

**Air Pollution Control for Waste to Energy Plants -
What Do We Do Now ?**

**Mark R. Sankey
Research-Cottrell**

**US Highway 22 West at Station Road
Branchburg, NJ 08876-3599**

**Anthony Licata
Licata Energy & Environmental Consultants, Inc.
345 Concord Road
Yonkers, NY 10710-1848**

INTRODUCTION

Recent regulations require owners and operators of many waste-to-energy facilities to upgrade their existing air pollution control equipment. While it makes sense for some of these to install systems which meet BACT (Best Available Control Technology) standards, for others such a route could be less than the best choice. For the purpose of this discussion we will consider BACT standards to be at least 90% SO₂ reduction and 95% HCl reduction. For SO₂, this is higher than required by new source performance standards (NSPS) as defined in December, 1995 and summarized in Table 1. An air pollution control system to meet BACT standards generally includes a spray dryer injecting lime slurry, addition of other reagents for control of mercury, etc., and use of a fabric filter. For many units, a less expensive upgrade which seeks only to meet the latest regulatory requirements might be optimum. In some instances, this could be the difference between a plant continuing in operation, or closing. Political uncertainties and the current economic climate make these decisions very difficult.

OVERVIEW OF THE SITUATION

Review of Regulations

After significant discussion and review, the latest federal regulations for waste-to-energy plants were promulgated in December, 1995. On the federal level guidelines were issued for existing municipal waste combustors. States have the authority to define their own requirements, but these must satisfy the guidelines as a minimum. A summary of these guidelines is included as Table 2. For new plants, the requirements are more stringent than the previously promulgated regulations. Actually, they represent a codification of typical existing permits. Spray dryers and baghouses will be the most commonly installed equipment for these with lime stoichiometry high enough to ensure the required removal rates of acid gases. The requirements for dioxins, furans, and heavy metals are generally attainable with such an equipment installation. The mercury emission specified is the same for all cases. Its evident that the developers of the guidelines sought to mitigate the financial hardship on smaller plants and those with Electrostatic Precipitators (ESPs) instead of fabric filters. One could also surmise that they did not believe the benefits of more thorough changes would justify the costs.

The most significant differences between the NSPS and existing plant guidelines are in the area of acid gas and dioxin/furan emissions. Recent litigation has brought more uncertainty to the situation. The lines of demarcation based on plant rather than unit size were successfully challenged in U.S. District Court. On March 21, 1997 the District Court granted EPA's motion to remand NSPS and Emission Guidelines for MWC greater than 250 tpd and vacate the standards for units 250 tpd or less. This ruling by the Court means that emission standards for large units remain in effect and EPA will have to redraft and promulgate the standard for small plants. The larger existing Municipal Waste Combustors (MWCs) will have to be in full compliance by December 19, 2000. While the compliance strategy for the larger existing units is now clear, it still makes sense to review equipment capabilities and potential modifications on the basis of the emission limits as shown in Table 1 and plan for upgrades now.

Equipment Capabilities

We have made some mention of the equipment typically used to achieve the performance levels referenced. As further background, we can consider typical performance levels guaranteed with use of ESPs as compared with fabric filters. Early in the development of acid gas removal systems for waste to energy plants, there were trends to use ESPs following a spray dryer. This was especially strong in Japan. Generally, these were applied where required removal rates were relatively low. Operating results from this market and elsewhere show that this equipment arrangement can perform above the requirements for small and large existing plants. Where fabric filters inherently have the ability to perform better than ESPs for collection of acid gas, there is potential for existing ESPs to be retained while maintaining acceptable performance. This is predicated on ESPs being of sufficient size. If an ESP is too small it may be sensible to increase the size or make other modifications rather than replace the unit with a fabric filter. Of course, the ESP must be capable of meeting the particulate emission limit as well as the maximum opacity of 10%. We will address modifications and other performance enhancements for ESPs in detail later.

Dry injection of lime or sodium based sorbents is used in some facilities for acid gas control. Generally this is followed by a fabric filter. For such existing installations classified as small units, no change should be required. For large units, the only necessary addition should be cooling equipment to bring the temperature to the level needed to optimize acid gas neutralization. This will usually mean installation of a water spray or quench tower. In duct quenching is not a reliable means of cooling in our opinion.

Some installations which only have ESPs may be able to achieve required performance with dry injection. Certainly higher amounts of lime are needed than with a fabric filter. Also operation at an optimal temperature is more critical. Since in most cases a quench tower is required, we would expect additions of spray dryers to be more common. Such a step also allows future upgrade of the ESP.

REVIEW OF LIME TECHNOLOGY

Technical Issues

For MWC air pollution control systems, lime is the principal sorbent used to control acid gas emissions. The authors have observed that many otherwise astute managers and administrators in the MWC industry are often not entirely aware of the unique economics, properties and reactions associated with the use of lime. We have seen numerous applications where quicklime was selected over other sorbents, most notably hydrated lime without any up-front assessment performed to fully analyze the technical and economical impacts of the selection. We considered it appropriate to review the technical aspects of the use of lime.

Calcium oxide (CaO) is called “pebble lime” or “quicklime”. CaO is not very reactive in absorbing acid gases at post combustion temperatures and conditions that exist in MWC facilities and has to be converted into the hydrate form to be reactive in scrubbing systems. The hydrated lime [Ca(OH)₂] has been demonstrated to remove acid gases in high temperature applications such as furnace injection. Hydrated lime is highly reactive and is made from CaO by adding controlled amounts of water in a hydrator to produce a powder. The resulting material has large reactive surface area with a mean particle size of 5 microns.

Pebble lime is slaked to form a slurry. CaO is converted to Ca(OH)₂ in the slaking process in which four parts of water are added to one part of CaO to form Ca(OH)₂ in a slurry that contains about 25% solids. The term slaking applies to the combining of varying proportions of excess water and quicklime, which yields a milk-of-lime, a lime slurry, or a viscous lime paste. This conversion requires two simultaneous steps that take place in the slaker. The first step converts the CaO into Ca(OH)₂ hydrate. The second step converts the hydrate to a slurry by mixing 3.96 lbs. of free water with one part hydrate (1.32 lbs) that results in a 25% solids slurry (5.28 lbs).

Hydrated lime can be introduced into the flue gas stream using several methods as follows:

- injection into the flue gas in a dry form;
- injection into the flue gas in a dry form after the gas has been conditioned by the addition of water which serves to increase the moisture content of the flue gas and to concurrently reduce the flue gas temperature; or
- injection into the flue gas as a wet slurry.

Quicklime is delivered to most sites as a “pebble” nominally 3/4" in diameter. In order to be reactive, quicklime has to be slaked and converted into a slurry form. Slaking is manpower intensive for most plants and is a high maintenance process. There are also capital costs associated with the purchase and replacement of equipment. Slaking is as much an art as it is a science.

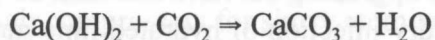
Many factors affect slaking including:

- reactivity of the lime
- lime quality
- particle size
- water quality and temperature
- distribution of water, and
- level of agitation

In order to analyze the cost differential between use of pebble and hydrated lime, we need to determine the relative usage. Please see Table 3 for details of this calculation.

A typical MWC would require either 12.9 lbs of hydrated lime or 10.5 lbs of pebble lime per ton of MSW burned to react with all of the SO₂ and HCl emitted. By ratio of the above, we can see that 23% more hydrated lime than quicklime is required to achieve the stoichiometric reduction of MWC acid gases. Both hydrated lime and quicklime sell for about the same unit price. However, when you purchase hydrated lime you are buying 32% water which reduces the actual calcium content. As you can see for the above, it is the Ca to SO₂ or HCl ratio that is important.

In actual applications, this theoretical balance never occurs. Due to the inability to provide perfect contact between all of the lime and the acid gas molecules, excess reagent is required in the process to achieve SO₂ and HCl emissions of less than 25 ppm. In addition, several secondary chemical reactions take place that also use some undefined portion of the lime. For example, lime will react with carbon dioxide in the flue gas as follows:



There is also a positive reaction that occurs. The presence of HCl in the flue gas actually improves the lime's capture of SO₂. This reaction has been discussed in numerous papers.

The ratio of the actual amount of lime used to the theoretical amount required is called the stoichiometric ratio. A typical MWC equipped with a spray dryer and an ESP will require about 35 lbs of pebble lime per ton of MSW while a MWC with a spray dryer baghouse will require about 20 to 25 lbs per ton to meet the current NSPS standards of 25 ppm of HCl (a 95.3% reduction) and 30 ppm of SO₂ (an 85.8% reduction). These values may vary for particular plants, depending on temperature and moisture conditions in the system. Based on the typical values cited, the stoichiometric ratio for a plant with an ESP would be:

$$35 \div 10.5 = 3.33$$

Typical air pollution system requirements developed by Dravo Lime's testing program to control acid gas emission to the NSPS requirements are as follows:

Technology	Hydrated Lime		Quick Lime	
	Lbs of Ca(OH) ₂ per ton of MSW	Stoichiometric Ratio	lbs of CaO per ton of MSW	Stoichiometric Ratio
Spray dryer/fabric filter	24	1.86	20	1.90
Spray dryer/ESP	35-40	2.71-3.10	30-35	2.85-3.33
Dry injection/fabric filter	50	3.87	n/a	
Conditioned dry injection/fabric filter	24	1.86	n/a	

These results are shown to compare results of hydrated lime versus quicklime and do not necessarily reflect actual MWC plant operation.

Economics of Lime Technologies

As previously stated, in order to obtain equivalent levels of acid gas removal, it requires more hydrated lime than quicklime which results in an increased operating expense. Quicklime, however, requires more capital equipment, more operational and maintenance personnel, and a higher level of skill. As a rule of thumb, smaller plants or plants that require upgrading but have less than 20 years of expected life may find that a dry lime injection or conditioned dry injection of hydrated lime may be less expensive. The following analysis was made to compare operating cost for applying hydrated lime (conditioned dry injection) vs. Quicklime (lime slurry) (see Table 4).

The analysis in Table 4 was based on the following inputs:

- Three plant sizes were selected: 250 T/D, 500 T/D and 1,500 T/D. Each plant has an annual capacity factor of 85% and a 20 year life expectancy.
- The delivered price of both hydrated lime and quicklime is \$80.00 per ton.
- The quicklime (slaker and slurry system) requires one person about half time for operations and maintenance which results in a personnel cost of \$30.00 per hour inclusive of all overheads and benefits. Alternatively, the hydrated lime system requires about half as much personnel time resulting in a cost of \$15.00 per hour on the same basis.
- 23% more hydrated lime is required than quicklime to meet the emission standards. For this analysis, we used a factor of 25 lbs of quicklime per ton of MSW burned and 30.7 lbs of hydrated lime per ton of MSW burned.

SPRAY DRYER / FABRIC FILTER SYSTEMS

A spray dryer followed by a fabric filter has become the standard approach to air pollution control at MSW plants in the United States. As we have mentioned, this has resulted from the regulatory requirements and determination of lowest fixed cost. We felt this presentation would be incomplete without addressing the scenario of a backfit of such a system. Based on a 3 train installation, with total plant capacity in the range of 750 to 1000 tons per day (TPD) and supply of one common lime storage, preparation, and pumping system we reviewed recent budgetary pricing. For a refractory type furnace with high excess air usage, the result is a cost of about \$10,000/TPD of capacity. For a water walled furnace with lower excess air and thus lower gas flow rate, the cost is about 10% less or \$9,000/TPD. These costs are also based on use of a dual fluid nozzle atomization system including compressors. While these cost ratios include installation, costs for demolition and other site work have not been included.

Operating costs will vary somewhat depending on the acid concentrations in the flue gas resulting of course from the make up of the waste burned. Based on actual industry experience, pebble lime usage can vary from roughly 20 to 30 lbs./ton of waste burned. Actual usage can vary because the slurry feed rate can be varied based on actual flue gas concentrations. As well as SO₂ monitors which are commonly in use today, HCl monitors have proven reliable. Use of such a signal could add a measure to reagent savings. We estimate power usage for a complete spray dryer and fabric filter system to be about 10 kWh/ton of garbage burned. This includes power to run air compressors for slurry atomization.

In many cases there is not a need to replace the particulate collection device, but addition of a spray dryer is the best approach. With existing ESPs, this is an approach which can keep a plant in compliance, especially for units smaller than 250 TPD.

SPRAY DRYER BACKFITS

For a variety of circumstances including existing equipment, plant layout, desire for higher performance, and more stringent state regulations, plants may choose to add spray dryers to ESP or fabric filter systems. As we have mentioned, a quench tower can often do the job. Where some tower designs can only accommodate water spray, designs which could easily handle use of lime slurry in the future should be considered. Without getting sidetracked to detailed analysis and comparisons, rotary atomizer and dual fluid nozzle designs are available. Conversion of quench towers to spray dryers is favored with spray nozzles which have been used extensively for quenching. Upflow and downflow designs are also variations which owners will encounter when investigating spray dryers. These differences impact design, capital cost, and operating expenses and are worth understanding, but it is not our purpose to do that here.

As with any backfit, there are layout issues to be considered. Room for the basic tower diameter plus inlet and outlet ductwork must be available. A rule of thumb for layout requirements would start with calculation of the tower outlet gas flow at 285°F. Evaporated quench water must of course be included. Various tower designs and manufacturers use differing design velocities, but an upflow, dual fluid nozzle design would have velocity in the range of 5.5 to 6.5 feet per second. Inlet and outlet duct velocities of 60 feet per second are typical. For a unit capacity of 250 TPD, an upflow tower would be about 15 foot diameter.

Costs for backfits will vary with size and layout difficulties. There are situations where existing silos or other equipment can be reused and reduce costs. Availability of compressed air for dual fluid atomization is also an important factor. For a two unit plant with total capacity of 500 TPD, costs for a spray dryer backfit will range from \$5000 to \$6000/TPD of capacity. This covers installation, a complete pebble lime storage, slaking, and pumping system and compressors.

DRY INJECTION

Dry injection has many potential uses for upgrading pollution control systems. Related to acid gas removal, injection of dry lime has been demonstrated to provide acid gas removal at the levels now required for small plants. Sufficient moisture must be present, but this should not be any problem for MSW applications since proper temperatures for reaction are usually achieved with water spray cooling. For installations where this is not available, a quench chamber must be added. For future performance upgrade by addition of lime slurry, a tower design which would permit future use of slurry could be considered. This technology works best when followed by a fabric filter but, with proper gas conditioning it can also be effective with ESP's.

While past practice has followed a trend of using spray dryers with lime slurry produced by on-site slaking, our discussion of lime technology shows potential advantages of using dry lime injection. This is a current trend in Japan. The problems and costs associated with slaking and handling of slurry are avoided. It is well established that when operating at the same conditions of temperature and moisture upstream of a particulate collection device, acid gas removal levels are about the same whether using lime as slaked slurry from pebble lime, or lime as dry hydrated reagent injected into the gas stream. Experience indicates a slightly higher lime usage for dry injection than for spray drying with slurry. This increase is about 10 to 15%. We attribute this to the more favorable reaction environment when slurry is "drying" and the acid gas is exposed to the lime in a "wet" environment.

There are a variety of means available for injection. Some manufacturers use specially designed vessels to promote good mixing of reagent with the acid gas. In other cases, lime has simply been introduced through a pipe into the ductwork. The desired effects are rapid, intimate contact of acid and lime. Turbulent gas flow zones can be developed to produce this. Another important aspect is treatment time. The longer the contact period, the better the reaction. We expect that some reaction occurs in the baghouse inlet section as the gas is dispersed to the filter bag surface.

The filter cake is the final area where the reaction can occur. The longer the lime is available here for reaction, the better the utilization, and the lower the stoichiometric ratio and the operating cost. Here the term utilization refers to the extent the lime is used in reaction. Minimizing pressure drop through the cake and maintaining long cycles between cleaning help this process. Various types of cake modifiers have been used to facilitate this. Tesisorb is the name of one family of such materials. These can be fed to the system along with hydrated lime if convenient. The resulting thicker, yet more porous filter cake also provides a better bed for acid gas neutralization. Sizing fabric filters with appropriate air to cloth ratios is important. Generally, we use 2.5 net (including reverse air) for reverse air systems and 4.0 net for high pressure pulse jet systems. Net is defined as the condition with one fabric filter section off line.

Other additives can also be delivered to the system in this area. This can include activated carbon for mercury emission control or, as discussed below, Sorbalit. Some systems call for use of recycled ash which is also introduced dry.

RELATED CAPITAL COST SAVING TECHNOLOGIES

Key components of EPA's regulatory efforts for MWC's have been directed at controlling emissions of mercury and dioxins. There are a number of technologies that can reduce emissions of these pollutants, however, the predominant technology presently used employs activated carbon as the adsorbent medium. Carbon-based adsorption technologies include moving carbon bed filters; dry carbon injection, carbon slurry injection; and Sorbalit and Sorbalime.

Sorbalit/Sorbalime is a system for controlling emissions of acid gases, mercury, and organics in a single application. The sorbent component of the technology is produced by mixing lime, either calcium hydroxide (Sorbalit) or calcium-oxide (Sorbalime) with surface-activated substances such as activated carbon or lignite coke and sulfur-based components in a proprietary process. Sorbalit can be produced with carbon contents ranging from .5 to 65% depending on the technical and economic requirements of each facility.

Sorbalit/Sorbalime replaces the normal lime used at a plant either dry injection or milk-of-lime slurry. The key economic feature of Sorbalit/Sorbalime is that in most applications, no additional capital equipment is required while additional equipment is required for the injection of carbon in both a dry or slurry injection system. Field testing to date indicates that the amount of total carbon required by the Sorbalit process to meet regulatory standards is about half that needed by traditional carbon injection methods.

Conditioned Dry Inject and Fabric Filter Test Results

There are a number of MWC plants that were built in North America which employ a dry injection followed by a fabric filter. One such plant is the 440 T/D plant in Peel, Ontario, Canada which went online in 1992. This plant uses a quench tower to lower the boiler exit temperature from 260°C (500°F) to 160°C (320°F). The quench tower is followed by a dry lime system and a fabric filter. The Peel facility was meeting all of their existing permit conditions, however, they wanted to comply with Ontario's Guideline A-7 which is applicable to new facilities. In order to meet the A-7 Guideline, they would have to reduce their mercury emissions. The facility was also meeting the dioxin limits but was looking for additional margin and control.

A test program was conducted at the Peel facility where Sorbalit with a 4% carbon-based formulation replaced their normal hydrated lime. It was not possible to test the boiler outlet gases, so the test program was set up to measure the stack emissions comparing hydrated lime and Sorbalit. The test clearly indicates that Sorbalit reduced the Dioxin emissions by an order of magnitude and brought the mercury emissions into compliance with the proposed Ontario Guideline A-7. The summary of the test results will be found in Table 5.

Spray Dryer and ESP Test Results

The quicklime-based product, Sorbalime, was tested at a U.S. based MWC that was equipped with a spray dryer and an ESP. In this program, Sorbalime replaced the regular quicklime that the plant slaked for acid gas control. For this operation, no capital equipment was required and no changes were made to the plant operations. Prior tests at the facility had indicated that the spray dryer/ESP removed approximately 40% of the Hg emissions and 80% of the dioxin emissions. The Sorbalime test showed that existing spray dryer/ESPs can be upgraded to meet the EPA proposed standards without a major retrofit. The summary of the test results will be found in Table 6.

PRECIPITATOR UPGRADE APPROACHES

Rebuilds

If an ESP Owner intends to keep that unit in service, he needs to be sure it is in peak operating condition. A thorough structural and operational inspection should be made to determine any deficiencies. Some rebuilding or parts replacement may be needed.

Corrosion can be a serious problem for ESPs in MWC applications. Material and structural degradation is a significant cause leading to replacement of ESP internals. However, operational problems and need to enhance performance have also led Owners to consider some measure of rebuild. A fairly common practice in other industries is replacement of internals and casing repairs to deal with these sort of problems. Avoidance of corrosion requires elimination of inleakage, proper insulation systems and control of operating conditions. Where a quench chamber is upstream of an ESP, or fabric filter, it is imperative that complete evaporation be maintained.

Installation of rigid discharge electrodes can avoid shutdown of ESP sections due to breakage of wire electrodes or other similar high voltage system components. Such a replacement may require alteration of collecting electrode spacing, or use of different collecting surfaces. Interelectrode spacing, configuration of electrodes, and orientation of discharge electrodes with collecting surface profiles all affect electrical operation and orientation of discharge electrodes with collecting surface profiles all affect electrical operation and performance.

Rebuilds are a potential step in upgrade of an existing air pollution control system. If needed, effective collecting surface area can be increased depending on equipment arrangements. Rebuilds can also incorporate some of the technical advances.

Technology Advances

As with all pollution control equipment, precipitation has seen significant advancements in recent years. One area of changes is with controls. Again, as with other equipment, microprocessors have been applied to transformer-rectifier sets (high voltage power supply) controls. These regulate operation to ensure the maximum amount of usable power is available to the ESP. Electrical parameters are continuously monitored and the control automatically adjusts power to avoid wasteful sparks and arcs. Rapper controls have been similarly redesigned to incorporate state-of-the-art microprocessor components.

Changes to internal components have been focused on discharge electrode design and gas passage spacing, i.e. spacing between collecting surfaces. In certain applications, spacing has been increased to as much as 16 inches, thereby saving cost. The number of internal elements saved is proportional to the ratio of the spacing. Weight savings decreases load on supports and permits use of taller collecting surfaces increasing ESP capacity if necessary. For a given ESP casing on an MWC application, performance at wider spacings is as good or better than for ESPs at narrower spacing. Treatment time is the same in either case. This effect occurs due to greater electrical field strength in the wider spacing units which operate at proportionally higher voltage.

COHPAC

Based on use of a polishing collector downstream from an electrostatic precipitator, this technology named COHPAC (COmpact Hybrid PArticulate Collector) provides enhanced particulate collection. In MSW installations with existing ESPs it provides the benefit of a fabric filter step in the pollution control train without the need to completely abandon the ESP. The result will be increased collection of acid gas. The technology was developed by and is licensed from the Electric Power Research Institute (EPRI).

The first application of COHPAC technology added an entire baghouse with a length of ductwork downstream from an existing ESP. A more recent development uses the outlet field of an ESP as space for fabric filter bags. This approach is known as COHPAC II. The ESP internals in the outlet field are removed and gas flow modifications made for a very compact arrangement. The particular fabric filter technology used by Research-Cottrell is based on low pressure high volume cleaning. The cleaning system is the pulse jet type with cleaning air produced by positive displacement blowers. Bags are oval in cross section with a unique rotating air manifold.

The nature of this upgrade makes it suitable without regard to the original ESP manufacturer's design. However, dimensional requirements could hinder its viability in some otherwise promising situations. Certainly, where it does fit, arrangement and space requirements become immaterial.

Performance wise, we can expect acid gas removal rates for this technology range between those expected with ESPs versus those with fabric filters. With high air-to-cloth ratios that usually accompany COHPAC designs, its unreasonable to expect results as good as can be achieved with conventional fabric filter. Again, as with all of the techniques and modifications possible, this should be considered carefully based on the specific plant circumstances. The cost for a COHPAC II conversion of one outlet field of an existing ESP is about \$2,000 per ton per day of unit capacity.

Complete Conversion to Fabric Filter

There may be cases where Owners choose to replace an ESP with a fabric filter. This is often approached by using a long duct run to a location beyond ID fans or stack, to build a new unit. Another approach, again used by some power plants, is to use the ESP casing as the housing for the new fabric filters. When some ESP configurations may not be well suited for this, it warrants some consideration. An advantage here is real estate savings. Ash handling systems may also be reusable. A disadvantage is that the MWC must be offline while the conversion work is done. Overtime, shift work, and/or extended outage costs will result.

CONCLUSION

While the legislative and economic atmosphere leaves many uncertainties, waste to energy plants must plan to upgrade. Full blown additions of spray dryers and fabric filters are not always necessary to comply with current regulations. Consideration of various alternatives should be made before committing to a strategy. Awareness of these alternatives could keep an otherwise viable plant from closing.

CONTACT

PRECIPITATED PARTICULATE APPROACHES

Based on our review of precipitation collection systems, the following information is provided. The information is intended to provide a general overview of the various systems available. It is not intended to provide a detailed description of any one system. For more information, contact the author at the address below.

The first system of precipitation collection is the traditional system. This system is based on the use of a collection system that is designed to collect precipitation from a specific area. The collection system is typically made of metal or plastic and is mounted on a structure. The collection system is typically made of metal or plastic and is mounted on a structure. The collection system is typically made of metal or plastic and is mounted on a structure.

The second system of precipitation collection is the roof-mounted system. This system is based on the use of a collection system that is mounted on a roof. The collection system is typically made of metal or plastic and is mounted on a structure. The collection system is typically made of metal or plastic and is mounted on a structure.

Complete conversion to fabric filter
There may be cases where fabric filter conversion is not a viable option. This is often the case when the plant is located in an area with high humidity. In these cases, the plant may need to consider other options for particulate control.

Table 1. 1995 NSPS for new MWC's

Pollutant	Plant Capacity > 250 tpd	Plant Capacity > 39 tpd but < 250 tpd
Dioxins/furans	13 ng/dscm	13 ng/dscm
PM	24 mg/dscm	24 mg/dscm
Opacity	10%	10%
SO ₂	30 ppmv or 80% reduction	30 ppmv or 80% reduction
HCl	25 ppmv or 95% reduction	25 ppmv or 95% reduction
NOx	150 ppmv (180 ppmv first year of operation)	No control limit
Cd	0.020 mg/dscm	0.020 mg/dscm
Pb	0.20 mg/dscm	0.20 mg/dscm
Hg	0.080 mg/dscm or 85% reduction	0.080 mg/dscm or 85% reduction
Flyash/bottom ash fugitives	No visible emissions (exception for up to 5% of the time and for maintenance/repair)	No visible emissions (exception for up to 5% of the time and for maintenance/repair)

Table 2. 1995 Emissions Guidelines for Existing MWC's

Pollutant	Unit Capacity > 250 tpd ¹	Plant Capacity > 39 tpd but < 250 tpd ²
Dioxins/furans	30 ng/dscm (non-ESP) 60 ng/dscm (ESP)	125 ng/dscm
PM	27 mg/dscm	70 mg/dscm
Opacity	10%	10%
SO ₂	31 ppmv or 75% reduction	80 ppmv or 50% reduction
HCl	31 ppmv or 95% reduction	250 ppmv or 50% reduction
NOx	200-250 ppmv (Varies by MWC type, except none for mass burn refractory)	No control limit
Cd	0.040 mg/dscm	0.10 mg/dscm
Pb	0.49 mg/dscm	1.6 mg/dscm
Hg	0.080 mg/dscm or 85% reduction	0.080 mg/dscm or 85% reduction
Flyash/bottom ash fugitives	No visible emissions (exception for up to 5% of the time and for maintenance/repair)	No visible emissions (exception for up to 5% of the time and for maintenance/repair)

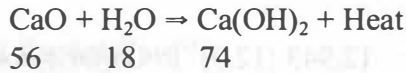
¹ U.S. EPA proposal - U.S. District Court - February 4, 1997

² U.S. EPA rule - December, 1996 Vacated by U.S. District Court

Table 3. Calculation of Comparative Usage Rates for Quicklime Versus Hydrated Lime

The theoretical reaction of the lime products (with their molecular weights) are as follows:

A. Hydrated lime and its production



1 lb of CaO yields 1.32 lbs of Ca(OH)₂

To clarify, capture ratio represents the theoretical amount of lime required to remove or capture acid gas on a weight (Lbs.) basis.

Thus, the stoichiometric, theoretically perfect, reaction of Ca(OH)₂ with acid gases requires:

1. 1.156 lbs of Ca(OH)₂ to capture 1.0 lbs of SO₂
2. 1.014 lbs of Ca(OH)₂ to capture 1.0 lbs of HCl

Without pollution controls, the average MWC facility has the potential to emit the following amounts of acid gases: [lbs/ton of municipal solid waste (MSW) burned]

SO₂ = 5.03 lbs/ton (Equivalent to 212 ppmdv @ 7% O₂)

HCl = 7.03 lbs/ton (Equivalent to 532 ppmdv @ 7% O₂)

Other acid gases such as HF and H₂SO₄ are also emitted in small amounts and are collected in the system but are not federally regulated in the U.S.

Table 3. Calculation of Comparative Usage Rates for Quicklime Versus Hydrated Lime. (Continued)

The characteristic stoichiometric requirement for Ca(OH)₂ per ton of MSW is:

SO ₂ = 5.03 lbs SO ₂ /ton MSW x 1.156 lbs Ca(OH) ₂ /lb SO ₂ =	5.815
HCl = 7.03 lbs HCl/ton MSW x 1.014 lbs Ca(OH) ₂ /lb HCl =	7.128
TOTAL	12.943 (12.9) lb Ca(OH)₂/ton MSW

B. Pebble lime (hydration process not included)



The stoichiometry of CaO with acid gases requires:

3. 0.875 lbs of CaO to capture 1.0 lbs of SO₂
4. 0.767 lbs of CaO to capture 1.0 lbs of HCl

The following is the stoichiometric reaction of CaO for typical MSW:

SO ₂ = 5.03 lbs SO ₂ /ton MSW x 0.875 lbs CaO/lb SO ₂ =	4.401
HCl = 7.03 lbs HCl/ton MSW x 0.767 lbs CaO/lb HCl =	5.392
TOTAL	9.793 lb CaO/ton MSW

Since CaO contains about 7% unreactive material and inerts that are lost in the slaking process, the usage is adjusted to compensate for impurities. Accordingly, the adjustment is made by the following computation:

$$1.07 \times 9.793 = 10.5 \text{ LB CaO/ton MSW}$$

Table 4. Cost Analysis

Plant design capacity - T/D		250	500	1,500
Plant operating capacity - T/Y		77,562	155,125	465,325
QUICKLIME ANALYSIS				
Annual Capital Cost ⁽¹⁾		\$8,000	\$10,000	\$15,000
Annual Replacement Cost		\$4,000	\$6,000	\$8,000
Labor (O & M) - \$/hr	\$30.00	\$134,400	\$134,000	\$134,400
Lime Cost - \$/Ton Lime	\$80.00	\$77,562	\$155,125	\$465,325
Quicklime Usage - lbs per ton MSW	25	970	1939	5817
Total Annual Cost		\$223,962	\$305,125	\$622,725
Unit Operating Cost - per ton MSW		\$2.89	\$1.97	\$1.34
DRY INJECTION ANALYSIS				
Annual Capital Cost		-	-	-
Capital Replacement Cost		\$4,000	\$6,000	\$8,000
Labor (O & M) - \$/hr	\$30.00	\$65,700	\$65,700	\$65,700
Lime Cost - \$/Ton Lime	\$80.00	\$95,246	\$190,494	\$571,419
Quicklime Usage - lbs per ton MSW	30.7	1191	2381	7143
Total Annual Cost		\$164,946	\$262,194	\$645,119
Unit Operating Cost - per ton MSW		\$2.13	\$1.69	\$1.39

Incremental capital costs above those required for the dry injection process.

Table 5. Peel Facility Test Results

Test ⁽¹⁾	Hg Stack Concentration $\mu\text{g}/\text{Rm}^3$ @ 11% O ₂ ² (@ 7% O ₂)	PCDD/PCDF - I-TEQ Stack Concentration ng/Rm^3 @ 11% O ₂ (@ 7% O ₂)
Hydrated Lime Only		
#1	127	0.1200
#2	172	0.0860
#3	217	0.1100
Average	172 (241.5)	0.1053 (0.1478)
Sorbalit		
#4	31	0.0180
#5	26	0.0087
#6	20	0.0027
#7	12	0.0023
#8	5	0.0010
Average	19 (26.6)	0.0065 (0.0091)
A-7 Guideline	57 (80)	0.14 (0.196)

Conditioned Dry Injection and Fabric Filter
²R = reference condition, 25°C

Table 6. Spray Dryer and ESP Test Results

Flue gas temperature - 295°F
 % C in Sorbalime 4%
 Average SO₂ emission during test - 22 ppm_{dv}
 All data corrected to 7% O₂

	Hg Emissions		Dioxin Emissions	
	μg/dscm	Total ng/dscm	I-TEQ ng/dscm	
Inlet				
#1	219.3	692.3	17.2	
#2	252.3	1172.4	21.4	
#3	209.9	3242.4	22.2	
Average	227.1	1702.3	20.3	
Outlet				
#1	34.0	31.4	0.54	
#2	36.8	64.1	1.14	
#3	22.7	32.9	0.6	
Average	31.1	42.8	0.76	
EPA Guideline	80 μg/dscm	60 ng/dscm		
Average % removal	86.2%	95.51%	96.35%	

