Health Aspects of Dioxins in U.S. Food: Cancer Risk Assessment for the General Population

Schecter, A.J [1], Kessler, H. [1], Olson, J. R[2].

[1] Department of Preventive Medicine, SUNY Health Science Center-Syracuse, Clinical Campus. 88 Aldrich Ave, Binghamton, NY, 13903.
[2] Department of Pharmacology and Toxicology, SUNY Buffalo Medical Center, Buffalo, NY 14214.

Abstract.

We previously measured polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in a variety of U.S. food and estimated the daily dioxin toxic equivalents (TEQs) intake range to be from 0.3 to 3.0 pg I-TEQ/kg body weight/day for adults assuming an average weight of 65 kg. These values are similar to values reported in Canada, Germany, England, and the Netherlands. The U.S. EPA Dioxin Reassessment Draft Documents currently propose a cancer risk-specific dose estimate of 0.01 pg TEQ/kg body weight/day (U.S. EPA, 1994). This risk-specific dose estimate represents a lifetime dose which results in a plausible upper bound cancer risk of 1×10^{-6} (one additional cancer per one million exposed). Using our data for daily dietary TEQ exposure it is estimated that a maximum of 30 to 300 excess cancers per million could result from the ingestion of dioxin containing food products. In the U.S. population of 260 million, a maximum range of 7,800 to 78,000 excess cancers might be linked to dioxin exposure from food. However, it is also important to note that this risk estimate may be less and may even be zero for some members of the population.

Introduction.

We have previously reported that individuals living in highly industrialized countries have measurable body burdens of dioxins even though there is no history of occupational or accidental exposure.[1] The existence of PCDDs and PCDFs in food is thought to be the primary source of background environmental dioxin exposure to the general population.[2] The low level daily consumption of these highly persistent compounds from various food products will result in their long-term retention and accumulation in various tissues. An outcome from this exposure is the potential for an increased risk of adverse health effects.

The bioavailability of PCDD/Fs from food is in most cases unknown at the present, although levels have been documented in a few previous studies. Bioavailability of PCDDs and PCDFs from human breast milk has been reported to approach 100%.[3] The bioavailability of TCDD from contaminated fish was estimated to be 95%.[4] In general, the bioavailability of PCDDs and PCDFs varies from 50-100% depending on the individual and the type of foods chosen for consumption. Based on animal (Kociba et al.)[5] and human studies, the U.S. EPA has previously proposed 1.6×10^{-4} $(pg/kg\text{-}day)^{-1}$ (U.S. EPA 1985)[6] as the unit cancer risk for oral intake of TCDD. The current value proposed for the unit cancer risk is 1.0×10^{-4} (U.S. EPA 1994).

Results.

Table I, from reference 7, presents a summary of dietary exposure to PCDDs and PCDFs in different U.S. food groups. Based on these data, the total adult daily dietary intake of PCDDs and PCDFs was calculated to be 18 to 192.3 pg TEQ. The average daily human intake range for an individual, assuming 65 kg average body weight, was calculated to be 0.3-3.0 pg TEQ/kg BW.[7]

Table II, taken from the EPA Dioxin Reassessment Draft Documents, shows the U.S. EPA's unit cancer risk estimates for TCDD oral intake. The figures listed in the table are based on well known animal and human studies. EPA's unit cancer risk value of 1.6×10^{-4} (pg/kg-day)$^{-1}$ (1985), has recently been reevaluated. The U.S. EPA is now proposing a unit cancer risk value of 1.0×10^{-4} (1994).

Table 1. Calculated PCDD and PCDF TEQ from Various Food Groups for the U.S. Adult General Population*

Food Group	Consumption Rate (g/day)**	Range of PCDD/F TEQ in Food (wet weight; pg/g)		Daily Human Intake			
				Range Total TEQ (pg)		Range TEQ/kg B/W (pg)***	
		LOW	HIGH	LOW	HIGH	LOW	HIGH
Beef	88	0.04	1.50	3.52	132.00	0.054	2.031
Pork	28	0.03	0.30	0.84	8.40	0.013	0.129
Poultry	31	0.03	0.03	0.93	0.93	0.014	0.014
Fish	18	0.02	0.13	0.36	2.34	0.006	0.036
Milk	254	0.04	0.04	10.16	10.16	0.156	0.156
Other Dairy Products	55	0.04	0.70	2.20	38.50	0.034	0.592
Fruits & Vegetables	283	—	—	—	—	—	—
		Total Range		18.0	192.3	0.3	3.0

* Copied from Ref 7
**Consumption rates from Yang and Nelson(ref 8)
*** Assuming a 65 kg adult weight

Table II. Estimates of U.S. EPA Unit Cancer Risk for TCDD Oral Intake, Based on Animal and Human Studies and U.S. EPA Current and Proposed Estimates

Source	Cancers	Oral Dose Range	Model	Estimates of Unit Risk (pg/kg-day)$^{-1}$ MLE	95% Upper Limit	Comments	Ref for calculation
Animal (Female Sprague-Dawley rat)	Liver	1-100 ng/kg-day	2-Stage*	0.9×10^{-1} *	—	Liver Pathology Readings by Sauer and Goodman (1992)	Chap 8, Sec.8.2.2
			LMS	—	0.5×10^{-4}		U.S. EPA (1992)**
All Based on Kociba et al (1978)			LMS	---	0.8×10^{-4}	Liver Pathology by Kociba (1978) and Squire (1980)	U.S. EPA (1992)**
	All (liver,lung, hard palate/nasal turbinate)		LMS	1.2×10^{-4}	1.6×10^{-4} #		U.S. EPA (1985)
			Multistage Weibull (Incidental Tumor Analysis)	2.1×10^{-4}	3.1×10^{-4}		U.S. EPA (1988)
Human (Males) *Fingerhut et al* (1991)	Lung	1-60 pg/kg-day***	Additive Risk	4.8×10^{-4}	—	*Calculations based on* Combined cohorts	*Chap. 8, Sec.* 8.5.3.3
Zober et al. (1990) Manz et al. (1991)	All		Multiplicative Risk	3.0×10^{-4}	—		
			Additive Risk	27×10^{-4}	—		
			Multiplicative Risk	17×10^{-4}	—		
U.S. EPA Proposed (1988)			Based on reciprocal of risk specific dose 10 incremental risk	0.1×10^{-4}		External Review Drafts	U.S. EPA (1988)
U.S. EPA Currently Proposed (1994)				1.0×10^{-4}			Chapter 9, Risk Characterization

* Animal estimate of 0.24 x 10 (pg/kg-day) times rat-to-human default conversion of 70/0.350.
** Unpublished
*** Estimates based on total concentration x time equivalence
# Estimate currently used by U.S. EPA
EPA practice is to use MLEs (maximum likelihood estimates) for estimates based on human data
Table from EPA Dioxin Reassessment Draft Documents (Table 8-12, pp 8-99; V.II)

Calculation of excess cancer risk is as follows using the recommended U.S. EPA 1×10^{-4} unit cancer risk estimate (ql*).

$$RL = LADD \times ql^*$$

RL = risk level over a life time of 75 years
LADD = lifetime average daily dose (pg/kg/day)
ql* = unit cancer risk or upper bound estimate of carcinogenesis potency of TCDD

$$RL = (0.01 \text{ pg/kg/day}) \times (1 \times 10^{-4} \text{ pg/kg/day})^{-1}$$
$$RL = 1 \times 10^{-6}$$

This unit cancer risk value of 1×10^{-6} can be interpreted as 1 excess cancer in a population of one million. However, this value can be compared to the value of what an average American consumes in his or her diet which was reported by Schecter and co-workers (1994). They reported that the average American diet contains PCDDs and PCDFs and results in an estimated daily dietary exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD, "dioxin") toxic equivalents (TEQs) ranging from 0.3 to 3.0 pg/kg body weight (BW) for an average adult of 65 kg.

$RL = (0.3 \text{ pg/kg/day}) \times 1 \times 10^{-4} (\text{pg/kg/day})^{-1}$ $\quad$ $RL = (3.0 \text{ pg/kg/day}) \times 1 \times 10^{-4} (\text{pg/kg/day})^{-1}$
$RL = 3 \times 10^{-5}$ $\quad$ $RL = 3 \times 10^{-4}$

These RL values indicate that in a population of one million there will be a maximum of 30 to 300 excess cancers due to PCDDs and PCDFs exposure through food consumption. Therefore, in the U.S., with an approximate population of 260 million, there might be a maximum of 7,800 to 78,000 excess cancers as a result of low level dietary exposure to PCDDs and PCDFs.

Conclusions.

We recently reported daily intake levels of dioxins from food in the general U.S. population, and at Dioxin 95 further data will be presented.[9] In this paper, using EPA's proposed dioxin cancer risk assumptions we estimate cancer risk from our I-TEQ values for the U.S. food supply. We calculated a maximum of 30 to 300 excess cancers in a population of one million as a result of low level daily dietary exposure to PCDDs and PCDFs. In addition, if dioxin-like, coplanar PCBs are also included in the estimate of daily dietary exposure this cancer risk assessment will increase, perhaps by a factor of two. EPA's cancer risk assumptions represent an upper bound or maximum risk, and the possibility exists, as noted by EPA, that the risk might be considerably less, including even zero for certain populations. Risk assessments for other toxic end points, such as immunotoxicity, or reproductive and developmental damage, were not discussed in this paper, although they may represent an additional concern (U.S. EPA, 1994).

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