An Assessment of Realistic Emissions from Municipal, Medical, and Hazardous Waste Incinerators

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ABSTRACT

Valid stack emissions measurements, resulting from burning actual wastes in commercial combustors with appropriate emissions control technology under usual operating conditions, must be used to assess the impact of organic and metals emissions from contemporary waste combustion systems on the environment. Unfortunately, emissions measurements at hazardous waste incinerators are usually made under trial-burn test conditions that are contrived to replicate worst case permit conditions, with feeds of organics and metals great enough to measure emissions control systems and destruction and removal efficiency. Testing at municipal waste combustors and medical waste incinerators, on the other hand, is conducted under normal operating conditions, but permitted values are higher values to prevent exceedances due to statistical chance. Risks and environmental impacts based on elevated trial-burn and permitted levels lead to unrealistically high emissions estimates. Nevertheless, current estimates of emissions from waste combustion indicate that its total contribution is far less than 1% of known U.S. dioxin loadings. Therefore, the attention focused on these sources is probably misplaced.

Key words: Emissions; dioxins; fabric filters; incinerators; combustion; risk; chlorine; environmental impact; municipal waste; medical waste; hazardous waste; line carbon injection; permits; standard deviation

INTRODUCTION

Emissions from combustion of municipal, medical, and hazardous wastes are regulated under the Clean Air Act of 1990 (CAA) and the Resource Conservation and Recovery Act (RCRA). Many states have developed their own limitations, generally more stringent than the federal regulations prior to 1995, during permitting. As a result, new waste combustion systems have been developed to meet high standards. Older systems have often been retrofit or shut down.

The 1990 amendments to the CAA require federal regulation of emissions of particulate matter (PM), SO₂, HCl, opacity, NOₓ, lead, cadmium, and mercury equivalent to the maximum achievable control technology (MACT). At MACT, the emissions levels achieved by the best performing 12% of operating units are to be equaled by all other installations. The U.S. Environmental Protection Agency (EPA) estimates overall reductions in emissions of 98% on the basis of these new standards and guidelines compared to plants designed to meet only the old 0.08 gr/dscf at 12% CO₂ emissions standard.

A great reduction in stack emissions from these various types of waste combustors has already taken place before the MACT standards become effective. A recent paper indicates that actual dioxin emissions from municipal waste combustors (MWCs) are 12% of EPA’s most recent estimate; hazardous waste incinerators (HWIs) are...
Comparison of Dioxin Emissions from Waste Combustion with All Sources

It has been difficult to estimate the annual contribution of waste combustors in the United States to the contribution from all sources. Estimates of total dioxin and furan homolog (total PCDD/F) emissions from all known sources range from 4000 to 6000 g/y, and perhaps from all sources from 20,000 to 40,000 g/y (Rigo 1995). Early U.S. Environmental Protection Agency (EPA) emission estimates indicated that these sources contribute roughly 50 percent of the known emissions; hence, they were scheduled for MACT regulation. These estimates have been drastically reduced, however, as real data and updated inventories become available and replace permit values and, to a very limited extent, highly biased trial-burn results.

For example, an early EPA estimate for international toxic equivalent (TEQ) dioxin and furan annual emissions of MWIs was 670 g/y, but the EPA has now published a revised estimate, based on information volunteered by the industry. The estimate for 1990 is now 600 gTEQ/y; for 1995, 150 g/y; and for 2002, 14–23 g/y, depending on various estimates of likely MACT rules (American Hospital Association, 1996).

In the case of HWIs, the EPA’s estimate of 79 gTEQ/y was criticized. A more accurate estimate of 14.9 g/y for 1996 was derived taking into account the actual number, design, and capacities of existing facilities; test data; and operating hours (Cudahy and Rigo, 1997). This estimate is still probably too high because it is based mainly on trial-burn, worst case, emissions. In RCRA trial burns, the feed is spiked with artificially high feed rates of selected organic compounds and metals, in order to demonstrate 99.99% destruction and removal efficiency in the presence of background or even the use of nondetect levels. In general, tests of normal operation are either not performed or the data are not published. Continuous metals monitoring tests of the WTI hazardous waste combustion facility in East Liverpool, Ohio during normal operation showed metals emissions to be essentially at or below the detection limit of EPA stack test procedures (Seltzer and Meyer, 1997). EPA has revised its estimated emissions from MWIs to 3333 gTEQ/y in 1993: 733 g/y in 1995; and when the 1995 rules are fully implemented, the contribution from MWIs is expected to be about 24 gTEQ/y (U.S. EPA, 1996b).

Major reductions in emissions that have already been achieved, and the minor contribution MWIs make to the environment, may seem incredible to the public. After all, they have been told repeatedly that waste combustors are major contributors.

Historical Measures Performed to Reduce Dioxin Emissions

In the early 1980s, total PCDD/F emissions from some municipal waste incinerators and waste-to-energy facilities were found to be as high as 10,000 ng/dsm³ at 7% O₂. Concern over such high concentrations led to worldwide research, from laboratory to full-scale testing, to determine the cause and universality of these emissions.

- A landmark test was performed at Pittsfield, Massachusetts under ASME sponsorship with New York State Energy Research and Development Authority (NYSERDA) financing, to obtain data over a wide range of operating conditions, burning industrial waste as well as municipal waste, including tests spiked with high polyvinyl chloride (PVC) levels (U.S. EPA 1996a). These tests found an effect of furnace temperature on PCDD/F leaving the boiler, but no other significant causal elements.
- Tests at the Montgomery County facility in Dayton, Ohio brought to light the production of PCDD/F in the electrostatic precipitator (ESP). PCDD/F con-
centrations proved to be an overwhelming function of ESP temperature (NYSERDA, 1987).
- Slip stream tests performed by Environment Canada at Quebec City showed that dry lime or spray-dry lime scrubbers followed by fabric filters could drastically reduce PCDD/F (as well as acid gases and metals) emissions (Kilgro et al., 1991).
- Joint tests by Environment Canada/EPA/DOE at the mid-Connecticut refuse-derived fuel fired (RDF) plant in Hartford showed that the carbon produced by less than perfect combustion of MSW removed both mercury and PCDD/F (NITEP, 1986). Other tests found that dry powdered activated carbon (PAC) injection effectively removed mercury and PCDD/F (Kilgro et al., 1993; NITEP, 1994).
- Recent tests sponsored by ASME and supported by the U.S. Department of Energy/National Renewable Energy Laboratory plus a consortium of facilities and trade organizations have shown that existing waste-to-energy facilities with ESPs could be upgraded to reduce PCDD/F, mercury, and acid gases ($SO_2$ and HCl) by dry injection of calcium- or sodium-based reagents and reduction of the ESP operating temperature to levels meeting the EPA's 1995 guidelines for small facilities (Rigo and Chandler, 1997).

As a result of these and other efforts, stack gas emissions controls for waste combustors have evolved as follows:
- No control;
- Wet scrubbers or low-efficiency ESPs
- Improved ESPs with spray-dryer absorber and dry reagent injection scrubbers
- Dry lime injection plus a fabric filter
- Spray-dryer absorber with a fabric filter, and
- Powdered activated carbon (PAC) injection

The reductions in PCDD/F emissions achieved during this evolution are best presented on logarithmic coordinates because they span six orders of magnitude (a million time reduction from top to bottom). Figure 2 shows total furans plotted versus dioxins indicating that the data fall in a clear but wide band; wherein the furans range from equal to dioxins to about 10 times dioxins. Data from hazardous waste and medical waste incinerators also fall in the same band.

Carbon Monoxide as an Indicator of Good Combustion

Figure 3 shows TEQ emissions from MSW combustors versus carbon monoxide (CO). The upper line shows a good fit to dioxin data taken at the Hampton, Virginia, Hamilton, Ontario, and Pulaski, Maryland, MWCs. An enormous reduction in TEQ was obtained by more effective mixing of oxygen and organics, and reduction in ESP
operating temperature in the process of upgrading the old-style refractory incinerator at the Pulaski facility (Hasselriis and Gaskin, 1995). Similar improvements were obtained at Hampton (Austin, 19XX). These two sets of data are essentially parallel, even though Pulaski has a refractory furnace followed by a water quench without boiler and Hampton has a refractory furnace followed by a waste heat boiler. The fundamental mechanisms are the same.

The Pittsfield data, based on analysis of gases leaving the waste heat boiler, showed that both CO and PCDD/F correlate with furnace temperature until low CO levels are achieved. At low CO, PCDD/F and CO are no longer proportional (Hasselriis, 1987). These results, expressed as TEQ, are shown in Figure 3.

Formation of PCDD/F
Extensive research has shown that one formation mechanism for PCDD/F is particulate and metal surface
reactions, especially at the temperatures experienced between the boiler outlet and ESP exhaust. Higher PCDD/F concentrations were found when the ESPs were operated at the historic 450–500°F temperature to avoid condensation and corrosion than at the 285–325°F operating range that is now commonly used.

**Temperature of Emissions Control Device**

Figure 4 shows the effect of the temperature at which the ESP emission control system is operated on TEQ emissions. Here we see that TEQ data fall on lines with similar slopes, but at different levels, indicating that other variables are involved. The differences in level may be attributed to the quality of combustion, hence the quantity of dioxin precursors available for conversion on fly ash, boiler, and ESP surfaces.

Use of acid gas controls produced a startling reduction in PCDD/F emissions. Figure 5 compares data from tests of facilities having just ESPs with those using scrubber/fabric filters in more detail, specifically showing TEQ levels entering and leaving the emissions control system. It is apparent that TEQ levels in the stack emissions of SD/FF facilities are essentially independent of CO, as well as of the inlet TEQ concentrations. Closer investigation of the ESP inlet/outlet points shows that TEQ has been produced rather than reduced in the ESP.

The early pilot tests, marked Quebec (Q), show inlet levels at about 100 ngTEQ/dsm³, with an outlet level of about 0.1 ng/dsm³, a reduction of 99.9% (NITEP, 1986). It was doubted that these pilot test results could be repeated: however, the tests at the Hartford, Connecticut facility (H) show similarly high TEQ levels entering and similar low exit levels (NITFP, 1994). During these tests, the Hartford facility was burning RDF under relatively erratic conditions resulting in high uncontrolled TEQ and CO levels. Better operating conditions and lower CO readings (80 ppm) showed similar inlet and outlet TEQ levels. It appears that the carbon associated with the relatively poor combustion conditions was serving as an effective total PCDD/F removal agent. The carbon also captured most of the mercury.

Conventional waterwall MWCs, which have CO emissions in the 30 ppm range, show stack concentrations similar to those at the Hartford facility. Marion County, Oregon (M) and Commerce, California (C) were two of the first with SD/FF to show this performance (U.S. EPA, 1996a).

The next step in reducing PCDD/F was the addition of PAC prior to the baghouse, either separately in the duct or along with dry injected lime. This produced further
reactions, especially at the temperatures experienced between the boiler outlet and ESP exhaust. Higher PCDD/F concentrations were found when the ESPs were operated at the historic 450–500°F temperature to avoid condensation and corrosion than at the 285–325°F operating range that is now commonly used.

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Chlorine in Waste Versus Dioxins in Stack

Some have raised the concern that chlorine in waste burned in incinerators and waste-to-energy facilities is the principal causative element of dioxin emissions. Anecdotes are cited that indicate a correlation between chlorine in the waste and uncontrolled dioxin emissions. An ASME study that analyzed all of the available data with HCl concentrations entering the APCs (an indication of chlorine in the waste feed) and PCDD/F concluded that there is no real correlation in the entire dataset. The principal factors influencing emitted PCDD/F concentrations are the type of emissions control device employed and its operating temperature (Rigo and Chandler, 1995).

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The Bronx-Lebanon facility has a two-stage reciprocating hearth refractory combustor followed by a heat recovery boiler, air-to-gas cooler, dry lime injection, lime control tower, and fabric filter. The data points at about 200 ppmv HCl were obtained during testing with trash, not medical waste, whereas the points in the 1000 ppmv range were medical waste. Here, TEQ was reduced from 0.8 ng/dsm³ to about 0.1 ng/dsm³ with PAC injection. The Morristown data for total PCDD/F show a strong reduction in PCDD/F as HCl levels increased. What is most striking about the Bronx data is that there was essentially no difference in TEQ emissions in spite of the range from 600 to 1700 ppmv HCl without carbon, and a range from 200 to 1000 ppmv HCl with PAC. These data indicate that combustors equipped with acid gas controls reduce PCDD/F to low levels, independent of the amount of HCl.
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FIG. 10. Total dioxins plus furans emissions at inlet to scrubber and entering stack of Morristown medical waste combustor—
with carbon injection.

from improvements in combustion and the use of acid gas scrubbers. Carbon injection has further reduced dioxin emissions to levels under the practical quantitation limit (0.2–0.5 ng/dsm$^3$ at 7% O$_2$. These reductions support the EPA estimate that the overall reduction will be about 98% compared to uncontrolled emissions, not the actual state of affairs in 1995 when the MWC rule was promulgated. The contribution of PCDD/F to the environment from regulated waste combustors is now a small fraction of the total environmental burden. With anticipated further reductions, this contribution will approach insignificance.

The EPA, in an effort to establish MACT standards, is challenged by the variability of emissions from individual facilities, as well as from different facilities employing essentially the same emissions control technology. The stack emissions from a given facility vary under normal operating conditions, approaching a log-normal rather than normal distribution. The level that probably will not be exceeded in 95% of the tests is likely to be range from 2 or 3 to as much as 8 times the data mean; hence permit conditions must allow for this possibility. On the other hand, environmental impacts depend on the average or median emissions because short-term peaks are not, by definition, sustained.

Waste-burning facilities having essentially the same emissions control technology, such as scrubber/baghouse technology, display a wide but low range of uncontrolled PCDD/F concentrations due to differences in design, operating conditions, and waste composition (but not chlorine content at the usual levels). Controlled concentrations depend on the temperature of the particulate APCS and retention time. Outlet PCDD/F is relatively independent of inlet concentrations.

Although CO is a reasonably good indication of good combustion, PCDD/F stack concentrations are independent of CO when acid gas controls are used, depending mainly on the temperature at which the controls are operated, and the design and operation of these controls.

CONCLUSIONS

The ratio of total PCDD/F to the TEQ ranges from 30 to 100, creating inconsistent control requirements in view of EPA's vacillation in choosing between PCDD/F or TEQ in regulatory standards. This effect is most pronounced at low concentrations where zero is used for nondetects in calculating TEQs. The variability of emissions is similar for MWCs, HWls, and MWIs. The standard deviation ranges from less than 1 to 2 times the mean.

Estimates of annual emissions of organics and metals must be based on the average of readings taken periodically throughout a year or several years. The maximum measurement reported over the course of time may range from 2 to 8 times the average, depending on the pollutant. This variation should be allowed for in the permit, but using such maximum values to evaluate environmental impact results in serious overestimation.

While CO has been found to be a good surrogate for good combustion, it is not a surrogate for dioxin stack emissions at low CO levels. It has been found that regardless of the PCDD/F levels entering scrubber/baghouse emissions controls, outlet levels are consistently low and strongly dependent on the temperature at which the baghouse is operated.

The "control efficiency" for organics (such as PCDD/F) is not a constant factor but rather is highly de-
pendent on the temperature of the gases in the emission control system relatively independent of inlet pollutant concentrations. The same may be the case for many heavy metals.

REFERENCES


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