다이옥신의 인체노출평가 접근방법

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ABSTRACT

The purpose of this paper is to assess background exposure to the dioxins among the general population in Korea. We estimates body burden using pharmacokinetic modeling from concentrations of dioxins in breast milk(n=15) and blood(n=9) of women living in urban areas in Korea. And this indirect approach of estimating dioxins intake was compared to direct approach of dietary intake and contact with other media containing dioxins using citable scientific literature in Korea. The average concentration of total dioxins in the breast milk(15.13 TEQ pg/g fat) was similar to that in the blood(16.01 TEQ pg/g lipid) for women in Korea. The ingestion of foods accounted for nearly 78% and intake of another exposure pathways accounted for approximately 22% of the total PCDDs/PCDFs TEQ exposure in Korea. The LADD of PCDDs/PCDFs is estimated to be 1.35 TEQ pg/kg/day and 1.25 TEQ pg/kg/day based on breast milk and blood, respectively. These values are about three times higher than the current background exposure estimate of 0.41 TEQ pg/kg/day as derived using typical media levels and contact rates.

Keywords : PCDDs, PCDFs, LADD(lifetime average daily dose), Human tissues, Environmental media

INTRODUCTION

In our previous study, we investigated concentration and distribution of PCDDs/PCDFs in breast milk and blood of women living in an urban area in Korea. The level of dioxins in our previous study was similar to that of another countries such as USA, Japan(Shin, et al., 2000, 2001).

The purpose of this paper is to assess background exposure to the dioxins among the general population in Korea. The general population consists of people who are exposed to background levels of dioxins in soil and air. Most of their exposure comes from the commercial food supply and they do not have significant occupational and personal(eg. Smoking) exposure. We estimates background exposure based on pharmacokinetic modeling using body burden data as concentration and distribution of dioxins in breast milk and blood of women living in an urban area in Korea. And the background exposure of our study compares to other background exposure estimates from dietary intake and contact with other media containing dioxins using citable scientific literature in Korea.

METHODS

Fifteen breast milk samples were obtained in 1997 from volunteer mothers living in an urban area of Korea. The participants in the study were 25-43 years of age, who had lived in the urban area for at least 5 years. And the blood samples were nine and the sampling period was the 1999. The women in the blood study were 32-42 years of age, who had lived in the urban area for at least 3 years.

Quantitative assessment of PCDDs/PCDFs in breast milk and blood was analyzed by high resolution gas chromatography-high resolution mass spectrometry(HRGC-HRMS) according to US EPA 1613 method. Instrumental Analysis was conducted by the School of Environmental Engineering at Pohang University and the Fisheries & Oceans Laboratory of Canada cooperated with our teams for quality assurance/quality control(QA/QC) program.

Calculation of PCDDs/PCDFs body burden was made according to a subjects body weight and percentage of body fat(Schecter et al., 1998). Lifetime average daily intake(LADD) of PCDDs/PCDFs may be estimated using human tissue data and pharmacokinetic modeling as follows(US EPA, 2000) :

$$Dose = [(\ln 2 / t_{1/2}) \times (V \times CF1) \times (C_{tissue}) \times CF2] \ / \ (A) \qquad \text{(Equation 1)}$$

$$LADD = Dose \ / \ BW_{subject} \qquad \text{(Equation 2)}$$

Where Dose (TEQ $_{pg/day}$) = Daily intake of PCDDs/PCDFs

$t_{1/2}$(years) = Half-life of PCDDs/PCDFs

V(kg) = Volume of body fat

C_{tissue}(TEQ ng/kg fat or lipid) = Concentration of dioxins in tissue such as blood, breast milk

CF1 = Conversion factor (1,000g/kg)

CF2 = Conversion factor (year/365days)

A = Fraction of dose that is absorbed

LADD(TEQ pg/kg/day) = Lifetime average daily dose of PCDDs/PCDFs

BWsubject(kg) = Body weight of subject

In the case of the LADD, a 7.2-year half-life was assumed for the dioxin-like compounds and A, absorbed rate used to 0.9 proposed by US EPA(2000).

The background exposure to PCDDs/CPDFs in Korea were estimated using: (1) the arithmetic mean TEQ levels in environmental media and food from citable scientific literature in Korea; (2) the standard contact rates for ingestion of soil and food, dermal uptake of soil, and inhalation of ambient air. The general equation is as follows:

$$LADD = (CR_{media} \times C_{media} \times CF) \ / \ BW_{subject} \qquad \text{(Equation 3)}$$

Where LADD(TEQ pg/kg/day) = Lifetime average daily dose of PCDDs/PCDFs

CR_{media}(m^3/day, g/day) = Contact rate of media such as daily inhalation rate

C_{media}(TEQ pg/g, pg/m^3) = Concentration of PCDDs/PCDFs in media

CF = Unit conversion factor

For the levels of PCDDs/PCDFs in environmental media and foods in Korea, citable scientific literature was summarized in Table 1. The food ingestion rates were derived from National Nutrition Survey report in Korea(MHWK, 1995). The contact rates for inhalation of ambient air and ingestion of soil were derived from the Exposure Factors Handbook(US EPA, 1997). The contact rate for dermal uptake with soil was calculated as the skin surface area that contact the soil(cm^2/day) multiplied by the soil adherence rate(mg/cm^2) and multiplied by the dermal absorption fraction for PCDDs/PCDFs(US EPA, 1999). To calculate of LADD for adult women in Korea, the body weight was assumed 54kg, the average body weight of participants for the breast milk or blood survey in our study.

RESULTS AND DISCUSSION

The average concentration of total dioxins in the breast milk(15.13 TEQ pg/g fat) was similar to that in the blood(16.01 TEQ pg/g lipid) for women in Korea(Table 2). In the breast milk and blood of women, 2,3,4,7,8-PeCF(about 34% and 28% to PCDDs/PCDFs TEQ concentration in the breast milk and blood, respectively) and 1,2,3,6,7,8-HxCDD(about 14% and 25% to PCDDs/PCDFs TEQ concentration in the breast milk and blood, respectively) were most predominant among the PCDDs/PCDFs congeners. The proportions of 2,3,7,8-TCDD to PCDDs/CPDFs TEQ concentration were about 1% both in breast milk and blood.

The body weight-adjusted body burdens of dioxins were 4.54 TEQ ng/kg(1.48 TEQ ng/kg for PCDDs, 3.06 TEQ ng/kg for PCDFs) and 4.21 TEQ ng/kg(2.36 TEQ ng/kg for PCDDs, 1.85 TEQ ng/kg for PCDFs) based on their concentrations in breast milk and blood, respectively(Table 3). These body burden levels were found to be similar to those of women in the USA(Schecter et al., 1998; Birnbaum et al., 1997)(figure 1). Van den Berg et al.(1994) compared lipid-based concentrations for all PCDDs/CPDFs congeners reported in breast milk, blood, and adipose, and concluded that the levels are strikingly similar across tissues. This tendency was observed the results in our study.

The estimated dioxins concentrations in exposure media were 0.124 TEQ pg/m3, 18.39 TEQ pg/g soil, 0.018 TEQ pg/g, 0.002 TEQ pg/g, 0.11 TEQ pg/g, 0.21 TEQ pg/g, 0.02 TEQ pg/g, and 0.02 TEQ pg/g for ambient air, soil, cereals, vegetables, fishes, shellfishes, beef and milk, respectively(Table 4 and Table 5). Based on the data presented in Table 4, Table 5, and the Equation 3, the women LADD for Korea was estimated to be 0.41 TEQ pg/kg/day(or 22 TEQ pg/day assuming a 54 kg woman), for all environmental media combined(Table 6). 2,3,4,7,8-PeCF(about 38% to total TEQ exposure) was most predominant among PCDDs/PCDFs congeners. Exposure to 2,3,7,8-TCDD accounts for approximately 3%(0.012 TEQ pg/kg/day) of the total TEQ exposure. The highest exposure were estimated to occur via ingestion of PCDDs/PCDFs in fish(0.104 TEQ pg/kg/day) and cereals(0.100 TEQ pg/kg/day), which accounted for about 25% and 24% of the total TEQ exposure, respectively. The ingestion of foods accounted for nearly 78% of the total TEQ exposure. Exposure via inhalation, soil ingestion, and dermal contact with soil are 0.046 TEQ pg/kg/day, 0.007 TEQ pg/kg/day, and 0.039 TEQ pg/kg/day, respectively. These exposures account for approximately 22% of the total PCDDs/PCDFs TEQ exposure in Korea.

The profiles for PCDDs/PCDFs concentrations in breast milk, blood, environmental media and some foods are presented in Figure 2. These profiles were generated by calculating the ratio of the concentrations of the 2,3,7,8-substituted congeners to total concentration of 2,3,7,8-substituted PCDDs/PCDFs. The profiles generated for breast milk, blood, fish and shellfish appeared to be similar and OCDD, higher-chlorinated PCDD, accounting for over 60% of total PCDDs/PCDFs in breast milk, blood and fish.

Using the body burden data presented in Table 2 and the pharmacokinetic model presented in Equation 1 and 2, the LADD of PCDDs/PCDFs is estimated to be 1.35 TEQ pg/kg/day and 1.25 TEQ pg/kg/day based on breast milk and blood, respectively(figure 3). These values are about three times higher than the current background exposure estimate of 0.41 TEQ pg/kg/day as derived using typical media levels and contact rates. This tendency was similar to the gap between direct and indirect estimated LADD in North America(US EPA, 2000). Because this pharmacokinetic model was originally developed for use with 2,3,7,8-TCDD, the effect of using it to model PCDDs/PCDFs introduces uncertainty into these estimated values. An important uncertainty in the pharmacokinetic modeling exercise described above was the assumption that the half-life estimate for 2,3,7,8-TCDD would apply to all PCDDs/PCDFs congeners as TEQ value. Another, perhaps more important, uncertainty in direct approach to estimate current dose is that this approach do not comprise all the relevant environmental exposures such as environmental tobacco smoke. Another limitation is that exposure data surveyed in Korea is not enough to estimate the total intake of dioxins.

This being the case, it is conc uded that phamacokinetic approach at the steady state will overestimate and direct approach using the levels of environmental media and contact rates will underestimate current dose in Korea.

ACKNOWLEDGEMENT

The authors wish to acknowledge the financial support of the Ministry of Environment in Korea made in program year 1998-2001(G7 project).

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Table 1. Scientific literatures cited for calculating the levels of PCDDs/PCDFs in environmental media and foods in Korea

Environmental media	Sampling area	Sampling period	Reference
Ambient air	Urban and suburban Urban and suburban	1998 1998 - 1999	IERY[1)](1999) Kim, et al(1999)
Soil	Urban	1997	Jang, et al(1998)
Foods	Coastal sites in southern 5 Cities	1995 – 1997 1999	Hashimoto, et al(1998) Lee, et al(2000)

1) IERY : The Institute for Environmental Research, Yonsei University

Table 2. The concentrations of PCDDs/PCDFs in breast milk and blood for women in Korea

(unit : TEQ pg/g fat)

Congeners	Breast milk (n=15)				Blood (n=9)			
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
2378-TCDD	0.16	0.34	0.00	0.94	0.16	0.49	0.00	1.47
12378-PeCDD	1.07	0.86	0.00	3.05	2.00	2.39	0.00	7.89
123478-HxCDD	0.32	0.23	0.00	0.98	0.25	0.26	0.00	0.63
123678-HxCDD	2.11	1.18	0.80	4.37	4.03	3.16	2.04	12.20
123789-HxCDD	0.47	0.60	0.00	2.57	1.70	1.99	0.58	6.90
1234678-HpCDD	0.34	0.37	0.07	1.47	0.46	0.20	0.31	0.97
OCDD	0.45	0.38	0.06	1.12	0.44	0.27	0.15	0.93
2378-TCDF	0.87	1.45	0.00	4.21	0.49	0.59	0.00	1.77
12378-PeCDF	0.06	0.09	0.00	0.28	0.01	0.03	0.00	0.10
23478-PeCDF	5.20	4.60	0.00	19.70	4.41	1.48	2.68	7.45
123478-HxCDF	0.95	1.20	0.00	5.01	0.75	0.33	0.00	1.18
123678-HxCDF	1.05	1.20	0.15	4.38	0.69	0.35	0.00	1.21
234678-HxCDF	1.24	2.98	0.00	11.77	0.19	0.30	0.00	0.91
123789-HxCDF	0.34	0.91	0.00	3.14	0.00	0.00	0.00	0.00
1234678-HpCDF	0.42	0.69	0.00	2.33	0.20	0.07	0.12	0.35
1234789-HpCDF	0.07	0.18	0.00	0.71	0.13	0.03	0.09	0.18
OCDF	0.02	0.05	0.00	0.19	0.10	0.03	0.07	0.15
PCDDs	4.92	2.44	1.96	10.51	9.05	7.61	4.35	28.75
PCDFs	10.21	11.63	1.47	48.30	6.96	2.68	3.56	13.20
Dioxins	**15.13**	**13.49**	**4.83**	**58.81**	**16.01**	**7.46**	**7.91**	**33.90**

Table 3. The body burden of PCDDs/PCDFs based on their concentration in human tissues of women in Korea

(unit : TEQ ng/kg BW)

	Breast milk (n=15)				Blood (n=9)			
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
PCDDs	1.48	0.73	0.59	3.15	2.36	1.89	1.12	7.28
PCDFs	3.06	3.49	0.44	14.49	1.85	0.73	0.92	3.58
Dioxins	**4.54**	**4.05**	**1.45**	**17.64**	**4.21**	**1.82**	**2.05**	**8.58**

Table 4. Concentration of PCDDs/PCDFs in the ambient air and soil of the urban area in Korea

Congeners	Ambient Air (n=6)[1] (TEQ pg/m^3)		Soil (n=5)[2] (TEQ pg/g soil)	
	Mean	SD	Mean	SD
2378-TCDD	0.000	0.000	0.366	0.393
12378-PeCDD	0.004	0.004	1.489	1.533
123478-HxCDD	0.003	0.004	0.577	0.624
123678-HxCDD	0.002	0.003	1.117	1.093
123789-HxCDD	0.004	0.005	1.283	1.390
1234678-HpCDD	0.001	0.001	0.780	0.850
OCDD	0.000	0.000	0.173	0.125
2378-TCDF	0.022	0.016	0.499	0.616
12378-PeCDF	0.002	0.002	0.317	0.301
23478-PeCDF	0.033	0.034	5.939	6.390
123478-HxCDF	0.019	0.016	1.387	1.465
123678-HxCDF	0.007	0.008	1.226	1.534
234678-HxCDF	0.010	0.008	2.156	3.040
123789-HxCDF	0.012	0.024	0.150	0.211
1234678-HpCDF	0.004	0.002	0.743	0.860
1234789-HpCDF	0.001	0.001	0.134	0.173
OCDF	0.000	0.000	0.058	0.069
PCDDs	0.014	0.015	5.785	5.929
PCDFs	0.110	0.090	12.609	14.625
Dioxins	0.124	0.103	18.394	20.538

1) Based on data from IERY(1999) and Kim, et al.(1999) 2) Based on data from Jang, et al.(1998)

Table 5. Concentration of PCDDs/PCDFs in the foods of Korea

Congeners	Foods (TEQ pg/g)[1]										
	Cereals	Lugumes	Vegetables	Fish	Shellfish	Milk	Cheese	Beef	Pork	Chicken	Eggs
2378-TCDD	0.00000	0.00260	0.00000	0.00111	0.01944	0.00305	0.00000	0.00000	0.00000	0.00000	0.00040
12378-PeCDD	0.00246	0.00459	0.00115	0.09111	0.02475	0.00395	0.00000	0.00314	0.00000	0.00000	0.00090
123478-HxCDD	0.00070	0.00034	0.00000	0.00000	0.00153	0.00151	0.00000	0.00010	0.00036	0.00000	0.00010
123678-HxCDD	0.00098	0.00089	0.00000	0.00052	0.00272	0.00141	0.00000	0.00451	0.00061	0.00002	0.00058
123789-HxCDD	0.00030	0.00008	0.00000	0.00000	0.00202	0.00086	0.00000	0.00037	0.00000	0.00000	0.00029
1234678-HpCDD	0.00033	0.00014	0.00000	0.00023	0.00090	0.00011	0.00000	0.00146	0.00065	0.00001	0.00017
OCDD	0.00007	0.00006	0.00010	0.00123	0.00180	0.00000	0.00018	0.00002	0.00003	0.00002	0.00244
2378-TCDF	0.00028	0.00068	0.00041	0.00782	0.07408	0.00039	0.00000	0.00027	0.00080	0.00000	0.00158
12378-PeCDF	0.00047	0.00043	0.00000	0.00127	0.00294	0.00059	0.00000	0.00002	0.00002	0.00003	0.00032
23478-PeCDF	0.00447	0.00201	0.00000	0.00000	0.06393	0.00335	0.01663	0.00500	0.00164	0.00010	0.00510
123478-HxCDF	0.00221	0.00080	0.00000	0.00000	0.00405	0.00091	0.00000	0.00131	0.00194	0.00002	0.00086
123678-HxCDF	0.00159	0.00096	0.00001	0.00063	0.00443	0.00082	0.00000	0.00089	0.00110	0.00000	0.00040
234678-HxCDF	0.00122	0.00064	0.00000	0.00000	0.00270	0.00077	0.00000	0.00073	0.00029	0.00004	0.00074
123789-HxCDF	0.00174	0.00065	0.00000	0.00067	0.00125	0.00112	0.00000	0.00000	0.00024	0.00000	0.00000
1234678-HpCDF	0.00033	0.00020	0.00061	0.00050	0.00168	0.00009	0.00121	0.00031	0.00068	0.00003	0.00017
1234789-HpCDF	0.00034	0.00018	0.00000	0.00059	0.00013	0.00012	0.00000	0.00001	0.00011	0.00001	0.00000
OCDF	0.00002	0.00000	0.00000	0.00002	0.00007	0.00000	0.00002	0.00010	0.00000	0.00000	0.00001
dioxin	0.00484	0.00869	0.00125	0.09420	0.05317	0.01089	0.00018	0.00961	0.00165	0.00004	0.00487
furan	0.01266	0.00655	0.00104	0.01150	0.15526	0.00815	0.01785	0.00864	0.00683	0.00023	0.00918
Tdioxin	0.01749	0.01524	0.00229	0.10570	0.20843	0.01904	0.01804	0.01825	0.00848	0.00027	0.01406

1) Based on data from Hashimoto, et al.(1998) and Lee, et al.(2000)

Table 6. The LADD of PCDDs/PCDFs based on their concentration in the environmental media and foods in Korea

Exposure media	Concentration PCDD	Concentration PCDF	Concentration Dioxins	Intake/uptake rate	ADI (pg/kg/day) PCDD	ADI (pg/kg/day) PCDF	ADI (pg/kg/day) Dioxins	Percent
Food[1)]		(TEQ pg/g)		(g/day)				
Cereals	0.0048	0.0127	0.0175	311.2	0.0279	0.0729	0.1008	24.5%
Soy beans	0.0087	0.0066	0.0152	15.0	0.0024	0.0018	0.0042	1.0%
Vegetables	0.0013	0.0010	0.0023	287.9	0.0067	0.0055	0.0122	3.0%
Fish	0.0942	0.0115	0.1057	53.0	0.0925	0.0113	0.1037	25.2%
Shellfish	0.0532	0.1553	0.2084	13.3	0.0131	0.0382	0.0513	12.5%
Milk	0.0109	0.0082	0.0190	69.5	0.0140	0.0105	0.0245	6.0%
Cheese	0.0002	0.0179	0.0180	0.2	6.78E-7	6.61E-5	6.68E-5	0.0%
Beef	0.0096	0.0086	0.0182	36.6	0.0065	0.0059	0.0124	3.0%
Pork	0.0017	0.0068	0.0085	20.4	0.0006	0.0026	0.0032	0.8%
Chicken	0.0000	0.0002	0.0003	8.1	6.60E-6	3.42E-5	4.08E-5	0.0%
Eggs	0.0049	0.0092	0.0141	24.6	0.0022	0.0042	0.0064	1.6%
Ambient air[2)]		(pg/m^3)		(m^3/day)				
inhalation	0.015	0.109	0.124	20	0.0055	0.0404	0.0460	11.2%
Soil[3)]		(pg/g)		(g/day)				
ingestion	5.79	12.61	18.39	0.02	0.0021	0.0047	0.0068	1.7%
dermal uptake	5.79	12.61	18.39	0.1156	0.0124	0.0270	0.0394	9.6%
Total					**0.1860**	**0.2251**	**0.4111**	**100.0%**

1) Based on data from Hashimoto, et al.(1998) and Lee, et al.(2000) for concentration, and MHWK(1995) for intake rate

2) Based on data from IERY(1999) and Kim, et al.(1999) for concentration, and US EPA(1997) for intake rate

3) Based on data from Jang, et al.(1998) for concentration, and US EPA(1997) for intake and uptake rates

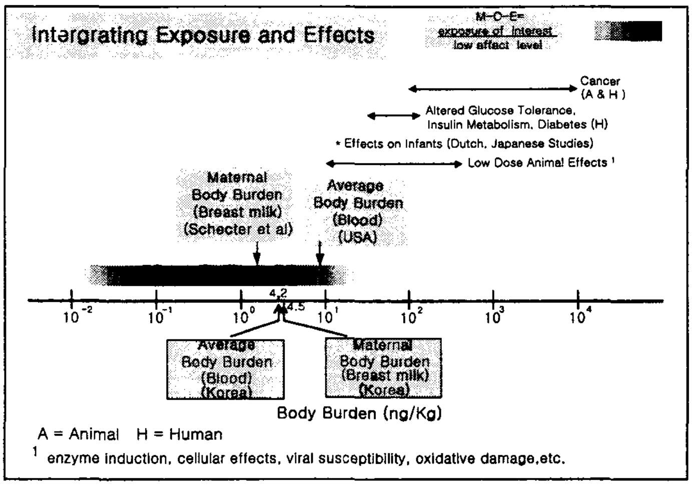

Figure 1. Comparison of body burdens of dioxins based on their concentrations in human tissues

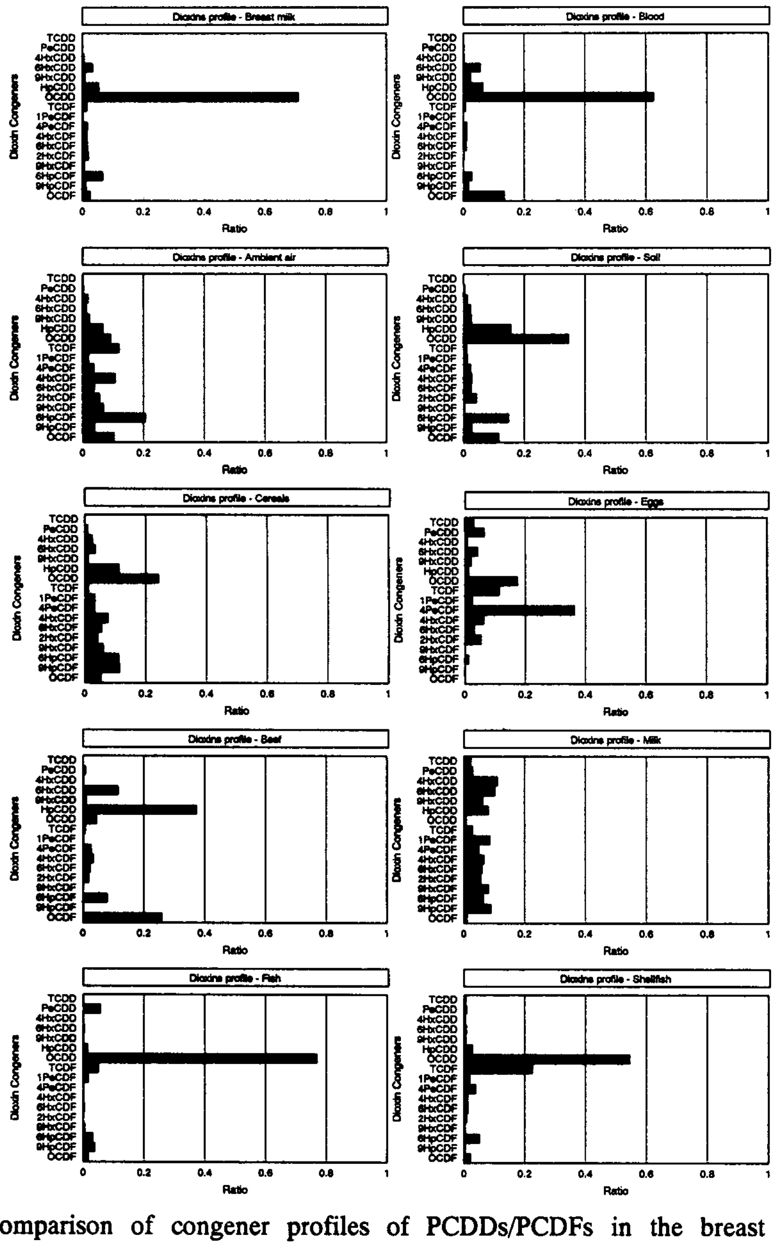

Figure 2. Comparison of congener profiles of PCDDs/PCDFs in the breast milk, blood environmental media and foods in Korea

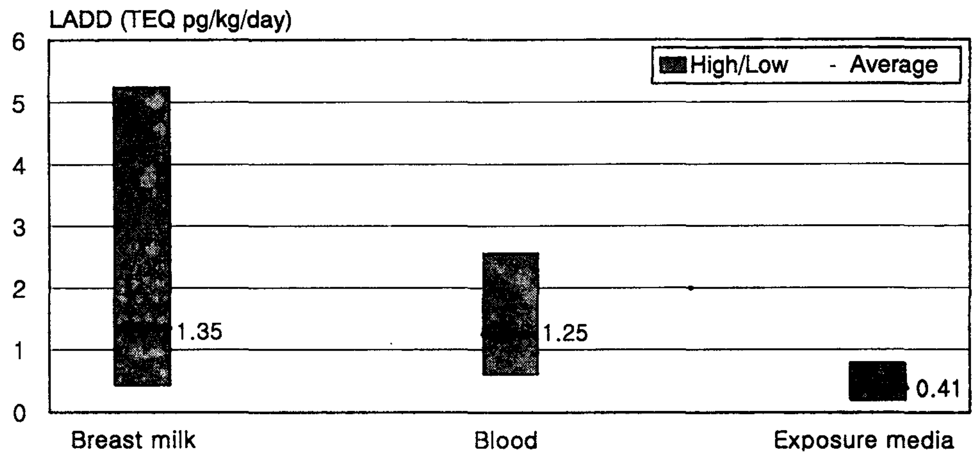

Figure 3. Comparison of lifetime average daily dose of PCDDs/PCDFs derived by direct(exposure media) and indirect(breast milk and blood) approaches