American Journal of Industrial Medicine 16:135–146 (1989)

Levels of Polychlorinated Dibenzo-P-Dioxins and Dibenzofurans in Workers Exposed to 2,3,7,8-Tetrachlorodibenzo-P-Dioxin

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Review of employment and chemical production records at a Missouri chemical plant and of questionnaires with self-reported occupational exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) for 16 Missouri workers has explained the wide diversity of 2,3,7,8-TCDD levels previously reported in the workers' adipose tissue (3.5–750 ppt on whole-weight basis). We show that the highest exposures reported to date in the United States occurred in a group of nine production workers who made products contaminated with 2,3,7,8-TCDD. The nine workers had adipose tissue levels with a mean of 246 ppt and a range of 42 to 750 ppt. Seven persons who worked at the same chemical company, but not in the 2,3,7,8-TCDD-contaminated process, had a mean of 8.7 ppt and a range of 3.5 to 25.8 ppt. We also report serum levels of 2,3,7,8-TCDD in these individuals. The adipose tissue from a subset of four production workers with elevated levels of 2,3,7,8-TCDD and seven Missouri residents with normal 2,3,7,8-TCDD levels was also analyzed for other isomers of the PCDDs and PCDFs. The mean adipose tissue level of 2,3,7,8-TCDD in the subset of production workers was 45 times higher than the mean level in the unexposed Missouri residents, but similar levels of the other PCDDs and PCDFs were found in both groups.

Key words: dioxin, production workers, serum, adipose tissue, dibenzofurans, PCDBs

INTRODUCTION

We reported previously the levels of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) in the adipose tissue of individuals with possible exposure in resi-

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Accepted for publication January 26, 1989.

dential, recreational, or occupational sites in Missouri which were contaminated with 2,3,7,8-TCDD [Patterson et al., 1986a]. In that paper, the levels of 2,3,7,8-TCDD of 15 persons who claimed to have occupational exposure ranged from 3.5 to 750 parts per trillion (ppt) in adipose tissue on a whole weight basis.

In an effort to explain the wide range of levels of 2,3,7,8-TCDD for the original 15 workers plus 4 others, we reviewed the questionnaires in which they reported their opportunities for occupational exposure to 2,3,7,8-TCDD. We learned that 16 of the 19 individuals reported exposure at a single chemical plant located in southern Missouri. We examined the employment records at the company to learn whether their work assignments could explain their adipose tissue levels of 2,3,7,8-TCDD. The chemical plant made 2,4,5-trichlorophenol (2,4,5,-TCP), which was used as a feedstock to make butyl esters of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T esters) and hexachlorophene for 559 days during several periods between May 1968 and January 1972. The 2,3,7,8-TCDD was generated as an unintended contaminant during the production of 2,4,5-TCP. Consequently, workers in these processes were potentially exposed to 2,3,7,8-TCDD. Three other persons reported potential occupational exposure at truck terminals that had been sprayed for dust control with 2,3,7,8-TCDD-contaminated waste oils.

We also investigated whether the workers with high levels of 2,3,7,8-TCDD also had elevated levels of other polychlorinated dibenzo-p-dioxins (PCDDs) or polychlorinated dibenzofurans (PCDFs).

MATERIALS AND METHODS

Recruitment and Sample Procurement

In January 1983 the Missouri Department of Health compiled a list of Missouri residents who believed that they had been exposed to 2,3,7,8-TCDD. This list included workers at a plant that made products contaminated with 2,3,7,8-TCDD, workers at truck terminals where the parking lots had been sprayed with waste oil that was contaminated with 2,3,7,8-TCDD, horseback riders who rode in arenas which had been sprayed with 2,3,7,8-TCDD-contaminated waste oils, and residents of areas where roads had been sprayed with 2,3,7,8-TCDD-contaminated waste oils. Individuals were invited under a protocol to donate 10–20 g of adipose tissue for analysis of body levels of 2,3,7,8-TCDD and to complete a questionnaire concerning past medical history, health habits, work history, and potential exposure to 2,3,7,8-TCDD. Each individual also donated 20–30 ml of blood which was to be used for analysis of chlorinated aromatic compounds such as PCBs or 2,3,7,8-TCDD, should such a serum test become available. The adipose tissue and blood samples were collected during the second half of 1985. The full details are described in an earlier report (Patterson et al., 1986a).

Analysis of Adipose Tissue and Serum for 2,3,7,8-TCDD

Adipose tissue and serum were analyzed for 2,3,7,8-TCDD using high-resolution gas chromatography/high-resolution mass spectrometry [Patterson et al., 1986b, 1987a] and a semiautomated sample preparation procedure [Lapeza et al., 1986]. The adipose tissue samples (approximately 10 g) were analyzed for 2,3,7,8-TCDD in analytical runs consisting of four unknown samples and a quality-control pool sample. Every fourth analytical run consisted of two unknown samples, a method blank,

TABLE I. Levels (Parts per Trillion) of 2,3,7,8-TCDD in Adipose Tissue and Serum From 19 Occupationally Exposed Individuals.

				Adipose tissue		Serum
Individual	Sex/race	Group[a]	Days in production	Whole weight	Lipid weight	Lipid weight
Nonproduction workers						
1	M/W	C	0	3.7	[b]	[c]
2	M/W	C	0	4.2	[b]	[c]
3	F/W	C	0	3.5	4.9	[c]
4	F/W	C	0	5.8	6.4	[c]
5	M/W	C	0	8.1	8.2	[c]
6	M/W	C	0	9.9	13.0	7.7
7	M/W	C	0	25.8	41.1	86.4
	Mean			8.7	14.7	47.1
	(SD)			(7.9)	(15.1)	
	Geometric mean			6.8	10.7	25.8
	(GSD)			(2.0)	(2.3)	
Truckers						
8	M/W	T	0	7.8	[b]	[c]
9	M/W	T	0	13.8	18.5	[c]
10	M/W	T	0	24.7	29.6	[c]
	Mean			15.4	24.1	
	(SD)			(8.6)		
	Geometric mean			13.9	23.4	
	(GSD)			(1.8)		
Production workers						
11	M/W	P	40	49.6	77.6	60.6
12	M/W	P	50	41.9	67.0	63.3
13	M/W	P	171	122	174	313
14	M/W	P	240	94.8	[b]	[c]
15	M/W	P	430	745	969	1090
16	M/W	P	449	750	978	781
17	M/W	P	457	131	162	181
18	M/W	P	548	166	261	236
19	M/W	P	559	111	154	180
	Mean			246	355	363
	(SD)			(287)	(386)	(372)
	Geometric mean			147	220	230
	(GSD)			(2.8)	(2.8)	(2.8)

[a]C = employed at Missouri chemical company, but not in processes contaminated with 2,3,7,8-TCDD; T = trucker; P = production worker employed in processes contaminated with 2,3,7,8-TCDD.
[b]Insufficient amount of sample to obtain the percent lipid.
[c]Insufficient amount of serum to analyze.

a duplicate selected at random from an earlier run, and a different quality-control pool sample. The percent lipid in the adipose tissue was determined by a gravimetric procedure—method B [Patterson et al., 1987b]. The lipid determinations and 2,3,7,8-TCDD measurements were performed on different subsamples of the adipose tissue and at different times. The adipose tissue samples were stored during the interim at −60°C. Because of inadequate sample volume, four of the adipose tissue samples were not analyzed for percent lipid.

The serum samples (~ 10 g samples), which were collected in 1985, were

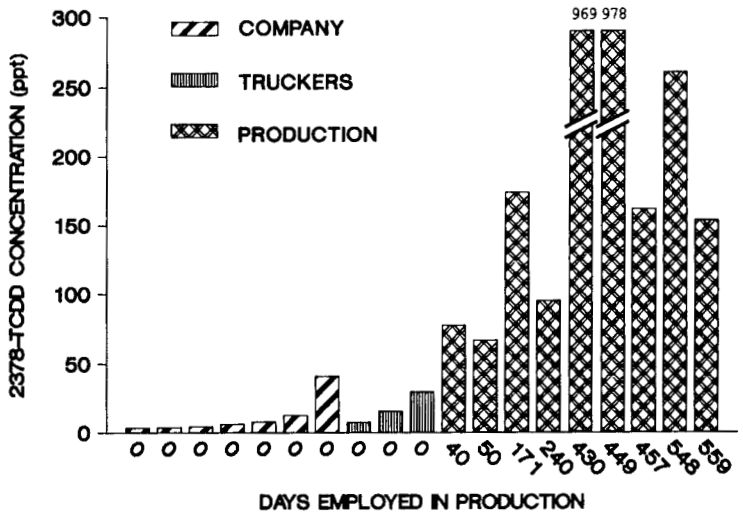

Fig. 1. 2,3,7,8-TCDD concentration versus number of days employed in production for the three potentially exposed subgroups.

analyzed for 2,3,7,8-TCDD in analytical runs that consisted of a method blank, three unknown samples, and a quality-control pool sample. We determined the percent lipid in the serum samples by summing the levels of triglycerides, free cholesterol, cholesterol esters, and phospholipids [Cheek and Wease 1969].

To test whether the mean levels of PCDDs and PCDFs were different in the various study subgroups, approximate p values were calculated by using the Wilcoxon Rank Sum Test [Snedecor and Cochran, 1976].

Analysis of Adipose Tissue for PCDDs and PCDFs

As part of a previous study [Patterson et al., 1986a] we reanalyzed adipose tissue from seven randomly chosen participants who had been found to have levels of 2,3,7,8-TCDD $>$ 50 ppt and from seven randomly chosen controls for the other PCDDs and PCDFs [Needham et al., 1987]. The analytical method was described previously [Patterson et al., 1986d]. The PCDD standards were synthesized in-house and from commercial sources, while the PCDF standards were courtesy of the General Electric Company.

Evaluation of Exposure

Employment records from the Missouri chemical plant were obtained by the National Institute for Occupational Safety and Health (NIOSH) and were reviewed to determine which of the 19 study participants had worked in processes where there was potential for exposure to 2,3,7,8-TCDD. Individuals were identified who had payroll and/or personnel records listing an assignment to production or maintenance in departments producing 2,4,5-TCP, 2,4,5-T, or hexachlorophene between 1968 and 1972, and their periods of employment in these processes were determined. The number of 8-hour days involved in production processes was calculated from the payroll records, assuming a 5-day work week. Company records describing the production processes in these departments were reviewed to ascertain opportunities

TABLE II. Comparison of Polychlorinated Dibenzo-p-Dioxin and Dibenzofuran Concentrations (Parts per Trillion) in Adipose Tissue on a Lipid-Adjusted Basis of Production Workers and Unexposed Missouri Residents

Congener	Mean exposed n = 4[a]	Mean unexposed n = 7	Ratio of exposed to unexposed
2378-TCDD	390	8.7	45
12378-PnCDD	14.7	11.5	1.3
123478-HxCDD	11.0	10.3	1.1
123678-HxCDD	98.7	85.1	1.2
123789-HxCDD	20.2	21.9	0.9
1234678-HpCDD	125	113	1.1
OCDD	624	742	0.8
2378-TCDF	1.3	1.2	1.1
23478-PnCDF	4.3	5.0	0.9
123478-HxCDF	4.3	4.5	1.0
123678-HxCDF	6.0	5.9	1.0
1234678-HpCDF	31.5	19.8	1.6

[a]The four chosen at random were workers 13, 15, 18, and 19 (see Table I).

for exposure to substances contaminated with 2,3,7,8-TCDD. Additionally, the questionnaires from the previous study [Patterson et al., 1986a] were examined to learn the employment history and job duties reported by each person.

RESULTS

From the personnel and payroll records of the Missouri chemical company, we determined that nine of the 19 individuals had been employed in areas where 2,4,5-TCP, 2,4,5-T-ester, or hexachlorophene was produced. Review of the employment information reported in the questionnaires found that seven of the remaining ten persons were also employed at the same chemical company, but in other departments, or at its outside lagoon disposal areas while employed by the company or by a contractor for the chemical company. Three individuals reported working at trucking terminals contaminated by waste oils containing 2,3,7,8-TCDD.

Table I lists the levels of 2,3,7,8-TCDD in the adipose tissue and serum of each individual. Adipose tissue levels (whole weight) of 2,3,7,8-TCDD in the nine production workers who made 2,4,5-TCP, 2,4,5-T-ester, or hexachlorophene ranged from 41.9 to 750 ppt, with a mean of 246 ppt.

By contrast, the mean adipose tissue levels of 2,3,7,8-TCDD in the seven persons who reported potential exposure to 2,3,7,8-TCDD in other areas of the company was 8.7 ppt, with a range of 3.5 to 25.8 ppt. The difference in the means for these two groups was statistically significant (p less than .01). The 2,3,7,8-TCDD adipose tissue levels (whole weight) in the three truckers ranged from 7.8 to 24.7 ppt with a mean of 15.4 ppt.

In Table I, we also report the adipose tissue levels of 2,3,7,8-TCDD on a lipid basis, and for individuals for whom we had adequate serum samples, we report levels of 2,3,7,8-TCDD on a serum lipid basis. The Pearson correlation coefficient for the adipose tissue to serum levels (both on a lipid basis; n = 10) is 0.97. The mean of the ten concentration ratios (adipose tissue/serum, both on a lipid basis) is 1.01 (standard deviation = 0.357, standard error = 0.113). This is in agreement with our

TABLE III. Concentration of 2,3,7,8-TCDD in Human Adipose Tissue and Serum From Individuals With Potential Exposure to 2,3,7,8-TCDD

Potentially exposed population, Year samples taken	Estimated years since exposure	Medium	N	Whole weight basis		Reference
				Mean (ppt)	Range (ppt)	
Factory workers						
Missouri, USA, 1985	13	Adipose[b]	9	246 (355)[a,b]	42–750 (67–978)[a,b]	Patterson et al. [present study]
		Serum[b]	8	363[a,b]	61–1090[a,b]	Patterson et al. [present study]
New Jersey, USA, 1987	18–33	Serum	25	208[a]	4.6–717	Fingerhut et al. [1989]
FRG[c]	31	Adipose	1	101	—	Nygren et al. [1986]
FRG, 1985	32	Adipose	6	49[a]	11–141	Schecter & Ryan [1988]
FRG, 1986	<1–32	Adipose	45	—	5.9–2,252[a]	Beck et al. [1987]
FRG	>30	Adipose	4	150	—	Rappe et al. [1987]
Vietnam veterans						
Agent Orange handlers						
U.S. Air Force, 1982	15	Serum	36	115[a]	16.9–423	Pirkle et al. [1989]
U.S. Air Force, 1987	20	Serum	147	49.4[a]	3.2–313	CDC [1988a]
U.S. Air Force	15–20	Adipose	10	23[a]	7–55	Schecter et al. [1987]
U.S. Air Force & Army	15–20	Adipose	10	41.7	4–155	Kahn et al. [1988]
U.S. Air Force & Army, 1978	10	Adipose	3	37	ND–99[d]	Gross et al. [1984]
Ground troops						
U.S. Army, 1987	15–20	Serum	646	4.2[a]	ND–45	CDC [1988b]
U.S. Army	15–20	Adipose	26	5.8[a]	ND–11	Schecter et al. [1987]
—	15–20	Adipose	10	5.1[c]	2–15	Kahn et al. [1988]
Residential						
Seveso, Italy	<1	Adipose	1	1840	—	Faccheti et al. [1981]
Seveso, Italy, 1976	<1 month	Serum	9	10,400	828–27,800	CDC [1988C]
Missouri, USA, 1985		Adipose	16	26.8	5.2–59.1	Patterson et al. [1986a] Andrews et al. [1989]

earlier work [Patterson et al., 1988] showing that 2,3,7,8-TCDD is equally distributed between adipose tissue and serum when the levels are adjusted for lipids.

Figure 1 illustrates the concentration of 2,3,7,8-TCDD in adipose tissue (lipid adjusted) for each of the three subgroups of subjects by the number of days involved in production of products contaminated with 2,3,7,8-TCDD.

Table II lists the mean concentrations (lipid adjusted) for the 12 PCDDs and PCDFs found in the adipose tissue of four production workers with high adipose levels of 2,3,7,8-TCDD and in seven Missouri residents with low 2,3,7,8-TCDD levels. The mean 2,3,7,8-TCDD concentration of 390 ppt for the four exposed workers was 45 times higher than the mean of 8.7 ppt for the seven unexposed

TABLE III. Concentration of 2,3,7,8-TCDD in Human Adipose Tissue and Serum From Individuals With Potential Exposure to 2,3,7,8-TCDD (Continued)

Potentially exposed population, Year samples taken	Estimated Years since exposure	Medium	N	Whole weight basis Mean (ppt)	Whole weight basis Range (ppt)	Reference
Others						
Waste Haulers, USA, 1985		Adipose	10	12.4	3.7–25.8	Patterson et al. [1986a] Andrews, et al. [1989]
Horse Arenas, USA, 1985		Adipose	16	145	5.0–577	Patterson, et al. [1986a] Andrews et al. [1989].
Missouri Truckers, USA, 1985		Adipose	3	15.4 (24.1,n = 2)[a]	7.8–24.7	Patterson [present study]
Agricultural Sprayer Binghampton, NY office	5	Adipose	1	72	—	Tong et al. [1987]
building workers	2–3	Adipose	4	17.4	11.6–28.3	Schecter et al. [1986]
Factory clerical workers New Jersey, 1987	18–21	Serum	2	18.6[a]	11.0–26.1	Fingerhut et al. [1989]
Factory clerical workers Missouri, 1985		Adipose	7	8.7 (14.7,n = 5)[a]	3.7–25.8	Patterson et al. [present study]

[a]Lipid adjusted.
[b]Paired serum/adipose tissue from the same individuals.
[c]FRG = Federal Republic of Germany.
[d]Mean of duplicate determinations.
[e]These Vietnam veterans were selected for an absence of exposure.

Missouri residents (Wilcoxon Rank Sum Test, p = .001), and the mean of 31.5 ppt for 1,2,3,4,6,7,8-HpCDF in the exposed group was 1.6 times greater than the mean of 19.8 in the unexposed group (Wilcoxon Rank Sum Test, p = .048). The ratio of the means for the other PCDDs and PCDFs was close to 1.0 (0.8–1.3) between the two groups.

DISCUSSION

The results of our review of employment records and self-reported occupational exposures for 19 individuals demonstrate that nine chemical workers who worked in production of substances contaminated with 2,3,7,8-TCDD have statistically significantly higher levels of this isomer of dioxin in their adipose tissue than do seven persons who worked at the same company but not in departments where 2,4,5-TCP, 2,4,5-T esters, or hexachlorophene were made (Table I, Fig. 1).

Two of the nine production workers (Fig. 1) had levels of 2,3,7,8-TCDD that were substantially higher than the levels in the other workers. These two individuals reported handling 2,4,5-TCP process wastes. Since company documents indicated that some process wastes contained very high concentrations of 2,3,7,8-TCDD, ranging from 200 to 400 ppm, it is possible that exposure to such wastes may account for

TABLE IV. Extrapolated 2,3,7,8-TCDD Levels (ppt) From Individuals With Various Types of Exposure*

	Conc. (C)	T (years)	Conc. (C_o)	Reference
Seveso, Italy resident	27,800	0	27,800	CDC [1988C]
New Jersey (USA) production worker	717	30.5	14,700	Fingerhut et al., [1989]
Missouri (USA) production workers	67–978	13	243–3,540	Patterson et al. [present study]
FRG production worker[a]	141	32	3,350	Schecter et al. [1988]
FRG production worker[a]	2,252	2	2,750	Beck et al. [1987]
Horse arena rider, Missouri (USA)	577	14	2,310	Patterson et al. [1986a]
FRG production worker[a]	101	31	2,170	Nygren et al. [1986]
US Air Force ranch hand	423	13	1,530	Pirkle et al. [1989]

*In C_o = In C + T (0.099021). Assuming a 7-year half-life, first-order kinetics; where C = concentration at time of sample collection; C_o = concentration at the time exposure stopped; T = time between the cessation of exposure and sample collection.
[a]FRG = Federal Republic of Germany.

their high levels of 2,3,7,8-TCDD. Alternatively, it is possible that the specific job duties of these two workers may have been different from the other production workers and may have resulted in greater exposure to substances contaminated with 2,3,7,8-TCDD. We do not have descriptions of the job duties for each individual, so we cannot draw any conclusions on this point.

In Table III, we list the adipose tissue and serum levels of 2,3,7,8-TCDD reported in the literature in persons with potential exposure to 2,3,7,8-TCDD. Currently, there is limited information which suggests that the half-life for elimination of 2,3,7,8-TCDD from humans is 5.8–7.1 years [Poiger and Schlatter, 1985; Patterson et al., 1986a; Pirkle et al., 1989]. Table IV lists the extrapolated 2,3,7,8-TCDD levels (assuming a 7-year half-life, first-order kinetics, and no change in body fat) for selected individuals from the studies listed in Table III with various types of exposure. These are extremely high levels of 2,3,7,8-TCDD compared to background levels reported in persons with no known exposure to 2,3,7,8-TCDD, which are listed in Table V. It can be seen from this table that, in general, the background levels of 2,3,7,8-TCDD in humans are under 20 ppt. The mean adipose tissue level of 8.7 ppt 2,3,7,8-TCDD (Table I), found in persons employed at the Missouri chemical company at jobs other than the production of substances contaminated with 2,3,7,8-TCDD, is comparable to levels found in unexposed persons.

With the exception of 2,3,7,8-TCDD and 1,2,3,4,6,7,8-HpCDF, Table II shows that the concentrations of the ten other PCDDs and PCDFs present in the adipose tissue of the four production workers from the Missouri plant are comparable to levels previously reported for nonexposed individuals in the U.S.A. and Canada [Graham et al., 1986; Stanley et al., 1986; Schecter et al., 1986; Needham et al., 1987; Kahn et al., 1988], Japan [Ono et al., 1986; Ryan, 1986]; Sweden [Rappe et al., 1986] and Germany [Beck et al., 1987]. The finding of a 45-fold elevation in the level of 2,3,7,8-TCDD in the subgroup of four production workers who made 2,4,5-TCP, 2,4,5-T esters and hexachlorophene but no elevation in their other isomers of dioxin and furan suggests that the source of the 2,3,7,8-TCDD was the production of 2,4,5-TCP and its use in making 2,4,5-T esters and hexachlorophene. We suspect that

TABLE V. Concentration of 2,3,7,8-TCDD in Human Adipose Tissue and Serum From Individuals With No Known Exposure to 2,3,7,8-TCDD

Source of adipose tissue	N	Whole weight basis		Mean age (range)	Reference
		Mean (ppt)	Range (ppt)		
Adipose tissue from elective surgical patients in Missouri, 1985	128	7.0(6.1)[a]	ND,1.4–20.2[b]	49.0 (18–85)	Patterson et al. [1986a] Andrews et al. [1989]
Adipose tissue from (autopsy) Georgia and Utah, 1984	35	7.1[a]	2.7–19	55.8 (16–85)	Patterson et al. [1986c]
Adipose tissue from (autopsy) sudden deaths in St. Louis, Missouri	35	7.2[a]	2.2–20.5	41.5 (15–88)	Graham et al. [1986]
Adipose tissue from (autopsy) the general Canadian adult population, 1976	25	6.4[c]	ND,2.0–13	39.7	Schecter et al. [1986]
Adipose tissue from (adult controls) Binghamton, New York	8	7.2	1.4–17.7	—	Schecter et al. [1986]
Adipose tissue from hospital patients, Umea, Sweden	31	3.0	0–9	—	Rappe et al. [1986]
Adipose tissue composites from the EPA FY'82 NHATS Repository, 1982[d]	46	5.0[e]	ND–10	—	Stanley et al. [1986]
Adipose tissue from cancer patients in Japan, 1985	12	9.0	6–18	—	Ono et al. [1986]
Adipose tissue from general surgical patients in Shanghai; China, 1984	7	ND	Detection limit 2 ppt	54	Ryan et al. [1987]
Adipose tissue from (autopsy) general adult population in Southern Japan, 1984	6	6.6[e,f]	ND–9.7	59 (46–70)	Ryan [1986]
Adipose tissue from (autopsy) accidental death or illness in Japan	17	13.2	2.6–33	49.5 (27–74)	Ogaki et al. [1987]
Serum from New Jersey controls, 1987	19	8.2[g]	3.7–17.1	54	Fingerhut et al. [1989]
Serum from elective surgical patients in Missouri, 1985	21	7.6[g]	1.9–26.0	42.5 (19–70)	Patterson et al. [1987a]
Serum from U.S. Army veterans (non-Vietnam), 1987	97	4.1[g]	ND–15	39 (33–46)	CDC [1987, 1988b]
Serum from U.S. Air Force (non-Vietnam) controls, 1987	49	4.8[g,h]	2–9.7	49	CDC [1988a]
Adipose tissue from U.S. Army controls (non-Vietnam)	7	3.2	1–5	—	Kahn et al. [1988]
Adipose tissue from veteran controls, 1978	4	5.1	3–8	—	Gross et al. [1984]

[a]Geometric mean.
[b]Not detected.
[c]Mean is of 25 positive samples, 21 samples were NDs.
[d]Composites from over 900 specimens.
[e]Lipid adjusted basis.
[f]Mean is of 4 positives, 2-NDs.
[g]Serum on a lipid adjusted basis.
[h]Excludes one person (21.3 ppt) documented to have had exposure to industrial chemicals.

the statistical significance of the 1.6-fold difference in 1,2,3,4,6,7,8-HpCDF concentrations may have occurred by chance and probably is not meaningful because the chemistry of the process reactions does not predict the generation of heptachlorinated furans. Elevation of only the 2,3,7,8-TCDD isomer in these U.S. production workers is similar to the situation reported for German workers [Nygren et al., 1986; Rappe et al., 1987; Schecter et al., 1988] but differs from the situation reported for German workers from a different company [Beck et al., 1987], who also had substantially higher than average levels of several PCDDs and PCDFs. This may reflect differences in commercial processes for producing 2,4,5-trichlorophenol [Jurgens and Roth, 1987].

We conclude that the individuals for whom the highest elevated levels of 2,3,7,8-TCDD have been reported in the literature were either employed in the production or use of substances contaminated with 2,3,7,8-TCDD or were present following an accidental release of 2,3,7,8-TCDD into the environment (Tables I, III, IV). However, much more has to be learned about the kinetics of dioxin metabolism and half-life before current levels can be used to fully explain historical levels of exposure. Ultimately, this information should be helpful in the analysis of the health effects studies of dioxin exposure.

ACKNOWLEDGMENTS

This study was supported by funds from the Superfund Trust Fund by Interagency Agreement with the Agency for Toxic Substances and Disease Registry, Public Health Service, U.S. Department of Health and Human Services, Atlanta, Georgia 30333. Chester R. Lapeza, Sandra Isaacs, Larry Hampton, and William Belser prepared the adipose tissue and serum samples for mass spectral analysis. Louis Alexander, Ph.D., Vincent Maggio, Vaughn Green, and James Gill performed the high-resolution, mass-spectral analysis. Henry Falk, M.D., Brenda Lewis, and Carolyn Newman provided technical assistance and consultation for the study. Richard Hoffman, M.D., and Paul Stehr-Green, Dr. P.H., prepared the protocol. We also thank Thomas Bernert, Ph.D., Omar Henderson, Ph.D., and Wayman Turner for performing the lipid analyses.

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