Metals Emissions Control Technologies For Waste Incineration

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INTRODUCTION

A major issue facing industrialized nations is the environmentally sound disposal of municipal solid wastes and industrial hazardous wastes. The amounts of these wastes generated has shown an annual growth rate over the past several decades [1] and improper disposal has resulted in numerous environmental problems. Incineration in properly designed combustion systems has been demonstrated as a method of achieving a very high degree of destruction and control for these wastes and is often combined with heat recovery systems to simultaneously recover energy in the form of steam or electricity. A wide variety of incinerator types as well as boiler and industrial furnaces are used for destroying these wastes.

Incineration of municipal and hazardous waste has the potential for increasing air pollution due to emissions of constituents contained in these waste streams and products of their combustion. Municipal and hazardous wastes are likely to contain sulfur and chlorine compounds as well as a wide number of toxic heavy metals (e.g. arsenic, beryllium, cadmium, chromium, lead, mercury, and silver). During combustion sulfur and chlorine compounds are converted to the acid gases SO_2 and HCl. Heavy metals are converted to their oxide or chloride forms. The high combustion temperature employed in modern incinerators will cause many of the metal compounds present to volatilize and be carried out of the incinerator device with the hot flue gases. These compounds then condense out as fine particulate matter or in some instances can leave the system still in the vapor form.

The increase in waste incineration has been accompanied by increased public concerns over air pollution and an increase in local, state, and federal regulations. The USEPA has recently revised federal regulations to further limit incinerator emissions. This increased regulatory climate has resulted in an increase in the complexity and efficiency of air pollution controls employed for emissions controls.

This paper presents a review of the current U.S. regulations covering incinerator emissions and describes technologies used for their control. Typical emission levels and control efficiencies achievable are presented.

AIR POLLUTION REGULATIONS

Air pollution regulations applied to incinerator flue gas emissions vary widely in the compounds controlled, emissions levels, removal efficiencies ies required, averaging times and testing requirements. On the national level, municipal waste incinerators are regulated under Clean Air Act provisions whereas hazardous waste incinerators are regulated under the Resource Conservation and Recovery Act (RCA). In addition to national regulations, local or state permitting agencies may require more stringent emissions controls or control of additional pollutants as a part of a facility's operating permit. The EPA has recently been active in setting standards for municipal waste incinerators, hazardous waste incinerators and boilers and industrial furnaces which burn hazardous wastes.

Municipal Waste Incinerators

EPA promulgated "New Source Performance Standards and Emissions Guidelines for Existing Facilities" for Municipal Waste Combustors in February 1991. These standards are summarized in Table 1.

In setting these standards, EPA recognized differences in facility size, type of incineration (mass burn fired versus refuse derived fuel fired) and new sources versus existing sources. The facility capacity refers to the total burn rate for all refuse combustors at a single site. EPA selected total particulate matter emission limits as the way of controlling trace heavy metal emission limits. EPA will add emission limits based on applying Maximum Achievable Control Technology (MACT) for mercury, cadmium and lead emissions in the coming year. EPA has until late 1992 to establish comparable emission standards for smaller combustors, those less than or equal to 250 tons per day per train.

Emissions limits are established for total emissions of poly-chlorinated dibenzyl-dioxins (PCDD) plus polychlorinated dibenzyl-furans (PCDF). These compounds were selected as surrogates for organic emissions because of their potential adverse health effects. In addition , EPA has established carbon monoxide (CO) emission limits as a measure of "good combustion practices" which limit the formation of PCDD, PCDF and their key precursors. CO emission limits vary from 50 to 150 ppm (1 at 7% O_2 dry gas conditions) depending on the type of combustion.

Acid gas emission limits (HCl and SO_2) are based on either a percent reduction or a maximum stack emission level whichever is the least stringent. Nitrogen Oxides (NO_x) emissions levels are proposed only for large new sources.

Hazardous Waste Incinerators

In April 1990, the EPA published a proposed rule and requests for comments in the Federal Register for Standards for Owners and Operators of Hazardous Waste Incinerators and Burning of Hazardous Wastes in Boilers and Industrial Furnaces". [3] The final rules for "Burning Hazardous Wastes in Boilers and Industrial Furnaces" was published in the Federal Register in February 1991. [4] Key provisions of these regulations are presented in Table 2.

EPA proposed extending current emissions limits covering Destruction and Removal Efficiencies for organic constituents and for particulate matter. EPA proposed to establish risk-based emission limits for individual toxic metals, hydrogen chloride, and organic emissions. EPA added limits for chlorine when they published their final rule for Boilers and Industrial Furnaces. [4] Reference Air Concentration (RAC's) were proposed for maximum modeled annual average ground concentrations of these pollutants. The RAC's for the carcinogenic metals were set at levels which would result in an increased cancer risk for a Maximum Exposed Individual of less than 1 in 100,000. The RAC's for the non-carcinogenic metals, and chlorine were set at 25 percent of the reference dose (RfD) with the exception of lead which was set at ten percent of the National Ambient Air Quality level. The RAC for HCl is based directly on inhalation studies. RfD's are estimates of a maximum daily exposure (via injection) for the human population that is not likely to cause deleterious effects.

In setting these standards, EPA established a three tiered approach for demonstrating compliance. The tiers are arranged from the easiest to demonstrate and most conservative to the more complex and less conservative. Compliance with any tier is considered to prove compliance with these regulations.

Tier I — EPA established conservative maximum feed rates (lb/hr) for each constituent as a function of effective stack height, terrain and land use. In setting these limits, EPA assumed no partitioning in the incinerator, no removal in an air pollution control system, and reasonable worst case dispersion. Demonstration of compliance is through monitoring of feed composition. Two examples of Tier I screening limits are 2.4×10^{-4} to 4.1×10^{-3} pounds per hour for arsenic and 9.4×10^{-3} to 1.6 pounds per hour for lead, depending on stack weight, terrain and land use.

Tier II — EPA established conservative emission rate limits for each constituent as a function of effective stack height, terrain, land use and assumed reasonable worst case dispersion. Demonstration of compliance in through periodic stack emission testing and continuous emission monitoring of carbon monoxide, hydrocarbons and oxygen. Two examples of Tier II screening limits are 3.1×10^{-5} to 5.3×10^{-3} grams per second for arsenic and 1.2×10^{-3} to 2.0×10^{-1} grams per second for lead.

Tier III — EPA established RAC's which must be met for each component. Demonstration of compliance is through periodic emissions testing and site specific dispersion modeling to demonstrate actual (measured) emissions do not exceed the RAC's. For the carcinogenic metals, the ratios of each metal's measured value to its RAC's are added to give a cumulative value which must be below ONE (a risk of 1 in 100,000). Tier III RAC's for all metals are shown in Table 2.

The standards will be implemented through limits on specific incinerator and air pollution control system operating parameters. In addition, emissions testing of all dioxin/furan tetra-octa congeners, calculation of toxic equivalents, dispersion modeling and health risk assessments will be required for incinerators equipped with a dry particulate control device (electrostatic precipitator of fabric filter operating at an inlet temperature between 450 and 750°), or if hydrocarbon emission levels exceed 20 ppmv (d).[4]

AIR POLLUTION CONTROLS

Heavy metals emissions from municipal and hazardous waste incinerators are controlled primarily through the use of particulate collection devices (electrostatic precipitators, fabric filters, wet scrubbers) or acid gas control systems (dry injection, spray dryer absorption, wet scrubbing). The major fraction of heavy toxic metals in the flue gas exists as fine particulates and is effectively controlled by properly sized electrostatic precipitators or fabric filters. Additional control of vaporized toxic metals is achieved in spray dryer absorption system or wet scrubbers.

Spray dryer absorption (SDA) has been widely applied for municipal waste incinerator emissions control and has demonstrated high collection efficiencies for most heavy toxic metals present in the flue gas. SDA has been specified as Best Available Control Technology (BACT) in a number of municipal waste incinerator air permits. Typical control efficiencies and emission levels achieved using SDA are presented in Table 3.

Figure 1 shows simplified process flow diagram for the SDA process. The SDA system is comprised of a spray dryer, absorber, a dust collector and a reagent preparation system. Incinerator flue gas enters the spray dryer where it is contacted by a cloud of finely atomized droplets of reagent (typically hydrated lime slurry). The flue gas temperature is decreased and the flue gas humidity is increased as the reagent slurry simultaneously reacts with acid gases present and evaporates to dryness. In some systems a portion of the dried product is removed from the bottom of the spray dryer, while in others it is carried over to the dust collector. Collected reaction products are sometimes recycled to the feed system to reduce reagent consumption.

Several different spray dryer design concepts have been employed for incinerator SDA applications. These include single rotary, multiple rotary and multiple dual fluid nozzle atomization; downflow, upflow and upflow with a cyclone pre-collector spray dryers; and single and multiple gas inlets. Flue gas retention times range from 10 to 18 seconds and flue gas temperatures leaving the spray dryers range from 230°F up to 300°F.

Heavy toxic metals removal in the downstream dust collector is enhanced through cooling of the incoming flue gas (from 450°-500°F) as it passes through the spray dryer with the subsequent condensation of some vaporized metal forms, and through impaction and agglomeration of fine particulate matter with the very high number of lime droplets produced by the atomization devices.

Generally, the lower the spray dryer outlet temperature, the more efficient acid gas absorption and vaporized toxic metals removal. The minimum reliable operating outlet temperature is a function of the spray dryer and dust collector design and the composition of the dry fly ash reaction product mixture. The spray dryer outlet temperature must be maintained high enough to ensure complete reagent evaporation and the production of a free flowing product. Low outlet temperature operation requires efficient reagent atomization, good gas dispersion and mixing, adequate residence time for drying and design of the dust collector to minimize heat loss and air in-leakage.

The dust collector downstream of the spray dryer may be an electrostatic precipitator, a reverse-air baghouse or a pulse-jet type baghouse. The selection of a specific type of dust collector is dependent on site specific factors such as particulate emission limits, overall acid gas removal requirements and project economics. Each of these dust collection devices offers process advantages and disadvantages that are evaluated on a site specific basis. Generally where high acid gas control is required, (95+ % HCl, 85+ % SO_2), a baghouse is utilized as it functions as a better chemical reactor than an electrostatic precipitator. Heavy toxic metals control efficiencies achievable with a SDA system are quite high (99+%) except for the relatively highly volatile mercury. Mercury emissions however, can be controlled at greater than 90 percent efficiency through the use of additives such as sodium sulfide or activated carbon. [1,7]

SDA has also been shown to be an effective method of controlling heavy toxic metals emissions from hazardous waste incinerators [6,3,8], however, wet scrubbing systems have been most commonly applied for overall emissions control. Wet scrubbing has been applied either alone or after a dust collection device to achieve acid gas control or to act as a polishing step for particulate and heavy toxic metals control. In some instances, wet scrubbers have been installed downstream of SDA systems with evaporation of the scrubber blowdown in the spray dryer to eliminate a liquid effluent stream. Figure 2 shows a typical emissions control system process flow scheme for hazardous waste incinerators.

Flue gases at approximately 2200°F are ducted from the incinerator to a quench tower (or a high temperature spray dryer) where they are cooled to 300-450°F. The cooled flue gas then enters a fabric filter (or electrostatic precipitator) where the majority of particulate matter and heavy toxic metals are removed. From the dust collection device, the flue gas enters a saturator venturi where the flue gas is further cooled to 160-200°F. Here HCl and some additional particulate matter as well as heavy toxic metals are removed. The flue gas then enters a packed tower where it is contacted with a caustic scrubbing solution for removal of SO_2.

The flue gas may then enter the induced draft fan or may pass through a secondary scrubber for additional fine particulate and heavy toxic metal removal. This secondary scrubber is typically a charged droplet or condensation type designed for light inlet particulate loading and fine particulate control.

Table 4 presents hazardous waste incinerator particulate and heavy toxic metals emissions levels achievable with these types of emissions control systems. The first column indicates conservative estimated removal efficiencies used by EPA in establishing Tier II screening levels for the ten heavy toxic metals of concern. These values are based on using a spray dryer absorption system incorporating a fabric filter as the dust collector or a system consisting of a four-field electrostatic precipitator followed by a wet scrubber as the control device. The next column presents data believed to be more representative of control efficiencies achieved in trial burns where these types of air pollution controls are employed. The final column presents typical ranges of emission rates for particulate matter and the toxic heavy metals. These values are obtained from our in-house emission data base compiled from a wide range of sources. These values are used to estimate incinerator metals emissions in permit support activities.

CONCLUSIONS

The increased use of incineration for control and destruction of municipal and hazardous wastes has lead to increasingly stringent air pollution control regulations. EPA has recently promulgated New Source

Performance Standards for municipal waste combustors which require health risk based emissions limits for specific metals to be established within the next year. EPA has proposed hazardous waste incinerator emissions limits which include risk based emissions limits for ten toxic heavy metals.

Spray dryer absorption is considered to represent BACT for many municipal waste incinerator application and is capable of achieving high collection efficiencies for the metals of concern. Spray dryer absorption is also used for emissions control from hazardous waste incinerator. Dust collectors followed by wet scrubbers or also often used to control metals emissions from hazardous waste incinerators. Both types of systems have demonstrated the ability to achieve high collection efficiencies for the ten toxic heavy metals proposed for regulation. Emission rates from medium to large incinerators equipped with properly designed air pollution control systems are capable of achieving the required emission levels.

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Table 1. USEPA Municipal Waste Combustion Emission Standards. [2]

	New Source Performance Standards	Emission Guidelines For Existing Facilities	
Capacity-Tons/day	Unit	Unit	Facility
	>250	>250 ≤ 1100	>1100
Particulate Matter-(gr/dscf)	0.015	0.030	0.015
Opacity-%	10	10	10
Organic Emissions-ng/dscm Total Chlorinated PCDD Plus PCDF			
-Mass burn units	30	125	60
-RDF fired units	30	250	60
Acid Gas Control % Reduction or Emissions-(ppm)			
HCl	95 (25)	50 (25)	90 (25)
SO_2	80 (30)	50 (30)	70 (30)
NO_x	(180)	None	None
Carbon Monoxide, ppm	50-150*	50-250*	50-250*

All emissions limits are referenced to dry gas conditions at 7% oxygen concentration.
Range of values reflect differing types of MWC's

Table 2. USEPA Proposed Hazardous Waste Incineration Standards [3]

Destruction and Removal Efficiency (DRE)		99.9999% Dioxin - Listed Wastes 99.99% All Other Wastes	
Particulate Matter		0.08 gr/dscf	@ 7% O_2
Carbon Monoxide (Tier I)		100 ppmv (d)	@ 7% O_2
Hydrocarbons (Tier II)		20 ppmv (d)	@ 7% O_2
Continuous Emissions Monitoring		CO, O_2, HC	
Tier III Reference Air Concentrations (annual limits, $\mu g/m^3$)			
Hydrogen Chloride	0.7	Free Chlorine	0.4
Carcinogenic Metals		Non Carcinogenic Metals	
Arsenic	2.3×10^{-3}	Antimony	0.3
Beryllium	4.1×10^{-3}	Barium	50
Cadmium	5.5×10^{-3}	Lead	0.09
Chromium	8.3×10^{-4}	Mercury	0.3
		Silver	3
		Thallium	0.3

Table 3. Typical Refuse Incinerator Uncontrolled and Controlled Emissions.

Pollutant	Uncontrolled Emissions	Controlled Emissions	Percent Reduction
Particulate Matter, gr/dscf	0.5-4.0	0.002-0.015	99.5+
Acid Gases ppmdv			
HCl	400-100	10-50	90-99+
SO_2	150-600	5-50	65-90+
HF	10-0	1-2	90-95+
NO_x	150-300	60-180	30-65*
Heavy Metals mg/nm^3			
Arsenic	<0.1-1	<0.01-0.1	90-99+
Cadmium	1-5	<0.01-0.5	90-99+
Lead	20-100	<0.1-1	90-99+
Mercury	<0.1-1	<0.1-0.7	10-90+
Total PCDD/PCDF ng/nm^3	20-500	<1-10	80-99

Reference conditions - Dry Gas @ 12%CO_2

Table 4. Hazardous Waste Incinerator Emissions Estimates

	EPA * Conservative Estimated Efficiencies	Typical Actual Control Efficiencies	Typical Range of Emissions Rates g/Nm^3
Particulate Matter	99+	99.9+	0.005-0.02 gr/dscf
Arsenic	95	99.9+	1-5
Beryllium	99	99.9	<0.01-0.1
Cadminum	95	99.7	0.1-5
Chromium	99	99.5	2-10
Antimony	95	99.5	20-50
Barium	99	99.9	10-25
Lead	95	99.8	10-100
Mercury	85-90	40-90+	10-200
Silver	99	99.9+	1-10
Thallium	95	99+	10-100

*Based on spray dryer fabric filter system or 4 field electrostatic precipitator followed by a wet scrubber [3]

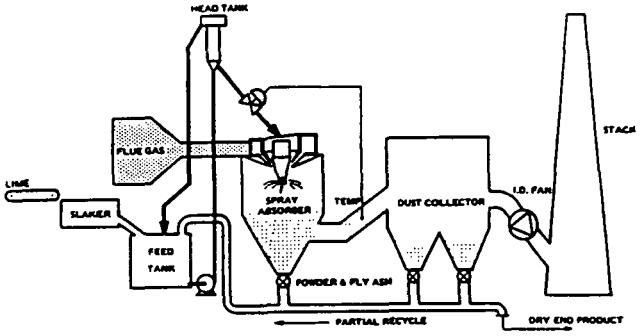

Figure 1. Spray Dryer Absorption Process
(Courtesy of Niro Atomizer)

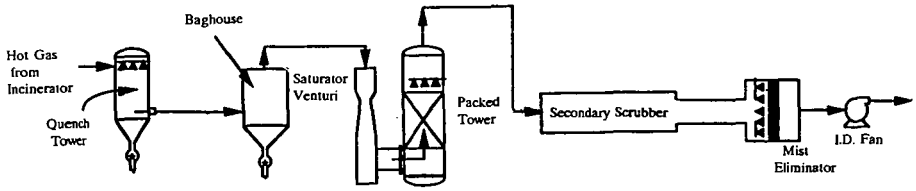

Figure 2. Hazardous Waste Incinerator - Emissions Control Scheme