DIETARY INTAKE OF DIOXIN-LIKE CHEMICALS IN KOREA

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Introduction

In the last decades South Korea has rapidly developed its industrial production and has become one of the leading economies in Asia. Dioxin-like chemicals include polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), chemicals that are mainly emitted from combustion processes including municipal solid waste incinerators, steel mills and/or selected manufacturing and chemical processes including kraft mills that use elemental chlorine. Dioxin-like PCBs (dl-PCBs) are components in PCB mixtures that have been widely used for example as dielectrical fluid and non-flammable oil and plasticizers. The uptake of these chemicals into humans can occur directly through intake/accumulation from exposure to abiotic phases (air, water, soil, dust) but typically the more important uptake pathway is via accumulation of these chemicals in the human food chain and ultimately intake of contaminated food. This study was initiated to estimate the exposure of potentially endocrine disrupting chemicals including dioxin-like chemicals in the Korean population. The study is based on systematic monitoring programs that estimate dioxin-like chemicals in environmental media conducted nationally (Ministry of Environment) and through the local governmental (Gyeonggi province) since 1999. In addition the Korea Food and Drug Agency (KFDA) carried out work to measure the level of dioxin-like chemicals in various key food items. Here we collate these data to provide an estimate of the daily intake of dioxin-like chemicals in the Korean population in the period from 1999 – 2005 and compare these with the Tolerable Daily Intake (TDI).

Material and methods

Data collection

Data for dioxin-like chemicals in environmental media and foodstuff were collected from 1999 to about 2005. Dioxin level in air (n=349), soil (n=324) and water (n=275) were determined through the Gyeonggi-do Institute of Health & Environment[1)] and NIER[2)]. All soil and air sampling sites were located in urban areas covering residential, commercial as well as industrial type locations. Food data was obtained from the KFDA[3)], the National Veterinary Research and Quarantine Service[4,5)] and Korea's National Fisheries Research & Development Institute[6)]. The intake assessment we present here is based on data converted to TEQ_{WHO98} using the WHO 1998 Toxicity Equivalency Factors.

Calculation of dietary intake of dioxin-like chemicals (ie PCDD/Fs and dl-PCBs)

To calculate the human intake of PCDD/Fs and dl-PCBs, we considered three uptake pathways namely: air inhalation, soil ingestion and food intake. From this the intake was calculated from:

$$\text{Total Daily Intake (pg TEQ/kg BW/day)} = \Sigma((C_i \times I_i) / BW) \qquad \text{Equation 1}$$

with C_i the concentration of dioxin like chemicals in a given medium i (air [pg/m^3], soil and food [pg/g]), I is the estimated intake of the respective volume or mass of a given media i per day (air [m^3/day], soil and food [g/day]) and BW represents the body weight (kg). For the inhalation rate I_A we used values of 20 m^3/day for adults and 5 m^3/day for children. For uptake of soil we assumed a daily ingestion rate I_S of 0.1 g/day for adults and 0.2 g/day for children. For the body weight we used estimates for 8 age groups as outlined in Table 1.

Table 1 Body weight used in the model for 8 different age groups

Age	**1~2** [7]	**3~6**[7]	**7~12**[8]	**13~19**	**20-29**	**30-49**	**50~64**	**65≤**
Body weight(kg)	11	17	32.35	53.96	58.75	62.02	60.00	60.00

Monte-Carlo simulation Method

To reduce the uncertainty of dioxin data and intake, we used a Monte-Carlo simulation (probabilistic approach). A Monte Carlo simulation is a computer based method that can be applied to the analysis of data obtained through statistical sampling techniques obtaining a probabilistic approximation to the solution of a mathematical equation (USEPA, 1997). Each factor is defined a distribution function based on real results from actual measurements. The estimation of dietary intake in this study was performed using a random sample size of 10,000 using the commercial software Crystal Ball ™.

Results and discussion

The results of the monitoring data in environmental media for the years 1999 to 2005 are summarized in Table 2. In brief, the mean concentration of dioxin-like chemicals in air (expressed as TEQ_{WHO98}) in the 1999-2005 period was about 0.38 pg/m^3 with more than 50 % of the measured concentrations less than 0.2 pg/m^3.

Table 2 Concentration of dioxin-like chemicals (expressed as WHO-TEQ_{98}) in environmental media [1, 2]

	Fiscal year	**n**	**Min**	**25% tile**	**Median**	**75%tile**	**Max**	**Mean**	**S.D**
Air (pg-TEQ/m^3)	1999~2005	349	<LOD	0.098	0.198	0.446	8.624	0.378	0.620
	2000~2002	136	0.012	0.121	0.230	0.543	2.599	0.409	0.471
	2003~2005	178	0.005	0.089	0.162	0.398	2.133	0.292	0.322
Soil (pg-TEQ/dry g)	1999~2005	324	<LOD	0.005	0.093	0.971	65.543	1.719	7.038
Water (pg-TEQ/L) (River/stream, lake)	1999~2005	275	<LOD	0.001	0.008	0.060	32.599	0.234	2.052

It is noteworthy that the concentration of dioxin-like chemicals in air declined from the earlier to the later period which is likely due to the government action resulting for example in the shut down of various medium and small size incinerators. In soil, the concentration of dioxin-like chemicals ranged from below the limit of detection (LOD) to 66 pg TEQ/g with a mean concentration of about 1.7 pg TEQ/g.

The estimated intake of dioxin-like chemicals from food and environmental media is summarized in Table 3. Based on the available data used for the Monte-Carlo simulation, the average dietary intake in adults (age > 20) is estimated to range between 1.38 and 1.75 pg TEQ/kg/day respectively (5 and 95 % percentiles respectively as provided in Fig. 2). The dietary intake for each age group was below recommended total daily intakes of approximately 2 and 4 pg-TEQ/BW-kg/day proposed by the WHO (converted from a monthly intake to a daily intake) and the MOE in Korea respectively. A relatively higher intake is calculated for younger age groups (ie < 12 years but even more for those below the age of 6 years) compared to older age groups. The youngest group that was considered in this study was the 1-2 year old toddlers for which we predict that the median intake in the 1999-2005 period was approximately 2.6 pg-TEQ/kg/day (95^{th} percentile: 3.3 pg-TEQ/kg/day).

This higher intake is due to a combination of relatively higher intake of milk and dairy products in this age group and a relatively low body mass compared to their intake**.**

Table 3 Dietary intake of food and environmental media based point intake estimate using mean values [3, 4, 5, 6)]

Food group	**Consump-tion (g/day)** [9)]	**No.**	**Dioxin concentrations (pg- WHO TEQ/g)**			**Dietary intake** pg-TEQ/kg/day	**Percent**
			Min	**Max**	**Mean**		
Rice, cereals and product	321.1	25	<LOD	0.007	0.002	0.0107	0.74
Potato and starches	20.2	6	<LOD	0.006	0.002	0.0007	0.05
Pulses	39.3	10	<LOD	0.026	0.007	0.0046	0.32
Vegetable	327.0	9	<LOD	0.005	0.002	0.0121	0.84
Fruits	87.4	9	<LOD	0.007	0.004	0.0063	0.44
Oil of vegetable origin	9.4	6	0.001	0.055	0.010	0.0015	0.11
Meats and meat product	95.1	396	<LOD	1.519	0.039	0.0615	4.28
Beef	32.9	271	<LOD	0.404	0.040	-	-
Pork	43.6	75	<LOD	1.519	0.056	-	-
Chicken	16.4	50	<LOD	0.060	0.006	-	-
Egg	25.8	17	<LOD	0.385	0.070	0.0300	2.09
Fish and shellfish	67.7	242	<LOD	19.441	1.013	1.1435	79.52
Fish	30.5	154	0.004	19.441	1.290	-	-
Crustaceans	3.3	24	0.001	10.400	1.325	-	-
Bivalves	4.4	48	<LOD	2.414	0.255	-	-
Gastropod	0.5	6	0.060	0.200	0.120	-	-
Cephalopod	7.8	10	<LOD	0.690	0.187	-	-
Milk and dairy product	89.7	97	<LOD	0.239	0.025	0.0374	2.60
Milk	66.5	72	<LOD	0.018	0.018	-	-
Cheese	0.6	25	<LOD	0.239	0.045	-	-
Oil of Animal origin	0.3	4	0.092	0.158	0.126	0.0006	0.04
Air inhalation	20 m^3/day		<LOD	8.624	0.378	0.1261	8.77
Soil ingestion	0.1 g/day		<LOD	65.543	1.719	0.0029	0.20

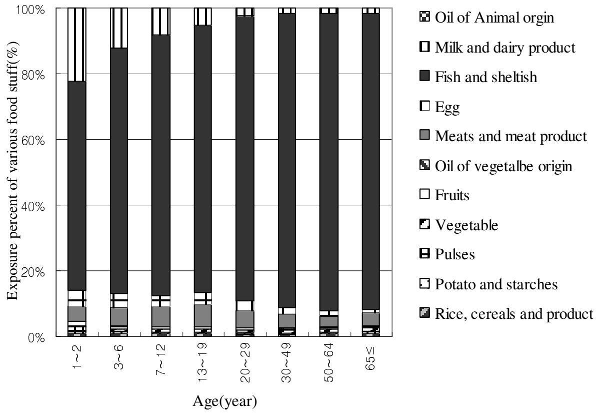

Fig. 2 Relative contribution of various foods to dietary intake according to age.

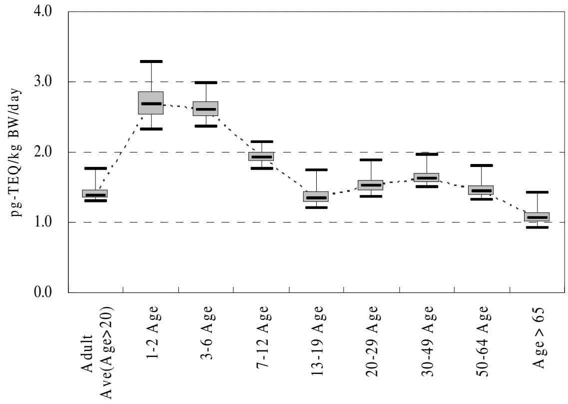

Fig.3 Box-whisker plot of dietary intake level including 5th, 25th, median, 75th and 95th percentile for different age groups

A comparison with data from other countries suggests that the daily intake of dioxin-like chemicals in the Korean population is relatively high compared to many industrialized countries such as Australia, USA or Europe. In our study, fish and shellfish contributed to almost 80 % to the exposure in adults with a decrease in contribution in children (see above). On the other hand despite soil and air data originating from urban/industrial sites the contribution to the exposure from environmental media was less than 10% in Korea.

In summary the results from our study are overall consistent with data from other countries (ie intake typically below the TDI and higher uptake in children compared to adults). On the other hand a high contribution via uptake of contaminated seafood reflects the special importance of seafood in the Korean diets and issues related to the contamination of the coastal waters in the region.

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