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Distribution of Organochlorines and PCB Congeners In Korean Human Tissues

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In order to investigate the residual amounts of organochlorines and polychlorinated biphenyls (PCBs) in Korean human tissues (blood, adipose tissue, liver, kidney cortex, and lung), the samples were collected from the autopsied cadavers of 40 men and 40 women (from teens to seventies of age). α-BHC, β-BHC, γ-BHC, δ-BHC, *p,p'*-DDT, *p,p'*-DDD, *p,p'*-DDE, endrin, dieldein, aldrin, and 7 marker PCBs (28, 52, 101, 118, 138, 153, and 180) were determined in human tissues. The levels of organochlorines and PCB congeners indicated that they have been widely distributed in Korean human body. Positive correlations in terms of age were observed for the following cases: *p,p'*-DDE, *p,p'*-DDT, Σ-DDT, PCB 118, PCB 138, PCB 153, and Σ-PCB in the adipose tissue, and *p,p'*-DDE in the lung. Concentration of these compounds showed a significant age-related increase. Accumulation of these compounds in aged people revealed that these compounds were more slowly eliminated in our environment and risk assessment was necessary for further proper action. Significant differences in the levels of PCBs between genders were found for PCB 118 in the adipose tissue and PCB 138 in the liver. Positive correlation coefficients between tissues were detected with *p,p'*-DDE and β-BHC.

Key words: Organochlorines, PCB congeners, Human tissues, Korean, Autopsy cases

INTRODUCTION

Organochlorines and PCB congeners are effective against a variety of insects. These chemicals were introduced in the 1940s and had widely been used because of their potent effect and relatively low cost but are rarely used today because of their environmental persistence.

Although production of organochlorines and PCB congeners has been stopped in Korea and most other parts of the world, but still they are considered as ubiquitous pollutants due to their persistence in the environment. In aquatic systems, organochlorines are adsorbed onto sediments in water that can bioconcentrate in marine mammals. Because these chemicals are soluble in fat, they are found at higher concentrations in fatty foods. Diets that contain fats that may be contaminated with organochlorines and PCB congeners (e.g., contaminated milk and dairy products, fish) lead to increased exposure to these chemicals. Bioaccumulation of organochlorines and PCB congeners through the food chain has resulted in high concentrations of these compounds in meat, milk and fish. Because of their lipophilic properties, organochlorines and PCB congeners are not readily eliminated from the body. Estimated half-lives of individual organochlorines and PCB congeners in humans ranges from < 1 month to > 40 years (Wolff *et al.*, 1992). An increased interest on endocrine disrupting substances has again attracted attention towards organochlorines and PCB congeners (Colborn *et al.*, 1993, Hillman, 1993, Soto *et al.*, 1995). The presence of organochlorines and PCB congeners in human adipose tissue has recently caused concern due to their antiandrogenic and estrogenic properties and their effects on sexual activity and development of breast cancer. Until recently, several studies have investigated the residual levels of these compounds in human milk, blood and adipose tissue collected from people of different countries (WHO, 1988, Schecter *et al.*, 1989). For the evaluation of the risk assessment, estimation of exposure level has to be performed. In Korea, there is

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a lack of data on the concentration of organochlorines and PCB congeners in human tissues. Therefore, we performed the present work for the purpose of determination of the levels of organochlorines and PCB congeners in human tissues such as blood, adipose tissue, liver, kidney cortex, and lung obtained from autopsy material. We have also correlated its relation with age, sex, and variation between the tissue samples. The halogenated compounds studied in this article include the organochlorines such as α-, β-, γ-, δ-benzenehexachloride (BHC), the DDT group (*p,p'*-DDE, *p,p'*-DDT, *p,p'*-DDE), aldrine, dieldrine, endrine, and 7 marker of PCB congeners (PCB 28, 52, 101, 118, 138, 153, and 180).

MATERIALS AND METHODS

Chemicals

α-BHC, β-BHC, γ-BHC, δ-BHC, *p,p'*-DDE, *p,p'*-DDT, and *p,p'*-DDE, aldrine, dieldrine, endrine, and mirex were purchased from Dr. Ehrenstorfer GmbH Co. (Atlanta, GA). PCB congeners (28, 52, 101, 118, 138, 153, 180, and 204) were purchased from ChemService Co. (West Chester, PA). All other chemicals and solvents were of organic residue analytical grade. The standard stock solutions of the organochlorines and PCB congeners were 1 mg/mL in methanol. Working standards were prepared by dilution with methanol. Mirex and PCB congener 204 were used as internal standard for organochlorines and PCB congeners, respectively.

Sample collection

The analyzed postmortem tissues were obtained from autopsied cadavers subjected to undergoing forensic medical examinations at the National Institute of Scientific Investigation of Korea, from 2000 to 2003. The number of male and female cadavers were 20~40 (Table I). We obtained samples from persons who died due to trauma, traffic accident, hanging, stangulation *etc.*, (people who died without any specific disease). Blood, adipose tissue, liver, kidney cortex, and lung were taken and stored at -30 °C until the analysis.

Table I. Distribution of age and gender of individual subjects

Age group	male	Female	Total
Teens	2	-	2
Twenties	7	13	20
Thirties	12	11	23
Forties	6	5	11
Fifties	3	5	8
Over Sixties	10	6	16
Total	40	40	80

Sample preparation and purification

Sample homogenization, extraction and column chromatographic cleanup were carried out according to the previously described procedure (Yoo *et al.*, 2001). Briefly, liver, kidney cortex, and lung were weighed to be 5 g and homogenized with sodium sulfate solution in a tissue grinder. Homogenized samples and adipose tissues were liquid phase extracted with *n*-hexane and exact weight of lipid component was determined. Thereafter, organochlorines and PCB congeners residues were extracted thrice with acetonitrile. The acetonitrile layer was pooled, and 2% sodium chloride was added and extracted thrice with *n*-hexane and evaporated to approximately 5 mL. The residual samples were subjected to chromatographic purification on deactivated Florisil column.

Instrumental condition

Organochlorines and PCB congeners were identified with GC coupled with electron capture detector (GC/ECD, ^{63}Ni) in a fused silica capillary DB-5 and DB-1 column (30 m×0.25 mm, 0.25 μm film thickness, respectively). Quantification was performed with DB-5 column. Mirex and PCB congener 204 solution (0.1 μg/mL) were used as internal standards for organochlorines and PCB congeners, respectively. The ratio of the peak area of target analytes to that of internal standard was utilized to calculate the concentration of the analytes in the specimen. Statistical

Table II. LOD (limit of detection) and recoveries of organochlorines and PCB congeners added to liver, adipose tissue, and blood (added amount : 0.1 μg)

Analytes	LOD (pg)	Recovery (Mean ± SD, %)		
		Blood (n=3)	Adipose tissue (n=3)	Liver (n=3)
α-BHC	1.25	84.5 ± 10.76	114.0 ± 10.16	106.0 ± 10.74
β-BHC	2.5	77.7 ± 3.64	85.2 ± 4.41	88.4 ± 6.17
γ-BHC	1.25	83.8 ± 5.41	75.8 ± 2.89	81.8 ± 9.31
δ-BHC	1.25	90.8 ± 9.55	96.3 ± 3.95	97.8 ± 6.25
p,p'-DDT	5	89.0 ± 3.63	98.4 ± 10.78	102.4 ± 11.15
p,p'-DDD	2.5	92.3 ± 4.36	86.7 ± 6.70	94.5 ± 12.53
p,p'-DDE	2.5	92.0 ± 5.74	83.4 ± 8.34	81.8 ± 4.07
endrin	1.25	78.4 ± 4.91	72.5 ± 6.39	71.0 ± 5.80
dieldein	1.25	91.6 ± 13.06	78.2 ± 13.84	70.7 ± 4.59
aldrin	0.625	65.4 ± 3.40	71.2 ± 6.91	65.5 ± 2.07
PCB 28	1.6	77.3 ± 9.81	80.9 ± 7.39	86.7 ± 5.49
PCB 52	1.6	81.3 ± 4.62	89.7 ± 2.92	80.5 ± 5.39
PCB 101	3.2	67.3 ± 0.94	75.3 ± 1.09	71.6 ± 5.56
PCB 118	3.2	107.2 ± 15.80	96.0 ± 15.89	101.8 ± 17.78
PCB 138	1.6	73.1 ± 0.19	91.7 ± 11.64	82.2 ± 6.31
PCB 153	1.6	77.8 ± 8.11	79.6 ± 9.03	85.6 ± 10.44
PCB 180	1.6	69.0 ± 0.83	72.8 ± 2.72	78.1 ± 3.30

Table III. Concentration of organochlorine pesticides and PCB congeners (μg/g extracted fat basis) in blood, adipose tissue, liver, kidney cortex, and lung

	Blood															
OCs	Sex	Fre.	Mean±SD	Range	N	OCs& PCBs	Sex	Fre.	Mean±SD	Range	N	PCBs	Sex	Fre.	Mean±SD	Range	N
	M	3%	0.0009±0.0054	ND~0.0344	40		M	0%	ND	ND	40		M	0%	ND	ND	30
α-BHC	F	10%	0.0269±0.0918	ND~0.4720	40	Aldrin	F	3%	0.0267±0.1687	ND~1.0670	40	PCB 101	F	0%	ND	ND	30
	T	6%	0.0139±0.0659	ND~0.4720	80		T	1%	0.0133±0.1193	ND~1.0670	80		T	0%	ND	ND	60
	M	5%	0.0350±0.1751	ND~1.0639	40		M	70%	0.4816±0.7713	ND~3.7810	40		M	33%	0.3570±0.8023	ND~3.1417	30
β-BHC	F	8%	0.0247±0.0914	ND~0.4503	40	*p,p'*-DDE	F	78%	0.5221±0.5716	ND~2.1640	40	PCB 118	F	23%	0.4608±1.0682	ND~4.4890	30
	T	6%	0.0298±0.1388	ND~1.0639	80		T	74%	0.5018±0.6748	ND~3.7810	80		T	28%	0.4089±0.9381	ND~4.4890	60
	M	3%	0.0306±0.1937	ND~1.2253	40		M	0%	ND	ND	40		M	0%	ND	ND	30
γ-BHC	F	8%	0.1431±0.7089	ND~4.4090	40	*p,p'*-DDT	F	0%	ND	ND	40	PCB 138	F	0%	ND	ND	30
	T	5%	0.0869±0.5195	ND~4.4090	80		T	0%	ND	ND	80		T	0%	ND	ND	60
	M	0%	ND	ND	40		M	0%	ND	ND	40		M	0%	ND	ND	30
δ-BHC	F	3%	0.0045±0.0283	ND~0.1792	40	*p,p'*-DDD	F	3%	0.0249±0.1575	ND~0.9960	40	PCB 153	F	0%	ND	ND	30
	T	1%	0.0022±0.0200	ND~0.1792	80		T	1%	0.0124±0.1114	ND~0.9960	80		T	0%	ND	ND	60
	M		0.0665±0.2567	ND~1.2253	40		M		0.4816±0.7713	ND~3.7810	40		M	3%	0.0695±0.3807	ND~2.0850	30
Σ-BHC	F		0.1991±0.7382	ND~4.4090	40	Σ-DDT	F		0.5470±0.6477	ND~2.8500	40	PCB 180	F	0%	ND	ND	30
	T		0.1328±0.5531	ND~4.4090	80		T		0.5143±0.7084	ND~3.7810	80		T	2%	0.0347±0.2692	ND~2.0850	60
	M	3%	0.0078±0.0490	ND~0.3100	40		M	3%	0.1216±0.6660	ND~3.6480	30		M		0.5481±1.1406	ND~3.6658	30
Endrin	F	5%	0.0073±0.0325	ND~0.1675	40	PCB 28	F	7%	0.0726±0.3298	ND~1.7752	30	Σ-PCB	F		0.5334±1.0865	ND~4.4890	30
	T	4%	0.0075±0.0413	ND~0.3100	80		T	5%	0.0971±0.5217	ND~3.6480	60		T		0.5408±1.1044	ND~4.4890	60
	M	0%	ND	ND	40		M	0%	ND	ND	30						
Dieldrin	F	0%	ND	ND	40	PCB 52	F	0%	ND	ND	30						
	T	0%	ND	ND	80		T	0%	ND	ND	60						

Table III. Continued

Adipose tissue																
OCs	Sex	Fre.	Mean±SD	Range	N	OCs& PCBs	Sex	Fre.	Mean±SD	Range	N	PCBs	Sex	Fre.	Mean±SD	Range	N
	M	5%	0.0005±0.0022	ND~0.0108	40		M	5%	0.0002±0.0010	ND~0.0049	40		M	0%	ND	ND	30
α-BHC	F	10%	0.0008±0.0028	ND~0.0159	40	Aldrin	F	10%	0.0025±0.0089	ND~0.0428	40	PCB 101	F	3%	0.0010±0.0053	ND~0.0293	30
	T	8%	0.0006±0.0025	ND~0.0159	80		T	8%	0.0014±0.0064	ND~0.0428	80		T	2%	0.0005±0.0038	ND~0.0293	60
	M	58%	0.0428±0.0712	ND~0.3995	40		M	100%	0.1443±0.1238	0.0015~0.6096	40		M	70%	0.0220±0.0346*	ND~0.1486	30
β-BHC	F	80%	0.0403±0.0441	ND~0.2160	40	*p,p'*-DDE	F	100%	0.2030±0.1915	0.0217~0.8987	40	PCB 118	F	77%	0.0167±0.0158	ND~0.0585	30
	T	69%	0.0415±0.0588	ND~0.3995	80		T	100%	0.1737±0.1629	0.0015~0.8987	80		T	73%	0.0193±0.0268	ND~0.1486	60
	M	5%	0.0014±0.0069	ND~0.0410	40		M	83%	0.0339±0.0350	ND~0.1748	40		M	93%	0.0312±0.0376	ND~0.1677	30
γ-BHC	F	5%	0.0024±0.0119	ND~0.0720	40	*p,p'*-DDT	F	75%	0.0243±0.0220	ND~0.0746	40	PCB 138	F	87%	0.0199±0.0144	ND~0.0612	30
	T	5%	0.0019±0.0097	ND~0.0720	80		T	79%	0.0291±0.0294	ND~0.1748	80		T	90%	0.0255±0.0288	ND~0.1677	60
	M	0%	ND	ND	40		M	58%	0.0067±0.0127	ND~0.0709	40		M	73%	0.0165±0.0206	ND~0.0699	30
δ-BHC	F	0%	ND	ND	40	*p,p'*-DDD	F	60%	0.0054±0.0075	ND~0.0288	40	PCB 153	F	57%	0.0105±0.0144	ND~0.0487	30
	T	0%	ND	ND	80		T	59%	0.0060±0.0104	ND~0.0709	80		T	65%	0.0135±0.0179	ND~0.0699	60
	M		0.0448±0.0721	ND~0.3995	40		M		0.1848±0.1479	0.0015~0.6845	40		M	87%	0.0226±0.0260	ND~0.1126	30
Σ-BHC	F		0.0434±0.0458	ND~0.2160	40	Σ-DDT	F		0.2327±0.1888	0.0217~0.8987	40	PCB 180	F	87%	0.0087±0.0067	ND~0.0265	30
	T		0.0441±0.0600	ND~0.3995	80		T		0.2088±0.1702	0.0015~0.8987	80		T	87%	0.0157±0.0201	ND~0.1126	60
	M	33%	0.0025±0.0051	ND~0.0178	40		M	7%	0.0015±0.0071	ND~0.0385	30		M		0.0950±0.1028	ND~0.4989	30
Endrin	F	28%	0.0035±0.0104	ND~0.0583	40	PCB 28	F	10%	0.0027±0.0094	ND~0.0374	30	Σ-PCB	F		0.0595±0.0370	ND~0.1462	30
	T	30%	0.0030±0.0081	ND~0.0583	80		T	8%	0.0021±0.0083	ND~0.0385	60		T		0.0772±0.0787	ND~0.4989	60
	M	3%	0.0001±0.0008	ND~0.0052	40		M	3%	0.0012±0.0066	ND~0.0360	30						
Dieldrin	F	0%	ND	ND	40	PCB 52	F	0%	ND	ND	30						
	T	1%	0.0001±0.0006	ND~0.0052	80		T	2%	0.0006±0.0047	ND~0.0360	60						

Table III. Continued

	Liver															
OCs	Sex	Fre.	Mean±SD	Range	N	OCs& PCBs	Sex	Fre.	Mean±SD	Range	N	PCBs	Sex	Fre.	Mean±SD	Range	N
	M	5%	0.0059±0.0298	ND~0.1819	40		M	3%	0.0004±0.0026	ND~0.0165	40		M	3%	0.0349±0.1909	ND~1.0457	30
α-BHC	F	10%	0.0076±0.0238	ND~0.0946	40	Aldrin	F	0%	ND	ND	40	PCB 101	F	3%	0.0215±0.1179	ND~0.6456	30
	T	8%	0.0068±0.0268	ND~0.1819	80		T	1%	0.0002±0.0018	ND~0.0165	80		T	3%	0.0282±0.1574	ND~1.0457	60
	M	58%	0.3581±0.7714	ND~4.5591	40		M	98%	0.3223±0.4765	ND~2.6883	40		M	43%	0.0568±0.1080	ND~0.4803	30
β-BHC	F	68%	0.3734±0.4759	ND~2.0620	40	*p,p'*-DDE	F	95%	0.3727±0.4159	ND~2.0759	40	PCB 118	F	53%	0.1277±0.2958	ND~1.5750	30
	T	63%	0.3658±0.6369	ND~4.5591	80		T	96%	0.3475±0.4451	ND~2.6883	80		T	48%	0.0922±0.2237	ND~1.5750	60
	M	3%	0.0005±0.0029	ND~0.0186	40		M	30%	0.0438±0.1114	ND~0.5169	40		M	27%	0.0241±0.0531*	ND~0.2346	30
γ-BHC	F	5%	0.0075±0.0344	ND~0.1901	40	*p,p'*-DDT	F	10%	0.0140±0.0577	ND~0.3461	40	PCB 138	F	10%	0.0022±0.0092	ND~0.0491	30
	T	4%	0.0040±0.0245	ND~0.1901	80		T	20%	0.0289±0.0894	ND~0.5169	80		T	18%	0.0132±0.0393	ND~0.2346	60
	M	3%	0.0011±0.0066	ND~0.0419	40		M	33%	0.0442±0.1315	ND~0.6676	40		M	20%	0.0095±0.0253	ND~0.1102	30
δ-BHC	F	0%	ND	ND	40	*p,p'*-DDD	F	23%	0.0514±0.1978	ND~1.1643	40	PCB 153	F	3%	0.0008±0.0045	ND~0.0248	30
	T	1%	0.0005±0.0047	ND~0.0419	80		T	28%	0.0478±0.1669	ND~1.1643	80		T	12%	0.0052±0.0186	ND~0.1102	60
	M		0.3655±0.7734	ND~4.5591	40		M		0.4103±0.6432	ND~3.4972	40		M	20%	0.0115±0.0383	ND~0.2042	30
Σ-BHC	F		0.3887±0.4783	ND~2.0620	40	Σ-DDT	F		0.4381±0.5279	ND~2.6390	40	PCB 180	F	3%	0.0033±0.0179	ND~0.0978	30
	T		0.3771±0.6390	ND~4.5591	80		T		0.4242±0.5849	ND~3.4972	80		T	12%	0.0074±0.0299	ND~0.2042	60
	M	18%	0.0176±0.0579	ND~0.3225	40		M	7%	0.0219±0.1163	ND~0.6373	30		M		0.1586±0.2721	ND~1.0457	30
Endrin	F	15%	0.0214±0.0823	ND~0.4300	40	PCB 28	F	20%	0.1755±0.6241	ND~3.2790	30	Σ-PCB	F		0.3310±0.9007	ND~4.8540	30
	T	16%	0.0195±0.0707	ND~0.4300	80		T	13%	0.0987±0.4518	ND~3.2790	60		T		0.2448±0.6654	ND~4.8540	60
	M	0%	ND	ND	40		M	0%	ND	ND	30						
Dieldrin	F	3%	0.0005±0.0030	ND~0.0192	40	PCB 52	F	0%	ND	ND	30						
	T	1%	0.0002±0.0022	ND~0.0192	80		T	0%	ND	ND	60						

Table III. Continued

Kidney Cortex																	
OCs	Sex	Fre.	Mean±SD	Range	N	OCs& PCBs	Sex	Fre.	Mean±SD	Range	N	PCBs	Sex	Fre.	Mean±SD	Range	N
	M	3%	0.0111±0.0606	ND~0.3322	30		M	0%	ND	ND	30		M	0%	ND	ND	20
α-BHC	F	3%	0.0070±0.0382	ND~0.2091	30	Aldrin	F	3%	0.0049±0.0269	ND~0.1473	30	PCB 101	F	0%	ND	ND	20
	T	3%	0.0090±0.0503	ND~0.3322	60		T	2%	0.0025±0.0190	ND~0.1473	60		T	0%	ND	ND	40
	M	30%	0.2245±0.4263	ND~1.3600	30		M	77%	0.2727±0.3906	ND~1.9215	30		M	15%	0.0313±0.1024	ND~0.4513	20
β-BHC	F	30%	0.2021±0.3714	ND~1.0814	30	*p,p'*-DDE	F	73%	0.3595±0.4571	ND~1.7370	30	PCB 118	F	15%	0.1310±0.4766	ND~2.1060	20
	T	30%	0.2133±0.3965	ND~1.3600	60		T	75%	0.3160±0.4238	ND~1.9215	60		T	15%	0.0812±0.3440	ND~2.1060	40
	M	0%	ND	ND	30		M	0%	ND	ND	30		M	0%	ND	ND	20
γ-BHC	F	7%	0.0295±0.1145	ND~0.5300	30	*p,p'*-DDT	F	0%	ND	ND	30	PCB 138	F	0%	ND	ND	20
	T	3%	0.0147±0.0816	ND~0.5300	60		T	0%	ND	ND	60		T	0%	ND	ND	40
	M	0%	ND	ND	30		M	3%	0.0010±0.0054	ND~0.0294	30		M	0%	ND	ND	20
δ-BHC	F	0%	ND	ND	30	*p,p'*-DDD	F	7%	0.0045±0.0185	ND~0.0940	30	PCB 153	F	0%	ND	ND	20
	T	0%	ND	ND	60		T	5%	0.0027±0.0136	ND~0.0940	60		T	0%	ND	ND	40
	M		0.2356±0.4246	ND~1.3600	30		M		0.2736±0.3924	ND~1.9215	30		M	0%	ND	ND	20
Σ-BHC	F		0.2386±0.4068	ND~1.3136	30	Σ-DDT	F		0.3640±0.4567	ND~1.7370	30	PCB 180	F	0%	ND	ND	20
	T		0.2371±0.4122	ND~1.3600	60		T		0.3188±0.4246	ND~1.9215	60		T	0%	ND	ND	40
	M	7%	0.0844±0.3407	ND~1.6980	30		M	5%	0.0125±0.0559	ND~0.2500	20		M		0.0438±0.1131	ND~0.4513	20
Endrin	F	10%	0.1201±0.4006	ND~1.7540	30	PCB 28	F	20%	0.1717±0.3669	ND~1.1677	20	Σ-PCB	F		0.3027±0.5607	ND~2.1060	20
	T	8%	0.1023±0.3691	ND~1.7540	60		T	13%	0.0921±0.2713	ND~1.1677	40		T		0.1733±0.4202	ND~2.1060	40
	M	3%	0.0009±0.0049	ND~0.0265	30		M	0%	ND	ND	20						
Dieldrin	F	3%	0.0044±0.0243	ND~0.1330	30	PCB 52	F	0%	ND	ND	20						
	T	3%	0.0027±0.0175	ND~0.1330	60		T	0%	ND	ND	40						

Table III. Continued

Lung																
OCs	Sex	Fre.	Mean±SD	Range	N	OCs& PCBs	Sex	Fre.	Mean±SD	Range	N	PCBs	Sex	Fre.	Mean±SD	Range	N
α-BHC	M	0%	ND	ND	20	Aldrin	M	0%	ND	ND	20	PCB 101	M	0%	ND	ND	20
	F	0%	ND	ND	20		F	5%	0.0653±0.2918	ND~1.3050	20		F	5%	0.0227±0.1015	ND~0.4540	20
	T	0%	ND	ND	40		T	3%	0.0326±0.2063	ND~1.3050	40		T	3%	0.0113±0.0718	ND~0.4540	40
β-BHC	M	10%	0.3340±1.1101	ND~4.6320	20	*p,p'*-DDE	M	60%	0.5883±0.9450	ND~3.7000	20	PCB 118	M	15%	0.0569±0.1395	ND~0.4211	20
	F	10%	0.0597±0.1908	ND~0.7553	20		F	55%	0.3437±0.5559	ND~2.3617	20		F	20%	0.1512±0.3645	ND~1.2166	20
	T	10%	0.1968±0.7984	ND~4.6320	40		T	58%	0.4660±0.7752	ND~3.7000	40		T	18%	0.1041±0.2766	ND~1.2166	40
γ-BHC	M	0%	ND	ND	20	*p,p'*-DDT	M	0%	ND	ND	20	PCB 138	M	0%	ND	ND	20
	F	5%	0.0360±0.1610	ND~0.7199	20		F	5%	0.1872±0.8372	ND~3.7440	20		F	0%	ND	ND	20
	T	3%	0.0180±0.1138	ND~0.7199	40		T	3%	0.0936±0.5921	ND~3.7440	40		T	0%	ND	ND	40
δ-BHC	M	0%	ND	ND	20	*p,p'*-DDD	M	10%	0.0247±0.0889	ND~0.3890	20	PCB 153	M	0%	ND	ND	20
	F	0%	ND	ND	20		F	10%	0.0170±0.0549	ND~0.2220	20		F	0%	ND	ND	20
	T	0%	ND	ND	40		T	10%	0.0209±0.0730	ND~0.3890	40		T	0%	ND	ND	40
Σ-BHC	M		0.3340±1.1101	ND~4.6320	20	Σ-DDT	M		0.6132±0.9501	ND~3.7000	20	PCB 180	M	0%	ND	ND	20
	F		0.0957±0.2404	ND~0.7553	20		F		0.5480±0.9808	ND~3.9948	20		F	0%	ND	ND	20
	T		0.2148±0.8019	ND~4.6320	40		T		0.5805±0.9537	ND~3.9948	40		T	0%	ND	ND	40
Endrin	M	10%	0.0442±0.1542	ND~0.6660	20	PCB 28	M	10%	0.2599±0.9753	ND~4.3190	20	Σ-PCB	M		0.3167±0.9693	ND~4.3190	20
	F	5%	0.0201±0.0897	ND~0.4010	20		F	15%	0.0846±0.2322	ND~0.9240	20		F		0.2585±0.5139	ND~1.8649	20
	T	8%	0.0321±0.1251	ND~0.6660	40		T	13%	0.1722±0.7054	ND~4.3190	40		T		0.2876±0.7664	ND~4.3190	40
Dieldrin	M	0%	ND	ND	20	PCB 52	M	0%	ND	ND	20						
	F	0%	ND	ND	20		F	0%	ND	ND	20						
	T	0%	ND	ND	40		T	0%	ND	ND	40						

M:Male, F: Female, Fre.: Frequency ND: under the limit of detection, Σ-BHC=α-BHC + β-BHC + γ-BHC + δ-BHC, Σ-DDT=*p,p'*-DDE + *p,p'*-DDT + *p,p'*-DDD, Σ-PCB=PCB28+PCB118+PCB180 (* =$p<0.05$)

analysis was performed with SPSS program and student's *t*-test.

RESULTS AND DISCUSSION

Calibration curves for organochlorines such as α-BHC, β-BHC, γ-BHC, δ-BHC, *p,p'*-DDE, *p,p'*-DDT, and *p,p'*-DDE, aldrine, dieldrine, endrine, and 7 markers PCB congeners were linear in the range of 0.00625~0.25 μg/mL (r >0.99, respectively). LOD (limit of detection) of all analytes ranged from 0.625 to 5 pg (Table II). Recovery test was done in triplicate by determining the amount of organochlorines and PCB congeners in target analytes-spiked liver, adipose tissues, and blood (Table II). Recoveries of organochlorines and PCB congeners ranged from 65.5 to 114.0% and 67.3~107.2%, respectively.

The concentration of α-BHC, β-BHC, γ-BHC, δ-BHC, *p,p'*-DDE, *p,p'*-DDT, *p,p'*-DDE, aldrine, dieldrine, endrine, PCB 28, 52, 101, 118, 138, 153, and 180 in blood, adipose tissue, liver, kidney cortex, and lung in terms of gender is shown in Table III. In blood, *p,p'*-DDE was the most frequently detected (74%) and had the highest concentration value (0.5018 ± 0.6748 μg/g extracted fat basis). In 1997, Archibeque-Engle *et al.* reported that the serum concentration of *p,p'*-DDE's in 35 women of Connecticut was 967 ng/g (Archibeque-Engle *et al.*, 1997). Compared to this report, the concentration of *p,p'*-DDE in our data was about the half of the reported value. The frequency of *p,p'*-DDE in adipose tissue was 100% and *p,p'*-DDT and *p,p'*-DDD were also detected in high frequencies. β-BHC was more frequently detected (69%) than other BHC isomers in adipose tissue. The obtained data was consistent with previous report which stated that, β-BHC is more persistent than other isomers (Kuts *et al.*, 1991). In adipose tissues, PCB 118, 138, 153, and 180 were more frequently detected than PCB 28, 52, and 101. This was consistent with the Pauwels' report that described the level of PCB congeners in adipose tissue of Belgium women (Pauwels *et al.*, 2000). Mean concentration of β-BHC, *p,p'*-DDT, *p,p'*-DDE, and PCB congeners in human adipose tissues from various countries are shown in Table IV. Significant differences in the levels of PCB congeners between genders were found at PCB 118 in adipose tissue. In this result, PCB 118's concentration in male was higher than that of female. For the proper and accurate correlation study, further examination of larger sample is needed.

All of the determined organochlorines and PCB congeners, except PCB 52 were detected in liver. *p,p'*-DDE was detected in 96% of liver samples and it's mean concentration was 0.3475 ± 0.4451 μg/g (extracted fat basis). This level was lower than the concentration level in liver of Swedish and Greenland people (836 ng/g and 2,209 ng/g, respectively) (Weistrand *et al.*, 1998, Dewailly *et al.*, 1999). Significant differences in the levels of PCB congeners between genders were found for PCB 138 in liver. In the case of kidney cortex and lung, δ-BHC, *p,p'*-DDT, PCB 52, 101, 138, 153, 180, and α-BHC, β-BHC, dieldrine, PCB 52, 138, 153, and 180 were not detected, respectively.

Correlation coefficients of levels of organochlorines and PCB congeners in terms of age and tissues were also determined. The concentrations below 50% frequency were not accounted, as non-detected samples could also increase the statistical correlation. In adipose tissue, the levels of *p,p'*-DDE (r=0.225), *p,p'*-DDT (r=0.236), total DDTs (r=0.266), PCB 118 (r=0.361), PCB 138 (r=0.315), PCB 153 (r=0.286), and total PCBs (r=0.366); and in lung, the level of *p,p'*-DDE (r=0.416) significantly varied with age ($p<0.05$). This result shows that these compounds accumulated more heavily in aged people and eliminated

Table IV. Mean concentration of β-BHC, *p,p'*-DDT, *p,p'*-DDE, and PCB congeners in human adipose tissue as reported from various countries (unit : μg/kg lipid weight basis)

Country	Year	β-BHC	*p,p'*-DDT	*p,p'*-DDE	PCBs	References
Canada	1991-1992	40	NA	765		Dewailly *et al.*, 1994
Italy	1989	213	64	395	NA	Gallelli *et al.*, 1995
Iran	1991-1992	728	190	2,450	NA	Burgaz *et al.*, 1995
Spain	1991	1,530	400	3,930	2,400	Gomez-Catalan *et al.*, 1995
U.S.A.	1994-1996	37	28	913		Stellman *et al.*, 1995
Vietnam	1991	30[a]		4,900[b]	300	Nakamura *et al.*, 1994
Mexico	1997-1998	143	1,224	4,355	NA	Waliszewski *et al.*, 1999
Japan	1986-1987	1,800[a]		2,400[b]		Kashimoto et al., 1989
Korea	1994-1995	190[a]		1,100[b]	400	Kang *et al.*, 1997
Korea	2000	23	27	153	NA	Yoo *et al.*, 2001
Korea	2001	61	29	160	89[c]	Yoo *et al.*, 2002

[a]: α-BHC+β-BHC+γ-BHC, [b]: *p,p'*-DDE+*p,p'*-DDT+*p,p'*-DDD, [c]: Sum of 7 marker PCBs, NA : not available

more slowly in our environment. The levels of *p,p'*-DDE and β-BHC were significantly different between tissues. Positive correlation coefficients between tissues were detected in the following cases: *p,p'*-DDE in the liver/blood ($p<0.01$, $r=0.376$), lung/blood ($p<0.01$, $r=0.436$), liver/lung ($p<0.01$, $r=0.732$), liver/adipose tissue ($p<0.01$, $r=0.382$), liver/kidney cortex ($p<0.01$, $r=0.367$), kidney cortex/adipose tissue ($p<0.05$, $r=0.313$), and lung/adipose tissue ($p<0.051$, $r=0.317$) : β-BHC in the liver/adipose tissue ($p<0.01$, $r=0.706$). As a result, *p,p'*-DDE was more readily accumulated and slowly eliminated from liver than from blood, lung, adipose tissue, and kidney cortex.

CONCLUSION

The levels of α-BHC, β-BHC, γ-BHC, δ-BHC, *p,p'*-DDE, *p,p'*-DDT, *p,p'*-DDE, aldrine, dieldrine, endrine, PCB 28, 52, 101, 118, 138, 153, and 180 in blood, adipose tissue, liver, kidney cortex, and lung in terms of gender were determined. On the whole, the values were relatively lower than the reported values from other countries, but we could estimate that these compounds were extensively distributed in Korean human bodies. This study would be useful to establish the risk assessment of persistent organochlorines and PCB congeners in Koreans.

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