COMBUSTION CONTROL OF PCDD/PCDF EMISSIONS FROM MUNICIPAL WASTE INCINERATORS IN NORTH AMERICA

James D. Kilgroe
U.S. Environmental Protection Agency
Office of Research and Development
Air and Energy Engineering Research Laboratory
Research Triangle Park, NC 27711

ABSTRACT

New regulations to control air pollution emissions from municipal waste incineration have been enacted in Canada and are being developed in the United States. Regulations in both countries will require the use of good combustion practice (GCP). The U.S. Environmental Protection Agency defines three goals for their GCP strategy: to maximize furnace destruction of organics, to limit the relative amount of flyash carried from combustors with flue gases, and to operate flyash collection devices at temperatures which minimize the de novo synthesis of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDF). This paper describes the rationale for this GCP strategy, presents data showing the effects of electrostatic precipitator operating temperature on PCDD/PCDF formation rates, and briefly describes current North American incinerator design and operating practices which must be changed to reduce formation and emission of PCDD/PCDF.

INTRODUCTION

New U.S. and Canadian air pollution emission regulations for municipal waste incinerators will require the use of good combustion practice (GCP) and the application of flue gas cleaning technology to control emissions.[1,2] The Canadian guidelines specify that all incinerators use GCP and flue gas cleaning technology to limit emissions to the levels achievable by a lime spray dryer absorber (SDA) and fabric filter (FF). The proposed U.S. guidelines which apply to existing facilities would require GCP for all facilities. The level of flue gas cleaning required would depend on the facility capacity.

The proposed EPA emission rules apply to municipal waste combustors (MWCs), a term used for municipal waste incinerators, refuse derived fuel (RDF) combustors, or any other combustor burning municipal solid waste. There are many MWC facilities in the U.S. which do not use flue gas cleaning equipment (small MWCs) or which use only electrostatic precipitators (ESPs). While some of these facilities will be required to use various techniques for acid gas control, all will be required to use GCP and control particulate, trace metal, and organic (PCDD/PCDF) emissions. This paper will discuss the use of good combustion techniques as abetted by the proper operation of particulate control devices for controlling PCDD/PCDF emissions.

CONTROL STRATEGY

Organic compounds such as PCDD/PCDF may originate in the waste and pass through the incinerator or combustor undestroyed. They may also originate in the high temperature regions of the furnace from thermal decomposition products which are not completely oxidized due to insufficient combustion air, mixing, temperature, or residence time. Or, they may originate from reactions downstream of the combustion chamber.

EPA has proposed the use of good combustion practice (GCP) to limit the formation and emission of PCDD/PCDF and other organics.[1] The GCP strategy is to maximize furnace destruction of organics and limit PCDD/PCDF formation downstream of the combustor. Implicit in the strategy is the proper design and operation of flue gas cleaning devices used to collect flyash. Downstream formation is to be limited by avoiding excessive transport of flyash from the furnace with flue gases and by

ensuring that ESPs and other particulate matter (PM) control devices operate at temperatures which minimize the formation of PCDD/PCDF.

EPA's proposed emission guidelines for existing incinerators are predicated on the use of ESPs at all but very large regional facilities (>2200 Mg/d capacity). These regional facilities would probably use GCP and SDA+FF to control emissions. Large facilities (>225 Mg/d ≤2200 Mg/d) would probably use GCP and ESPs in combination with furnace or duct injection of calcium based compounds for acid gas control (dry sorbent injection). Small facilities (<225 mg/d) would probably use GCP and ESPs.[1]

The proposed EPA emission guidelines for existing MWCs are:

Pollutant	Facility Capacity		
	Small	Large	Regional
MWC Metals, mg/dscm (as PM)	69[a]	69	34
MWC Organics, ng/Nm^3 (as PCDD/PCDF)	500	125	5-30
	(1000)[b]	(250)	
MWC Acid Gases			
HCl, % Red.[c]	none	50	95
SO_2, % Red.[d]	none	50	85
NO_x, ppmv	none	none	none

[a] All emissions corrected to 7% oxygen, dry basis.
[b] Values in ( ) are for RDF facilities.
[c] Indicated percent reduotion or less than 25 ppmv.
[d] Indicated percent reduction or less than 30 ppmv.

These proposed guidelines are to be finalized in December 1990. Some modifications are expected, including selection of a specific PCDD/PCDF emission limit for regional facilities.

CO Emission Limits

Low combustion gas concentrations of organics and CO are associated with good combustion conditions. Poor combustion conditions generally lead to increased concentration of CO and organics in flue gases.

Test results from a mass burn incinerator in Quebec City, Quebec, and a RDF combustor in Hartford, Connecticut(United States), have shown a moderately strong correlation between CO and flue gas concentrations of PCDD/PCDF. (See Figure 1.)[3,4] Tests at these two facilities were performed while the incinerators were operating over a range of good and poor combustion conditions. Examination of data from these tests shows that combustion efficiency deteriorates gradually with changing conditions and that there is no readily discernible CO concentration at which combustion efficiency changes from good to bad. Also, many factors affect PCDD/PCDF emission, and it is impossible to define a CO concentration which results in any specified limitation of PCDD/PCDF emissions. Since different types of incinerators exhibit inherently different CO emission characteristics, the EPA has proposed as a limit the lowest continuous CO emission that has been demonstrated for each technology. The proposed rules, which are based on a 4-hour averaging time, would limit modular incinerators to 50 ppm, mass burn incinerators to 100 ppm, fluidized bed combustors to 100 ppm, RDF combustors to 150 ppm, rotary waterwall combustors to 150 ppm, and coal-RDF co-fired combustors to 150 ppm (all concentrations corrected to 7% O_2 in dry gas).

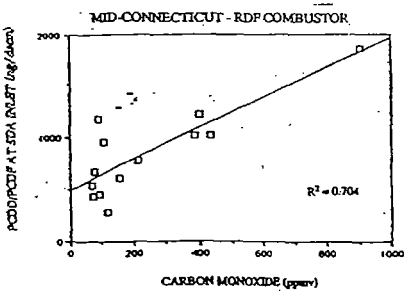

Figure 1. Correlation of CO and PCDD/PCDF.

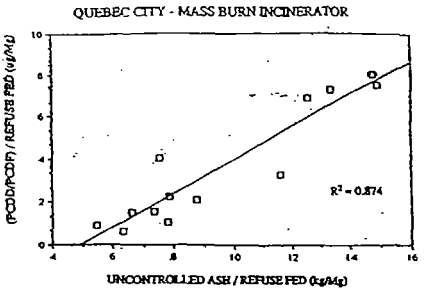

Figure 2. Correlation of PM carryover and PCDD/PCDF.

Operating Load Limit

PCDD/PCDF can be formed downstream of the furnace by de novo synthesis reactions on the surface of flyash. The amount formed is believed to be proportional to the amount of flyash and the time individual particles reside at temperatures ranging from about 150 to 400°C. A limit on maximum operating load as measured by steam flowrate has been proposed by EPA to avoid excessive flyash entrainment and subsequent flyash carryover to downstream locations where de novo synthesis reactions occur.

The results of tests at the Quebec incinerator and other facilities have shown that PCDD/PCDF concentrations in flue gases are strongly correlated to the amount of entrained flyash in flue gases (see Figure 2).[5] Incinerators should therefore minimize, within practical considerations, the amounts of PM entrained in flue gases to limit PCDD/PCDF formation downstream of the furnace/combustor.

The relative amount of flyash in flue gases depends on the type of combustion technology and the specific combustion parameters such as under-to-overfire air ratio. However, excessive amounts of flyash, relative to normal conditions, are entrained in flue gases if the rate of waste burned exceeds the design capacity of the combustor. Higher volumetric flue gas flowrates and increased particle entrainment result from operation above the design load. Since there are no commercially available systems in the U.S. for measuring the amounts of entrained flyash or validated techniques for continuously measuring flue gas flowrates, EPA has proposed a maximum limit on operating load as measured by steam flowrate. Facilities which do not produce steam are not subject to this requirement.

Maximum PM Control Device Inlet Temperature

Maximum rates of PCDD/PCDF formation by de novo reactions are believed to occur at temperatures near 300°C.[6,7] Net formation results from competing reactions involving PCDD/PCDF formation, dechlorination, and destruction (transformation to other compounds). Below 300°C, net formation rates diminish with decreasing reaction temperatures.

Dry flue gas cleaning devices for collecting PM, such as ESPs, retain large amounts of flyash which can serve as a source of de novo reactions. EPA has proposed that

PM control devices be limited to operation at inlet temperatures below 230°C to avoid excessive formation of PCDD/PCDF.

ESPs can simultaneously collect PM associated PCDD/PCDF and function as chemical reactors that generate and emit PCDD/PCDF. A large fraction of the PCDD/PCDF entering an ESP is probably associated with flyash which can be collected. However, accumulated flyash within the ESP can serve as a source for de novo synthesis of PCDD/PCDF. Newly formed PCDD/PCDF can remain with the collected flyash: it can be re-entrained along with associated flyash, or it can be desorbed into the flue gas stream as a vapor. The amount formed within an ESP will depend primarily on the rate at which flyash and organic precursors enter the ESP, the composition of flue gases (O_2 and water vapor), the length of time flyash is retained (amount accumulated), and the temperature. If other factors are relatively constant, then the temperature at which the PM control device is operated will play a dominant role in determining the PCDD/PCDF collection, formation, and stack emission rate. At inlet temperatures near 300°C, formation will dominate and outlet concentrations of PCDD/PCDF will generally exceed inlet concentrations. At some lower inlet temperatures, the inlet and outlet concentrations will approach a balance, and as inlet temperature is further reduced, formation rates will become negligible or cease.

In tests conducted by EPA to investigate the effects of ESP inlet temperature on PCDD/PCDF collection, formation, and emission rates, it was found that the measurable rates of formation occur at temperatures as low as 150°C.[5] These tests were conducted at a Montgomery County, Ohio, mass burn refractory incinerator equipped with an ESP. Temperatures at the inlet to the ESP were controlled by the amount of water sprayed into a quench chamber upstream of the ESP. PCDD/PCDF measurements were made in triplicate at each of six test conditions (see Table 1). Test variables included: combustion conditions (normal and poor), ESP inlet temperature (300 to 150°C), and method of acid gas control [none, injection of $CaCO_3$ into the furnace, or injection of $Ca(OH)_2$ into the duct upstream of the ESP].

PCDD/PCDF concentrations at the ESP inlet were observed to decrease with decreasing ESP inlet temperature because of the scrubbing effect of water sprays in the quench chamber. PCDD/PCDF concentrations at ESP outlet were higher than the corresponding PCDD/PCDF concentrations at the inlet for all test conditions. For tests without sorbent addition, the reduction of the average ESP inlet temperature from 299 to 202°C reduced the average stack concentration of PCDD/PCDF from 17,100 to 870 ng/Nm^3, respectively.

Although no tests were conducted at 150°C without sorbent injection, the tests with furnace injection of $CaCO_3$ indicated that further reductions of inlet temperature will lead to lower PCDD/PCDF formation rates.

Injection of sorbents into the furnace or duct has been advocated as a method for controlling PCDD/PCDF. It is believed that the reduction of HCl concentrations will reduce the overall number of reactions leading to the formation of chlorinated organics. Results of the Montgomery tests show that, on a weight basis, furnace injection at 200°C inlet temperature produced higher concentrations of PCDD/PCDF (1480 ng/Nm^3) than tests at this temperature without sorbent injection (870 ng/Nm^3). However, on a 2378 toxic equivalent basis, the sorbent injection tests had lower PCDD/PCDF concentration (5.0 ng/Nm^3) than comparable tests without sorbent injection (6.2 ng/Nm^3). It is possible that furnace sorbent injection retards dechlorination of octa- and hepta-isomers to penta- and tetra-isomers. Duct injection of $Ca(OH_2)$ produced lower stack concentrations of PCDD/PCDF, both on a weight basis and a toxic equivalent basis, than furnace injection of $CaCO_3$. However, the furnace injection system was not optimized and it did not remove HCl as efficiently as the duct injection system. Poor combustion conditions resulted in marginally higher stack emissions of PCDD/PCDF on a toxic equivalency basis.

Table 1. Montgomery County Incinerator Test Results[a]

Test Conditions			PCDD/PCDF Test Results[b]	
			Weight Basis (2378 Toxic Equiv.)[c]	
Combustion	Sorbent Injection	ESP Inlet Temp., °C	ESP Inlet	ESP Outlet
Normal	None	299	250 (1.3)	17,100 (103)
Poor	None	279	210 (1.3)	14,800 (118)
Normal	None	202	34 (0.2)	870 (6.2)
Normal	Furnace	201	35 (0.2)	1480 (5.0)
Normal	Furnace	148	14 (0.05)	670 (2.9)
Normal	Duct	152	5 (0.08)	57 (0.1)

[a] Mean temperature and PCDD/PCDF concentrations for 3 tests at each of 6 sets of conditions.

[b] PCDD/PCDF concentrations adjusted to 7% O_2, dry basis.

[c] Based on U.S. EPA toxic equivalency factors.

Additional tests are needed to evaluate the effects of dry sorbent injection either into the furnace or flue gas duct, on PCDD/PCDF emission control.

RETROFIT OF EXISTING FACILITIES

Many existing facilities in the U.S. will require equipment and operating procedure modifications to comply with combustion and emission requirements specified in new rules proposed by EPA. Furnace destruction of organic compounds (low CO) and minimization of flyash entrained in combustion gases will be important means of controlling downstream formation of PCDD/PCDF in small and large facilities. However, ESPs and FFs can function as reactors in which PCDD/PCDF forms, and in many cases the operating temperature of the PM control device will be the dominant factor in determining the rate at which PCDD/PCDF is emitted to the atmosphere or discharged as solid waste with collected flyash. In systems which do not use wet scrubbers or spray dryers, the PM control device should be operated at the lowest possible temperature to minimize formation of organic pollutants.

Many mass burn facilities in the U.S. do not control acid gas emissions, and it is the practice of these facilities to operate with ESP inlet temperatures ranging from approximately 200 to 350°C. Of 19 mass burn facilities for which data are available, 14 operate with ESP inlet temperatures which exceed EPA's proposed limit of 230°C. Tests at two mass burn facilities with ESP inlet temperatures exceeding 230°C had PCDD/PCDF concentrations at the ESP outlet which normally exceeded PCDD/PCDF concentrations at the inlet by 5 to more than 100 percent. At another facility, tests at ESP inlet temperatures ranging from 225 to 247°C indicated outlet concentrations which were lower than inlet concentrations by 10 to 80 percent.

Several RDF spreader stokers have combustion gas air preheaters downstream of the ESP and operate with ESP inlet temperatures close to 300°C. A 2200 Mg/day RDF facility in Detroit, Michigan, which began operation in 1988 has exhibited stack emissions of PCDD/PCDF which range from approximately 3000 to 5000 ng/Nm^3.

Modular starved air incinerators equipped with ESPs also indicate PCDD/PCDF formation when the control devices are operated at temperatures near 300°C.

There is now ample evidence that PM control devices can function as chemical reactors which form PCDD/PCDF and other organics. In incinerator systems which do not employ wet or dry (both duct sorbent injection and SDA) scrubbers, the PM control device should be operated at the lowest possible temperature to minimize formation of organic pollutants.

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