Congener Profiles of PCBs and New Proposal of Indicator Congeners

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Introduction

Full homologue analysis for PCB has been standardized in Japan since 2002 as JIS K0093 [1] and since 1992 as Methods of Examining Standards of General Waste under Special Control and Industrial Waste under Special Control with HRGC/HRMS [2]. GC-ECD was also used as the standard method for PCB analysis [1,3]. Same type of analytical method was specified as EPA Method1668 in US [4]. On the other hand, a simple analytical method has been established in Europe, DIN 51527, where six indicator congeners are identified and quantified and total PCB are calculated as 5 times the sum of the individual congeners [5,6]. Balfanz et al. reported the investigation about PCB-related indoor air contamination due to sealants determined according to DIN 51527[7]. When the homologue pattern of samples is similar to that of technical PCB, DIN method is reasonable. But PCB has origins from both technical PCB and thermally and/or chemically by-products. The purpose of this research is to establish simplified methods for PCB analysis without failure of the precision, for example, which congeners should be selected and how total PCB should be calculated in the different media of target samples.

Materials and methods

The technical PCB, Kanechlor (KC-300, KC-400, KC-500, KC-600), Aroclor1268, ClophenT64, and Chlorofen were used for the measurement by HRGC/HRMS (resolution >10,000). The data of Aloclor (Ar1016, Ar1242, Ar1254, Ar1260) and Clophen (A30, A40, A50, A60) were derived from Takasuga et al. [8]. The indoor-air samples were prepared in the different 5 days from the facility where the transformer and the capacitor were dismantled and cleaned (Facility A), and in the different 2 days from the room where the sealants containing PCB were used (Facility B). The details of the simple sampling method using PS-Air cartridge (cartridge method) were presented elsewhere [9,10]. The flue and emission gases were sampled in the municipal solid waste (MSW) incinerator (Facility C), and in the four cement plants (Facilities D1, D2, D3, D4). The wastes, bag filter ash and bottom ash were also sampled in the Facility C. Sample extraction and clean up methods were based on the Standard Manual on Dioxins Analysis in Waste Management [11] and the JIS K0311 method [12].

From the congener specific data analyzed by HRGC-HRMS, the indicator congeners were selected and the total PCB were calculated from the sum of the individual congeners, such as 6 indicator congeners (IUPAC No. # 28, # 52, # 101, # 138, # 153, and # 180) by DIN 51527 (DIN method) and 15 indicator congeners (IUPAC No. # 18, # 20, # 28, # 31, # 44, # 52, # 101, # 105, # 118, # 138, # 149, # 153, # 170, # 180, and # 194) by CEN/TC19/WG22 (CEN method) [13,14], and further 4 congeners of #3, #8(#5), #206 and #209 were selected for calculations as possible congeners.

Results and Discussion

Table 1 shows the composition (%) of homologues, and 19 possible indicator congeners, and the factors for the calculation of total PCB in technical PCB formulations. In DIN method, the ratios of the sum of the individual six congeners to total PCB were 19.0-27.8% (Kanechlor), 18.5-33.7% (Aroclor except for Ar1268), 18.8-38.8% (Clophen), and 29.7% (Chlorofen). The factors were calculated as 3.60-5.26 in Kanechlor, 2.97-5.41 in Aroclor except for Ar1268,

Table1. Composition(%) and factors to total PCB in Kanechlor, Aroclor, Clophen and Clorofen

	Kanechlor (Japan)				Aroclor (USA)				
Homologue	KC-300	KC-400	KC-500	KC-600	Ar1016	Ar1242	Ar1254	Ar1260	Ar1268
MoCBs	0.35	0.10	0.10	0.11	1.1	1.4	0.024	0.054	<0.00000009
DiCBs	18	1.2	0.21	0.050	17	18	0.30	0.24	<0.00000012
TrCBs	55	20	1.6	1.3	48	37	0.73	0.41	0.020
TeCBs	25	60	14	3.9	33	37	14	0.95	0.10
PeCBs	2.3	19	47	8.8	0.77	6.5	55	8.2	0.15
HxCBs	0.40	3.6	31	37	0.0033	0.49	26	39	0.49
HpCBs	0.063	0.77	4.2	41	<0.0001	0.057	4.1	43	5.6
OcCBs	0.0013	0.18	0.60	11	<0.0001	0.011	0.43	7.3	41
NoCBs	0.00010	0.016	0.044	0.52	<0.0001	0.00047	0.041	0.71	46
DeCB	0.0015	0.0036	0.0037	0.0067	<0.0001	<0.0001	0.0030	0.056	7.1
Congener									
#3	0.17	0.094	0.09	0.1	-	-	-	-	<0.00000009
#8	9.7	0.66	0.16	0.029	8.8	8.9	0.13	0.12	<0.00000012
#18	8.2	2.8	0.24	0.21	6.9	5.2	0.10	0.056	0.0046
#20	7.6	2.4	0.20	0.15	6.7	5.0	0.10	0.061	0.0032
#28/31	18	8.6	0.55	0.49	19	14	0.28	0.15	0.0082
#44	2.2	5.4	1.5	0.30	4.6	2.8	1.4	0.039	0.0079
#52	2.3	6.5	5.2	0.46	6.0	3.5	4.8	0.31	0.014
#101	0.32	2.4	8.6	2.3	0.057	0.84	9.7	2.8	0.024
#105	0.15	1.5	2.3	0.47	0.0031	0.41	2.6	<0.0001	0.0073
#118	0.24	2.3	6.6	0.77	0.0029	0.59	6.9	0.56	0.019
#138	0.069	0.75	6.3	4.4	<0.0001	0.060	7.0	8.3	0.017
#149	0.062	0.44	4.4	7.6	<0.0001	0.075	3.6	7.7	<0.00000004
#153	0.069	0.53	5.2	9.1	0.0021	0.058	4.6	9.5	0.056
#170	0.0044	0.13	0.59	3.0	<0.0001	0.0048	0.56	4.8	0.0065
#180	0.016	0.24	1.1	11	<0.0001	0.011	0.95	13	1.1
#194	0.0011	0.051	0.18	2.1	<0.0001	0.0036	0.092	1.7	2.6
#206	0.00007	0.012	0.04	0.42	-	-	-	-	26
#209	0.0015	0.0036	0.0036	0.0067	<0.0001	<0.0001	0.0030	0.050	7.1
Ratio (%) and factor to total PCB									
Ratio (DIN method)	21.0	19.0	26.8	27.8	24.9	18.5	27.3	33.7	1.2
Factor (DIN method)	4.77	5.26	3.73	3.60	4.01	5.41	3.66	2.97	83.8
Ratio (CEN method)	39.4	34.0	42.9	42.4	43.1	32.5	42.6	48.6	3.89
Factor (CEN method)	2.54	2.94	2.33	2.36	2.32	3.07	2.35	2.06	25.7

	Clophen (Germany)					Chlorofen (Poland)
Homologue	A30	A40	A50	A60	T64	
MoCBs	0.030	0.0050	0.0054	0.0030	0.0013	0.0019
DiCBs	16	0.34	0.050	0.027	<0.00000012	0.38
TrCBs	55	16	0.27	0.10	0.0034	0.93
TeCBs	25	63	18	1.0	0.014	6.2
PeCBs	2.5	19	56	16	0.12	26
HxCBs	0.6	1.6	24	54	11	44
HpCBs	0.3	0.48	1.9	28	45	19
OcCBs	0.051	0.063	0.10	0.25	39	2.7
NoCBs	<0.0001	0.0036	0.013	0.081	4.5	0.16
DeCB	<0.0001	0.00044	0.0034	0.0018	0.19	0.017
Congener						
#3	-	-	-	-	<0.00000009	<0.00000009
#8/5	9.3	0.20	0.025	0.015	<0.000000012	0.21
#18	7.3	2.2	0.026	0.014	<0.00000004	0.16
#20	7.8	1.8	0.025	0.012	0.0034	0.10
#28/31	22	7.7	0.18	0.039	<0.00000004	0.28
#44	1.9	5.4	1.7	0.033	<0.00000011	0.65
#52	2.3	7.9	5.0	0.51	0.0034	2.0
#101	0.39	2.4	8.9	5.3	0.049	6.3
#105	0.22	1.3	3.6	0.12	0.010	0.97
#118	0.32	2.2	9.1	1.4	0.006	3.0
#138	0.13	0.39	6.6	12	0.53	7.1
#149	0.080	0.22	3.6	10	0.056	0.64
#153	0.10	0.26	3.9	13	5.96	8.7
#170	0.046	0.053	0.26	2.3	1.6	2.2
#180	0.067	0.12	0.42	8.1	20	5.3
#194	0.015	0.013	0.020	0.058	11	0.61
#206	-	-	-	-	4.5	0.083
#209	<0.0001	0.00044	0.0034	0.0018	0.19	0.017
Ratio (%) and factor to total PCB						
Ratio (DIN method)	24.6	18.8	25.0	38.8	26.5	29.7
Factor (DIN method)	4.06	5.33	3.99	2.58	3.78	3.37
Ratio (CEN method)	42.4	32.0	43.4	53.1	39.6	38.1
Factor (CEN method)	2.36	3.13	2.30	1.88	2.52	2.63

-: not analyzed

2.58-5.33 in Clophen, and 3.37 in Chlorofen. The factor of 83.8 obtained from Ar1268 is extremely high because Ar1268 is occupied in highly chlorinated biphenyls, the sum of OcCB and NoCB comes to 86.5%. By the similar procedures, the factors by CEN mehod were calculated as 2.06-3.07 in Aroclor except for Ar1268, 1.88-3.13 in Clophen, and 2.63 in Chlorofen, almost similar to those of Kanechlor (2.33-2.94). Sauvain et al. [13] reported the factors for Ar1254 and Ar1260 analyzed by ECD. They are 4.81 and 3.18 by DIN method, and 2.60 and 2.14 by CEN method, in Ar1254 and Ar1260, respectively. They are almost similar to our study.

Table 2 shows the concentration of homologues, and 19 possible indicator congeners, and the factors for the calculation of total PCB in indoor-air samples, sealant, emission gases, wastes, and ashes. PCB concentration in the Facility A, the dismantling area of capacitors, was 49.1-325ng/m^{3}N. The ratio of the sum of six indicator congeners to total PCB by DIN method were 12.0-21.7%, and the factors were 4.62-8.31, while those of Kanechlor were 3.60-5.26. The ratios of the sum of 15 individual congeners by CEN method were 26.0-39.2%, and the factors were 2.55-3.84, while those of Kanechlor were 2.33-2.94. The homologue patterns of these samples were similar to those of KC-300 and the correlation coefficients were 0.72-0.94. When the index was more than 0.9, A1, the factor was similar to Kanechlor. In other samples, A2-A5, the indices were less than 0.9 and the factors were over the Kanechlor because lower chlorinated biphenyls might be increased by the high vapor pressure.

In the Facility B, PCB concentrations in the sealant and in indoor-air were 4.7% and 129 ng/m^3 N and 180ng/m^3 N, respectively. The factors in indoor-air were 5.90-6.24 by DIN method and 3.55-3.72 by CEN method, while those of the sealant were 9.36 and 4.05. The factors were higher than that of Kanechlor, especially the sealant. Although the homologue pattern of the sealant was relatively similar to KC-400, it was shifted to the highly chlorinated biphenyl, especially the increasing of pentachlorobiphenyl (PeCB), because trichlorobiphenyl (TrCB) might have vaporized in the room.

In the Facility C, MSW incinerator, waste samples (C1-C3), flue gas samples (C4-C6) and ashes (C7, C8) were analyzed. PCB concentrations were 8.48-14.1ng/g in wastes, 3.36-39.1ng/m^{3}N in flue gas, 10.3 ng/g in bag filter ash and 0.662ng/g in bottom ash. The factors in waste were 4.73-5.41 by DIN method and 2.86-3.25 by CEN method. These homologue patterns were similar to Kanechlor to some extent. The factors of the flue gas were widespread, 5.42-23.2 and 3.45-9.77 and those of ashes were within the flue gas. These homologue patterns were different from Kanechlors because PCB in gases and ashes were mainly formed as by-product. They were relatively high in mono- (MoCB) and di-chlorobiphenyl (DiCB), This might influence the widespread factors.

PCB concentrations in the emission gases from the cement plant (D1-D4) were 250-7200ng/m^{3}N. The emission gases from the cement plant have very peculiar homologue pattern whose major homologues were MoCB and DiCB. The percentage of the sum of MoCB and DiCB was 78.8-97.3%. Therefore the factors, 20.7-227 by DIN method and 11.0-103 by CEN method, were much different from those of technical PCB. This showed that the samples from cement plant could not be precisely calculated using the factors by DIN or CEN method.

CEN method is very reasonable because major congeners in technical PCB are selected from TrCB to OcCB and the sum of the congeners occupies 30~50% of total PCB. Therefore when the homologue pattern is similar to that of technical PCB, the factors of the samples originated from technical PCB are very useful and calculated total PCB concentration is relatively accurate. When homologue pattern is far from technical PCB, it seems not to be accurate to calculate total PCB using the factor from the sum of indicator congeners in the existing method such as DIN or CEN

Table2. Concentration and factors to total PCB in the samples

	Facilit™of PCB dismantling and cleaning					Room used sealant containing PCB		
	A1	A2	A3	A4	A5	B1	B2	B3
	Indoor-air	Indoor-air	Indoor-air	Indoor-air	Indoor-air	Indoor-air	Indoor-air	Sealant
Homologue	ng/m^{3}N	ng/m^{3}N	ng/m^{3}N	ng/m^{3}N	ng/m^{3}N	ng/m^{3}N	ng/m^{3}N	Ê g/g
MoCBs	3.52	17.2	31.8	44.6	59.3	0.040	0.041	0.074
DiCBs	6.80	15.0	38.7	54.6	84.9	3.8	4.5	5.4
TrCBs	18.3	20.3	50.2	58.3	106	20	25	1800
TeCBs	13.7	8.74	30.2	26.6	59.7	86	120	26000
PeCBs	5.47	2.38	8.03	7.04	13.3	18	29	17000
HxCBs	1.12	0.597	1.41	1.35	2.02	0.86	1.2	1600
HpCBs	0.0913	0.106	0.110	0.139	0.166	0.027	0.029	94
OcCBs	<0.00016	0.00870	0.0123	0.0182	0.0144	<0.005	<0.005	13
NoCBs	0.00471	<0.00036	0.00196	<0.00026	0.00121	<0.005	<0.005	0.93
DeCB	0.000908	<0.00011	<0.00011	<0.000081	<0.00014	<0.004	<0.004	0.041
Total	49.1	64.3	160	193	325	129	180	47000
Congener								
#3	0.593	1.90	3.71	4.92	7.19	0.015	0.019	0.042
#8/5	3.24	6.78	17.0	24.8	38.5	2.2	2.4	0.77
#18	5.15	7.05	17.5	20.5	38.5	2.1	2.3	20
#20	1.38	1.07	3.07	3.09	6.13	2.6	3.2	260
#28/31	5.68	4.79	13.3	13.6	26.9	8.9	11	790
#44	1.50	0.919	3.26	2.70	6.37	7.9	11	1900
#52	3.61	2.46	8.56	7.86	17.3	10	13	1800
#101	1.03	0.389	1.59	1.31	2.52	2.7	4.4	1800
#105	0.0922	0.114	0.112	0.104	0.174	0.49	0.85	1800
#118	0.277	0.209	0.366	0.326	0.577	1.2	1.9	2500
#138	0.151	0.133	0.173	0.185	0.248	0.10	0.13	280
#149	0.225	0.0909	0.287	0.266	0.418	0.18	0.27	190
#153	0.152	0.0900	0.190	0.180	0.282	0.12	0.17	220
#170	0.00697	0.0139	<0.00026	0.0113	0.00364	<0.005	<0.005	14
#180	0.0174	0.0234	0.0232	0.0270	0.0359	0.010	0.0092	27
#194	<0.00016	0.00381	0.00316	0.00467	0.00912	<0.005	<0.005	3.0
#206	0.0047	<0.00036	<0.00037	<0.00026	0.00121	<0.005	<0.005	0.65
#209	0.0009	<0.00011	<0.00011	<0.000081	<0.00014	<0.004	<0.004	0.041
Ratio (%) and factor to total PCB								
Ratio (DIN method)	21.7	12.3	14.8	12.0	14.5	17.0	16.0	10.7
Factor (DIN method)	4.62	8.15	6.73	8.31	6.88	5.90	6.24	9.36
Ratio (CEN method)	39.2	27.0	30.2	26.0	30.6	28.2	26.9	25.2
Factor (CEN method)	2.55	3.70	3.31	3.84	3.27	3.55	3.72	4.05

	MSW incineration facilit™								Cement plant			
	C1	C2	C3	C4	C5	C6	C7	C8	D1	D2	D3	D4
	Waste	Waste	Waste	Flue gas at boiler exit	Flue gas at BF exit	Flue gas at the final exit	BF ash	Bottom ash	Emission gas	Emission gas	Emission gas	Emission gas
Homologue	ng/g	ng/g	ng/g	ng/m^{3}N	ng/m^{3}N	ng/m^{3}N	ng/g	ng/g	ng/m^{3}N	ng/m^{3}N	ng/m^{3}N	ng/m^{3}N
MoCBs	0.142	0.11	0.563	5.42	0.28	1.91	1.12	0.109	290	6600	1100	140
DiCBs	2.59	2.89	1.90	3.19	0.31	3.53	0.917	0.150	31	350	240	80
TrCBs	2.90	3.65	1.90	3.55	0.35	5.57	1.17	0.104	5.2	170	180	25
TeCBs	3.01	3.22	1.83	4.52	0.724	4.61	1.19	0.0896	2.2	76	110	4.7
PeCBs	1.72	2.33	1.12	5.84	0.954	1.70	1.33	0.0619	0.65	8.0	53	1.3
HxCBs	1.07	1.33	0.781	6.03	0.451	0.476	1.35	0.0521	0.28	1.9	13	0.30
HpCBs	0.398	0.496	0.334	5.30	0.167	0.199	1.58	0.0463	<0.02	0.18	2.5	0.085
OcCBs	0.0467	0.0481	0.0404	2.63	0.0706	0.0500	0.873	0.0209	<0.02	<0.03	0.23	<0.02
NoCBs	0.0136	0.0153	0.00726	2.04	0.0438	0.0227	0.558	0.0195	<0.01	<0.02	0.039	<0.01
DeCB	0.0329	0.0254	0.00528	0.62	0.0152	0.0146	0.185	0.00857	<0.01	<0.02	0.030	<0.01
Total	11.9	14.1	8.48	39.1	3.36	18.1	10.3	0.662	330	7200	1700	250
Congener												
#3	0.0490	0.0331	0.160	1.96	0.0777	1.04	0.433	0.0494	69	1600	340	47
#8/5	0.181	0.447	0.137	0.334	0.0491	0.102	0.0843	0.00995	6.5	68	39	15
#18	0.258	0.406	0.147	0.0770	0.0331	0.0418	0.0164	0.00592	0.46	32	28	1.3
#20	0.454	0.521	0.281	0.424	0.0448	0.136	0.132	0.0111	0.93	18	24	2.9
#28/31	1.08	1.29	0.704	0.400	0.0892	0.282	0.103	0.0144	0.84	47	41	1.4
#44	0.221	0.233	0.131	0.119	0.0645	0.0691	0.0125	0.00424	0.24	13	12	0.34
#52	0.435	0.555	0.232	0.247	0.202	0.132	0.0237	0.0105	0.34	13	22	0.62
#101	0.299	0.355	0.149	0.488	0.169	0.146	0.0545	0.00492	0.16	2.1	14	0.42
#105	0.111	0.149	0.0988	0.383	0.0321	0.615	0.107	0.00402	<0.02	<0.3	0.92	0.044
#118	0.239	0.393	0.243	0.603	0.0908	0.113	0.133	0.00592	0.055	<0.3	3.9	0.084
#138	0.226	0.302	0.169	0.533	0.0777	0.0965	0.0950	<0.02	0.050	0.25	1.9	0.064
#149	0.151	0.188	0.102	0.467	0.0676	0.0663	0.0568	0.00413	0.074	0.52	3.2	0.065
#153	0.285	0.349	0.220	0.377	0.0613	0.0814	0.0493	0.00414	0.062	0.32	2.8	0.077
#170	0.0431	0.0538	0.0325	0.511	0.0119	0.0217	0.182	0.00556	<0.01	0.032	0.19	<0.01
#180	0.106	0.133	0.0933	0.527	0.0200	0.0398	0.155	0.00297	<0.02	0.049	0.46	0.042
#194	0.00904	0.00491	0.00491	0.297	0.00923	0.00957	0.105	0.00339	<0.01	<0.02	0.039	<0.02
#206	0.00555	0.00611	0.0047	0.982	0.023	0.013	0.28	0.00947	<0.01	<0.02	0.022	<0.01
#209	0.0329	0.0254	0.00528	0.624	0.015	0.015	0.185	0.00857	<0.01	<0.02	0.030	<0.01
Ratio (%) and factor to total PCB												
Ratio (DIN method)	20.4	21.1	18.5	6.57	18.5	4.30	4.68	5.58	0.440	0.871	4.83	1.05
Factor (DIN method)	4.90	4.73	5.41	15.2	5.42	23.2	21.4	17.9	227	115	20.7	95.7
Ratio (CEN method)	32.9	34.9	30.7	13.9	29.0	10.2	11.9	12.3	0.973	1.75	9.08	2.94
Factor (CEN method)	3.04	2.86	3.25	7.18	3.45	9.77	8.38	8.15	103	57.0	11.0	34.0

method. Especially in the case of by-product PCB and Ar1268, CEN method and also DIN method are not applicable.

Therefore we studied the most adequate congeners to be selected and how the factor should be decided from both points of technical and by-product PCB. Firstly, at least one congener was selected in each homologue group. 4 congeners (#3, #8, #206, #209) were selected in order to add to 15 congeners by CEN method, which is the most major congener in each MoCB, DiCB, NoCB and DeCB homologue. The factors were in the range of 1.88-3.11(Av=2.34, CV=0.15%) in technical PCB including Ar1268 (Table3). The factors of indoor-air samples in both Facilities A and B, 2.13-3.54 (Av=2.64, CV=0.21%), showed almost similar but a little wide range of technical PCB. As for the gases they were 2.95-5.99 (Av=4.02, CV=0.25%), about twice as large as those of technical PCB in both MSW incinerator and cement plants. The method selected as these 19 indicator congeners should be the most precise method because the factors and the variation of each medium were small. It is natural that the more congeners are quantified, the calculated total PCB are more accurate. We challenged to reduce the number of congeners, considering the range of the factors and the variation without failure of the precision.

Table3. Factors to total PCB in Technical PCB and samples

	Technical PCB										Indoor-air					
	Kanechlor			Aroclor			Clophen			Chlorofen	Facility A			Facility B		
	Min-max	Average	CV(%)	Min-max	Average	CV(%)	Min-max	Average	CV(%)		Min-max	Average	CV(%)	Min-max	Average	CV(%)
DIN method	3.60-5.26	4.34	0.19	2.97-83.8	19.97	1.79	2.58-5.33	3.95	0.25	3.37	4.62-8.31	6.94	0.21	5.90-6.24	6.07	0.04
CEN method	2.33-2.94	2.54	0.11	2.06-25.7	7.10	1.47	1.88-3.13	2.44	0.18	2.63	2.55-3.84	3.33	0.15	3.55-3.72	3.63	0.03
CEN+#3+#8+#206+#209	2.03-2.87	2.39	0.15	1.93-2.68	2.28	0.13	1.88-3.11	2.30	0.21	2.60	2.13-2.47	2.31	0.06	3.34-3.54	3.44	0.04
DIN+#3+#8	3.24-5.06	3.89	0.21	2.96-19.4	19.40	1.86	2.57-5.28	3.71	0.28	3.34	3.39-3.88	3.60	0.05	5.35-5.76	5.56	0.05
DIN+#3+#8+#206+#209	3.24-5.05	3.88	0.21	2.89-3.65	3.21	0.12	2.57-5.28	3.60	0.30	3.33	3.39-3.88	3.60	0.05	5.35-5.76	5.56	0.05
J method	3.23-4.71	3.74	0.18	2.68-3.66	3.19	0.14	2.34-4.98	3.32	0.31	3.53	3.55-3.90	3.68	0.04	5.59-6.08	5.83	0.06

	Flue and emission gas						Waste			Ash			Sealant
	Facility C			Facility D									
	Min-max	Average	CV(%)	Min-max	Average	CV(%)	Min-max	Average	CV(%)	Min-max	Average	CV(%)	
DIN method	5.42-23.2	14.63	0.61	20.7-227	114.61	0.75	4.73-5.41	5.02	0.071	17.9-21.4	19.65	0.12	9.36
CEN method	3.45-9.77	6.80	0.47	11.0-103	51.21	0.76	2.86-3.25	3.05	0.064	8.15-8.38	8.27	0.020	4.05
CEN+#3+#8+#206+#209	2.95-5.99	4.37	0.35	3.19-4.19	3.75	0.12	2.59-2.91	2.78	0.060	4.17-4.65	4.41	0.077	4.05
DIN+#3+#8	4.50-9.42	7.32	0.35	3.69-4.29	4.00	0.07	4.07-4.55	4.37	0.059	6.87-10.3	8.59	0.28	9.35
DIN+#3+#8+#206+#209	4.40-9.35	6.96	0.36	3.69-4.29	4.00	0.07	4.04-4.54	4.34	0.059	6.31-8.69	7.50	0.22	9.35
J method	4.49-7.12	5.67	0.24	3.76-4.29	4.03	0.06	3.83-4.32	4.08	0.060	5.39-5.86	5.63	0.059	6.33

J method: #3, #8, #28, #52, #105, #118, #138, #153, #180, #194, #206, #209

At First, 2 congeners (#3, #8) were selected to add to 6 congeners by DIN method, because MoCB and DiCB were major homologues in the flue gases. Although the variation of flue gas from facility C and D became small, it was not improved in Aroclor. Secondly, 2 congeners (#206 and #209) were added to pre-nominate 8 congeners, which was predominant in Ar1268. In the result, the factor and variation became smaller than that of 8 congeners. #194 was selected from HpCB homologue similar to CEN method. It was thought to be better that each 2 congeners were selected from each PeCB and HxCB homologue because they have many congeners. #138 and #153 were selected from HxCB similar to DIN and CEN method. In the case of PeCB homologue, it showed almost similar variation which congeners were selected among #101, #105 and #118. Therefore #105 and #118 were selected as coplanar PCB. The toxic equivalent (TEQ) of coplanar PCB in Kanechlor was able to calculate from the sum of #105 and #118 by multiplying the factor. The factors calculated in our data were 0.00049 (KC-300), 0.00039 (KC-400), 0.00021 (KC-500) and 0.00056 (KC-600). Thus, we selected 12 congeners, #3, #8, #28, #52, #105, #118, #138, #153, #180, #194, #206, and #209, as the indicator congeners and named J Method. The average of the factors were in the range of 3.19-3.74 (Av=3.40, CV=0.21%) in all technical PCB. The average of factors of indoor-air samples in both Facility A and B were 3.68-5.83 (Av=4.30, CV=0.25%). As for the gases they were 4.03-5.67 (Av=4.73, CV=0.25%) in both MSW incinerator and cement plants. The factor of waste was Av=4.08, CV=0.060%, ash was Av=5.63, CV=0.059%. And the factor of sealant was 6.33. This new "J Method" is not inferior to that selected as 19 congeners in the accuracy and much more convenient.

As a result, we could propose J Method using only 12 indicator congener as #3, #8,#28, #52, #105, #118, #138, #153, #180, #194, #206, #209. Furthermore we would like to propose the factors for each medium to calculate total PCB, when we have the information of the sample source. This study is the first challenge to propose both simplified and improved precision method for many media with technical and by-product PCB. Further investigations are necessary to obtain more accurate factor for each medium by the analysis of more samples and the collection of more data.

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