Measures to Prevent Emissions of PCDDs/DFs and Co-planar PCBs from Crematories in Japan

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Introduction

In Japan, 98.8% of dead bodies were cremated in 1997 and the percentage is highest in the world. Emissions of PCDDs/DFs from crematories were unknown until recently. There were only few researches on PCDDs/DFs emission from crematories in the world[1,2,3].

In this study, PCDDs/DFs and co-planar PCBs concentrations in flue gases from 17 crematories and in fly ashes and bottom ashes (mainly borne) from several crematories were measured. The effects of factors such as CO concentration and temperature on PCDDs/DFs emissions were discussed. Finally, measures to prevent PCDDs/DFs emissions from crematories were proposed.

Material and Methods

Table 1 shows the configuration of 17crematories and sampling conditions. The number of crematories studied was equivalent to 1.1% of total number of crematories (1607) in Japan. As 70% of crematories were not equipped with dust collector, 8 crematories without dust collector were selected. The sampling of PCDDs/DFs and co-PCBs in flue gas was carried out twice a

Table 1 Configuration of Crematory and Sampling Condition

No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
secondary chamber		○	○	○	○	○	○	○	○	○	○	○	○	?	○	○	○	○
the number of main chambers connected to a secondary chamber		1	2	4	1	3	1	1	1	1	1	4	1	0	1	1	1	1
dust collector		○	?	?	○	?	○	○	○	○	?	?	○	?	?	○	○	?
burner fuel		town gas	kero-sene	kero-sene	kero-sene	heavy oil	kero-sene	town gas	town gas	kero-sene	kero-sene	kero-sene	kero-sene	heavy oil	kero-sene	kero-sene	kero-sene	kero-sene
tempe-rature	main	○	?	○	?	?	?	○	?	○	?	?	○	?	?	○	○	○
	secondary	○	○	○	○	?	○	○	○	○	○	○	○	?	○	○	○	○
sampling 1	period (min)	48	72	74	64	107	72	50	87	54	71	85	63	97	53	89	72	67
	sex	F	F	F	M	F/M/F	M	M	M	F	F	F	F	M	F	M	F	M
	age	95	90	77	81	83/62/86	76	76	61	87	87	82	91	76	88	66	85	72
	the number of cremations	1	1	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1
sampling 2	period (min)	59	104	60	87	114	66	50	75	66	99	104	74	66	113	67	77	61
	sex	M	F / F	F / M	M	M/M/M	F	M	F	M	M	M	M	F	M / F	F	F	M
	age	63	83/61	73/81	61	71/62/91	59	79	87	56	84	76	81	74	71/55	88	80	92
	the number of cremations	1	2	1.95	1	3	1	1	1	1	1	1	1	1	2	1	1	1

crematory. Flue gas was sampled throughout a cremation (i.e. from ignition of the secondary burner to extinction of the main burner). During the sampling period, concentrations of dust, O_2, CO, HCl, and NOx were measured simultaneously. Moreover, age and sex of the dead bodies, and accompanied materials in the coffin were recorded. In crematories No.1, 2, 4, 8 and 9, PCDDs/DFs and co-PCBs in fly ash collected by precipitator and bottom ash were sampled and measured. The sampling and analysis of PCDDs/DFs and co-PCBs were based on the manual of the Ministry of Health and Welfare of Japan.

Results and Discussion

PCDDs/DFs, co-planar PCBs concentration

The results of PCDDs/DFs and co-PCBs concentration in flue gases are shown in Table 2. Total concentration ($O_2$12% normalized) of PCDDs/DFs was ranged from 4.9 to 1200ng/m3N, whose toxic equivalent concentration was ranged from 0.064 to 24 ng-TEQ/m3N. TEQ concentration of co-PCBs was ranged from 0.000034 to 1.2 ng-TEQ/m3N. Co-PCBs had a highly close relation to PCDDs/DFs and equaled to 4.4% of TEQ concentration of PCDDs/DFs.

TEQ level of PCDDs/DFs in fly ash collected by precipitator was ranged from 0.0046 to 62 ng-TEQ/g. Whereas, that in bottom ash was very low and ranged from 0.00017 to 0.0021ng-TEQ/g. It was necessary to detoxify the fly ash, because PCDDs/ DFs level in fly ash from crematories is higher than that in fly ash from municipal solid waste incinerator.

Table 2 The results of PCDDs/DFs and co-planar PCBs

		PCDDs/DFs				co-PCBs
		flue gas ng /m3N	flue gas ng-TEQ /m3N	fly ash ng-TEQ/g	bottom ash ng-TEQ/g	flue gas ng-TEQ /m3N
No.1	1	44	0.9	0.0046	0.00087	0.026
	2	17	0.36			0.010
No.2	1	100	2	0.025		0.062
	2	390	7.5			0.29
No.3	1	270	4.9			0.16
	2	1200	24			1.2
No.4	1	180	3.8	62	0.0021	0.063
	2	450	10			0.21
No.5	1	11	0.19			0.0047
	2	65	1.1			0.08
No.6	1	13	0.21			0.013
	2	220	3.8			0.28
No.7	1	40	1			0.051
	2	33	0.81			0.037
No.8	1	7.5	0.14	7	0.0011	0.000034
	2	19	0.33			0.014
No.9	1	4.9	0.064	15	0.00017	0.00013
	2	20	0.33			0.022
No.10	1	42	1.1			0.015
	2	38	0.88			0.017
No.11	1	23	0.44			0.015
	2	23	0.51			0.020
No.12	1	110	2.4			0.068
	2	45	1.1			0.020
No.13	1	73	1.3			0.054
	2	94	1.9			0.041
No.14	1	30	0.57			0.024
	2	33	0.83			0.036
No.15	1	130	3.1			0.12
	2	87	2.2			0.078
No.16	1	94	1.5			0.028
	2	200	3.1			0.10
No.17	1	24	0.32			0.012
	2	10	0.15			0.0059

Dust, CO concentration

The relationship between dust concentration and PCDDs/DFs is shown in Fig.1. Total concentration of PCDDs/DFs was slightly high when dust concentration was more than 0.2g/m3N, whereas it was low in the crematories with less than 0.01g/m3N of dust concentration.

The relationship between CO concentration and PCDDs/DFs is shown in Fig.2.Though they seemed a slightly positive correlation, but the correlation factor was low. It was difficult to grasp the relationship between CO concentration and PCDDs/DFs in a cremation period as the peak of over 1000ppm of CO concentration appeared in most crematories even if secondary burner was ignited before the ignition of main burner.

The effect of temperature and dust collector

As the temperature in main chamber became higher, total concentration of PCDDs/DFs decreased except for data in crematory No.3. Total concentration of PCDDs/DFs was estimated to be 40-50 ng/m3N at the temperature of 830˚C. It was indicated that keeping over 800˚C in main chamber was important to prevent PCDDs/DFs emissions during a cremation period.

The relationship between the temperature in secondary chamber and PCDDs/DFs was not clear in crematories with dust collector as shown in Fig.3. In crematories without dust collector, however, total concentration of PCDDs/DFs decreased with the rise of the temperature in secondary chamber. This fact expresses that raising the temperature in secondary chamber is only measure to prevent PCDDs/DFs emissions.

The relationship between the temperature in flue gas and PCDDs/DFs is not significant in crematories without dust collector as shown in Fig.4.Whereas, total concentration of PCDDs/DFs increased with the rise of the temperature in flue gas in crematories with dust collector. If the flue gas temperature is taken to be the temperature in dust collector, it was considered that de novo synthesis of PCDDs/DFs was caused with the rise of temperature in dust collector. As a simple type of dust collector is not capable of removing dust completely from

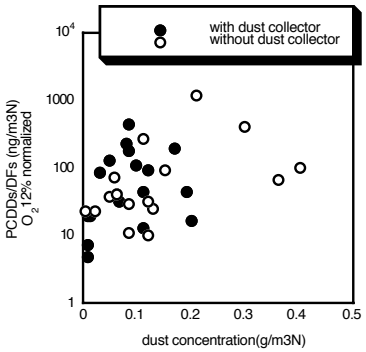

Fig.1 The relationship between dust concentration and PCDDs/DFs

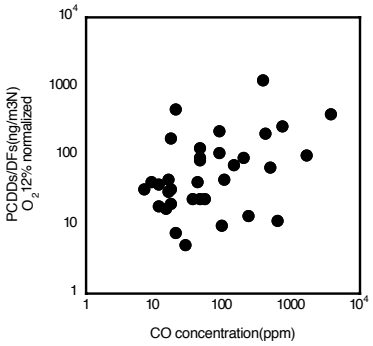

Fig.2 The relationship between CO concentration and PCDDs/DFs

flue gas, replacing it with highly-efficiency dust collector and lowering the temperature in the dust collector are very important.

The effect of combustion of accompanied materials and coffin

In order to grasp the effect of combustion of accompanied materials and a coffin on PCDDs/DFs emissions, 5 combustion experiments without dead body were performed in crematory No.17. TEQ concentration of PCDDs/DFs generated from the combustion of only accompanied materials and a coffin was ranged from 0.087 to 0.31ng-TEQ/m3N. It was found that their combustion emitted 10 - 90% of the total PCDDs/DFs from a cremation. This indicated that PCDDs/DFs was also generated from the combustion of the dead body and that controlling the temperature was needed during a whole cremation time.

Total emission from all crematories in Japan

Total emission from all crematories in Japan was estimated by using the following equations:

Total emission (ng-TEQ/year)=Emission quantity (ng-TEQ/body) x the number of cremation (bodies/year)

Emission quantity (ng-TEQ/body)=TEQ concentration (ng-TEQ/m3N) x Dry gas volume (m3N/h) x Cremation period (h)

The emission quantity was ranged from120 to 24000 ng-TEQ/bodies. The total emission was estimated to be 1.3 - 3.8 g-TEQ/year at present. Total emission will become 3.2 - 6.9 g-TEQ/year in 2036 using both the statistics of mortality in the future and the emission quantity obtained in this work. As the crematory is predicted to become one of large sources of PCDDs/DFs emission in near future, it is necessary to take measures immediately.

As the results obtained in this research, following measures to reduce PCDDs/DFs emission are recommended for existing crematories; 1) keeping the temperature of 800˚C in main/secondary chambers during a cremation period, 2) lowering the temperature in dust collector. For new installed crematories, following measures to prevent PCDDs/DFs emission including the measures for existing ones are recommended; 1) connecting one secondary chamber to one main chamber, 2) installing the highly-efficiency dust collector and decreasing dust concentration to less than 0.01g/m3N, 3) installing the sampling point for monitoring PCDDs/DFs.

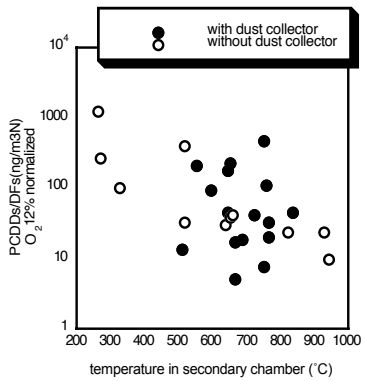

Fig.3 The relationship between temperature in secondary chamber and PCDDs/DFs

Acknowledgements

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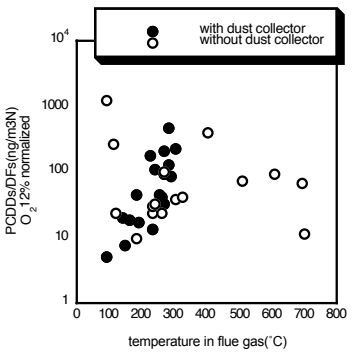

Fig.4 The relationship between temperature in flue gas and PCDDs/DFs