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The Changes in Dioxin Concentrations in the Blood of Yusho Patients from 2004 to 2010

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Abstract We measured the concentrations of polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and polychlorinated biphenyls (PCBs) in blood collected from Yusho patients during medical health examinations performed from 2004 to 2010. Out of the 242 and 200 Yusho patients who received medical health examinations in 2004 and 2010, respectively, the concentrations of PCDDs, PCDFs, and PCBs in the blood of 136 patients were measured in both of those years. The concentrations of individual congeners of PCDDs, PCDFs, and PCBs in the blood of these 136 Yusho patients measured in 2004 were compared with those measured in 2010. Among individual congeners of PCDDs, PCDFs, and PCBs, most congeners of these compounds did not significantly decrease from 2004 to 2010. However, the concentrations of 1, 2, 3, 4, 6, 7, 8-heptaCDD, octaCDD, 1, 2, 3, 4, 7, 8-hexaCDF, tetraCB 52/69, pentaCB 101, octaCB 198/201, and octaCB 196/203 in the blood of Yusho patients were significantly decreased from 2004 to 2010. In addition, the concentrations of 1, 2, 3, 6, 7, 8-hexaCDD, 2, 3, 4, 7, 8-pentaCDF, and 1, 2, 3, 6, 7, 8-hexaCDF tended to decrease slightly from 2004 to 2010. These findings suggest that the PCDDs, PCDFs, and PCBs have remained in the blood of Yusho patients for a very long time, with over 40 years having passed since the outbreak of Yusho.

Key words : Polychlorinated dibenzo-*p*-dioxins・Polychlorinated dibenzopfurans・Non-*ortho*-coplanar polychlorinated biphenyls・Human blood・Yusho

Introduction

The Yusho poisoning accident, which affected over 1800 people, occurred in 1968 in western Japan, and was caused by the ingestion of rice bran oil that contained the following contaminants : PCBs, PCDFs, PCDDs, polychlorinated quarterphenyls (PCQs), and polychlorinated terphenyls (PCTs)[1)]. Since the Yusho outbreak, medical care services and health examinations of the subjects have been carried out by the Yusho study group. In 2001, the measurement of PCDDs, PCDFs, and non-*ortho* PCBs in the blood has become possible using small amounts of blood collected from participants in annual medical health examinations of Yusho patients[2)~4)]. We have measured the concentrations of PCDDs, PCDFs, and dioxin-like PCBs in the blood collected from Yusho patients in medical health examinations since 2002[5)~7)]. Moreover, we have carried out a congener-specific analysis of non-dioxin-like PCBs in the blood of Yusho patients since 2004[8)~10)]. Based on these results, we have previously reported that the concentra-

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tions of 1, 2, 3, 6, 7, 8-hexaCDD, 2, 3, 4, 7, 8-pentaCDF, 1, 2, 3, 4, 7, 8-hexaCDF, 1, 2, 3, 6, 7, 8-hexaCDF, hexaCB-169, hexaCB-156, hexaCB-157, heptaCB-181, and heptaCB-189 in the blood of Yusho patients were higher than those of normal controls[5)~10)]. These nine congeners can be considered the important congeners for evaluating the dioxin exposure of Yusho patients. In particular, 2, 3, 4, 7, 8-pentaCDF is still present at very high concentrations. The date regarding PCDDs, PCDFs, and PCBs in the blood of Yusho patients may provide useful information related to the health risk of these compounds in Yusho patients.

In this study, out of 242 and 200 Yusho patients who received medical health examinations in 2004 and 2010, respectively, the concentrations of PCDDs, PCDFs, and PCBs in the blood of 136 patients were measured in both of those years. We compared the individual congener concentrations of PCDDs, PCDFs, and PCBs in the blood of these 136 Yusho patients measured in 2004 with those measured in 2010 and studied the changes in the concentrations of these compounds in the blood of Yusho patients from 2004 to 2010.

Materials and Methods

1. Sampling

Medical health examinations of Yusho patients have been conducted annually to determine their health status since the Yusho incident. The medical health examination is open not only to those persons officially registered as Yusho patients but also to Yusho-suspected persons who regard themselves as potential victims. Both officially registered Yusho patients and Yusho-suspected persons are examined based on the "Diagnostic Criteria for Yusho" [11)]. The blood samples examined in this study were collected from 242 and 200 participants who received medical health examinations in 2004 and 2010, respectively, and each of whom gave informed consent to participate in this study. Blood samples of 10 ml were collected using a vacuum blood-collecting tube containing heparin and were stored at 4℃ until analyses for the concentrations of PCDDs, PCDFs, and PCBs.

2. Materials

Native congeners of PCDDs, PCDFs, dioxin-like PCBs, and non-dioxin-like PCBs were purchased from Wellington Laboratories (Guelph, Canada) . [$^{13}C_{12}$]-congeners of PCDDs, PCDFs, dioxin-like PCBs, and non-dioxin-like PCBs as internal standards, were also purchased from Wellington Laboratories. An active carbon column was prepared as follows : active carbon was purchased from Nacalai Tesque (Kyoto, Japan) , refluxed 3 times with toluene for 1 hour, and dried in vacuum, after which 500 mg of the active carbon was mixed with 500 g of anhydrous sodium sulfate (Wako Pure Chemical Industries, Ltd., Tokyo, Japan) . A silver nitrate/silica gel was purchased from Wako Pure Chemical Industries, Ltd. All reagents and solvents used in this experiment were of the analytic grade of dioxin that is commercially available.

3. Analysis of PCDDs, PCDFs, dioxin-like PCBs, and non-dioxin-like PCBs

The extraction and purification of PCDDs, PCDFs, dioxin-like PCBs, and non-dioxin-like PCBs from blood sample were performed using a previously reported method[2)8)]. Concentrations of the PCDDs, PCDFs, and dioxin-like PCBs and concentrations of 56 non-dioxin-like PCB congeners were also performed using a previously reported method[2)8)].

4. Quality control

To evaluate the accuracy and reliability of the analysis of PCDDs, PCDFs, dioxin-like PCBs, and non-dioxin-like PCBs, our laboratory has prepared human blood samples for quality control and conducted quality control studies of the analysis of these compounds since 2008. Our results were compared with those of various laboratories that performed measurements of

PCDDs, PCDFs, dioxin-like PCBs, and non-dioxin-like PCBs in human blood in Japan, and tests confirmed that the results obtained by our laboratories in each quality control study were almost identical to those obtained by the different organizations performing the analysis. These results indicated that our laboratory's analytical methods regarding PCDDs, PCDFs, dioxin-like PCBs, and non-dioxin-like PCBs in human blood provided correct results.

5. Data analysis

To estimate the total toxic equivalents (TEQ) concentrations, we introduced ND (less than the detection limit) values to half values of the detection limit and calculated based on the toxic equivalency factor (TEF) values proposed by the World Health Organization (WHO)[12].

Results and discussion

We measured the concentrations of PCDDs, PCDFs, dioxin-like PCBs, and non-dioxin-like PCBs in blood collected from Yusho patients during medical health examinations performed from 2004 to 2010[5)~10)]. Out of 242 and 200 Yusho patients who received medical health examinations in 2004 and 2010, respectively, the concentrations of PCDDs, PCDFs, and PCBs were measured in the blood of 136 patients in both years. The individual congener concentrations of PCDDs, PCDFs, and PCBs in the blood of these 136 Yusho patients measured in 2004 were compared with those measured in 2010 (Tables 1-2).

The total TEQ concentrations of PCDDs, PCDFs, non-*ortho* PCBs, and mono-*ortho* PCBs in the blood of 136 Yusho patients in 2004 and 2010 were 5.2-533 (mean : 91, median : 60) and 8.2-640 (mean : 95, median : 68) pg TEQ g^{-1} lipid, respectively. The TEQ concentrations of PCDDs, PCDFs, non-*ortho* PCBs, and mono-*ortho* PCBs in the blood of Yusho patients were 17, 59, 13, and 1.9 pg TEQ g^{-1} lipid in 2004, respectively, and 18, 58, 17, and 2.2 pg TEQ g^{-1} lipid in 2010, respectively. Regarding the non-dioxin-like PCB concentrations, the sums of the concentrations of 56 PCB congeners in the blood in 2004 and 2010 were 83-1613 (mean : 538, median : 451) and 83-2539 (mean : 613, median : 514) ng g^{-1} lipid, respectively. The arithmetic mean concentrations of triCBs, tetraCBs, pentaCBs, hexaCBs, heptaCBs, octaCBs, and nonaCBs in the blood of Yusho patients were 1.7, 15, 20, 236, 209, 52, and 4.3 ng g^{-1} lipid in 2004, respectively, and 2.1, 15, 21, 270, 249, 50, and 5.1 ng g^{-1} lipid in 2010, respectively. These findings indicated that the concentrations of PCDFs and octaCBs in the blood of Yusho patients tended to decrease slightly from 2004 to 2010.

We have previously reported that the concentrations of 1, 2, 3, 6, 7, 8-hexaCDD, 2, 3, 4, 7, 8-pentaCDF, 1, 2, 3, 4, 7, 8-hexaCDF, 1, 2, 3, 6, 7, 8-hexaCDF, hexaCB-169, hexaCB-156, hexaCB-157, heptaCB-181, and heptaCB-189 in the blood of Yusho patients were higher than those of the normal controls[5)~10)]. These nine congeners can be considered the characteristic congeners in the blood of Yusho patients. Of these nine congeners, the concentrations of 1, 2, 3, 6, 7, 8-hexaCDD, 2, 3, 4, 7,8-pentaCDF, 1, 2, 3, 4, 7, 8-hexaCDF, and 1, 2, 3, 6, 7, 8-hexaCDF were 50, 174, 47, and 18 pg TEQ g^{-1} lipid in 2004, respectively, and 48, 172, 37, and 16 pg TEQ g^{-1} lipid in 2010, respectively, indicating that 1, 2, 3, 4, 7, 8-hexaCDF decreased significantly from 2004 to 2010. In addition, the concentrations of 1, 2, 3, 6, 7, 8-hexaCDD, 2, 3, 4, 7, 8-pentaCDF, and 1, 2, 3, 6, 7, 8-hexaCDF tended to decrease slightly from 2004 to 2010.

The concentrations of 2, 3, 4, 7, 8-pentaCDF in the blood of 136 patients were under 100 pg TEQ g^{-1} lipid in 73 patients and over 100 pg TEQ g^{-1} lipid in 63 patients. In the over 100 pg TEQ g^{-1} lipid group, the arithmetic mean TEQ concentrations of PCDDs, PCDFs, non-*ortho* PCBs, and mono-*ortho* PCBs in the blood of 63 patients were 23, 113, 14, and 2.5 pg TEQ g^{-1} lipid in 2004, respectively, and 24, 109, 19, and 3.1 pg TEQ g^{-1} lipid in 2010, respectively, with the total TEQ

Table 1 Concentrations of PCDDs, PCDFs, and dioxin-like PCBs in the blood of 136 Yusho patients

Congeners	Concentration (pg g-1 lipid)										Ratio
	2004					2010					
	Mean	Median	SD	Maximum	Minimum	Mean	Median	SD	Maximum	Minimum	2010/2004
2,3,7,8-TetraCDD	1.3	1.3	0.7	4.4	0.5	1.8	1.7	0.9	4.6	0.5	1.3
1,2,3,7,8-PentaCDD	9.4	8.3	4.9	33	1.0	10.5	9.6	5.8	45	1.5	1.1
1,2,3,4,7,8-HexaCDD	2.6	2.4	1.7	8.5	1.0	2.9	2.5	2.0	14	1.0	1.1
1,2,3,6,7,8-HexaCDD	50	39	41	247	4.8	48	36	39	267	3.5	1.0
1,2,3,7,8,9-HexaCDD	4.4	3.6	3.4	23	1.0	4.1	3.3	3.8	26	1.0	0.9
1,2,3,4,6,7,8-HeptaCDD	50	45	25	196	16	39	30	30	269	1.0	0.8
OctaCDD	727	638	372	2305	181	642	550	383	2881	158	0.9
Total PCDDs	844	760	408	2459	205	748	667	427	3321	179	0.9
2,3,7,8-TetraCDF	1.7	1.4	1.4	9.5	0.5	2.2	1.7	1.9	11	0.5	1.3
1,2,3,7,8-PentaCDF	0.9	0.5	0.8	5.4	0.5	1.2	0.5	1.0	6.4	0.5	1.3
2,3,4,7,8-PentaCDF	174	86	219	1240	4.1	172	83	222	1494	4.0	1.0
1,2,3,4,7,8-HexaCDF	47	15	76	514	1.0	37	13	66	488	1.0	0.8
1,2,3,6,7,8-HexaCDF	18	9.6	23	176	1.0	16	8.3	24	199	1.0	0.9
2,3,4,6,7,8-HexaCDF	ND					ND					
1,2,3,7,8,9-HexaCDF	ND					ND					
1,2,3,4,6,7,8-HeptaCDF	2.7	2.1	3.5	32	1.0	2.7	1.0	4.4	39	1.0	1.0
1,2,3,4,7,8,9-HeptaCDF	ND					ND					
OctaCDF	ND					ND					
Total PCDFs	250	125	315	1946	13	237	126	312	2249	14	0.9
TriCB-77	ND					ND					
TriCB-81	ND					ND					
PentaCB-126	87	69	65	441	5.0	107	90	72	491	5.0	1.2
HexaCB-169	134	114	92	604	11	207	172	137	713	25	1.5
Total Non-*ortho* PCBs	237	218	130	711	26	326	309	174	868	53	1.4
PentaCB-105	3258	2512	2494	563	15888	3452	2804	2377	432	16172	1.1
PentaCB-114	1867	1481	1543	208	8872	2236	1766	2017	187	15773	1.2
PentaCB-118	15467	11924	11378	2355	62223	18181	14882	12003	2170	78269	1.2
PentaCB-123	271	219	217	5.0	1385	240	194	198	5.0	1228	0.9
HexaCB-156	26245	19985	25066	5.0	154846	33219	24528	33080	2956	229740	1.3
HexaCB-157	7622	5572	7044	351	41426	8257	5982	8940	627	58707	1.1
HexaCB-167	3407	2627	2501	483	14958	4443	3374	3182	391	20412	1.3
HeptaCB-189	3880	2859	3355	5.0	18640	4811	3768	4440	332	31411	1.2
Total Mono-*ortho* PCBs	62018	51818	40270	231294	5971	74838	66303	51732	336132	7807	1.2
TEQ from PCDDs	17	15	9.4	63	2.4	18	16	10	79	3.2	1.1
TEQ from PCDFs	59	29	75	442	1.7	58	28	75	519	1.8	1.0
TEQ from PCDDs/PCDFs	76	43	83	505	4.1	76	46	84	599	5.3	1.0
TEQ from non-*ortho* PCBs	13	11	7.7	50	0.8	17	16	9.3	60	2.0	1.3
TEQ from mono-*ortho* PCBs	1.9	1.6	1.2	6.9	0.2	2.2	2.0	1.6	10	0.2	1.2
TEQ from dioxin-like PCBs	15	13	8.6	54	1.0	19	17	10	65	2.4	1.3
Total TEQ	91	60	87	533	5.2	95	68	89	640	8.2	1.0

ND : less than the determination limit.
SD : standard deviation.
CDD : chlorinated dibenzo-*p*-dioxin.
CDF : chlorinated dibenzofuran.
CB : chlorinated biphenyl.

Table 2 Concentrations of non-dioxin-like PCBs in blood of 136 Yusho patients

Congeners	Concentration (pg g-1 lipid)										Ratio
	2004					2010					
	Mean	Median	SD	Maximum	Minimum	Mean	Median	SD	Maximum	Minimum	2010/2004
TriCB-28	1637	1400	938	5649	5.0	2071	1420	3194	24812	5.0	1.3
TriCB-29	36	31	20	136	5.0	37	5.0	207	2274	5.0	1.0
TetraCB-44	404	379	204	2057	32	304	262	193	1513	5.0	0.8
TetraCB-47/48	581	519	259	1887	47	421	359	333	3302	69	0.7
TetraCB-49	277	255	138	943	63	212	193	129	929	5.0	0.8
TetraCB-52/69	1179	1022	764	5555	346	902	708	687	5396	213	0.8
TetraCBs-56/60	625	479	445	2842	120	260	204	184	1086	5.0	0.4
TetraCB-63	112	93	69	313	5.0	116	113	75	460	5.0	1.0
TetraCB-66	1591	1245	1299	8427	303	1800	1369	1318	7727	221	1.1
TetraCB-70	230	210	112	964	78	226	211	132	598	5.0	1.0
TetraCB-71	185	178	111	1035	27	34	21	37	252	5.0	0.2
TetraCB-74	9589	7656	7296	41967	1491	11070	8954	7650	37856	1043	1.2
PentaCB-85	214	172	178	1535	5.0	182	147	216	2253	5.0	0.8
PentaCB-87	740	623	419	2196	118	786	703	411	1949	5.0	1.1
PentaCB-92	681	538	520	3262	88	640	541	456	2679	55	0.9
PentaCB-93/95/98	755	695	346	2104	86	566	509	275	1491	137	0.7
PentaCB-99	13726	11016	9962	65276	1738	14780	12806	9414	42666	1877	1.1
PentaCB-101	1695	1359	1194	7854	137	1605	1397	1046	6360	249	0.9
PentaCB-107/108	681	552	508	2958	62	872	770	560	2988	5.0	1.3
PentaCB-110	395	334	260	2116	103	344	308	249	2391	13	0.9
PentaCB-117	1251	835	1346	7781	5.0	1505	1052	1607	10720	121	1.2
HexaCB-128	740	551	577	3514	116	839	721	634	4793	5.0	1.1
HexaCB-130	3852	3085	3162	20530	233	4570	3660	3701	22015	5.0	1.2
HexaCB-132	273	239	174	1183	19	223	179	187	1093	5.0	0.8
HexaCB-134	29	10	31	125	5.0	9	5	17	128	5.0	0.3
HexaCB-135	458	381	303	1774	67	394	354	264	1595	5.0	0.9
HexaCB-137	5086	3965	4092	29712	340	5993	5010	4565	26719	661	1.2
HexaCB-138	53373	44069	35405	205304	7821	58674	51816	37737	199342	7723	1.1
HexaCB-139/149	815	632	689	5831	72	158	98	229	1981	5.0	0.2
HexaCB-141	263	193	179	992	5.0	264	229	221	1384	5.0	1.0
HexaCB-146	19123	16719	11740	58115	2330	23939	21039	14793	81359	2680	1.3
HexaCB-147	519	458	380	2409	5.0	573	464	445	2266	5.0	1.1
HexaCB-151	1163	849	958	6212	141	1106	895	892	6528	122	1.0
HexaCB-153	118186	100550	77336	370468	19014	138781	116999	91574	579924	19887	1.2
HexaCB-163/164	31822	28212	20914	99134	3176	34793	29612	21969	115312	3806	1.1
HeptaCB-170	34126	28711	23470	108309	4220	40057	33346	27943	149018	5279	1.2
HeptaCB-172	5302	4383	3630	17760	571	6682	5362	4826	26992	858	1.3
HeptaCB-177	7817	6463	5814	33944	1116	9882	7897	7398	47138	1239	1.3
HeptaCB-178	8362	6198	6140	29710	1134	10843	8273	8026	48382	1319	1.3
HeptaCB-179	202	157	149	734	15	165	133	144	1008	5.0	0.8
HeptaCB-180	103060	81290	75715	344881	12390	125285	96126	95919	585746	17585	1.2
HeptaCB-181	250	161	299	2295	5.0	263	183	307	2190	5.0	1.1
HeptaCB-182/187	39481	29990	30850	152875	4979	44976	32308	37924	261657	5717	1.1
HeptaCB-183	8546	6534	6767	34797	997	9015	7056	7508	54151	1251	1.1
HeptaCB-191	1691	1331	1303	7837	161	1864	1541	1413	6713	134	1.1
OctaCB-194	15751	12525	11498	56366	2086	19811	15190	16249	107018	2162	1.3
OctaCB-195	3488	2773	2483	11877	521	3902	3231	3034	22012	415	1.1
OctaCB-196/203	13567	10986	9659	51001	1969	10810	8164	8435	57870	1186	0.8
OctaCB-198/201	16434	12294	12799	67982	2803	10247	7383	8510	53490	1323	0.6
OctaCB-200	400	306	324	1888	52	442	320	453	4069	5.0	1.1
OctaCB-202	2262	1820	2047	11623	5.0	4000	2888	3227	21096	458	1.8
OctaCB-205	597	463	398	1745	70	636	552	442	2302	5.0	1.1
NonaCB-206	2823	2470	1543	6971	465	3380	2907	1974	12974	509	1.2
NonaCB-207	451	401	250	1271	95	498	444	303	2048	5.0	1.1
NonaCB-208	978	864	525	2592	192	1247	1084	705	3967	193	1.3
DecaCB-209	1323	1161	636	3637	330	1690	1484	903	6400	364	1.3
Total TrCBs	1673	1446	941	5714	10	2107	1461	3332	27086	10	1.3
Total TeCBs	14773	12624	8830	48761	4741	15346	13666	8890	44750	1999	1.0
Total PeCBs	20137	17039	12760	77397	2548	21280	19622	12035	58830	2821	1.1
Total HxCBs	235702	202136	146270	678796	36780	270316	224179	167770	988345	36910	1.1
Total HpCBs	208837	170203	148503	706642	26133	249029	203976	184742	1181297	34482	1.2
Total OcCBs	52498	41433	37999	202466	8025	49848	37084	39413	267856	5801	0.9
Total NoCBs	4252	3776	2257	10723	760	5126	4514	2905	18989	844	1.2
Total PCBs	537872	450709	342814	1612505	82803	613053	513823	400524	2538991	83461	1.1

CB : chlorinated biphenyl ; SD : standared deviation.

Table 3 Concentrations of PCDDs, PCDFs, and dioxin-like PCBs in the blood of 63 Yusho patients

Congeners	Concentration (pg g-1 lipid)										Ratio
	2004					2010					
	Mean	Median	SD	Maximum	Minimum	Mean	Median	SD	Maximum	Minimum	2010/2004
2,3,7,8-TetraCDD	1.4	1.4	0.8	4.4	0.5	1.8	1.8	0.7	4.5	0.5	1.3
1,2,3,7,8-PentaCDD	12	11	5.3	33	4.1	13	12	6.3	45	5.5	1.1
1,2,3,4,7,8-HexaCDD	2.9	2.6	1.8	8.5	1.0	3.0	2.7	1.8	9.6	1.0	1.1
1,2,3,6,7,8-HexaCDD	76	64	45	247	23	72	59	43	267	18	0.9
1,2,3,7,8,9-HexaCDD	5.1	4.1	3.9	23.1	1.0	4.8	3.5	4.3	25.8	1.0	0.9
1,2,3,4,6,7,8-HeptaCDD	49	44	20	113	16	40	34	24	142	16	0.8
OctaCDD	712	627	323	1760	265	627	600	272	1509	231	0.9
Total PCDDs	858	760	358	1976	324	762	707	308	1665	292	0.9
2,3,7,8-TetraCDF	2.2	1.8	1.8	9.5	0.5	2.7	2.4	1.9	9.5	0.5	1.2
1,2,3,7,8-PentaCDF	1.1	0.5	0.9	5.4	0.5	1.4	1.3	1.1	6.4	0.5	1.3
2,3,4,7,8-PentaCDF	334	266	234	1240	106	327	246	247	1494	101	1.0
1,2,3,4,7,8-HexaCDF	93	61	93	514	14	73	45	84	488	8.7	0.8
1,2,3,6,7,8-HexaCDF	32	23	29	176	6.6	29	18	31	199	5.3	0.9
2,3,4,6,7,8-HexaCDF	ND					ND					
1,2,3,7,8,9-HexaCDF	ND					ND					
1,2,3,4,6,7,8-HeptaCDF	3.1	2.4	4.1	32	1.0	3.0	1.0	5.3	39	1.0	1.0
1,2,3,4,7,8,9-HeptaCDF	ND					ND					
OctaCDF	ND					ND					
Total PCDFs	470	370	350	1946	135	442	343	363	2249	129	0.9
TriCB-77	ND					ND					
TriCB-81	ND					ND					
PentaCB-126	82	67	54	354	27	104	92	58	371	33	1.3
HexaCB-169	191	169	95	604	49	288	264	137	713	79	1.5
Total Non-*ortho* PCBs	289	276	125	711	91	404	379	162	826	134	1.4
PentaCB-105	2970	2211	2159	12894	901	3177	2671	1964	11095	547	1.1
PentaCB-114	2760	2198	1738	8872	848	3265	2568	2428	15773	255	1.2
PentaCB-118	14399	11013	10143	59893	4613	17136	14295	9911	50706	3063	1.2
PentaCB-123	238	194	201	1268	5.0	199	158	143	763	5.0	0.8
HexaCB-156	41947	34051	28060	154846	7320	52477	41598	38809	229740	10584	1.3
HexaCB-157	11699	9609	7933	41426	1996	13562	10318	10584	58707	2866	1.2
HexaCB-167	3745	2790	2280	10040	1002	4830	4034	2795	12413	678	1.3
HeptaCB-189	5776	4989	3627	18640	960	7159	6255	5135	31411	1346	1.2
Total Mono-*ortho* PCBs	83534	76106	41977	231294	22680	101805	86418	56908	336132	31016	1.2
TEQ from PCDDs	23	20	10	63	7.5	24	21	11	79	8.4	1.1
TEQ from PCDFs	113	90	82	442	34	109	83	85	519	34	1.0
TEQ from PCDDs/PCDFs	136	111	90	505	44	133	104	95	599	43	1.0
TEQ from non-*ortho* PCBs	14	13	6.7	43	4.7	19	18	7.8	47	6.8	1.4
TEQ from mono-*ortho* PCBs	2.5	2.3	1.3	6.9	0.7	3.1	2.6	1.7	10	0.9	1.2
TEQ from dioxin-like PCBs	16	15	7.6	48	5.5	22	21	9.1	51	7.8	1.3
Total TEQ	152	124	94	533	50	155	125	99	640	51	1.0

ND : less than the determination limit.
SD : standard deviation.
CDD : chlorinated dibenzo-*p*-dioxin.
CDF : chlorinated dibenzofuran.
CB : chlorinated biphenyl.

Table 4 Concentrations of non-dioxin-like PCBs in blood of 63 Yusho patients

Congeners	Concentration (pg g-1 lipid)										Ratio
	2004					2010					
	Mean	Median	SD	Maximum	Minimum	Mean	Median	SD	Maximum	Minimum	2010/2004
TriCB-28	1455	1293	753	5552	5	1799	1355	2843	23195	5.0	1.2
TriCB-29	33	29	20	103	5	14	5.0	22	155	5.0	0.4
TetraCB-44	376	375	143	727	32	291	250	202	1513	5.0	0.8
TetraCB-47/48	572	503	274	1887	203	387	325	219	981	114	0.7
TetraCB-49	263	245	130	943	63	195	187	123	822	39	0.7
TetraCB-52/69	1133	1032	685	5555	412	851	696	592	3588	213	0.8
TetraCBs-56/60	635	482	407	2215	212	230	196	140	848	16	0.4
TetraCB-63	102	92	56	270	14	105	101	63	343	5.0	1.0
TetraCB-66	1359	1095	1115	8427	370	1563	1234	1139	7727	393	1.2
TetraCB-70	214	206	90	507	78	227	196	132	554	5.0	1.1
TetraCB-71	174	181	74	414	27	33	19	41	252	5.0	0.2
TetraCB-74	10149	8560	7094	39804	3138	11812	10985	7442	36309	1678	1.2
PentaCB-85	205	142	216	1535	5.0	166	139	136	765	5.0	0.8
PentaCB-87	870	696	494	2196	118	868	731	411	1849	230	1.0
PentaCB-92	637	522	415	2290	155	614	537	372	1895	118	1.0
PentaCB-93/95/98	732	671	355	2104	262	546	503	264	1300	137	0.7
PentaCB-99	17312	13690	11281	65276	3109	17672	15165	9690	42666	2450	1.0
PentaCB-101	1699	1400	1163	7854	403	1608	1551	1005	5468	257	0.9
PentaCB-107/108	603	503	432	2733	90	776	665	458	2704	158	1.3
PentaCB-110	401	328	304	2116	103	327	304	190	904	13	0.8
PentaCB-117	1846	1302	1692	7781	371	2157	1475	2057	10720	200	1.2
HexaCB-128	704	517	549	3514	116	758	669	487	2567	5.0	1.1
HexaCB-130	5377	4446	3596	20530	1386	6366	5490	4224	22015	761	1.2
HexaCB-132	289	230	200	1183	19	257	250	202	1093	5.0	0.9
HexaCB-134	30	21	31	125	5.0	8.9	5.0	14	78	5.0	0.3
HexaCB-135	440	362	292	1482	87	393	342	257	1366	66	0.9
HexaCB-137	7459	6491	4561	29712	1925	8653	7601	5000	26719	2095	1.2
HexaCB-138	69560	58451	36880	205304	11277	73822	65117	36267	180473	12511	1.1
HexaCB-139/149	867	637	800	5831	227	185	108	292	1981	5.0	0.2
HexaCB-141	243	186	153	698	5.0	266	234	189	784	5.0	1.1
HexaCB-146	22641	19630	11394	54823	6602	28025	25173	13411	68473	6284	1.2
HexaCB-147	547	471	381	2409	5.0	595	489	388	1938	32	1.1
HexaCB-151	1139	855	931	6212	194	1108	945	943	6528	127	1.0
HexaCB-153	137161	116874	76399	370468	34902	157687	137334	80118	439299	36601	1.1
HexaCB-163/164	40776	35709	21668	99134	9457	43177	37969	21462	115312	10673	1.1
HeptaCB-170	44220	37360	23504	108309	8667	51223	44361	26696	139874	12957	1.2
HeptaCB-172	6505	5337	3597	16557	1354	8041	6773	4379	19830	2019	1.2
HeptaCB-177	8913	6864	5565	27107	1887	10953	8762	6266	31362	1596	1.2
HeptaCB-178	8939	6593	6123	26070	2132	11332	9616	6939	32620	2425	1.3
HeptaCB-179	190	152	140	734	15	152	116	127	607	5.0	0.8
HeptaCB-180	118964	91306	72617	327796	27414	143590	122711	83312	430540	36375	1.2
HeptaCB-181	410	268	368	2295	5.0	418	331	374	2190	5.0	1.0
HeptaCB-182/187	41652	29939	29847	135156	9745	45902	36081	30698	161535	9238	1.1
HeptaCB-183	9816	7437	6687	33400	1597	9947	8389	5996	33924	1692	1.0
HeptaCB-191	2359	2077	1389	7837	428	2570	2200	1402	6713	723	1.1
OctaCB-194	17614	13867	10535	48181	4062	21831	17305	13357	68732	5337	1.2
OctaCB-195	4338	3477	2472	11200	1013	4743	3946	2546	14070	1223	1.1
OctaCB-196/203	15764	12452	9282	42874	3770	12733	9778	7609	39257	2863	0.8
OctaCB-198/201	17786	13093	12139	56904	4394	10954	8551	7219	36874	2570	0.6
OctaCB-200	416	300	308	1622	65	442	328	324	1858	30	1.1
OctaCB-202	2187	1776	2183	9378	5.0	4049	3206	2802	13128	839	1.9
OctaCB-205	779	674	398	1745	201	824	710	417	1919	220	1.1
NonaCB-206	3421	3192	1536	6971	1016	4030	3657	1812	9594	1139	1.2
NonaCB-207	527	493	252	1271	112	573	549	253	1378	189	1.1
NonaCB-208	1090	1009	521	2592	267	1397	1238	665	3456	376	1.3
DecaCB-209	1415	1316	665	3637	376	1823	1624	995	6400	459	1.3
Total TrCBs	1489	1333	759	5602	10	1813	1360	2842	23200	10	1.2
Total TeCBs	14977	12554	8427	47266	6619	15694	13881	8441	41621	3270	1.0
Total PeCBs	24306	20708	13940	77397	6508	24735	21727	11900	58830	3880	1.0
Total HxCBs	287232	249993	144887	678796	92983	321301	279874	149860	789674	69328	1.1
Total HpCBs	241968	186405	143053	655834	57360	284128	237441	157370	825526	74268	1.2
Total OcCBs	58885	46213	36020	167010	14479	55576	45451	33068	175626	13548	0.9
Total NoCBs	5037	4674	2240	10723	1394	6000	5381	2642	13878	1848	1.2
Total PCBs	633894	540320	333305	1575459	192600	709247	608464	343987	1868770	201307	1.1

CB : chlorinated biphenyl ; SD : standared deviation.

concentrations of these dioxin-like compounds ranging from 50–533 (mean : 152, median : 124) and 51–640 (mean : 155, median : 125) pg TEQ g^{-1} lipid in 2004 and 2010, respectively (Table 3). With regard to the non-dioxin-like PCB concentrations, the sums of the concentrations of 56 PCB congeners in the blood in 2004 and 2010 were 193–1575 (mean : 634, median : 540) and 201–1869 (mean : 709, median : 608) ng g^{-1} lipid, respectively. The arithmetic mean concentrations of triCBs, tetraCBs, pentaCBs, hexaCBs, heptaCBs, octaCBs, and nonaCBs in the blood of Yusho patients were 1.5, 15, 24, 287, 242, 59, and 5.0 ng g^{-1} lipid in 2004, respectively, and 1.8, 16, 25, 321, 284, 56, and 6.0 ng g^{-1} lipid in 2010, respectively (Table 4). The concentrations of PCDFs and octaPCBs in the blood of Yusho patient tended to slightly decrease from 2004 to 2010. With respect to the characteristic congeners in the blood of Yusho patients, the concentration of 1,2,3,4,7,8-hexaCDF was found to significantly decrease from year to year. Among non-dioxin-like PCB congeners that present at high concentration over 1000 pg g^{-1} lipid in the blood of Yusho patients, the concentrations of tetraCB 52/69, pentaCB 101, octaCB 198/201, and octaCB 196/203 were shown to significantly decrease from 2004 to 2010. There results were almost the same as those obtained in 136 Yusho patients.

According to the results of the present study, no significant decrease could be confirmed in most congeners of PCDDs, PCDFs, and PCBs in the blood of Yusho patients from 2004 to 2010. Hence, it is thought that the concentrations of PCDDs, PCDFs, and PCBs in the blood of Yusho patients measured in 2010 probably reflect the effects of dioxin exposure via the intake of food. However, the concentrations of 1, 2, 3, 4, 6, 7, 8-heptaCDD, octaCDD, 1, 2, 3, 4, 7, 8-hexaCDF, tetraCB 52/69, pentaCB 101, octaCB 198/201, and octaCB 196/203 in the blood of Yusho patients decreased significantly from 2004 to 2010. In addition, the concentrations of 1, 2, 3, 6, 7, 8-hexaCDD, 2, 3, 4, 7, 8-pentaCDF, and 1, 2, 3, 6, 7, 8-hexaCDF tended to decrease slightly from 2004 to 2010. These findings suggest that the PCDDs, PCDFs, and PCBs have remained in the blood of Yusho patients for a very long time, with over 40 years having passed since the outbreak of Yusho, and are very difficult to excrete from the body.

In the future, the collection of these data from many more patients would be indispensable. Further research regarding the concentrations of PCDDs, PCDFs, and PCBs in the blood of Yusho patients to more accurately assess the effects of these compounds in Yusho patients is needed.

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（和文抄録）

2004 年から 2010 年の期間における油症患者血液中ダイオキシン類濃度の推移

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油症患者のダイオキシン類による人体汚染とその健康影響を把握する目的で，平成 16 年から 22 年度の期間に油症患者から採取した血液中 PCDDs，PCDFs および PCBs 濃度の測定を行った．平成 16 および 22 年度に油症検診を受診した患者は，それぞれ 242 および 200 名で，その中で 136 名の患者が両年度に受診を行った．平成 16 年度に測定した 136 名の油症患者血液中 PCDDs，PCDFs および PCBs の各異性体濃度を平成 22 年度の測定結果と比較した．その結果，油症患者血液中 PCDDs，PCDFs および PCBs のほとんどの異性体が，平成 16 年から 22 年の期間に濃度減少を示さなかった．しかしながら，油症患者血液中 1,2,3,4,6,7,8-heptaCDD，octaCDD，1,2,3,4,7,8-hexaCDF，tetraCB52/69，pentaCB101，octaCB198/201 および octaCB196/203 の濃度は，平成 16 年度の結果と比べて減少していた．加えて，1,2,3,6,7,8-hexaCDD，2,3,4,7,8-pentaCDF および 1,2,3,6,7,8-hexaCDF の濃度も減少傾向を示した．