COMPARISON OF DIRECT AND INDIRECT APPROACH FOR ESTIMATING AVERAGE DAILY DOSE OF DIOXINS IN KOREA

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Introduction

In our previous study, we investigated concentration and distribution of PCDDs/PCDFs in breast milk and blood of women living in urban areas in Korea. The level of dioxins in our previous study was similar to that of another countries such as USA, Japan(Shin DC, et al., 1999, Shin DC, et al., 2000).

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 and blood 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.

Methods

Fifteen breast milk samples were obtained in 1997 from volunteer mothers living in an urban area of Korea. The participants were 25-43 years of age who had lived in the urban area for at least 5 years. The number of the blood samples was nine sampling in 1999. The women in the blood analysis 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 HRGC-HRMS according to US EPA 1613 method.

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

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

$$\text{ADI} = \text{Dose} / BW_{subject} \quad \text{(Equation 2)}$$

Where Dose (TEQ pg/day) = Daily intake of PCDDs/PCDFs
$t_{1/2}$(years) = Half-life of PCDDs/PCDFs (7.2 years)
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 (90%)
ADI(TEQ pg/kg/day) = Average daily intake of PCDDs/PCDFs
$BW_{subject}$(kg) = Body weight of subject

The background exposure to PCDDs/PCDFs in Korea were estimated using the arithmetic mean TEQ levels in environmental media and food, and the contact rates for ingestion of soil and food, dermal uptake of soil, and inhalation of ambient air. The general equation is as follows:

$$ADI = (CR_{rmedia} * C_{media} * CF) / BW_{subject} \quad \text{(Equation 3)}$$

Where ADI(TEQ pg/kg/day) = Average daily intake 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 ADI 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 and 1,2,3,6,7,8-HxCDD were most predominant among the PCDDs/PCDFs congeners. The proportions of 2,3,7,8-TCDD to PCDDs/PCDFs TEQ concentration were about 1% both breast milk and blood.

The body weight-adjusted body burdens of dioxins were 4.54 TEQ ng/kg and 4.21 TEQ ng/kg 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 also observed the results in our study.

Based on the data presented in Table 4 and the Equation 3, the women ADI for Korea was estimated to be 0.41 TEQ pg/kg/day, for all environmental media combined(Table 4). 2,3,4,7,8-PeCF(about 38% to total TEQ exposure) was most predominant among the PCDDs/PCDFs congeners. Exposure to 2,3,7,8-TCDD accounts for approximately 3% of the total TEQ exposure. The ingestion of foods accounted for nearly 78% of the total TEQ exposure. Exposure via inhalation, soil ingestion, and dermal contact with soil accounted for approximately 22% of the total PCDDs/PCDFs TEQ exposure in Korea.

Using the body burden data presented in Table 2 and the pharmacokinetic model presented in Equation 1 and 2, the ADI 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 0.41 TEQ pg/kg/day as derived from typical media levels and contact rates. This tendency was similar to the gap between directly and indirectly estimated ADI 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 described above was the assumption that the half-life estimate for 2,3,7,8-TCDD would apply to all PCDDs/PCDFs congeners. 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 concluded 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.

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Table 1. The summarized the citable scientific literature for the levels of PCDDs/PCDFs in environmental media and foods in Korea

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

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 for 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. The ADI of PCDDs/PCDFs based on their concentration in the environmental media and foods in Korea

Exposure media	Concentration			Intake/uptake rate	ADI (pg/kg/day)			Percent
	PCDD	PCDF	Dioxins		PCDD	PCDF	Dioxins	
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

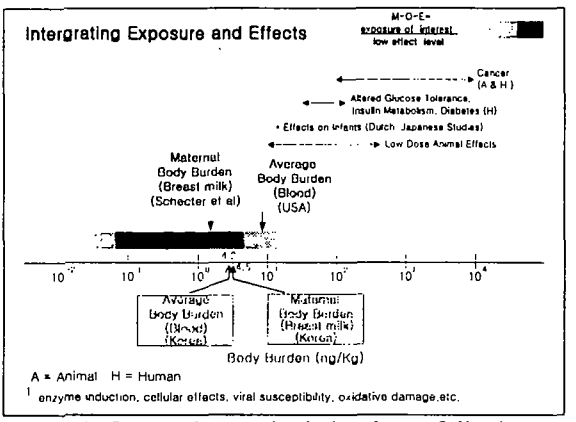

Figure 1. Comparison to body burdens of dioxins based on their concentrations in human tissues

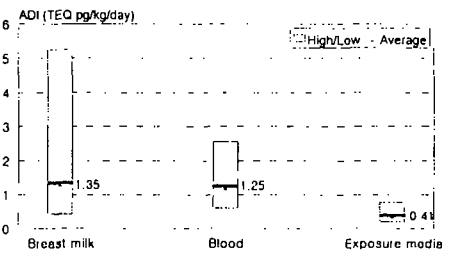

Figure 2. Comparison to ADIs of dioxins derived to several approaches