EMISSION FACTOR OF PCDDS/DFS FROM THE COMBUSTION OF CHLORINE CONTAINING MATERIALS

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Introduction

PCDDs/DFs are hazardous persistent chemical substances, most of which are unintentionally formed during the process of incineration. Many countries have made efforts to reduce the amount of PCDDs/DFs released from waste incineration facilities. However, as for small-sized incinerators without a sophisticated flue gas treatment equipment and open burning of domestic and industrial waste and fires, their combustion conditions are not controlled and flue gases are not treated. They are potentially major PCDDs/DFs sources. The actual results of waste combustion by open burning and small-sized incinerators are not clarified nor has PCDDs/DFs formation behavior under the uncontrolled combustion been investigated.

This research focuses on the formational behavior of PCDDs/DFs under uncontrolled combustion conditions. An incineration experiment was conducted to identify PCDDs/DFs formation behavior during primary combustion, secondary combustion and flue gas treatment using a laboratory-scale incineration system designed for easy control of combustion parameters. The results were assessed using emission factors of PCDDs/DFs. Since the lab-scale incinerator can stabilize combustion conditions through proper combustion control, the incinerator can be considered to be appropriate for investigating PCDDs/DFs behavior with combustion parameters.

Material and Methods

Experimental equipment consists of a primary combustion chamber with the capacity of ca. 1 kg/hr (a rotary kiln electric furnace is used), a secondary combustion chamber (a vertical electric furnace), a gas cooling duct, a scrubber and an activated carbon adsorption. The primary and secondary combustion furnaces with external heating system can set the furnace temperature at any degree. The gas cooling duct can also change the cooling rate through cooling the duct wall by water or heating it by electric heater. For the activated carbon adsorption tower, the fixed layers of carbon adsorb PCDDs/DFs. Flue gas samples were taken at four points; outlets of the primary and secondary combustion chambers, the gas cooling duct and the activated carbon adsorption tower.

Compositions of six material samples to be combusted (Cl levels: 0.21 ~ 1.7%) were based on actual municipal waste collected by local governments and TV casing materials containing brominated flame retardants, and various other materials, such as polyvinyl chloride, polyvinylidene chloride, iron and copper, which were added to each sample at different percentages. The primary combustion temperature and the inside O_2 concentration were set at 600°C and 18% (equivalent to 7 of air ratio), respectively. The secondary combustion temperature and gas residence time were 900°C and 1 sec, respectively. Those settings simulated small-sized incinerator combustion conditions. In some runs, the primary combustion temperature, the air ratio, the secondary combustion temperature and gas residence time were set at 600°C, 1.5, 900°C and 2 sec, respectively. Flue gas in the gas cooling duct was cooled down from 900°C to 200°C in all runs.

Results and Discussion

In this study, PCDDs/DFs emission factors from combustion flue gas and residues for combusted material samples are shown in Table 1. PCDDs/DFs emission factors declined from the primary combustion chamber outlet to the secondary combustion chamber outlet in some runs, while they increased in other runs. Flue gas treatment with scrubber and carbon adsorption decreased PCDDs/DFs emission by one to three orders of magnitude.

Table 1 Results of combustion experiment

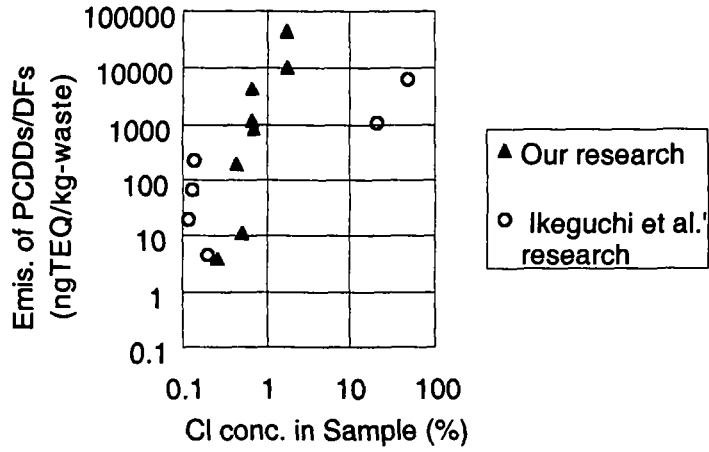
Input Sample	Chlorine conc. in sample	Primary combustion conditions	Secondary combustion conditions	Emission factors of PCDDs/DFs (ngTEQ/kg-waste)				
				Residue	Pri.	Sec.	Cool.	Ads.
Paper and wood	0.26%	600°C, ϕ7	900°C, 1sec	4.3	3.9	47	3.0	0.59
Paper, Wood and Putrescibles	0.43%	600°C, ϕ7	900°C, 1sec	11	190	860	42	15
Paper, wood and Vinyl Chloride	0.52%	600°C, ϕ7	900°C, 1sec	1.1	11	150	3.6	0.88
Paper, Wood, Putrescibles and Vinyl Chloride	0.69%	600°C, ϕ7	900°C, 1sec	15	830	1,000	13	3.8
Paper, Wood, Putrescibles, Vinyl Chloride and Metal	0.67%	600°C, ϕ7	900°C, 1sec	26	3,400	210	10	5.0
Waste TV and PVC	1.7%	600°C, ϕ7	900°C, 1sec	950	46,000	32	14	13
Waste TV and PVC	1.7%	600°C, ϕ1.5	900°C, 2sec	3,000	10,000	51	16	6.2

Pri.: Flue gas at the outlet of primary combustion chamber
Sec.: Flue gas at the outlet of secondary combustion chamber
Cool.: Flue gas at the outlet of cooling tower
Ads.: Flue gas at the outlet of adsorption tower

The relationship between PCDDs/DFs emission factors in flue gases sampled at the primary combustion chamber outlet, which is considered to be equivalent to a small-sized incinerator outlet, and chlorine levels in material samples is shown in Figure 1. This figure also shows research data by Ikeguchi et al., which is from an open burning simulating experiment to autogenetically combust various wastes, such as construction woods, tires, electric wire coatings and agricultural plastics (PVC) in a small-sized incinerator into which combustion air flows under uncontrolled conditions. In this experiment, a correlation was recognized between the Cl contents in the material samples to be combusted and PCDDs/DFs emission factors in the primary combustion flue gases. As a result, the input material compositions impacts on the PCDDs/DFs amount in emission gas from uncontrolled combustion and incineration facilities without proper flue gas treating equipment.

In this experiment, material samples to be combusted included waste TV casing which contain PBDDs/DFs as impurities from brominated flame retardants. Therefore, bromine in the input materials might promote the PCDDs/DFs formation.

Figure 1 Relationship between Cl levels in input materials and PCDDs/DFs emission factors in flue gases of the primary combustion outlet



In this experiment, sequential PCDDs/DFs data in emission gas from the primary combustion outlet to the end of the flue gas treatment process were obtained. The relationship between Cl levels in input material samples and PCDDs/DFs emission factors in flue gas are shown in Figure 2, following the flue gas flow. From this figure, it is obvious that the flue gas treatment reduced PCDDs/DFs emission factors. There was not an apparent relationship between Cl levels in input materials and PCDDs/DFs emission factors in flue gases at the outlet of activated carbon adsorption tower. In other words, it is suggested that proper flue gas treatment lowers the impact of input waste composition.

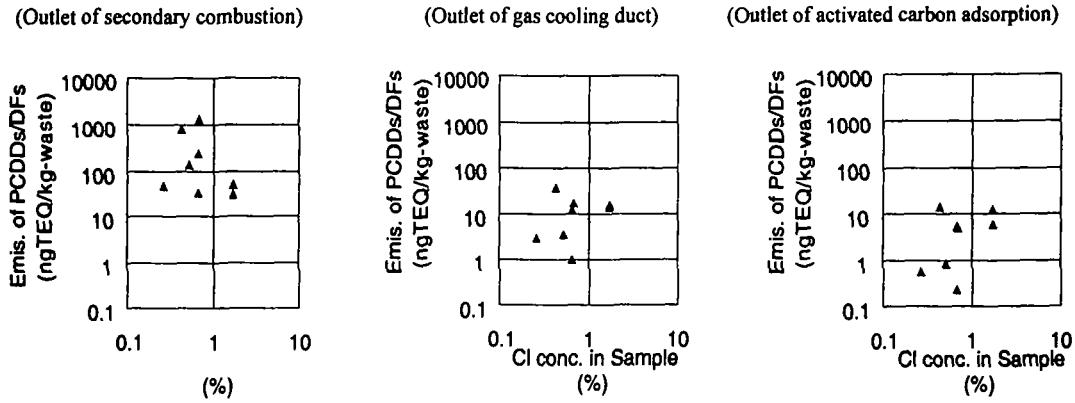


Figure 2 Relationship between Cl levels in input materials and PCDDs/DFs emission factors in flue gas flow

Lemieux et al.[2] performed an open burning simulating experiment at the EPA's Open Burning Test Facility, using two waste samples, or ordinary municipal solid waste (Non-recycler) and the left of municipal solid waste from which recyclables (papers, PETs and putrescibles) were removed (Recycler). They evaluated PCDDs/DFs emission factors in flue gases and incineration residues. Gullett et al.[3] prepared artificial waste samples (PVC level: 0.2%) for their experiment based on the typical percentages of various materials characterized and quantified by domestic household waste composition. They used four waste samples of which PVC levels were 0%, 1.0% or 7.5%. They also evaluated PCDDs/DFs emission factors in flue gases. PCDDs/DFs emission factors in both experiments are defined as the PCDDs/DFs released amount for the combusted waste sample amount. PCDDs/DFs emission factors in flue gases were 14 ~ 4,900 (ng-TEQ/kg-waste), which were the same in the order of the values with those in primary combustion gases in this experiment. Their results suggest that PCDDs/DFs emission factors are proportional to chlorine levels in the waste samples to be combusted. And both organic chlorines and inorganic chlorines can be chlorine source. These results were consistent with the results of our experiment.

Conclusions

1. PCDDs/DFs emission factors in flue gases at the outlet of the primary combustion chamber were very high. The emission factors in flue gases declined during the flue gas treatment process.
2. PCDDs/DFs emission factors in the primary combustion gases were comparable to those in other open burning simulating experiments.
3. A correlation was observed between Cl concentrations in waste samples to be combusted and PCDDs/DFs in the primary combustion gas, even if the contained chlorine was either organic chlorine or inorganic one. The correlation was not observed after the flue gas treatment.

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