Research on PCDDs/DFs Emissions from Crematories in Japan

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Introduction

Recently dioxins emission from refuse incinerators has become a serious problem in Japan. Although there are studies to estimate the quantity of dioxins emitted from industrial waste incinerator, steel manufacturing factories and automobiles, only few studies have been carried out to investigate the dioxin emissions from crematories. Eguchi et al. (1) reported the concentration of dioxins from a crematory in Japan to be 0.14 ~ 2.56 ng-TEQ/Nm3. This is less than the concentration from crematories in Germay which is 8ng-TEQ/Nm3 as reported by Hutzinger and Fiedler (2). Since more than 98% of dead bodies are cremated in 1607 crematories in Japan, it is necessary to investigate many crematories of various types to grasp exact quantity of dioxins emitted from crematories.

In this research, concentrations of PCDDs and PCDFs in emission gases from ten crematories were measured. The relationship between dioxins and several factors in terms of structure, equipments and operational state of crematory is discussed. Furthermore, total emission of PCDDs/DFs from crematories in Japan is estimated.

Material and Method

Table 1 shows the ten crematories studied in this work. The number of cremation in these crematories occupied 4.0% of the number of total cremation in Japan.

In crematories A, C and J, a secondary combustion chamber is connected to three or four main combustion chambers, so that, the flue gases from more than two main chambers go into the secondary chamber simultaneously. In order to take account of overlapped cremation during measurement, the effective number of cremation was calculated by dividing the sum of cremation period in all of main chambers by average cremation period for a dead body.

Flue gas was sampled throughout a cremation (i.e. from ignition of the secondary burner to extinction of the main burner). During sampling period, concentrations of dust, O_2, CO, HCl and NOx were measured, and temperatures of main/secondary chambers and flue gas were observed. Moreover, age and sex of the dead bodies, and accompanied equipment in coffins were recorded.

Concentrations of PCDDs/DFs were measured according to the manual of the Ministry of Health and Welfare of Japan and the USEPA methods23.

Results and Discussion

Results of PCDDs/DFs

Measured concentrations of PCDDs/DFs are shown in Table 2. Total concentration (O_2 12% normalized) of PCDDs/DFs was 2.2 ~ 290 ng/Nm3, whose toxic equivalent concentration was 0.0099 ~ 6.5 ng-TEQ/Nm3. The total concentration of PCDFs was higher than that of PCDDs in all samples except a sample in crematory A.

1) The total and the TEQ concentrations

The relationship between the total and the TEQ concentrations is shown in Fig. 1, and the regression line for refuse incinerator is also shown using a dotted line for comparison. The ratio of the two concentrations for crematory was about 2.1%, and it was larger than that for refuse incinerator, 1.6%. The reason for this is that greater amount of T4CDFs which has a large TEF are included in PCDFs.

2) Homologue and isomer patterns

Homologue and isomer patterns of crematory C are shown in Figs.2 and 3. The concentration of T4CDFs was the highest in the homologue pattern of PCDFs and the concentration lowers as the number of bonded chlorine atoms increases. Although the pattern of PCDDs was not uniform and its magnitude was small, high concentration of T4CDDs is considered to be a characteristic for crematory. From patterns of 17 kinds of toxic isomers which include chlorine atoms at least at 2,3,7 and 8 positions, it was found that the concentration of 2,3,7,8-T4CDF is the largest.

3) Time trend of concentration

To identify the time trend of PCDDs/DFs concentrations, the flue gas was sampled during 0 ~20min, 20 ~ 40min, and 40min ~ the end, respectively, in crematory H. It was assumed that the coffin and other funeral materials caught fire in the first period, and easily combustible parts and the other parts of the dead body started to burn in the second and the last periods, respectively. The TEQ concentration was the greatest in the first period (0.027), which was followed by the second (0.023), and the third (0.018) . Although the differences among these concentrations were small, it can be said that the total TEQ concentration in the first 20 minutes is higher than that in the second 20 minutes. This is similar to the result shown by Eguchi et al.(1) It is considered that burning of the coffin and other funeral materials caused high concentrations of PCDDs/DFs.

PCDDs/DFs and related factors

1) Dust concentration

High concentration of dust was detected in the crematories without dust collector. Black smoke from a stack and excessively high concentration of CO were observed in such crematories. However, total concentration of

Table 1 Configuration of Crematory and Sampling Condition

code of crematory			A			B	C		D	E	F	G	H	I	J	
secondary chamber			○			○	○		○	○	○	○	○	○	○	
dust collector			○			○	×		○	○	○	×	×	×	×	
ventilation			induced			induced	induced		induced	induced	induced	induced	induced	induced	not induced	
the number of main chambers connected to a secondary chamber			3			1	4		1	1	1	1	1	1	3	
burnt fuel			kerosene			town gas	kerosene		town gas	kerosene	kerosene	kerosene	A heavy oil	kerosene	A heavy oil	
temperature	main		○			○	○		×	○	○	×	×	×	×	
	second		○			○	○		○	○	○	○	○	○	×	
	flue gas		○			○	○		×	×	○	○	×	×	×	
sampling 1	sampling period (m)		82			47	83		77	64	83	87	75	90	117	
	dead body	sex	F	M	M	M	F	F	F	F	M	M	M	M	F	M
		age	93	70	68	85	70	72	93	86	62	56	85	61	101	72
	the number of cremations		3			1	2.4		1	1	1	1.1	1	1	3	
sampling 2	sampling period (m)		83			67	84		94	57	66	68	114	78	92	
	dead body	sex	M			M	F		M	F	M	M	M	F	F	F
		age	72			75	92		52	72	82	57	23	61	74	89
	the number of cremations		1			1	1.5		1	1	1	1.2	1	1	2.4	
sampling 3	sampling period (m)										64	58				
	dead body	sex									M	F				
		age									74	89				
	the number of cremations										1	1.3				

Table 2 Results of PCDDs/DFs concentrations

code of crematory		A		B		C		D		E		F		G		H*		I		J	
C:ng/Nm3, T:ng-TEQ/Nm3		C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T
sampling 1	Total PCDDs	98	1.4	0.96	-	70	2.0	-	-	0.89	-	0.33	-	5.4	0.0070	6.1	-	0.37	-	0.99	0.084
	Total PCDFs	96	2.4	5.5	0.030	220	4.5	3.5	0.028	19	0.049	2.5	0.013	14	0.38	9.2	0.027	7.8	0.045	26	0.34
sampling 2	Total PCDDs	34	0.60	8.0	0.017	53	0.94	0.41	-	0.31	-	0.47	-	8.6	0.17	0.28	-	1.5	0.13	5.3	0.24
	Total PCDFs	49	1.0	34	0.94	180	3.1	6.9	0.024	18	0.047	2.7	0.091	22	0.65	4.4	0.023	21	0.63	41	0.75
sampling 3	Total PCDDs											0.091	-	24	0.23	0.092	-				
	Total PCDFs											2.1	0.0099	42	1.3	4.5	0.018				
sampling 4	Total PCDDs															0.48	-				
	Total PCDFs															3.7	0.064				

* Sampling 1,2 and 3 were conducted during 0~20 min, 20~40min, 40min~the end, respectively, in crematory H. -: N.D.

PCDDs/DFs was not very high (27ng/Nm3). The concentration was low in the crematories whose dust concentration was less than 50mg/Nm3. Thus, it is considered that emissions of PCDDs/DFs are reduced by dust collectors.

2) Temperature

In every crematory, temperature in the main chambers increased rapidly up to 800 °C in the first 10 minutes from the start up. The relationship between the temperature in the secondary chamber at a stady state and total concentration of PCDDs/DFs is shown in Fig.4. The concentration was low in the crematory whose temperature was above 850 °C.

3) O_2, CO concentration

Because air is blown into a duct which connected to an exit of the secondary chamber to dilute and cool down combustion gas, O_2 concentration was higher (about 18%) than that of refuse incinerator. Since addition of large amount of air makes concentrations of PCDDs/PCDFs lower than the detection limit, an appropriate method to measure the

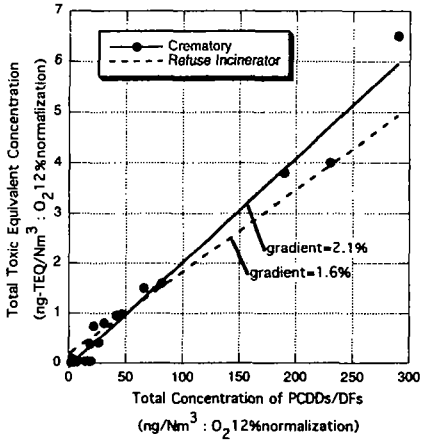

Fig.1 Total Toxic Equivalent Concentration vs. Total Concentration of PCDDs/DFs

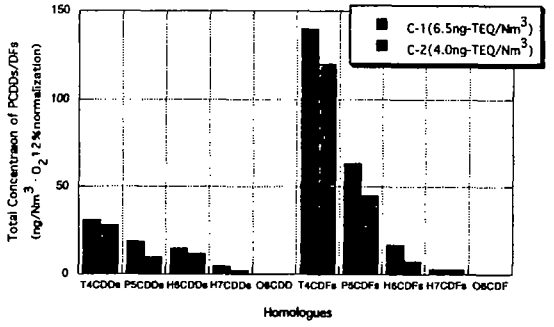

Fig.2 Homologue pattern of PCDDs/DFs of Crematory C

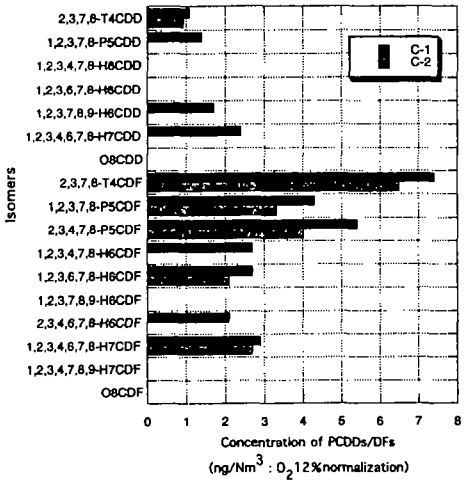

Fig.3 Isomer Pattern of PCDDs/DFs of Crematory C

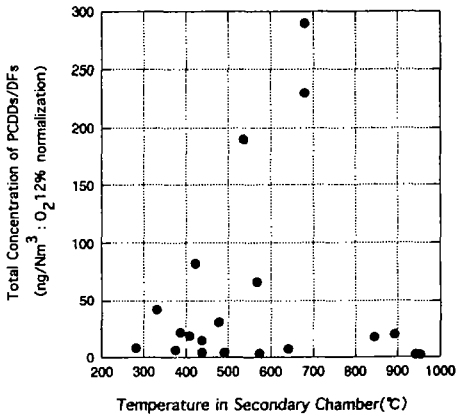

Fig.4 Total Concentration of PCDDs/DFs vs. Temperature in Secondary Chamber

concentrations for the crematory should be considered.

In some crematories, it was found that concentration of CO increases and decreases keenly soon after ignition of main/secondary burners and extinction of the secondary burner. Moreover, CO concentration rises slightly for a short time period when a rake is used to move the dead body in the furnace.

4) Age and sex of dead body

Difference of the concentration by age and sex of the dead body could not be identified, but the number of samples was not enough to draw any conclusion.

5) Age and structure of crematory

The total concentration of PCDDs/DFs for the crematories constructed in 1990s was lower than that for the crematories constructed before 1990. The total concentration was high in the crematories whose secondary chambers are connected to more than two main chambers.

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 x the number of cremation (bodies/year)

Emission quantity (ng-TEQ/body) = an average of

(TEQ concentration (ng-TEQ/Nm3) x Dry gas volume (Nm3/h) x Cremation period (h))

The result is shown in column (A) of Table 3. The emission quantity was 42 ~62,000 (ng-TEQ/body) and the average resulted in 9,200 (ng-TEQ/ body). To avoid underestimation, additional emission quantity was calculated by regarding N.D. as a half value of the detection limit. The result was shown in column (B) of Table 3. The lower estimation was about ten times greater than that in column (A), and the average became 11,000 (ng-TEQ/body). Total emission was calculated by multiplying the average by the number of cremation in Japan, 963,318 (bodies/year), and resulted in (A)8.9 (g-TEQ/year) and (B)11 (g-TEQ/year). The expected error caused by neglecting concentrations which were lower than the detection limit was about 24%. The total amount of emission was equal to one five hundredth of that from refuse incinerators and was greater than that from sewage sludge incinerators. Since there are many crematories without secondary chambers, crematories is considered as one of the largest emission sources.

Table 3 Estimated total emission of PCDDs/DFs from all crematories in Japan

		unit	(A)	(B)	(B)/(A)
per body	lower level	ng-TEQ/body	42	450	10.7
	upper level	ng-TEQ/body	62,000	63,000	1.02
	average	ng-TEQ/body	9,200	11,000	1.20
total emission		g-TEQ/year	8.9	11	1.24

(A) The case of regarding N.D. as 0.0.

(B) The case of regarding N.D. as half value of the detection limit.

Conclusion

The PCDDs/DFs concentrations in flue gases from ten crematories were measured. Total concentration of PCDDs/DFs was 2.2 ~ 290 ng/Nm3, and TEQ concentration was 0.0099 ~ 6.5 ng-TEQ/Nm3. Concentration of PCDFs was higher than that of PCDDs, especially T4CDFs was the highest and 2,3,7,8-T4CDF was detected in almost all of samples. The total concentration was higher in first 20 minutes from the start. The existence of dust collector, temperature in the secondary chamber and the number of main chambers connected to a secondary chamber were found to affect the concentrations of PCDDs/DFs. The total amount of PCDDs/DFs emitted from crematories in Japan was estimated to be 8.9 g-TEQ/year.

Acknowledgement

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References

1 Eguchi. S, Takeda N, Sakai S; **1996**,27,127

2 Hutzinger O, Fiedler H; **1993**, 27,121