC/EC (on site)
Organic compound speciation	SASS train	GC/MS
Ambient Air		
Particulate matter	High volume gas sampler	EPA-Appendix B FR 121 0105
Process Water		
Organics (3 species)	Integrated sample	EPA priority pollutant methodology, GC/MS
No. 6 Fuel Oil		
Btu content	Grab	ASTM D240-64
Chlorinated methanes	Grab	GC/EC
Sulfur content	Grab	ASTM D-3177
Trace metals	Grab	ICAP
Principal organics	Grab	GC/MS
Waste fuel		
Btu content	Grab	ASTM D240-64
Moisture content	Grab	GC/MS
Total chlorine	Grab	ASTM D8081
Total nitrogen	Grab	Kjeldahl
Total sulfur	Grab	ASTM D129
Trace metals	Grab	ICAP
Principal organics	Grab	GC/MS
PCBs and pesticides	Grab	GC/MS and GC/EC
Ash content	Grab	ASTM D-482-IP4
Solid Waste (kiln dust)		
Principal organics	Grab	Extraction and GC/MS
Furans and dioxins		
Chlorine content	Grab	ASTM D-808
E.P. toxicity	Grab	
Furans and dioxins		Extraction and GC/MS
Trace metals		ICAP

Table 3. *Summary of Waste Fuel Analyses for Cemento San Juan Demonstration Burn (volume basis)*

Compound	Batch 1, vol %	Batch 2, vol %	Batch 3, vol %	Batch 4, vol %	Batch 5, vol %	Batch 6, vol %	Batch 4/6, vol %	Density, g/mL	TLV,[c] mg/m³
Water	<1 0	4.1	4.3	8 9	23 0	2 0	NA	1.000	-[d]
Methanol	10 4	7.1	13 9	6.2	10.9	ND[a]	NA	0.7914	260
Ethanol	0 8	3 2	8 6	4.7	16.8	5.6	NA	0.7983	1,900
Acetone	14.2	12.2	11.2	10.5	4.6	2 2	NA	0.7899	2,400
2-Propanol	4.7	5.2	5.3	4.5	3.1	1.6	NA	0.7855	500
Methylene chloride (POHC)	24.4	16.9	12 0	12 1	1 4	5.0	5.1	1.3266	360
Hexane isomers	3.9	3.2	1.8	1.5	ND	1.5	NA	0.6532	-[d]
3-Methylpentane	5 4	4.6	2 7	3.2	ND	3.6	NA	0.6645	-[d]
Hexane	19 8	17.3	7 2	8 5	5.9	15.7	NA	0 6603.	1,800
Chloroform (POHC)	1 0	0.8	3 4	5.4	4 0	0.1	0.9	1 4832	50[f]
Ethyl acetate	4.0	14.0	9 0	6.6	3.5	22.7	NA	0.9003	1,400
Methyl acetate	ND	NA[b]	0.4	<1.0	ND	ND	NA	0.9330	610
Carbon tetrachloride (POHC)	0.8	0 6	1 4	10.2	7 8	0 01	1.5	1 5940	35[f]
Benzene	0.4	0 4	0.2	0.3	0.1	0 05	NA	0 8787	35[f]
Hexamethyl disiloxane	0 1	ND	ND	NA	NA	NA	NA	0.8923	-[d]
Toluene	0 2	0.1	0.02	<0.5	ND	ND	NA	0.8669	375
Acrylonitrile	ND	1.0	1 1	<0.7	1.0	ND	NA	0.8060	5[f]
Methyl ethyl ketone	NA	NA	0.08	1.1	NA	NA	NA	0.8054	590
C_5-benzene isomer	NA	NA	1 33	0.5	0 9	2.2	NA	0 90[e]	-[d]
C_6-benzene isomer	NA	NA	ND	NA	ND	23.8	NA	0.90[e]	-[d]
Sec-butyl ethylbenzene	NA	NA	1 23	1.7	NA	NA	NA	0.90[e]	-[d]
Xylene isomers	NA	NA	0 24	NA	NA	ND	NA	0.87[e]	435
Dimethylphenol isomer	NA	NA	0 04	NA	ND	ND	NA	0.90[e]	-[d]
1,1'-(1,2-ethanediol)bis-4-methoxybenzene	NA	NA	0 23	NA	NA	NA	NA	0.90[e]	-[d]
Unknowns	8.9	9 3	14.3	11 9	17.9	12.9	NA		
PCBs, ppm	<50	<100	<100	<100	<100	<100	<100		
Pesticides[g], ppm	<100	<100	<100	<100	<100	<100	<100		
Properties									
Btu content, Btu/lb	11,188	11,198	11,022	10,099	4,546	13,098	NA		
Specific gravity	NA	NA	0 9948	0.9885	1.0092	0.9163	0 9410		
Chlorine content, wt %	32 0	22 9	21 4	35.1	18.7	6.5	10 1		
Ash content, wt %	0.30	0 20	0.38	0.23	0.31	0.046	NA		

[a] ND = not detected, generally <0.1% by volume. Components were quantified in volume % because external standards were prepared on a volume basis.
[b] NA = not analyzed
[c] Threshold limit value for workplace air
[d] No TLV assigned to this compound or isomer
[e] Estimated values
[f] Suspected or known carcinogen.
[g] As per priority pollutant list.

Table 4. *Comparison of Pollutant Levels Between Normal Operation and Waste Fuel Firing in Cement Kiln No 2, San Juan Cement Company*

Pollutant	Mean loading		Statistical significance at 95% degree of certainty
	Baseline	Waste firing	
Particulate matter	93 ± 65 mg/m³[a] (n=4)	99 ± 65 mg/m³ (n=7)	No significant difference
NO_x	136 ± 83 ppm (n=4)	68 ± 23 ppm (n=9)	Significant difference
SO_2	279 ± 243 ppm (n=4)	450 ± 245 ppm (n=6)	Significant difference
Total hydrocarbons	8.3 ± 2.1 ppm (n=9)	12 7 ± 2.1 ppm (n=7)	Significant difference
HCl	0 82 mg/m³ (n=2)	3.3 ± 1.7 mg/m³ (n=9)	Significant difference

[a] 95% confidence level

Chloroform and carbon tetrachloride were more difficult to destroy than methylene chloride. Also, in most waste batches, methylene chloride was the POHC of highest concentration in the waste. Waste batches #4 and #5 contained the most chloroform and carbon tetrachloride, and the best DRE results for carbon tetrachloride were observed for the test runs on these two batches.

In one instance, run number W6-1 for CCl_4, the W_{out} exceeded the W_{in}. The mass feed rate to the kiln was less than 0.11 kg/hr. The higher mass emission rate observed suggests that CCl_4 could be formed as a product of incomplete combustion from the combustion of methylene chloride and chloroform.

The probable reasons for the low DRE results are: (1) lack of air atomization of the waste fuel, and (2) difficulty of incinerability of highly chlorinated monocarbons and poor combustion of the primary fuel. According to company practice, the waste fuel injection had to match the fuel oil injection pattern in order to prevent flame impingement on inner wall of the kiln and pre-ignition, or back-puffing, of the fuel oil stream. Therefore, methods to air-atomize the waste fuel were not attempted.

Table 5. *Destruction and Removal Efficiencies of POHC's for Demonstration Burn Tests at San Juan Cement Company Kiln #2*

Run number	Methylene chloride	Chloroform	Carbon tetrachloride
W1-2[a]	>99 997	>99.842	99.309
W2-1[a]	99.995	>99.859	>99.996
W3-a	>99.991	99.887	91.043
W3-2	99.960	99 932	96 864
W3-3	99 659	>99.960	98.977
W4-1	98.237	98.592	97 732
W4-2	99.418	99.470	98 122
W4-3	99.461	99.283	99.142
W4-4	99.984	98 975	99.684
W4-5[c]	99.335	99 950	99.069
W5-1[c]	93.292	98 388	99.553
W5-2[c]	96.663	96 099	99 460
W6-1	99.223	-[b]	-[b]
W4/6-1[c]	99.760	95.617	94 129
W4/6-2[c]	99.668	92.171	99 325
W4/6-3[c]	99 564	98.703	94.512
W4/6-4[c]	99.133	>99 737	92.253
W4/6-5[c]	99.474	97 515	95.873

[a]*Waste feed rate was estimated.*
[b]*Not present in waste fuel*
[c]*Stack gas volumetric flow rate of 1619 dscmpm used.*

Other compounds eluted from the GC column at retention times of 0.51 min (CH_2Cl_2), 0.80 min ($CHCl_3$), and 1.01 min (CCl_4). The most commonly seen compound had a retention time (R.T.) of 0.57 to 0.61 min, and a post-test laboratory experiment with duplicate GC conditions tentatively identified it as a trichlorotrifluoroethane. Another compound which was seen in several instances eluted at about 1.1. min and was tentatively identified as trichloroethylene, a likely PIC from chloromethane combustion; 1,1,1-trichloroethane (1.54 min R.T.), tetrachloroethylene (1 68 min R T.), acetone (2.11 min R T.), acetonitrite (2 15 min R.T.), and acrylonitrile (2.16 min R.T.) were never detected by the in-field GC/EC analyses.

The SASS samples collected for chlorinated dioxins and chlorinated dibenzofurans were also analyzed for products of incomplete combustion. Four samples (one baseline and 3 waste burning) were analyzed for PIC's The baseline sample was analyzed, since the cement plant burns fuel oil as its primary energy source. During the program, fuel oil accounted for 87 to 100% of kiln's energy requirement. Products of incomplete *fuel oil* combustion need to be distinguishable from products of incomplete hazardous waste combustion, hence the baseline sample. Three SASS samples were collected during hazardous waste burning representing different feed compositions, feed rates, and operating conditions.

The PIC's which were not detected during the baseline test and may be attributable to hazardous waste burning are Trichloroethylene (100-100,000 mg/hr), Phenol (2.4-11.0 mg/hr), C_2-naphthalene isomers (10-50 mg/hr), and C_3-naphthalene isomers (14-46 mg/hr)

HCl Emissions

Based on the amount of chlorine charged to the kiln in the waste and analyses of HCl in the stack gas, results showed an average removal of 99.7% of the HCl generated by the combustion. In any event, the emissions of HCl were considerably less than 4 lb/hr, the regulatory threshold emission rate for requiring control equipment on incinerators. However, statistical analysis indicates a discernable difference in HCl emissions between baseline and waste burning tests.

One of the objectives of the program was to determine whether polychlorinated dibenzodioxins (PCDD) and polychlorinated dibenzofurans (PCDF) might be found as products of incomplete combustion while hazardous wastes are being fired to the kiln Because chlorinated dioxins and dibenzofurans are believed to be among the most toxic substances to humans, EPA officials required that during the demonstration program, extensive sampling and analysis be conducted for these compounds Thus, a total of 28 different samples were collected for analyses, as shown below.

- 4 SASS train samples (particulates and vapors in stack gas);
- 5 EPA Method 5 samples (particulates in stack gas);
- 11 baghouse dust samples (plant solid waste);
- 8 RCRA extracts of baghouse dust samples (plant solid waste).

Eight samples were taken during baseline conditions and 20 samples were taken during hazardous waste burning operations. The SASS train samples resulted in three sections for analysis: 1) methylene chloride rinses of the sampling probe, teflon line, filter holder, and organic module, 2) combined filter and XAD-2 absorbent resin, and 3) the condensate water removed from the organic module during sampling.

The baseline SASS run (BW-SASS) showed some positive, detectable values of hexachloro-and heptachlorodibenzofuran in the absorbent resin extract, although none could be detected in the other portions of the train. This caused the reported values to be less than the average detection limit for the entire train, which was 3.4 ng/m^3. It is noteworthy that no dioxins or furans were detected in any waste burning SASS samples at a detection limit ranging from 1.6 ng/m^3 for tetrachloro-isomers to 4 9 ng/m^3 for octachloro-isomers.

In the analyses of the particulate catch from EPA Method 5 runs, no detectable quantities of PCDD's were found in any of the particulate samples. In only one sample, run W3-3, 11.0 ng/m^3 of pentachloro dibenzofuran, 26 ng/m^3 of hexachloro-, and 8 ng/m^3 of dibenzofuran heptachloro-PCDF isomers were found. These detectable emissions occurred when the kiln was fed 2.75 x 10^{-4} m^3/s (4.35 gpm) of waste which contained 21.4% chlorine. This corresponds to a chlorine input of 3.5% by weight of total fuel input (fuel oil plus hazardous waste) which resulted in the production of off-spec cement clinker and a potentially kiln-damaging condition. Excessive chlorine in the clinker will lengthen cement set time and reduce strength. The Chlorine Material Balance (CMB) section of the full report describes how this is an intolerable operating conditions for the cement plant. Thus, the generation of detectable quantities of PCDF's occurred only when operating an "upset" or "out-of-control" kiln. Under other conditions, the cement process did not emit PCDF's or PCDD's under any waste burning conditions.

Major Conclusions

Some of the results observed in this demonstration program contradicted results from other cement kiln incineration

tests: for example, lower DRE's, no change in particulate emissions, and significant changes in SO_2 and NO_x emissions. The following conclusions apply only to this particular kiln and the results of this demonstration program.

1. The inability of this kiln to consistently achieve 99.99% DRE (a level which hazardous waste incinerators must demonstrate) of the POHC's is attributed to unatomized waste introduction to the kiln flame and the difficult incinerability of the POHC's. In the past, these compounds (CH_2CL_2, $CHCl_3$, and CCl_4) were employed as fire retardants because they were able to remove hydrogen atoms from the free-radical branching combustion reactions to form HCl. Combustion of chlorinated species containing less chlorine may have resulted in higher DRE's.
2 Chlorinated dioxins and chlorinated dibenzofurans were not produced at detectable levels (1 6 ng/m^3) when the cement kiln was operating normally
3 Less than 0 3% of the chlorine introduced into the cement kiln with the waste is emitted in the stack gas as HCl The majority (99.7%) of the chlorine reacts with the alkaline material in the kiln and is incorporated into the clinker and the baghouse dust.
   At San Juan Cement, approximately 82% of the chlorine fed to the cement kiln appears in the clinker. This may vary at different cement plants, since process feedstock alkalinity (ability to absorb chlorine) varies at each cement plant
4. Achievable fuel savings are a function of the chlorine content of the waste and each plant's ability to absorb chlorine At San Juan Cement, a hazardous waste containing less than 5% will result in at least a 20% savings in fuel costs. Higher fuel savings may be possible for higher chlorine contents at other plants.
5. At this facility, there was no significant increase in particulate emissions due to the burning of chlorinated hazardous wastes.
6 Emissions of sulfur dioxide, total hydrocarbons, and hydrogen chloride increased significantly when waste was burned.
7 HCl emissions rates were below the 4 lb/hr, which is the limitation imposed on incinerators by RCRA, above which additional HCl removal treatment is required.
8 Emissions of nitrogen oxides decreased significantly when waste was burned.

References

1. Lauber, J D., "Burning Chemical Wastes as Fuels in Cement Kilns." Journal of the Air Pollution Control Association, 32(7): 771-777, July 1982.

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The complete report, entitled "Evaluation of Hazardous Waste Incineration in Cement Kilns at San Juan Cement Company," (Order No. PB 84-226 935; Cost: $20.50, subject to change) will be available only from:
National Technical Information Service
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