IMPACT OF THE CHANGES IN WHO TEF VALUES FROM 1998 TO 2005 ON THE TOTAL TEQ VALUES IN SERUM, HOUSEHOLD DUST AND SOIL

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Abstract

The University of Michigan Dioxin Exposure Study (UMDES) previously calculated the toxic equivalency (TEQ) values based on the World Health Organization (WHO) 1998 consensus toxicity equivalency factors (TEFs),[1] in serum, household dust and soil from a sample of adults in Michigan, USA. In June 2005, the TEFs were reevaluated in a WHO expert meeting in Geneva, Switzerland and new WHO 2005 TEFs were presented.[2] All the TEQ values in the study samples have been recalculated based on the 2005 TEFs. Compared to the 1998 TEFs, the overall median TEQ values decreased 26% in serum samples, 6% in dust samples, and 6% in soil house perimeter samples; the percent contribution of polychlorinated dibenzodioxins (PCDDs) to the serum TEQ increased about 16%, polychlorinated dibenzofurans (PCDFs) slightly decreased about 0.4%, and polychlorinated biphenyls (PCBs) decreased about 16%. Among the seven congeners (2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,6,7,8-HxCDD, 2,3,4,7,8-PeCDF, PCB-118, PCB-126 and PCB-156) that had the highest contribution to the serum TEQ using 1998 TEFs in the studied blood samples, PCB-118 and PCB-156 together contributed only 3% and were not among the top 7 contributed congeners to TEQ using 2005 TEFs.

Introduction

The University of Michigan Dioxin Exposure Study (UMDES) was designed to assess exposures to polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs) in adults in 5 counties of Michigan, USA, and to identify factors that explain variation in serum dioxin levels.[3] All TEQ values for serum, household dust and soil samples in the study, originally calculated based on WHO 1998 TEF values, were recalculated based on the WHO 2005 TEFs (See Appendix 1). The goal of this report is to present the changes in the total TEQ levels of serum, household dust and soil samples, after implementation of 2005 TEFs.

Materials and Methods

The study included Michigan populations who live in Midland County, Saginaw County, and part of Bay County, both in and out of the Tittabawassee River flood plain (Midland/Saginaw), and who live in Jackson and Calhoun Counties (Jackson/Calhoun), which represent a referent county with no appreciable industrial sources of dioxins. The studied populations were sampled using a two-stage area probability household sample design,[4] and the statistical analyses were sample weighted to reflect the population from which the sample was selected.

To contribute a blood sample, participants had to be at least age 18 years, have lived in the current residence for 5 years or more, and be capable of safely donating 80 milliliters of blood. All serum results were lipid adjusted. To contribute dust or soil samples, participants had to also be the owner of their property. For soil samples, this report only shows the results for the top 1 inch house perimeter samples. Full details on the study are posted on the website (www.umdioxin.org). Results below the limit of detection (LOD) were substituted with LOD/√2 for analysis. All statistical analyses were performed using SAS® version 9.1.

Results and Discussion

A total of 946 serum samples, 764 household dust samples and 766 soil samples from around participant homes were collected. Table 1 presents descriptive statistics (Minimum, Mean, Median, 75th percentile, and Maximum) for both TEQ-1998 and TEQ-2005 values for the serum, dust, and soil house perimeter top 1 inch (Soil HP1) samples in our study. Results are shown in Table 1 for all samples in the entire studied area (Overall), samples from the combined geographic area Midland/Saginaw (M/S), and samples from the referent county Jackson/Calhoun (J/C). There are two major findings from Table 1:

1. In general, the TEQ-2005 values are lower than the TEQ-1998 values across serum, household dust and Soil HP1 samples.

- For serum samples, the overall median TEQ-2005 value (19.6 ppt) decreased 26% compared to the overall median TEQ-1998 value (26.4 ppt).
- For household dust samples, the overall median TEQ-2005 value (16.2 ppt) decreased 6% compared to the overall median TEQ-1998 value (17.3 ppt).
- For Soil house perimeter samples, the over median TEQ-2005 value (4.5 ppt) decreased 6% compared to the overall median TEQ-1998 value (4.8 ppt).

2. Regarding the comparison between the TEQ levels in Midland/Saginaw and Jackson/Calhoun, the following relationships remain the same for both TEQ-1998 and TEQ-2005:

- People who lived in Midland/Saginaw had higher levels of serum dioxins than people in Jackson/Calhoun, with the median TEQ value about 2 ppt higher.
- For household dust samples, the mean TEQ level is higher in Jackson/Calhoun, while the median level is higher in Midland/Saginaw.
- For soil house perimeter samples, the median TEQ levels are about 2 to 3 ppt higher in Midland/Saginaw compared to Jackson/Calhoun.

Table 1: Descriptive statistics for UMDES samples (unit: Parts Per Trillion)

			TEQ calculated from 1998 TEFs					TEQ calculated from 2005 TEFs				
Samples	Region	N	Min	Mean	Median	P75*	Max	Min	Mean	Median	P75*	Max
Serum	Overall	946	4.7	32.4	26.4	39.9	238	3.8	23.9	19.6	29.2	210.7
	M/S$^+$	695	4.7	35.2	27.3	44.1	238	3.8	26.5	20.7	32.3	210.7
	J/C†	251	5.2	29.7	24.8	36.2	150.4	4.7	21.3	18.5	25.3	109
Dust	Overall	764	1.5	41.9	17.3	33.1	1746	1.4	36.7	16.2	29.7	1749
	M/S$^+$	566	1.5	38.2	19.0	31.5	1746	1.4	34.9	17.6	29.0	1749
	J/C†	198	2.2	46.0	14.4	35.3	1080	2.1	38.8	13.8	32.2	1114
Soil HP1**	Overall	766	0.4	16.6	4.8	11.7	3056	0.4	14.3	4.5	10.3	2300
	M/S$^+$	572	0.9	24.9	6.4	19.2	3056	0.8	21.6	6.0	17.2	2300
	J/C†	194	0.4	8.3	3.6	8.5	329.7	0.4	6.9	3.6	7.6	186.2

P75*: 75th percentile; Soil HP1**: Soil House Perimeter Top 1 inch; M/S$^+$: Midland/Saginaw; J/C†: Jackson/Calhoun.

Previously, most statistical analyses focused on the TEQ and the seven specific congeners that had the highest contribution to the serum TEQ-1998: 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,6,7,8-HxCDD, 2,3,4,7,8-PeCDF, PCB-126, PCB-118, and PCB-156. We have recalculated the percent contribution of each congener to the total serum TEQ-2005. The results show that the top 7 congeners contributing to the serum TEQ-2005 are 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 2,3,4,7,8-PeCDF, PCB-126, and PCB-169. PCB-118 and PCB-156 together contribute only 3% and are not among the top 7 congeners contributing to the serum TEQ-2005.

Across blood, household dust and soil house perimeter samples, 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,6,7,8-HxCDD, 2,3,4,7,8-PeCDF and PCB-126 remain among the top 7 congeners for the total TEQ-2005, and are the top 5 congener contributors for serum TEQ-2005. Among these five congeners, the TEF only changed for 2,3,4,7,8-PeCDF: 1998 TEF=0.5 vs. 2005 TEF=0.3. Table 2 shows details of their percent contributions to the total TEQ using 1998 and 2005 TEFs.

- For serum samples, these five congeners contributed more in TEQ-2005 (about 76% to the total TEQ), compared to 62% in TEQ-1998.
- For household dust, they contributed a similar percent to both TEQ-1998 and TEQ-2005, about 41%-42%.
- For soil house perimeter, they contributed a similar percent to both TEQ-1998 and TEQ-2005, about 60%-62%.

Table 2: Percent contribution to total TEQ in UMDES samples
(Numbers in the table are the average percent contribution over all eligible samples)

	Serum		**Household Dust**		**Soil House Perimeter**	
Percent contribution to total TEQ (%)	TEQ-1998	TEQ-2005	TEQ-1998	TEQ-2005	TEQ-1998	TEQ-2005
2,3,7,8-TCDD	7.25	9.58	4.19	4.49	14.56	15.4
1,2,3,7,8-PeCDD	20.59	27.29	9.16	9.75	14.37	15.37
1,2,3,6,7,8-HxCDD	14.63	19.49	9.31	9.84	4.53	4.83
2,3,4,7,8-PeCDF	10.86	8.69	6.39	4.24	18.02	12.28
PCB-126	8.6	11.41	12.07	14.07	10.93	12.24
Sum	61.93	76.46	41.12	42.39	62.41	60.12

Table 3 presents the percent contribution of PCDDs, PCDFs, and PCBs to total TEQ-1998 and TEQ-2005.

- The percent contribution of PCDD increased about 16% for serum, 7% for dust, and 5% for soil house perimeter, after implementation of 2005 TEFs.
- The percent contribution of PCDFs decreased about 1% to 4% after implementation of the 2005 TEFs.
- The percent contribution of PCBs decreased about 16% for serum, 6% for dust and 1% for Soil house perimeter, after implementation of 2005 TEFs.

Table 3: percent contribution to total TEQ for PCDDs, PCDFs, and PCBs

Percent Contribution to the TEQ (%)		**1998 TEFs**	**2005 TEFs**	**Changes in % by using 2005 TEFs**
Serum	PCDDs	48.65	64.72	Increases 16%
	PCDFs	16.83	16.43	Decreases <1%
	PCBs	34.53	18.85	Decreases 16%
Dust	PCDDs	59.51	66.79	Increases 7%
	PCDFs	16.95	15.62	Decreases 1%
	PCBs	23.54	17.59	Decreases 6%
Soil HP1**	PCDDs	49.44	54.35	Increases 5%
	PCDFs	36.20	32.07	Decreases 4%
	PCBs	14.36	13.58	Decreases 1%

Soil HP1**: Soil House Perimeter Top 1 inch

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References

1. Van den Berg M, Birnbaum L, Bosveld ATC, Brunstrom B, Cook P, Feeley M, Giesy JP, Hanberg A, Hasegawa R, Kennedy SW, Kubiak T, Larsen JC, Van Leeuwen FXR, Liem AKD, Nolt C, Peterson RE, Poellinger L, Safe S, Schrenk D, Tillitt D, Tysklind M, Younes M, Waern F, Zacharewski T. *Environmental Health Perspectives* 1998; 106:775.
2. Van den Berg M, Birnbaum L, Denison M, De Vito M, Farland W, Feeley M, Fiedler H, Hakansson H, Hanberg A, Haws L, Rose M, Safe S, Schrenk D, Tohyama C, Tritscher A, Tuomisto J, Tysklind M, Walker N, Peterson RE. *Toxicological Sciences* 2006; 93: 223.
3. Franzblau A, Garabrant D, Adriaens P, Gillespie BW, Demond A, Olson K, Ward B, Hedgeman E, Knutson K, Zwica L, Towey T, Chen Q, Ladronka K, Sinibaldi J, Chang S-C, Lee S-Y, Gwinn D, Sima C, Swan S, Lepkowski J. *Organohalogen Comp* 2006; 68:205
4. Lepkowski J, Olson K, Ward B, Ladronka K, Sinibaldi J, Franzblau A, Adriaens P, Gillespie BW, Chang SC, Chen Q, Demond A, Gwinn D, Hedgeman E, Knutson K, Lee S-Y, Sima C, Swan S, Towey T, Zwica L, Garabrant D. *Organohalogen Comp* 2006; 68:209

Appendix 1: Summary of WHO 1998 and WHO 2005 TEF values

Compound	**WHO 1998 TEF**	**WHO 2005 TEF***
chlorinated dibenzo-p-dioxins		
2,3,7,8-TCDD	1	1
1,2,3,7,8-PeCDD	1	1
1,2,3,4,7,8-HxCDD	0.1	0.1
1,2,3,6,7,8-HxCDD	0.1	0.1
1,2,3,7,8,9-HxCDD	0.1	0.1
1,2,3,4,6,7,8-HpCDD	0.01	0.01
OCDD	0.0001	**0.0003**
chlorinated dibenzofurans		
2,3,7,8-TCDF	0.1	0.1
1,2,3,7,8-PeCDF	0.05	**0.03**
2,3,4,7,8-PeCDF	0.5	**0.3**
1,2,3,4,7,8-HxCDF	0.1	0.1
1,2,3,6,7,8-HxCDF	0.1	0.1
1,2,3,7,8,9-HxCDF	0.1	0.1
2,3,4,6,7,8-HxCDF	0.1	0.1
1,2,3,4,6,7,8-HpCDF	0.01	0.01
1,2,3,6,7,8,9-HpCDF	0.01	0.01
OCDF	0.0001	**0.0003**
non-ortho substituted PCBs		
PCB 77	0.0001	0.0001
PCB 81	0.0001	**0.0003**
PCB 126	0.1	0.1
PCB 169	0.01	**0.03**
mono-*ortho substituted PCBs*		
PCB 105	0.0001	**0.00003**
PCB 114	0.0005	**0.00003**
PCB 118	0.0001	**0.00003**
PCB 123	0.0001	**0.00003**
PCB 156	0.0005	**0.00003**
PCB 157	0.0005	**0.00003**
PCB 167	0.00001	**0.00003**
PCB 189	0.0001	**0.00003**

* numbers in bold indicate a change in TEF