

Dioxins, dibenzofurans, and non-ortho polychlorinated biphenyls in US Air Force veterans who did not spray herbicides

Marian Pavuk¹, Joel E Michalek²

¹Spec-pro Inc

²Air Force Research Laboratory

Introduction

The Air Force Health Study is a 20-year prospective study examining the health, mortality and reproductive outcomes in US Air Force veterans of Operation Ranch Hand, the unit responsible for the aerial spraying of herbicides, including 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)-contaminated Agent Orange and other herbicides, in Vietnam from 1962 to 1971. Included as referents, were the comparison Air Force veterans who flew or serviced transport aircraft in Southeast Asia (SEA) during the same time period and did not spray herbicides. They were matched on age, race and military occupation to Ranch Hand veterans. These veterans spent on average less than 30% of their time served in Southeast Asia in Vietnam and were stationed in other SEA countries like the Philippines, Thailand, Taiwan, Guam and Japan. The present study is the first to measure dioxins, dibenzofurans and PCBs in this cohort of US veterans of Vietnam War.

Materials and Methods

Ninety four Comparison veterans who attended 2002 physical examination and did not have a previous TCDD measurement were included in the study. Comparison veterans did not have an earlier TCDD measurement either because they did not attend any of the previous medical examinations (n=63), or did not have a valid TCDD measurement at some previous exam, had refused to have serum collected, or for other reasons (n=31). Polychlorinated dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDF), and non-ortho polychlorinated biphenyls (PCBs) were measured in serum by high-resolution gas chromatography/isotope-dilution high-resolution mass spectrometry (HRGC/ ID-HRMS) in the dioxin laboratory at the Center for Disease Control and Prevention in Atlanta.^{1,2} The World Health Organization's Toxic Equivalent Factors (WHO-TEF) were used to report PCDDs, PCDFs, and non-ortho PCBs Toxic Equivalents (TEQs).³ For levels measured below the limit of detection we substituted the limit of detection divided by the square root of 2.

Results and Discussion

The mean serum TCDD in the Comparison veterans without previous dioxin measure which were collected in 2002 were about 50% lower (1.74 pg/g of lipid) than levels previously measured in the Comparison group (4.1 pg/g of lipid).⁴ The sum of the dioxin congeners was 475 pg/g of lipid, 35.9 for dibenzofurans and 85.9 pg/g of lipid for non-ortho PCB congeners. Corresponding mean TEQs were 12.63 for dioxins, 5.35 for dibenzofurans and 5.16 for non-ortho PCBs, yielding the total mean TEQ of 23.2. These levels were similar to current background levels observed in the general population of United States or Germany,⁵⁻⁷ twice as high as the general population levels in Australia,⁸ and represent about an one-half of dioxin and dioxin-like compounds measured in Michigan veterans in 1991-92.⁹ Data presented here show the dominant contribution of mostly other dioxins (PCDD TEQ = 12.6, 54.3%), and to a lesser extent also dibenzofurans (PCDF TEQ 5.35, 23.1%) and non-ortho PCB congeners (PCB TEQ = 5.16, 22.2%) on the total TEQ. TCDD contributed only 7.5% of the total TEQ (1.74 out of 23.2). There was a high correlation between TCDD and the total TEQ ($r = 0.81$, $p < 0.001$), despite a low proportion of TCDD levels above the limit of detection – 36.8%.

We have found background levels of exposure to dioxins, dibenzofurans and polychlorinated biphenyls in 94 AFHS Comparison veterans. Results presented here were similar to levels observed in the general US population, and to those in other industrialized countries such as Germany.

References

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Table 1. Dioxins, dibenzofurans and non-ortho polychlorinated biphenyls levels in Air Force Health Study Comparison veterans, 2003 (N=94, pg/g of lipid).

		% Det	Mean	Median	Min-Max	10%- 90%
2,3,7,8-TCDD	1	36.2	1.74	0.95	0.42-11.7	0.49-3.5
1,2,3,7,8-PnCDD	1	60.4	4.97	5.15	0.49-21.7	0.78-9.8
1,2,3,4,7,8-HxCDD	0.1	42.5	3.61	1.80	0.64-14.3	0.85-8.9
1,2,3,6,7,8-HxCDD	0.1	98.9	48.2	47.4	1.62-107	24.8-69.3
1,2,3,7,8,9-HxCDD	0.1	19.1	2.6	1.31	0.64-13	0.78-8
1,2,3,4,6,7,8-HpCDD	0.01	100	44.7	42.9	5.7-129	16.6-72
OCDD	0.0001	99	369	335	43-900	146-655
2,3,7,8-TCDF	0.1	2.1	0.73	0.71	0.42-1.91	0.42-1.06
1,2,3,7,8-PnCDF	0.05	1.0	0.77	0.71	0.42-2.26	0.49-1.06
2,3,4,7,8-PnCDF	0.5	88.3	7.54	7.2	0.57-23.2	1.13-11.7
1,2,3,4,7,8-HxCDF	0.1	96.8	5.56	5.2	0.49-14.5	3-8.3
1,2,3,6,7,8-HxCDF	0.1	94.7	5.46	5.05	0.84-15.7	2.6-8.3
2,3,4,6,7,8-HxCDF	0.1	0	0.79	0.71	0.42-2.19	0.49-1.13
1,2,3,7,8,9-HxCDF	0.1	50	1.54	1.32	0.57-4.7	0.71-2.33
1,2,3,4,6,7,8-HpCDF	0.01	100	12.6	11	3.7-36.5	6.9-20.2
1,2,3,4,7,8,9-HpCDF	0.01	0	0.9	0.85	0.42-2.33	0.57-1.27
OCDF	0.0001	--	--	--	--	--
TeCB 77	0.0001	--	--	--	--	--
TeCB 81	0.0001	31.9	4.26	3.6	0.1-23.5	1.7-6.6
PnCB 126	0.1	95.7	48.3	27.2	1.2-1570	13-57.9
HxCB 169	0.01	100	33.3	29.4	9.7-346	18-40.8
Σ PCDD			475	445	55.7-1060	207-797
Σ PCDF			35.9	33.2	12.8-76.6	19.2-53.7
Σ Non-ortho PCB TEQ			85.9	60.1	17.6-1940	34.6-102
Σ PCDD TEQ			12.6	10.8	2.86-41.8	5.92-21.9
Σ PCDF TEQ			5.35	4.93	0.93-13.8	2.28-8.11
Σ Non-ortho PCB TEQ			5.16	2.97	0.25-160	1.43-6.13
Total TEQ			23.2	19.5	5.71-212	12.1-33.5

% Det. - % above detection limit; -- not-analyzed.

Table 2. Dioxin, dibenzofurans, and non-ortho PCB levels; Air Force Health Study Comparisons and five other populations (pg/g of lipid).

		AFHS	Michigan ^a	Dallas ^b	Dallas ^c	Germany ^d	Australia ^e
2,3,7,8-TCDD	1	1.74	3.8	2.4	3.2	2.4	0.9
1,2,3,7,8-PnCDD	1	4.97	9.3	6.1	5.4	5.7	2.1
1,2,3,4,7,8-HxCDD	0.1	3.61	9.8	4.8	9.7	6.5	2.0
1,2,3,6,7,8-HxCDD	0.1	48.2	72.1	28.3	29	28	13
1,2,3,7,8,9-HxCDD	0.1	2.6	11.9	3.0	4.5	3.6	2.4
1,2,3,4,6,7,8-HpCDD	0.01	44.7	119	32.9	53	31	24
OCDD	0.0001	369	794	262.6	386	246	250
2,3,7,8-TCDF	0.1	0.73	2.3	ND (1.7)	ND (1)	ND (1)	0.5
1,2,3,7,8-PnCDF	0.05	0.77	1.2	ND (1.0)	ND (1)	ND (1)	0.6
2,3,4,7,8-PnCDF	0.5	7.54	8.8	14.6	5.1	13	1.8
1,2,3,4,7,8-HxCDF	0.1	5.56	10.6	7.4	5.9	6.7	1.6
1,2,3,6,7,8-HxCDF	0.1	5.46	6.9	6.0	3.5	5.4	1.4
2,3,4,6,7,8-HxCDF	0.1	0.79	2.8	ND (16.4)	ND (17)	ND (1)	--
1,2,3,7,8,9-HxCDF	0.1	1.54	2.8	1.6	ND (1.3)	1.5	1.3
1,2,3,4,6,7,8-HpCDF	0.01	12.6	19.6	4.8	ND (9)	ND (4)	3.0
1,2,3,4,7,8,9-HpCDF	0.01	0.9	3.1	ND (3.0)	ND (2)	ND (3)	3.2
OCDF	0.0001	--	9.3	ND (4.4)	ND (8)	ND (10)	--
TeCB 81	0.0001	4.26	--	--	--	ND (50)	1.3
TeCB 77	0.0001	--	78.6	--	--	ND (6)	--
PnCB 126	0.1	48.3	104	--	--	71	19
HxCB 169	0.01	33.3	45.8	--	--	90	13
∑ PCDD		475	NA	340	491	NA	290
∑ PCDF		35.9	NA	48	14.5	NA	19
∑ Non-ortho PCB		85.9	NA	--	--	NA	27
∑ PCDD TEQ		12.6	19.5	12.47	13.46	12.24	3.2
∑ PCDF TEQ		5.35	7.2	9.76	5.86	8.02	3.5
∑ Non-ortho PCB TEQ		5.16	13.5	--	--	8.00	4.1
Total TEQ		23.2	40.2	--	--	28.27	11

-- not-analyzed; ND – non-detected; NA – not available; detection limit in brackets; a – ref. #12; b – ref.#8; c – ref.#10; d – ref.#9; e – ref.#11.