EFFECT OF FEED CHARACTERISTICS ON THE PERFORMANCE OF EPA'S MOBILE INCINERATION SYSTEM

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ABSTRACT

During the past four years, the EPA Mobile Incineration System (MIS), has processed a wide variety of feeds. Besides the incinerating the hazardous materials for which the MIS was designed, the unit has also incinerated contaminated debris including wood pallets, steel and fiber drums, and plastics. This paper identifies significant physical and chemical characteristics of various feed materials and their relationship to MIS performance. The paper also correlates the effect of these feed characteristics on specific MIS components. Corrective actions taken to mitigate several problem characteristics are presented. The operating experience with the MIS has provided valuable data on the limits of incineration capacity as well as reliability of the unit in relation to various feed stocks. This information is also discussed. The information contained in this paper is directly applicable to field use of mobile and transportable incinerators at Superfund and other industrial cleanup sites.

INTRODUCTION

Under the sponsorship of the Office of Research and Development of the U.S. Environmental Protection Agency (EPA), the Mobile Incineration System (MIS) was designed and constructed to demonstrate high-temperature incineration of hazardous wastes (1). The system essentially consisted of a refractory-lined rotary kiln, a secondary combustion chamber (SCC), and an air pollution control system. These three components are mounted on three separate heavy-duty semi-trailers. Monitoring equipment is carried by a fourth trailer.

The MIS was rigorously tested in Edison, New Jersey, during 1982 and 1983 with PCB-contaminated and other chlorinated organic liquids (2). The system was transported to the Denney Farm site in McDowell, Missouri, in December 1984 for a dioxin trial burn and field demonstration (3,4). A total of 900,000 kg of solid and 81,600 kg of liquid dioxin-contaminated materials was incinerated between July 1985 and February 1986. During 1987, the MIS was modified to double its capacity and to improve its reliability. A second trial burn was conducted on both solids and liquids contaminated with chlorinated organic compounds and PCBs during August and September of 1987 (5). Since 1987, an additional 3,200,000 kg of solids and 31,000 kg of liquids have been decontaminated or destroyed.

Over the lifetime of the MIS, a wide variety of feed materials have been processed. These materials exhibited differences in characteristics that affected the MIS in various ways. Often a particular characteristic or a combination of characteristics would affect the MIS performance adversely. The experiences gained from field operations of the MIS during the past four years have increased the understanding of the interplay of feed characteristics with hardware.

This paper describes the effects of feed characteristics on the MIS performance; correlates various feed characteristics with affected parts of the system; describes actions taken to mitigate the resulting problems; and discusses the limits imposed on capacity and reliability by the various feed characteristics.

FEED CHARACTERISTICS

Both the physical and the chemical properties of the feed determine incineration system performance (6). Important physical properties include: heating value, morphology, density, rheology, ash particle-size distribution and fusion characteristics. Important chemical properties include the composition of the feed as shown by: organic content, organic hazardous constituents, acid forming elements such as sulfur and the halogens, moisture content, and inorganic ash components. These properties can affect the operating parameters, the capacity, and the reliability of the incineration system. Many of these properties are interdependent as far as their effect on the incinerator performance. The manner in which these properties affect the performance of incineration systems, based on the experience with the MIS, is summarized in Table 1.

TABLE 1. PROPERTIES AFFECTING INCINERATION SYSTEM PERFORMANCE

Property	Hardware affected	Operating parameter affected	Effect on performance	Feeds of concern
Heating value	Rotary kiln	Rotary kiln temperature, Flue gas residence time in SCC	Feed capacity, Fuel usage	Plastics, Trash, Wooden pallets, Brominated sludge
Morphology	Feed system, Ash gates		Feed interruptions	Steel barrels, Steel rings, Plastics, Wooden pallets,
Density	Rotary kiln, Corbel	Weight of material held by kiln	Feed capacity	Vermiculite
Rheology	Feed system, Rotary kiln	Frequency of feeding, Ash purity, Kiln rotation speed	Feed capacity	Brominated sludge
Halogen and sulfur content	Quench system, Air pollution control equipment design and operation	Pump cavitation, pH control, Blowdown rate, Particulate emissions	Feed capacity, Caustic usage	Trial burn mixture, Brominated sludge
Moisture	Feed system, SCC	Flue gas residence time in SCC, Rotary kiln temperature	Feed capacity, Fuel usage	Muddy soil, Brominated sludge
Particle size distribution	Cyclone, SCC, Ducts, Wet Electrostatic Precipitator (WEP), Instrumentation	Kiln draft, Particulate emissions Excess oxygen control, Temperature Control	Fouling of ducts, cyclone, SCC, process water system, & Instruments	Erwin Farm soil, Brominated sludge, Vermiculite
Ash fusion characteristics (Determined by chemical characteristics, e.g. alkalis)	Rotary kiln, Cyclone, Ducts, Quench elbow, Instrumentation	Kiln draft, Temperature, Excess O_2 control	Slagging of kiln, Plugging of instruments & downstream equipment	Plastics, Trash Brominated sludge

EFFECT OF HEATING VALUE

Heating value of the feed material affects both feed capacity and fuel usage of the incinerator. As the heating value of feed material increases, kiln temperature can increase and sometimes become uncontrollable. The kiln also requires greater amounts of oxidant to complete combustion and greater quantities of inert material to control kiln temperature. This temperature increase can limit feed capacity. The MIS reached its capacity limit at 1.33 to 1.61 megawatts (MW) heat input to the kiln. Feed materials, such as plastics, trash, wooden pallets, and brominated sludge, had capacity constraints caused by high calorific values. Maximum feed capacities for these materials ranged from 90 kg/hr for pure plastics to 859 kg/hr for brominated sludge as shown in Table 2.

Solid materials with high calorific values cause transient behaviors that sometimes further limit feed capacity. Plastics, trash, and wood ignite almost immediately after they are fed to the kiln. Gases evolved from these materials burn rapidly producing a sharp increase in kiln temperature and a sharp decrease in excess oxygen. Prior to the 1987 modifications, the MIS was extremely sensitive to these transients, which caused many feed stoppages.

After the addition of the LINDE® Oxygen Combustion System (OCS), the MIS response to the above transient behavior was improved, and feed stoppages due to low oxygen were virtually eliminated (7). However, there were still many feed cut-offs caused by excessive kiln temperatures. These were minimized by operating the kiln at the lower end (790°C) of the temperature range, allowed by the RCRA permit, and by using water injection to control kiln temperatures.

For brominated sludge, the behavior of the MIS was somewhat different. Large oscillations of the kiln temperature and excess oxygen level occurred even when the kiln was operated at 790°C. The resulting over-temperatures (greater than 1040 °C) caused feed cut-offs and loss of the kiln burners. Loss of the burners increased the length of the feed cut-off period. The operating changes required to alleviate this phenomenon are described below.

To reduce the amplitude of the temperature excursions, an automatic feed cut-off was introduced into the kiln control system. This stopped feed whenever the kiln temperature exceeded 945°C or the oxygen level dropped below 4% (wet). This action minimized overtemperature incidents, but the oscillation frequency was still large. As shown in Figure 1, about four oscillations occurred per hour. Feed was cut off for approximately eight minutes during each oscillation. Feed rate was limited to 450 kg/hr under these operating conditions.

Observations of the kiln during the oscillations showed that the sludge was not igniting rapidly. Several batches of sludge would be fed by the ram before ignition occurred. After ignition, flame would fill the kiln and oxygen flow and temperature would increase rapidly. After the sludge

TABLE 2. FEED CHARACTERISTICS AND EFFECT OF VARIOUS FEEDS ON MIS PERFORMANCE

Feed material	% of Particles <100 microns (Ash)	Heating value (cal/g)	% Moisture	Organic content (%)	Halogen content (%)	Kiln temp. (°C)	Maximum feed rate (kg/hr)	Limitation on feed	Operating concerns
Denney Farm soil-clay (1985-1986 before mods) 1.24 g/cc density	4.8	47	20	2.5	0.13	871-927	900	SCC res. time, Ram capacity	Jamming of Ram, 3-day SCC cleanout req. every 20 days
(1987-1988 after mods)	"	"	"	"	"	788-815	2275 dry	Overflow of kiln corbel	
Mud + Soil	"	"	>70	"	"	"	1140 mud	Doctor blade jamming	
Mud + Plastics	"	1500	"	"	"	"	680	Doctor blade, Kiln Slagging, Kiln temp. BTU input	3-day kiln cleanout cleanout every 10 days
Erwin Farm soil-silt (1985-1986 before mods)	33.4		20			871-927	900	SCC res. time, Ram capacity	Jamming of ram, 3-day SCC cleanout every 5 days
(1987-1988 after mods)	"	"	"	"	"	788-815	2275 dry	Overflow of kiln corbel	
Mud + Soil	"	"	>70	"	"	"	1140 mud	Doctor blade jamming	
Mud + Plastics	"	1500	"	"	"	"	680	Doctor blade, Kiln Slagging, Kiln temp. BTU input	3-day kiln cleanout every 10 days
Plastics & trash	0	3600-10500	0-10	50-100	0-57	788-815	90-320	Doctor blade jamming	3-day kiln clean out
0.9-2.2 g/cc								Kiln slagging, Kiln temp., BTU input	cleanout every 10 days

(continued)

TABLE 2 (continued)

Feed material	% of Particles <100 microns (Ash)	Heating value (cal/g)	% Moisture	Organic content (%)	Halogen content (%)	Kiln temp. (°C)	Maximum feed rate (kg/hr)	Limitation on feed	Operating concerns
Wooden pallets 0.5-0.8 g/cc	0	3500	20	80	0	900-925	325	Kiln temp., BTU input	Cut into small pieces
Steel barrels	0	0	0	0	0	788-815	82-125	Shredder capability	Dull teeth causes balling and ash gate jamming
Vermiculite	0	0	--	0	0	788-815	364	Ram capacity	
Brominated sludge	86	1470-3400	35-42	15-34	1	900-1035	370-859	Kiln temp., Solids residence time, BTU input.	3-day system clean-out every 12 days, fouling of duct - work between Kiln and SCC, fouling of instrumentation, draft control
Trial burn mixture									
Solids	--	190	19.8	4-5	2.6	800-910	1675-1840	Quench system pump Cavitation at 114 kg/hr organic chloride input	Quench system instability, process water TDS
Liquids	NA	3980-4180	0	100	19.6	" "	66-160		

had burned several minutes, the flames would extinguish and the oxygen flow and temperature would decrease rapidly to complete the cycle of oscillation. It became apparent that steady ignition of the material was required to prevent the oscillations.

The kiln temperature was increased from 790°C to 900°C to provide the necessary energy to evaporate the water and volatile organics so that ignition could be sustained. This operating change was successful in reducing the oscillations to a minimum as shown in Figure 2. Maximum feed rate was increased to 900 kg/hr by the above changes.

For feeds with high heat content such as brominated sludge, the capacity of the MIS is increased by water injection. Due to its high heat capacity, water provides a very effective heat sink. Consequently, when it is used to control kiln temperature, moisture increases the SCC residence time as compared to the use of excess air. Figure 3 shows that the use of water injection can increase capacity by about 20% over the use of excess air at a given SCC residence time. The use of oxygen in the kiln enhances the effect of water injection by allowing further capacity increases. At an enrichment to 40% O_2 in the combustion air, capacity can increase by 60%.

EFFECT OF MORPHOLOGY

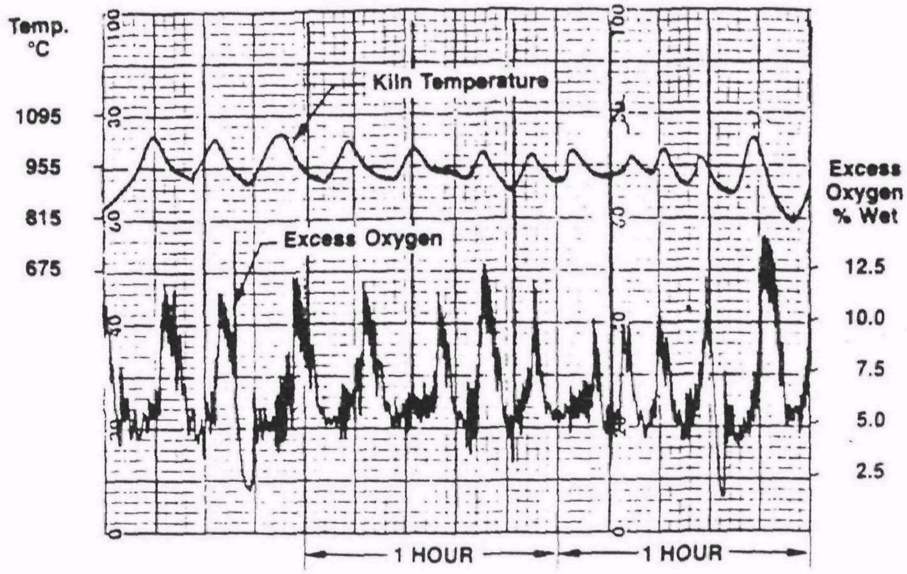
The morphology of the feed material affects the feed system by causing periodic jams. Most of these problems are caused by materials that are poorly prepared by the shredder due to their morphological characteristics. Problem materials consist of wooden pallets, metal drum closure rings, plastics, trash, clothing, and mud (8,9).

The feeding of these materials restricts the MIS capacity. As shown in Table 2, relatively dry soils can be fed at rates up to 2275 kg/hr but the presence of plastics and mud reduces the feed rate to 680 kg/hr.

The shredder is used to prepare the solid feed materials for incineration. For most materials, the shredder works extremely well. However, wooden pallets and metal drum closure rings often cause feed blockages when shredded in the present equipment. While the shredder breaks most of the wooden pallet into 5-cm wood chips, an occasional board will position itself to go through the shredder as a 5-cm wide by 1.3-m long sliver. The same is true for the drum lid rings. The shredder sometimes drags a ring through, straightening it but not cutting it. In each case, plugging of the conveyor, weigh scale, or ram follows. The best solution has been to manually separate and prepare these feed materials by cutting them into small pieces (about 24 cm in length) prior to shredding.

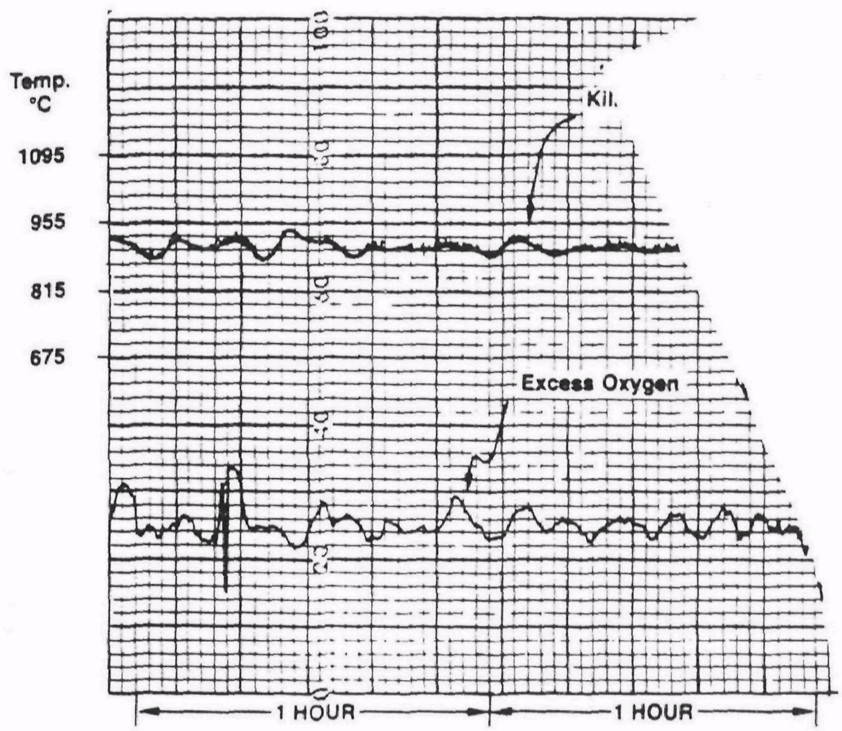
The shredder is unable to handle pipe or thick metal pieces. These must be manually classified, cut to proper size, and placed on the main feed conveyor downstream of the shredder.

The shredder also performs poorly on materials such as plastic, clothing, trash, and mud. These poorly shredded materials often jammed at



NOTES:
- Brominated Sludge
- September 2, 1988
- Before Operating Changes

Figure 1. Oscillations in temperature and excess oxygen in rotary kiln.



NOTES:
- Brominated Sludge
- September 8, 1988
- After Operating Changes

Figure 2. Kiln temperature and excess oxygen after operating change.

the doctor blade or restricting dam that was originally used to level the granular material on the conveyor belt as the belt exits the shredder hopper. The doctor blade worked quite well for granular material but it created large blockages when materials such as shredded plastic, clothing, trash, metal, or mud were fed. A roller has been installed to replace the doctor blade, and this has reduced the number of jamming incidents.

In one instance, the combination of metal and mud damaged the main conveyor belt. The belt was slit for 21 of its 26-m length by a metal shard which was embedded in mud. The clump of mud containing the shard had stuck to the belt, passed under the top-end belt wiper, and lodged in the underside rollers. The top-end wiper was repositioned to provide a more positive wiping action.

Finely granulated material affected the operation of the ram feeder. It would bypass the ram head and collect on the backside. The material on the backside would periodically prevent the ram from fully retracting. A small chain-plug conveyor was installed and timed to convey the bypassed material to the front side of the ram. This solution has worked quite well.

EFFECT OF DENSITY

The density of the feed determines capacity for many feed materials. For feeds of typical densities (1.5 g/cc), such as soils, the maximum feed rates were 2275 kg/hr. The maximum feed rate was obtained at a kiln revolution rate of 1.6 rpm, which gives a typical solids residence time of 30 minutes. For low density materials such as vermiculite (0.096 g/cc), feed rates up to 364 kg/hr were feasible.

The density of the feed determines capacity for many feed materials, because the density of a material is inversely proportional to the volume it occupies, and the ultimate feed rate for a given material is limited by the volume capacity of the kiln. The volume capacity of the kiln is determined by the amount of material that can be held by the kiln without overflowing the corbel. The corbel is an annular lip on the front end of the kiln, which rotates with the kiln. There is a space between the corbel and the front plate of the kiln. When material gets into this space, the seals of the kiln are damaged. The maximum volume that the kiln can hold without spilling over the corbel is about 15% of its total volume.

EFFECT OF RHEOLOGY

The rheology of the material affects either the feed system or the decontamination behavior. Muddy soils, fed to the MIS, formed clumps of material, which were caught by the doctor blade and also would stick to the conveyor belt, weigh scale and ram trough. The resulting buildup would periodically plug various parts of the feed system thus reducing overall feed rates to about 1140 kg/hr. This is approximately 50% of the maximum rates achievable with dry soils. Addition of vermiculite has eliminated the sticking of the muddy material while adding only a small amount to the throughput weight.

The brominated sludge that was fed had a tendency to form balls up to 8 cm in diameter. Since the time required for burnout of a sphere is proportional to the square of its diameter, the large balls require a much longer residence time in the kiln for decontamination. At the normal 1.6 rpm revolution speed of the kiln for soil, small smoking particles would exit the kiln with the kiln ash. This required limiting feed rate to about 450 kg/hr. However, when the residence time of the sludge was increased by reducing the revolution speed to 0.8 rpm, feed rates up to 900 kg/hr were achievable without smoking.

EFFECT OF HALOGEN AND SULFUR CONTENT

Incineration of brominated and chlorinated wastes generate the acid gases hydrogen bromide (HBr) and hydrogen chloride (HCl). These acid gases affect the capacity, the blowdown rates that control total dissolved solids (TDS) in the process water system and the particulate emissions.

A capacity limit of 115 kg/hr of acid-forming organic chlorides was encountered during the 1987 trial burn (5). The capacity limit was caused by pump cavitation in the quench system, which cools the gases exiting from the SCC to about 95^{o}C. The cavitation reduced the quench water flow rate which activates the protective instrumentation resulting in cut-off of the feed and shutdown of the burners. This cavitation was produced by excessive chlorinated waste feed rate as follows: The quench water is treated with caustic solution to neutralize acid gases. Reaction between HCl in the combustion gases and sodium hydroxide (NaOH) in the quench sump produces effervescence. The amount of effervescence increases to violent levels as HCl flow rate increases. The violent effervescence reduces the available net positive suction head (NPSH) of the pump, which causes cavitation at very high HCl loads.

High organic chloride loads also affect particulate emissions through the phenomenon of mist carry-over into the stack. The amount of carry-over is determined by both the HCl loading of the flue gas and the TDS of the process water (5,10).

In tests performed prior to the trial burn, particulate emissions were found to exceed the allowable emissions (180 mg/dscm) by as much as a factor of three. The relationship between particulate emissions and organic chloride loading is shown in Figure 4. Table 3 presents the analysis of the Method 5 particulate filter cakes, which shows that the major portion of the particulate was sodium chloride (NaCl) and sodium hydroxide (NaOH). The emissions were brought into compliance after a mist eliminator was installed.

However, data taken during the 1987 trial burn showed that TDS of the process water also affected particulate emissions. As shown in Figure 5, particulate emissions were proportional to TDS during the trial burn tests. The data shows that operation with TDS at 20,000 ppm adequately controls particulate levels at high chlorine loadings.

The TDS is controlled by adjusting the blowdown rates as follows: For

TABLE 3. RESULTS OF ANALYSES OF METHOD 5 PARTICULATE FILTER CAKES FROM HIGH ORGANIC CHLORIDE LOADING TESTS OF MIS

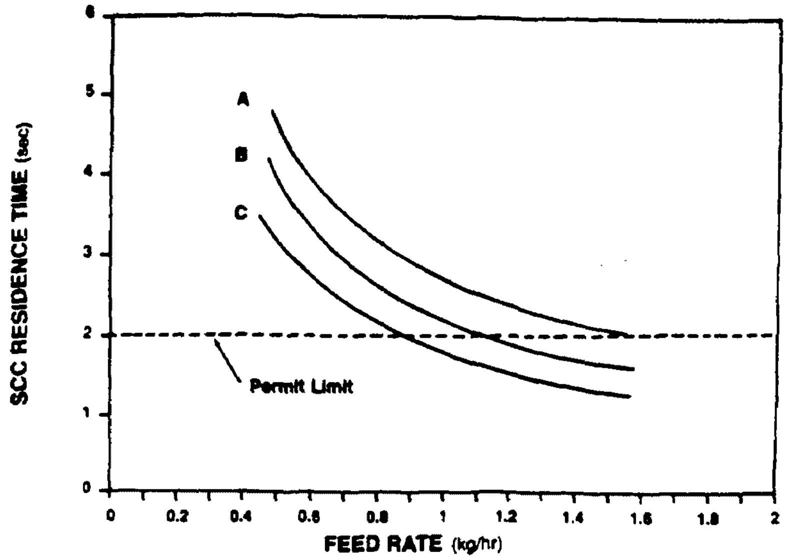
Test Description	High Chloride * without mist eliminator	High Chloride ** with mist eliminator
Date (1987)	6/18-19	7/20
	(weight in grams)	(weight in grams)
Total particulates	0.3412	0.0524
Iron (Fe)	0.0202	0.0057
Chromium (Cr)	0.0022	------
Sodium (Na)	0.1560	0.0175
Chloride (Cl)	0.1367	0.0200
Aluminum (Al)	------	0.0022
As Sodium Chloride (NaCl)	0.2253	0.0329
Remaining Na as Sodium Hydroxide (NaOH) (Excess caustic)	0.1174	0.0079

* Organic chloride loading = 71.5 kg/hr
** Organic chloride loading = 83.4 kg/hr

TABLE 4. RESULTS OF ASH DEPOSIT ANALYSIS FROM MIS CYCLONE RISER DUCT

Analyte		Reported as	Amount (wt. %)	Analytical technique
Silicon	(Si)	Silicon Dioxide	25.6	X-ray
Aluminum	(Al)	Aluminum Dioxide	8.5	X-ray
Titanium	(Ti)	Titanium Dioxide	0.3	X-ray
Iron	(Fe)	Ferric Oxide	5.0	X-ray
Calcium	(Ca)	Calcium Oxide	36.7	X-ray
Magnesium	(Mg)	Magnesium Oxide	1.5	AA
Sodium	(Na)	Sodium Oxide	0.4	AA
Potassium	(K)	Potassium Oxide	0.4	X-ray
Sulfur	(S)	Sulfur Trioxide	21.0	X-ray
Phosphorous	(P)	Phos. Pentoxide	0.5	X-ray

AA = Atomic Absorption Spectroscopy



NOTES:

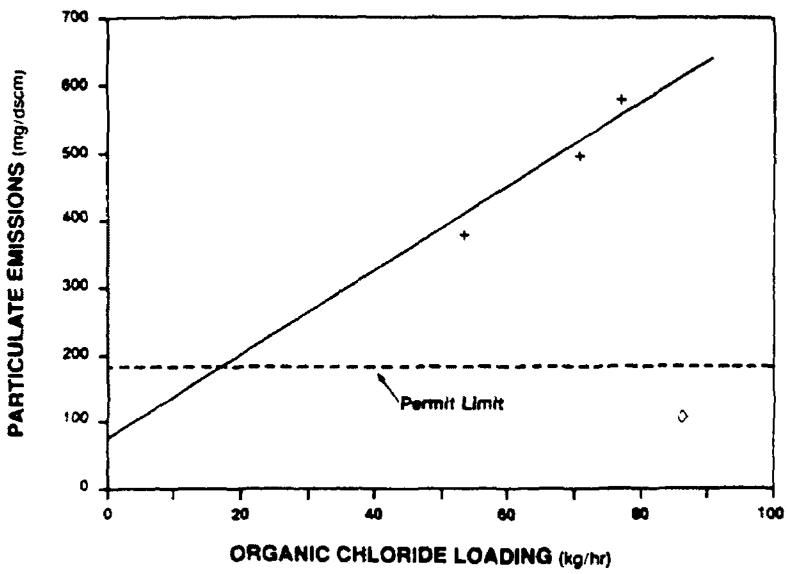
Solid Feed Heating Value	1.50 Kcal/g
Kiln Temperature	925°C
SCC Temperature	1200°C

A – Water injection using 40% oxygen-enriched air for combustion

B – Water injection using air for combustion

C – Air cooled using either air or 40% oxygen-enriched air for combustion

Figure 3. Effect of cooling media on SCC residence time.



NOTES:

+ Before Addition of Mist Eliminator

◇ After Addition of Mist Eliminator

Figure 4. Effect of organic chloride loading on particulate emissions.

a chlorinated waste 1.65 kg NaCl is formed per kg Cl in the waste. To maintain the TDS at 20,000 ppm, 82.4 kg of process water must be drawn from the system for every kilogram of Cl processed. This illustrates that the acid content determines the required process water blowdown rate.

EFFECT OF MOISTURE

Moisture content affects incinerator performance and can adversely affect rheological behavior as described above. Depending upon the heat content of the waste, moisture can either improve or impede incinerator performance.

When using feeds with high heat content moisture acts as a heat sink to control kiln temperatures.

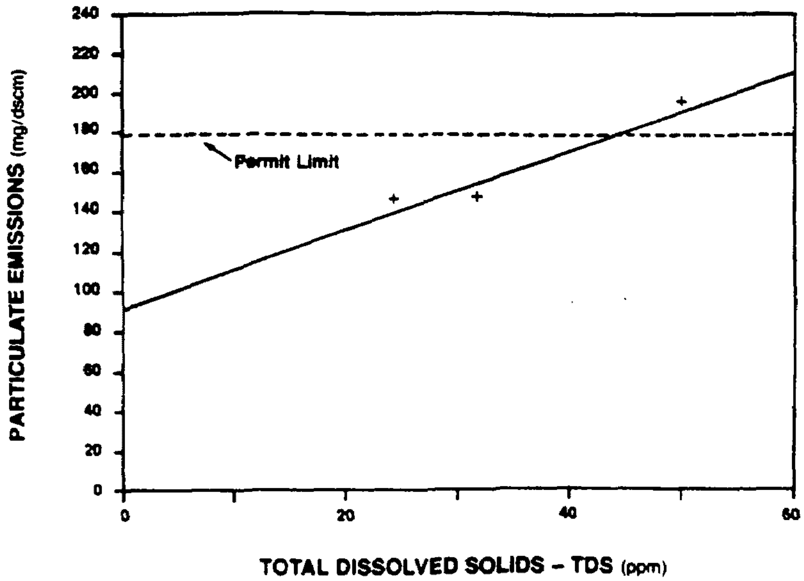
Conversely, when using feeds with low heat content, moisture increases auxiliary fuel requirements and decreases SCC residence time causing a capacity debit. The effect of moisture on SCC residence time is shown in Figure 6.

EFFECT OF PARTICLE SIZE DISTRIBUTION

The particle size distribution of the ash generated from the waste determines the amount of particulate carry-over from the rotary kiln to the rest of the system. The importance of this characteristic can be demonstrated by the MIS experience with Denney Farm soil and Erwin Farm soil. As shown in Table 2, Denney Farm soil is much coarser than the Erwin Farm soil. Up to 25% of the Erwin Farm soil would carry over from the kiln to the SCC. This caused a rapid buildup of solids in the SCC. The solids buildup necessitated a 70-hr shutdown for removal of the slag after each 96 to 120 hours of operation (45,000 kg of soil processed). The behavior of the silt caused the unit to be unavailable for operation an average of 40% of the time due to the need to clean out the SCC. On the other hand, the unit could process the coarser Denney Farm soil for about 600 hours (270,000 kg of soil processed) before a shutdown for slag removal from the SCC was required. The unit was unavailable for 10% of the time due to SCC clean-outs with the coarser Denney Farm soil. In both cases, the buildup of solids in the SCC significantly reduced the availability of the incinerator.

The problem was mitigated in 1987 when a cyclone was added, between the kiln and the SCC, to remove the fines carried over from the kiln. The system operated over a three-month period and processed over 500,000 kg of solid material without requiring a shutdown for slag removal from the SCC.

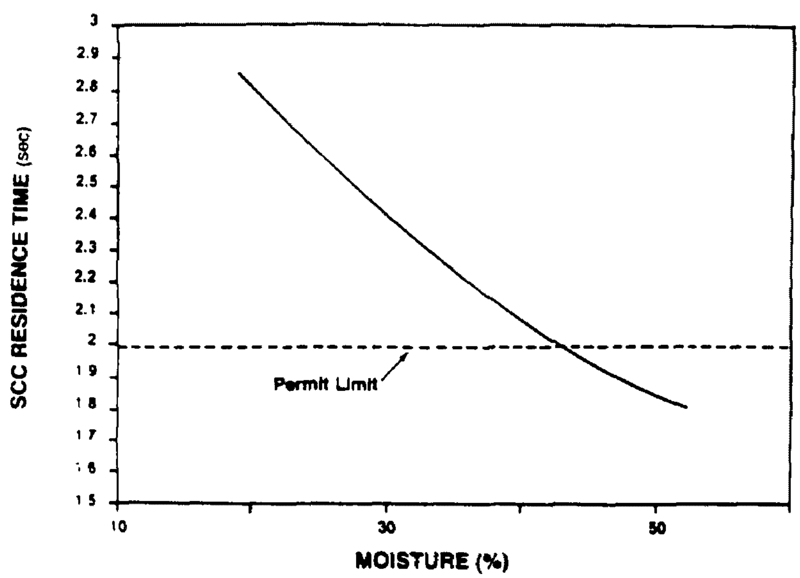
Although the cyclone has alleviated the solids buildup in the SCC, fine particulates still have caused problems with the operating instruments. The large number of fine particulates associated with brominated sludge fouled the kiln oxygen meter and the SCC thermocouple about once every eight hours. This increased the number of over-temperature incidents in the rotary kiln, caused the incinerator feed cutoff to actuate due to a false SCC low temperature measurement, and increased the fuel flow to SCC



NOTES:

Solids Feed Rate	1800 kg/hr
Liquids Feed Rate	60-160 kg/hr
Organic Chloride Feed Rate	50-74 kg/hr

Figure 5. Effect of TDS on particulate emissions.



NOTES:

Solid Feed Rate	1820 kg/hr
Kiln Temperature	925°C
SCC Temperature	1200°C
30% Oxygen-Enriched Air	

Figure 6. Effect of feed moisture content on SCC residence time.

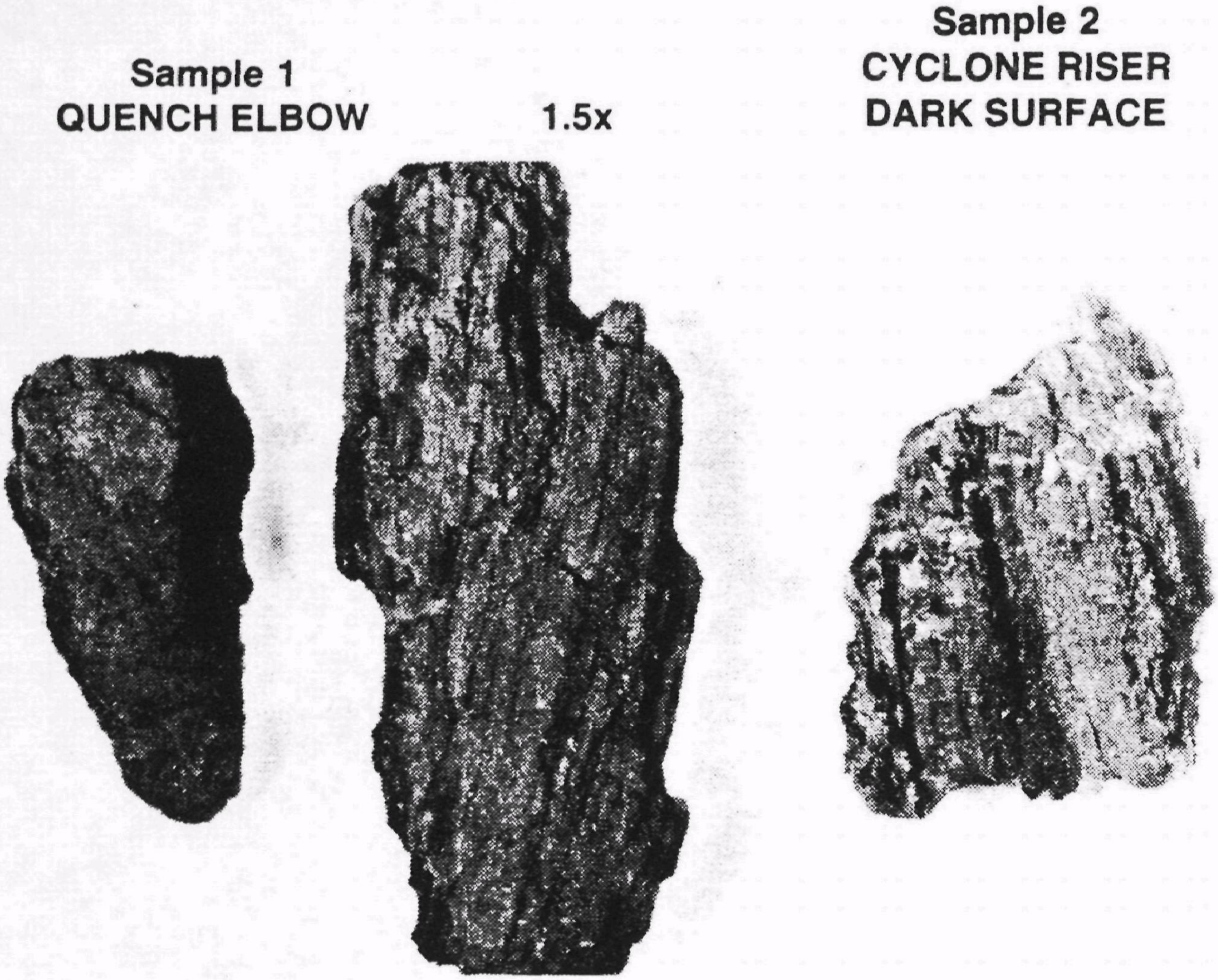


Figure 7. Macrophotograph of samples from Quench Elbow (1) and Cyclone Riser (2).

Figure 8. SEM photomicrographs of the cross section of the deposit from the Cyclone Riser.

burners. The thermocouple problems have been eased by changing the thermocouple location and using a thermowell rather than an aspirating thermocouple. No satisfactory solution has been found for the kiln oxygen measurement.

EFFECT OF ASH FUSION CHARACTERISTICS

The ash fusion characteristics of some feed materials caused the formation of hard slag deposits in the kiln; consolidated deposits in the ductwork between the kiln and cyclone, between the cyclone and SCC, and in the cyclone exit tube; and consolidated deposits in the SCC exit venturi. The ash fusion characteristics are determined by the chemical composition of the ash.

Ashes containing elements such as sodium (Na) and potassium (K) have low slagging temperatures. Ashes from plastics, glasses, wood, and other components of trash are rich in these compounds. The increased slagging tendency of trash was experienced in the rotary kiln, which required a system shutdown about every ten days to remove the slag build up caused by incineration of trash.

Ashes containing significant quantities of calcium (Ca), iron (Fe), sulfur (S), or phosphorous (P) have moderate slagging temperatures. Although brominated sludge, containing both Ca and S did not slag the kiln, the ash produced a consolidated deposit, shown in Figure 7, which fouled the ductwork between the kiln and the SCC. A consolidated deposit also occasionally formed in the quench elbow upstream of the quench nozzles. This fouling necessitated a system shutdown about every twelve days to remove the deposits.

Samples of the deposits were analyzed to determine the mechanism of deposition. More details on this topic are provided in reference 11. The deposit mechanism was found to be similar to those operative in boilers fired with subbituminous coal. The deposits were formed by sintering of calcium sulfate ($CaSO_4$) in the temperature range of 870 and 980^oC in an ash containing 14% $CaSO_4$, 23% calcium oxide (CaO), and about 2.5% sodium oxide (Na_2O). The formation of fused calcium silicates as a result of the decomposition of $CaSO_4$ in the presence of quartz and aluminosilicates between 870-980^oC was also an important factor in the mechanism of deposition. A photomicrograph showing the sintering is presented in Figure 8. Table 4 gives the bulk composition of the deposit from the cyclone riser.

Most ashes consist mainly of aluminum (Al) and silicon (Si), which generally have good fusion characteristics (fusion temperatures above 1650^oC). Both the Denney Farm and Erwin soils were composed mainly of SiO_2 and Al_2O_3. The lack of slagging and of troublesome deposits experienced with the MIS when processing these materials demonstrates these good fusion characteristics of Al and Si.

CONCLUSIONS

The paper has shown how various feed characteristics affected the MIS performance. Concerns stemming from these effects have been discussed and are summarized below:

- Increased heating value of the feed often reduces the fuel requirements of the unit. However, as heating value increases control of kiln temperature becomes important and feed capacity can be restricted. Water injection can increase kiln capacity under these conditions. The experience with the MIS also shows that operating conditions must be adjusted to insure rapid ignition of solids that have high heating value.

- Proper feed preparation is very important for maximizing throughput. Problem materials should be sorted out and specially prepared prior to feeding.

- Rheology can affect either the feed system or the decontamination behavior.

- Increased halogen content increases mist formation and can increase particulate emissions. TDS of process water can also be important in controlling particulate emissions.

- Moisture content increases fuel requirements and can create feeding problems for muddy feeds.

- Materials containing large quantities of micron-sized particles can foul critical instruments and decrease reliability of the system.

- Ash fusion characteristics can cause formation of slag or other deposits in various parts of the system. This also decreases reliability. The processing of pure trash produced slagging problems in the rotary kiln.

Most of this experience is directly applicable to other mobile or transportable incinerator systems.

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