EXPOSURE TO DIOXINS AMONG INCINERATOR WORKERS: VALIDATING SURROGATE EXPOSURE INDICES

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Abstract
Good surrogate indices for blood dioxin levels are needed for epidemiologic studies of dioxin exposure, as measurement of blood dioxin levels requires huge financial resources. This study aimed to validate the surrogate indices that are used in an ongoing cohort study of Japanese municipal incinerator workers. We included 58 subjects from the cohort who had job histories at municipal incinerators. Validity of two surrogate exposure indices, that is, duration and frequency of exposure to fly ash, were evaluated by comparing those indices with blood dioxin levels in these 58 subjects. Although total PCDD/PCDF in TEQ was not associated with these surrogate indices, 1,2,3,4,6,7,8-HpCDF levels showed a significant association with duration of exposure. The period of exposure is an applicable surrogate exposure index for dioxin exposure in epidemiologic studies of Japanese municipal incinerator workers.

Introduction
In 2002, we launched a cohort study focusing on risk assessment for cancer mortality and changes in the sex ratio of offspring among municipal solid waste incinerator workers. We assessed exposure to dioxins for each subject using surrogate indices, including as duration and frequency of exposure to fly ash, as determined from a self-administered questionnaire, as personal blood dioxin measurements are extremely expensive. The present study examined the validity of our surrogate indices by comparing those indices with blood dioxin levels in a subgroup of the cohort in whom blood tests were done.

Materials and Methods
Figure 1 shows how participants were recruited. Our cohort consisted of 2,866 workers having a job history at municipal incinerators and 6,239 workers without such job histories (mostly sanitation workers). We assumed that the former were exposed to fly ash and consequently dioxins. Among them, 38 workers had blood dioxin levels measured as part of a periodical medical surveillance program provided by their parent municipality (Area I) from 2000 to 2005. We used that data for the present study. We also included another 20 cohort members in another municipality (Area II) and measured their blood dioxin levels in 2005.

We obtained job histories and information on frequency (0: none, 1: once in 1~3 years, 2: several times per year, 3: several times per month) of cleaning/maintenance work in the inside of incinerators for the 58 subjects from a baseline survey for all cohort members conducted during 2002-2004. For the subjects in Group II, we also measured body mass index (BMI) and other biological/physiological indices along with blood dioxin measurements.

Based on the questionnaire, we developed three different exposure indices: 1) duration of exposure (DOE), 2) cumulative exposure index (duration x frequency) (EI) and 3) frequency of

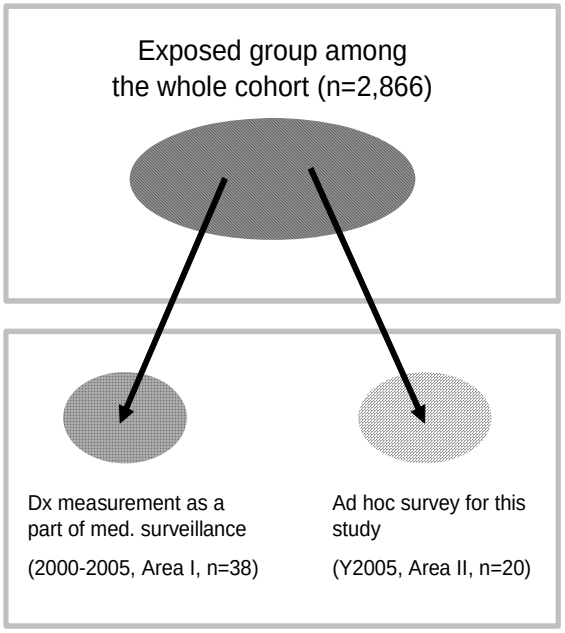

Figure 1. Recruitment of the participants

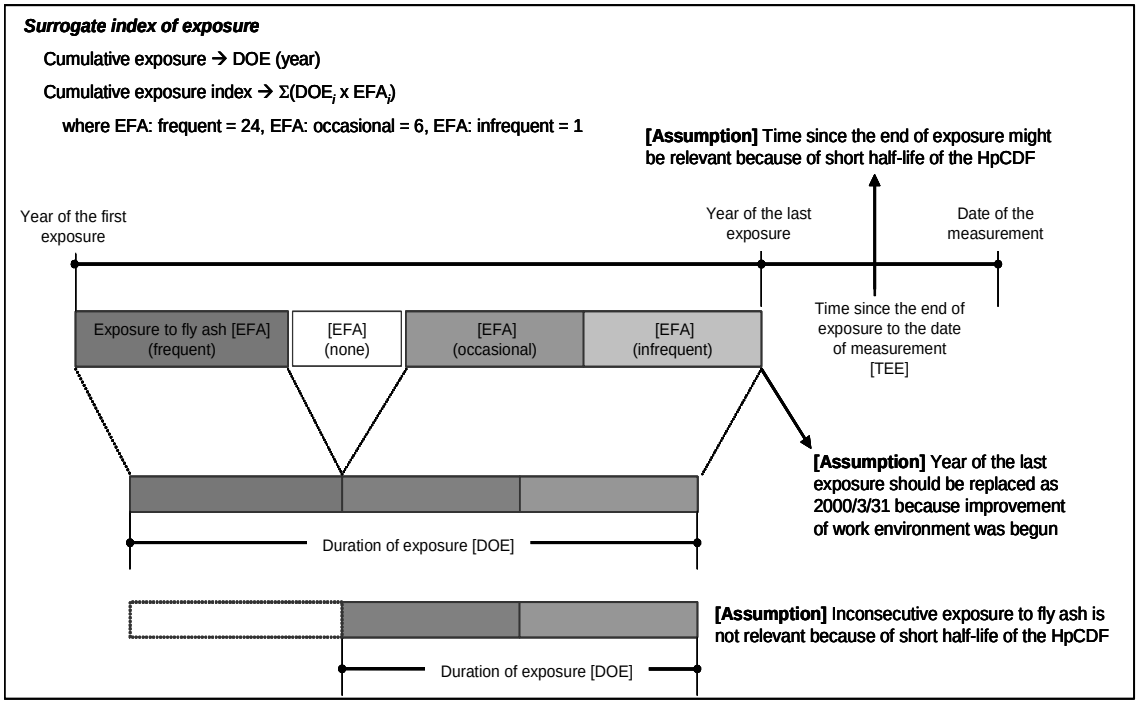

Figure 2. Calculation of exposure indices and factors affected to blood dioxin levels

cleaning/maintenance work (FE]). Figure 2 shows how we calculated those indices.

In addition to those indices, we considered the area in which the incinerators were located, age at measurement, and time since the end of exposure to the date of measurement. Most of the municipal incinerators began to implement work improvements around the year 2000, and workers have seldom gone into incinerators since then. Therefore, we assumed that major exposure to fly ash ended March 31, 2000. We then examined the association between exposure indices and blood dioxin levels under different scenarios (assumptions; see Table 4, footnotes).

Previous studies[1, 2] revealed that total PCDD/PCDF in TEQ is not necessarily associated with duration of employment but 1,2,3,4,6,7,8-HpCDF, which was dominant in deposited dust, showed a good correlation with it. Because the studies covered 6 different municipalities, including rural and urban areas, it can be expected that the same associations would be observed in our cohort. Therefore, we focused on HpCDF in our multivariate analysis.

Table 1 Demographic characteristics of incinerator workers

	Total	*Area*	
		I	*II*
No. of workers [n]	58	38	20
Age at measurement [year, mean (SD)]	47.4 (10.0)	48.2 (7.7)	45.9 (13.4)
Duration of exposure (self-report) [year, mean (SD)]	14.5 (11.7)	15.6 (11.1)	12.5 (12.7)
Time since last exposure to measurement [year, mean (SD)]	2.9 (5.8)	0.7 (2.0)	5.1 (8.7)

Table 2 PCDDs and PCDFs (pg/g lipid) in blood samples of incinerator workers

	Total (n=58)			*Area I (n=38)*			*Area II (n=20)*		
	Mean	*Median*	*Range*	*Mean*	*Median*	*Range*	*Mean*	*Median*	*Range*
2,3,7,8-TCDD	0.6	0.7	(ND - 2.0)	0.7	0.9	(ND - 1.8)	0.4	0.0	* (ND - 2.0)
1,2,3,7,8-PeCDD	3.8	3.4	(1.4 - 6.9)	4.0	3.6	(2.2 - 6.9)	3.4	3.3	(1.4 - 6.6)
1,2,3,4,7,8-HxCDD	1.5	1.6	(ND - 4.5)	1.6	1.7	(ND - 4.3)	1.3	0.0	(ND - 4.5)
1,2,3,6,7,8-HxCDD	15.4	14.0	(4.0 - 29.0)	16.3	16.0	(8.5 - 29.0)	13.7	12.0	(4.0 - 28.0)
1,2,3,7,8,9-HxCDD	2.2	2.2	(ND - 6.3)	2.7	2.6	(ND - 6.3)	1.3	0.0	* (ND - 4.5)
1,2,3,4,6,7,8-HpCDD	15.1	13.0	(4.4 - 100.0)	12.5	12.0	(4.4 - 31.0)	20.2	16.0	* (7.1 - 100.0)
OCDD	209.6	165.0	(56.0 - 1600.0)	197.1	170.0	(56.0 - 640.0)	233.5	155.0	(59.0 - 1600.0)
2,3,7,8-TCDF	0.6	0.7	(ND - 2.5)	0.7	0.8	(ND - 2.1)	0.5	0.0	(ND - 2.5)
1,2,3,7,8-PeCDF	0.3	0.0	(ND - 1.8)	0.4	0.0	(ND - 1.8)	0.1	0.0	* (ND - 1.1)
2,3,4,7,8-PeCDF	8.5	7.7	(4.4 - 24.0)	8.4	7.7	(4.4 - 17.0)	8.6	7.8	(4.4 - 24.0)
1,2,3,4,7,8-HxCDF	3.3	2.8	(ND - 11.0)	3.7	3.2	(ND - 9.8)	2.4	2.1	* (ND - 11.0)
1,2,3,6,7,8-HxCDF	5.4	4.6	(ND - 17.0)	5.7	5.1	(2.7 - 17.0)	4.7	3.4	* (ND - 13.0)
1,2,3,7,8,9-HxCDF	1.0	0.0	(ND - 12.0)	0.4	0.0	(ND - 2.4)	2.1	0.0	(ND - 12.0)
2,3,4,6,7,8-HxCDF	1.4	0.0	(ND - 5.3)	2.1	2.3	(ND - 5.3)	0.0	0.0	* (ND - ND)
1,2,3,4,6,7,8-HpCDF	7.6	4.2	(ND - 54.0)	7.4	4.8	(1.6 - 29.0)	8.1	2.4	* (ND - 54.0)
1,2,3,4,7,8,9-HpCDF	0.3	0.0	(ND - 3.8)	0.4	0.0	(ND - 2.4)	0.3	0.0	(ND - 3.8)
OCDF	1.1	0.0	(ND - 26.0)	0.9	0.0	(ND - 6.1)	1.3	0.0	(ND - 26.0)
TEQ-PCDD	6.5	5.9	(2.3 - 12.4)	6.9	6.4	(3.5 - 12.0)	5.6	5.1	(2.3 - 12.4)
TEQ-PCDF	5.5	5.0	(2.2 - 15.3)	5.6	4.9	(2.6 - 10.8)	5.3	5.1	(2.2 - 15.3)
TEQ-PCDD/PCDF	11.9	11.1	(4.5 - 27.7)	12.4	11.3	(6.1 - 22.7)	11.0	10.2	(4.5 - 27.7)

*p<0.05, Mann-Whitney U test for medians between Area I and II

Table 3 Correlation between verious surrogate indices for exposure and blood dioxin level

	Duration of exposure	*Exposure index*	*Frequency of exposure to fly ash at the last job*	*Frequency of exposure to fly ash at 2000/03/31*
2,3,7,8-TCDD	0.085	0.079	-0.145	-0.232
1,2,3,7,8-PeCDD	-0.081	-0.059	-0.232	-0.241
1,2,3,4,7,8-HxCDD	0.068	0.026	-0.068	-0.063
1,2,3,6,7,8-HxCDD	-0.009	0.058	0.012	0.004
1,2,3,7,8,9-HxCDD	0.057	0.080	0.060	0.137
1,2,3,4,6,7,8-HpCDD	0.173	0.040	0.088	0.111
OCDD	0.179	0.078	0.051	0.057
2,3,7,8-TCDF	-0.047	-0.001	0.006	-0.058
1,2,3,7,8-PeCDF	0.131	0.094	-0.057	0.026
2,3,4,7,8-PeCDF	-0.153	-0.121	-0.263*	-0.326*
1,2,3,4,7,8-HxCDF	0.059	0.128	-0.036	0.067
1,2,3,6,7,8-HxCDF	0.003	0.051	-0.053	0.022
1,2,3,7,8,9-HxCDF	-0.019	-0.066	0.010	0.059
2,3,4,6,7,8-HxCDF	0.078	0.141	-0.042	0.072
1,2,3,4,6,7,8-HpCDF	0.061	0.042	0.063	0.169
1,2,3,4,7,8,9-HpCDF	0.170	0.131	0.141	0.172
OCDF	0.347	0.211	-0.034	0.018
TEQ-PCDD	-0.007	0.011	-0.150	-0.171
TEQ-PCDF	-0.102	-0.066	-0.206	-0.215
TEQ-PCDD/PCDF	-0.055	-0.027	-0.183	-0.199

*p<0.05

Results and Discussion

Table 1 shows the demographic characteristics of subjects. There is no difference in mean age at measurement and duration of exposure between Area I and II, but the time since the end of exposure to the measurement was much longer for workers belong to Area II. Distribution of PCDDs and PCDFs are shown in Table 2. For some congeners, blood levels were high among Area I workers. Generally, the correlations between exposure indices and blood dioxin levels were weak (Table 3). After adjusting for related factors such as time since the end of exposure and the age at measurement, duration of exposure was significantly associated with HpCDF under one assumption (Table 4, Scenario VI; model p-value 0.028; adjusted R2 0.144; p-value for DOE 0.028).

Due to the limitations of the baseline survey data, we could not adjust for important confounding factors such as BMI, smoking, or dietary habits. However, our data is consistent with previous studies[1, 2] thus supports the use of duration of exposure as a surrogate index of dioxin exposure in epidemiological studies of Japanese municipal incinerator workers.

Acknowledgements

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References

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Table 4 Validity of verious exposure indices as surrogates of 1,2,3,4,6,7,8-HpCDF exposure according to different scenarios; results of multiple regression analysis

	Standardized slope (ß)							
			Frequency of exposure to fly ash		*Time since end of exposure to the date of measurement*			
Scenario	*Duration of exposure*	*Exposure index*	*At the last job*	*At 2000/03/31*	*End of exposure = last job*	*End of exposure = 2000/3/31*	*Age at measurement*	*Area*
I	0.16						-0.27	0.03
		0.09					-0.23	0.04
II	**0.20**				**-0.11**		**-0.35**	**0.14**
		0.09			-0.18		-0.26	0.16
III	0.14						-0.27	0.03
		0.09					-0.24	0.04
IV	0.17					-0.15	-0.33	0.18
		0.08				-0.21	-0.26	0.21
V	**0.20**						**-0.27**	**0.07**
		0.13					-0.23	0.06
VI	**0.25**					**-0.13**	**-0.35**	**0.23**
		0.15				-0.19	-0.27	0.24
VII			0.04				-0.21	0.02
				0.17			-0.21	0.06
VIII			0.04		-0.21		-0.22	0.15
				0.15		-0.18	-0.24	0.21

I Duration of exposure is relevant to 1,2,3,4,6,7,8-HpCDF concentration in blood sample

II Duration of exposure is relevant; consider time since end of exposure to the date of measurement (TEE)

III Duration of exposure is relevant; exposure end at 2000/03/31

IV Duration of exposure is relevant; exposure end at 2000/03/31; consider TEE

V Duration of exposure is relevant, but exclude inconsecutive exposure history; exposure end at 2000/03/31

VI Duration of exposure is relevant, but exclude inconsecutive exposure history; exposure end at 2000/03/31; consider TEE

VII Frequency of exposure to fly ash is relevant

VIII Frequency of exposure to fly ash is relevant; consider TEE