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Chlorinated Dioxins and Dibenzofurans in Human Tissue from General Populations: A Selective Review

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During the past decade a considerable amount of data has been generated concerning polychlorinated dibenzodioxin (PCDD) and polychlorinated dibenzofuran (PCDF) levels in humans from many geographical locations. To organize these data in a useful fashion for environmental purposes and for consideration of human toxicity, selected portions of our data are presented in a somewhat atypical fashion, by percentage contribution of individual congeners to total PCDD/Fs in human tissue, and to the total dioxin equivalents (TEq). This is done to better characterize congener contributions from environmental contamination in various geographical regions at this time and health-related levels. To present the findings in a global perspective, data from widely different locations are presented including the United States, Germany, Vietnam, the former Soviet Union, Thailand, Cambodia, China, South Africa, and Guam.

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Introduction

The first measurement of dioxin in human tissues and food was reported in the early 1970s by Baughman (*1,2*). He measured 2,3,7,8-TCDD (TCDD) in human milk and fish from the south of Vietnam from areas sprayed with Agent Orange, a mixture of phenoxyherbicides contaminated with dioxin. Human milk samples from the United States general population were used as controls. A level of 1450 ppt TCDD on a lipid basis was found in one woman's milk, levels between 200 and 400 ppt were found in other samples, and there were specimens from the same villages where no TCDD was measured at detection limits ranging from 29 to 429 ppt, lipid. Later in the 1970s, Rappe, Masuda and others reported human tissue levels of polychlorinated dioxins and dibenzofurans (PCDDs and PCDFs) (*3–5*). The first measurement of dioxins and dibenzofurans in potentially exposed American workers and the general public was reported in 1983 and published in 1985 (*6,7*). This documented dioxins and dibenzofurans in the blood and adipose tissue of the general public and also elevated PCDD/Fs in some exposed workers. With marked improvements in specificity and sensitivity, a large number of

reports worldwide have described human tissue and food levels of these chemicals which, for the most part, are synthetic and of recent origin (*8–25*).

This paper reviews recent findings in human tissues from a number of countries, which vary in level of industrialization. The geographic regions include North America, Europe, Asia, South Africa and a geographically isolated South Pacific island, Guam. This diverse and widespread geographical sampling presents evidence for the industrial origin of most dioxins and dibenzofurans and illustrates the use of dioxin levels in human tissue as a reflection of regional industrialization and environmental contamination. Evidence for industrial origin of most dioxins has also previously been demonstrated from environmental data (*26–29*) and from human tissue measurements of frozen ancient Eskimo tissue compared to modern tissue (*31,32*). Food consumption is the primary form of human intake in these cases, specifically meat, milk, fish, and their by-products (*18,22–24,30*). PCDD/F levels are presented for various organs of the body considered to be target organs for dioxin toxicity, and these levels are compared to adipose tissue, which, along with blood, is usually used as a signal tissue or reference for dioxin levels and estimates of body burden in potentially exposed persons. However, the number of human organs that have been analyzed for dioxins at the present time is insufficient to characterize the levels and their ratios in human tissues.

Dioxins are extremely toxic to many animal species and appear to be carcinogenic for humans as well as laboratory animals (*33–37*). For some dioxins, certain biochemical markers of exposure and sensitivity appear to have similar responses in humans and laboratory animals (*38,39*). It is possible that the levels currently found in human tissues may have health consequences for individuals or may cause increased rates of disease on a population basis. Most previous publications, including our own work (*40*), have described actual dioxin tissue levels, without detailed or congener pattern analysis by percentage, which is the focus of this paper. The data are compared in terms of both measured PCDD/F tissue congener levels and by dioxin toxic equivalents (*41–43*). The data are from the general population rather than from exposed populations. In many cases sample size is insufficient to generalize about populations; pooled samples are sometimes used in an attempt to increase sample size for each of these difficult and costly analyses. With a larger sample size and a more systematic sampling in the future, along with a decrease in the costs for dioxin analysis and an increase in laboratory capacity, these values may change and be found not representative of general populations of these specific geographical areas. At this time, however, they do constitute a substantial amount of the data available by countries, and so seem reasonable to present and use, despite potential limitations with regard to being adequately representative of the adult populations for the countries involved. Also, as environmental contamination decreases, it is hoped and expected that PCDD/F tissue levels in the general population will also decrease gradually over time. Because of the extreme persistence of dioxins and related chemicals in the environment, this decrease may take a very long time. A recent Environmental Protection Agency report on human tissue levels in the United States suggests that such a decrease in dioxin body burden may have begun this past decade (*44*).

Methods

The analytic methods used have been previously described and will only be referenced in this paper (*16,31,32,46,47*). All laboratories reporting data in this paper successfully participated in the recent World Health Organization's interlaboratory validation study for human milk or blood (*45*).

Results and Discussion

Dioxin Levels in Blood

Tables 1 and 2 present blood lipid dioxin and dibenzofuran levels from locations in Vietnam, two from the south (Ho Chi Minh City and Dong Nai), and one from the north (Hanoi); Germany; the United States; St Petersburg (formerly Leningrad), in the European part of the Soviet Union, Baikalsk, on the shores of Lake Baikal, a small city in eastern Siberia in Russian Asia; and Guam, an island in the South Pacific Ocean (*48*). The data represent the mean of individual analyses from Germany and Guam and values from pooled blood for the other areas.

The data are presented by actual levels as well as by percent contribution from each congener to the total levels and also by percent contribution in dioxin toxic equivalents (TEqs) using the current international units (*41–43*). For the actual levels, the more industrialized countries or parts of countries can be identified readily by the total dioxin levels. In the former USSR, total PCDD values are low in both St. Petersburg (130 ppt) and Baikalsk (88 ppt), as in the case for Hanoi, with a value of 126 ppt. Levels are higher in Germany, where the total PCDD is 788 ppt, in the United States (1499 ppt), in Guam (1810 ppt), in Dong Nai (1938 ppt), and in Ho Chi Minh City (1087 ppt). In the south of Vietnam, elevated dioxin levels are consistent with former French and American industrialization and use of chemicals, whereas in Guam, imported food from more industrial areas, such as the United States and Japan, may be causing a more typical industrial pattern of PCDD/Fs in human tissue. Guam is also the home of a U.S. naval and air base, which could also contribute to the toxic chemical burden. Dibenzofuran levels are highest at 133 ppt in Dong Nai, Vietnam, surprisingly, followed by Germany (98 ppt), the United States (92 ppt), and the lowest levels are from Hanoi (41 ppt), and St. Petersburg (31 ppt). It is noteworthy and somewhat surprising that St. Petersburg, a European city, has such low levels.

The values for the toxic equivalents in Table 2 for whole blood show Dong Nai and the U.S. values are highest for dioxins, 31 and 30 ppt, respectively, with Guam at 24 and Germany at 20 ppt. The lowest value of 6 ppt is found in Hanoi, with Baikalsk (8 ppt) and St. Petersburg (11 ppt) in the same range. For dibenzofuran TEqs, the German value is highest at 22 ppt, followed by Dong Nai (18 ppt), Ho Chi Minh City (14 ppt), the United States (11 ppt), Baikalsk (10 ppt), and Guam (8 ppt). Hanoi and St. Petersburg both have a value of 6 ppt.

Tables 1 and 2 also list the percent contribution from the individual congeners to the total levels. For Ho Chi Minh City, an area from the south of Vietnam formerly sprayed with Agent Orange, it is most striking that the percentage of the total PCDD/Fs from TCDD is now only 0.29% and, expressed in dioxin toxic equivalents, only 12%. Octa (OCDD), which is usually the congener found in the largest amount in human

Table 1. Amounts and percent contribution of individual congeners to total PCDD and PCDFs in human blood from various general populations (ppt, lipid).

	Ho Chi Minh City (n=50)		Dong Nai (n=33)		Hanoi (n=32)		Germany (n=102)		USA (n=100)		Baikalsk (n=8)		St. Petersburg (n=50)		Guam (mean=10)	
Cogeners	Level	% Contribution	Level	% Contribution	Level	% Contribution	Level	% Contribution	Level	% Contribution	Level	% Contribution	Level	% Contribution	Level	% Contribution
2,3,7,8-TCDD	3.4	0.29	12	0.58	<2.4	0.72	3.6	0.4	5.2	0.33	3.7	2.7	4.5	2.8	4.07	0.21
1,2,3,7,8-PeCDD	8.8	0.75	14	0.68	4.2	2.5	13.8	1.5	21	1.3	4.7	3.4	9.3	5.8	14	0.73
Total HxCdd	45.1	3.9	81	3.9	21	12.6	78.9	8.8	112	7.0	13	9.5	13	8.1	99.64	5.2
1,2,3,4,6,7,8-HpCDD	97	8.3	176	8.5	13	7.8	92.4	10.3	187	11.8	9.6	7	14	8.7	163.8	8.5
OCDD	933	79.8	1655	79.9	87	52.1	610.3	68.2	1174	73.8	57	41.6	89	55.3	1526	81
2,3,7,8-TCDF	4.6	0.39	3.9	0.2	2.6	1.6	2.3	0.26	3.1	0.19	3	2.2	2.3	1.4	2.07	0.12
1,2,3,7,8-PeCDF	3.2	0.27	2.9	0.14	<1.1	0.33	2.0	0.22	2.8	0.18	<1.8	0.66	ND	ND	ND	ND
2,3,4,7,8-PeCDF	21	1.8	22	1.1	8.6	5.1	37.0	4.1	13	0.82	15	11	9.2	5.7	9.82	.49
Total HxCDF	28.3	2.4	59	2.9	14.7	8.8	34.1	3.8	32.6	2.0	21.9	16	13.2	8.2	21.42	1.1
Total HpCDF	24.6	2.1	33.7	1.6	12.6	7.5	24.5	2.7	36	2.3	4.6	3.4	6.3	3.9	40.4	2.1
OCDF	ND	ND	11	0.5	<3	0.9	4.2	0.47	4.2	0.26	<8	2.9	NA	NA	4.9	0.26
Total PCDD	1087	93	1938	94	126	76	798	89	1499	94	88	64	130	81	1810	96
Total PCDF	82	7	133	6	41	24	97	11	92	6	49	36	31	19	80	4
Total PCDD/F	1,169	100	2,071	100	167	100	895	100	1,591	100	137	100	161	100	1,890	100

[a]Data from Schecter et al. (*48*). Baikalsk and St. Petersburg are cities in the eastern and western former USSR, respectively. Samples are from whole blood, except for the U.S. Sample, which is from plasma. Samples are from pooled blood except Germany, which is the mean of 102 individual analyses.

Abbreviations: CDD, chlorinated dibenzodioxin; CDF, chlorinated dibenzofuran; P, poly; T, tetra; Pe, penta; HX, hexa; Hp, hepta; o, octa; NA, not available; ND, not detected.

Table 2. Dioxin toxic equivalents (TEq) and percent contribution of individual congeners to total PCDD/Fs TEqs in human blood from general populations (ppt, lipid).

		Ho Chi Minh City (n=50)		Dong Nai (n=33)		Hanoi (n=32)		Germany (n=85)		USA (n=100)		Baikalsk (n=8)		St. Petersburg (n=50)		Guam (mean=10)	
Cogeners	TEq	TEq	% Contribution	TEq	% Contribution	TEq	% Contribution	TEq	% Contribution	TEq	% Contribution	TEq	% Contribution	TEq	% Contribution	TEq	% Contribution
2,3,7,8-TCDD	1	3.4	12	12	24.5	1.2	10	3.6	8.6	5.2	12.7	3.7	20.5	4.5	26.5	4.07	12.7
1,2,3,7,8-PeCDD	0.5	4.4	16	7	14.3	2.1	17.5	7	16.7	10.5	25.6	2.35	13	4.65	27.4	7	21.9
Total HxCDD	0.1	4.51	16	8.1	16.5	2.1	17.5	8.11	19.3	11.2	27.3	1.3	7.2	1.3	7.6	9.96	31.1
1,2,3,4,6,7,8-HpCDD	0.01	0.97	3.5	1.76	3.6	0.13	1.1	0.938	2.23	1.87	4.6	0.096	0.53	0.14	0.82	1.64	5.1
OCDD	0.001	0.933	3.3	1.655	3.4	0.087	0.73	0.596	1.42	1.17	2.9	0.057	0.32	.089	0.52	1.526	4.8
2,3,7,8-TCDF	0.1	0.46	1.6	0.39	0.8	0.26	2.2	0.25	0.6	0.31	0.76	0.3	1.7	0.23	1.4	.207	0.65
1,2,3,7,8-PeCDF	0.05	0.16	0.57	0.15	0.31	0.055	0.46	ND	ND	0.14	0.34	0.05	0.28	ND	ND	ND	ND
2,3,4,7,8-PeCDF	0.5	10.5	37.5	11	22.5	4.3	35.8	18.4	43.8	6.5	15.9	7.5	41.7	4.6	27.1	4.91	15
Total HxCDF	0.1	2.83	10	5.9	12	1.47	12.3	3.16	7.5	3.26	8	2.19	12.2	1.32	7.8	2.14	6.8
Total HpCDF	0.01	0.246	0.88	0.337	0.69	0.126	1.1	0.218	0.52	.36	0.89	0.046	0.26	0.063	0.37	0.404	1.3
OCDF	0.001		ND	0.011	0.022	0.0015	0.01	0.0055	0.013	.004	0.01	0.004	0.02	NA	NA	0.0049	0.02
Total PCDD		14	50	31	63	6	47	20	48	30	73	8	44	11	65	24	75
Total PCDF		14	50	18	37	6	53	22	52	11	27	10	56	6	35	8	25
Total PCDD/Fs		28	100	49	100	12	100	42	100	41	100	18	100	17	100	32	100

[a]Data from Schecter et al. (*48*). Baikalsk and St. Petersburg are cities in the eastern and western former USSR, respectively. Samples are from whole blood, except for the U.S. sample, which is from plasma. Samples are from pooled blood except Germany, which is the mean of 102 individual analyses.

Abbreviations: CDD, chlorinated dibenzodioxin; CDF, chlorinated dibenzofuran; P, poly; T, tetra; Pe, penta; Hx, hexa; Hp, hepta; o, octa; NA, not available; ND, not detected.

tissues for most countries, for unknown reasons, provides almost 80% of the total PCDD/F but only 3.3% of the toxicity using current toxicity estimates for the Ho Chi Minh City blood. A larger portion of the toxicity is contributed by the 5- and 6-chlorinated dioxin and dibenzofuran congeners. The relatively little discussed, but toxic 2,3,4,7,8-PeCDF, makes a substantial contribution to dioxin toxicity here, providing almost 38% of the total dioxin toxic equivalents. Although total dioxins contribute 93% and dibenzofurans 7% to total levels, they each contribute 50% of the dioxin toxic equivalents in the specimen from Ho Chi Minh City. It should be noted that Agent Orange spraying occurred from 1962 to 1970 in Vietnam. For that reason, levels of 2,3,7,8-TCDD in human tissue collected in Vietnam between 1984 to 1990 are probably, on average, lower than was previously the case.

In Dong Nai province, also a heavily Agent Orange-sprayed area in the south of Vietnam, TCDD levels found in the 1980s were quite high, contributing about 25% to the total PCDD/F toxicity. Although the congener totals for dioxins and dibenzofurans in Dong Nai are similar to the Ho Chi Minh City levels, approximately 94 and 6%, respectively, the dioxin toxic equivalent pattern reflects a larger contribution from TCDD.

Here, the dioxin toxic equivalent contribution from the dioxins are 63% and, from dibenzofurans, 37%.

In Hanoi, in the north of Vietnam where little industry is present and where no Agent Orange was sprayed, the total PCDD/F levels are quite low, at 167 ppt, compared with the 1000–2000-ppt levels found in the blood specimen from the south of Vietnam. However, the relative dioxin and dibenzofuran toxicity resembles that seen in the specimens from Ho Chi Minh in that almost half, 47%, is from PCDDs and 53% is from PCDFs. A somewhat unusual pattern exists in that there is more dioxinlike toxicity from the dibenzofurans than from the dioxins themselves, although the dioxins predominate in absolute amount, 126 ppt compared to 41 ppt.

Germany and the United States represent typical industrial countries with massive production and disposal of synthetic chemicals. Total dioxins and dibenzofurans in human tissue from each of these countries have previously been noted to be relatively similar in amount. Here in these samples, the total dibenzofuran levels are similar, but there is higher dioxin content in the American blood, to a considerable extent due to the OCDD. The finding that the 2,3,4,7,8-penta (Pe CDF) level is markedly higher in German blood (a typical European finding), with 37 ppt, than in the U.S. sample, with 13 ppt, is characteristic and worthy of note. This converts to a 44 (German) versus 16% (U.S.) contribution to the total in dioxin toxic equivalents for this congener. For total dibenzofuran TEq, toxicity is higher in Germany when compared to the United States, 52 versus 27%, respectively. TCDD TEq, however, plays a relatively minor role in each country, with values of 9 and 13% in German and American blood, respectively. This finding suggests that too much attention may have historically been given to the well-known 2,3,7,8-TCDD congener as compared with other PCDDs and PCDFs, which contribute far more to the total toxicity.

The former Soviet Union is of interest for a number of reasons. It was a large country, with varying degrees of industrialization that have been rapid and relatively recent, especially in Siberia. If airborne dioxins and dibenzofurans play a major role in environmental levels, we would expect human tissue levels to be similar in geographically remote areas. For that reason, we chose to sample blood from Baikalsk, located far into Asiatic Siberia, on the southern bank of remote Lake Baikal, and St. Petersburg, in Europe, several thousand miles west of Baikalsk. In Baikalsk, the total PCDD/PCDF levels are low, 137 ppt, with a PCDD/PCDF ratio of about 2:1, whereas in St. Petersburg, the total PCDD/F level was also low at 161 ppt, but with a PCDD/PCDF ratio of approximately 4:1. These levels are considerably lower than those seen in most industrial locations.

In Guam, a relatively isolated island in the South Pacific Ocean, almost all the PCDD/F congeners detected are dioxins (1810 ppt) which contribute 96% to the total, of which 81.1% is from OCDD, while dibenzofurans (80 ppt) contribute only 4%. The total PCDD/F level of 1,890 ppt is the second highest in this series. This pattern holds for the toxic equivalents also, with 75% from dioxins and 25% from dibenzofurans. Guamanians' blood congener total and TEqs are similar to the continental United States, which is the source of most of their food and where some reside periodically.

Figures 1 and 2 present the total dioxin and dibenzofuran levels and the total TEq values in graphical form, for ease in visualization and comparison. Table 3 compares blood dioxin levels from samples collected from 1980 to 1990 from 10 locations in the north, central, and south regions of Vietnam, which, as noted previously, is the country with the most extensive known dioxin contamination (from Agent Orange). The highest 2,3,7,8-TCDD blood level is 28 ppt from Binh Hoa in the south followed by 18 and 15 ppt from Da Nang and A Luoi, respectively, which are both in central Vietnam. Dong Nai and Ma Da Forest in the south both have the same level of 12 ppt. In the central region, the sample from Hue has 11 ppt, and the remaining locations have levels of 9.5, 6.8, and 3.4 ppt. Hanoi in the north has the lowest level, as expected, of less than 2.4 ppt. For total levels, Dong Nai has the highest dioxin level of 1,938 ppt, followed by 1,529 ppt in Da Nang. Hanoi has the lowest total dioxin level of 126 ppt.

For the dibenzofurans, there is a different pattern, with Da Nang and Hue from the central region having the highest total of 315 and 265 ppt, respectively; the lowest PCDF levels are in Tay Ninh, with 26, and Ma Da Forest with 29 ppt. The northern specimens have a higher dibenzofuran level of 41 ppt. The highest total PCDD/Fs TEq value is 77 for Da Nang, followed by 57 for Hue, and 12 ppt from Hanoi is the lowest value found in Vietnam. The remaining values range from 49 to 16 ppt. These values compare with the higher total estimated TEqs ranging between 200 and 1500 ppt in Vietnamese milk from the original Baughman specimens collected in 1970 by Constable and Meselson, primarily reflecting contamination by Agent Orange (*1*).

Dioxin Levels in Milk

A second type of sample frequently used for measuring dioxins in human tissue is milk. Table 4 presents the percent contribution by congener from human milk samples. Vietnam specimens are from Hanoi in the north, Da Nang in Central Vietnam, and Dong Nai Province in the south. Phnom Penh, Cambodia, a markedly nonindustrial country, and Bangkok, in Thailand, a country undergoing rapid industrialization, complete the three Asian countries represented. Germany in Europe and the United States in North America represent the more industrialized countries. Siberia, representing an Asian portion of the former USSR, and South Africa, where we have samples from both the black and the white population, represent areas of less industrialization. Pooled samples were usually used because of time and cost constraints, as well as the desire to increase sample size from each geographical area (*49–51*).

The contribution of TCDD, the most toxic dioxin, to total PCDD/Fs varies from 0.33% in Thailand to 4.3% in Dong Nai. Contribution to TEqs is highest at 38.5% in Dong Nai, an Agent Orange-sprayed province in the south of Vietnam, and 10–23.9% for the other countries. 1,2,3,7,8-PeCDD values are more uniform, with contribution to the total ranging from 1.2 to 3.3% and the TEq percent contribution varying from 13.8% in Dong Nai and Siberia to 26.7% in Cambodia. Among the dibenzofurans in milk, as is typical for most human tissue studied to date, especially from European countries, 2,3,4,7,8-PeCDF is most striking in its contribution to TEqs, with values ranging from 44.8% in Germany and 41.9% in Thailand to 21.8% and 12% in the samples from South Africa. For HxCDDs, South Africa's black population sample has the highest contribution (9.2%) and Thailand has the lowest (2.5%). The HxCDFs have

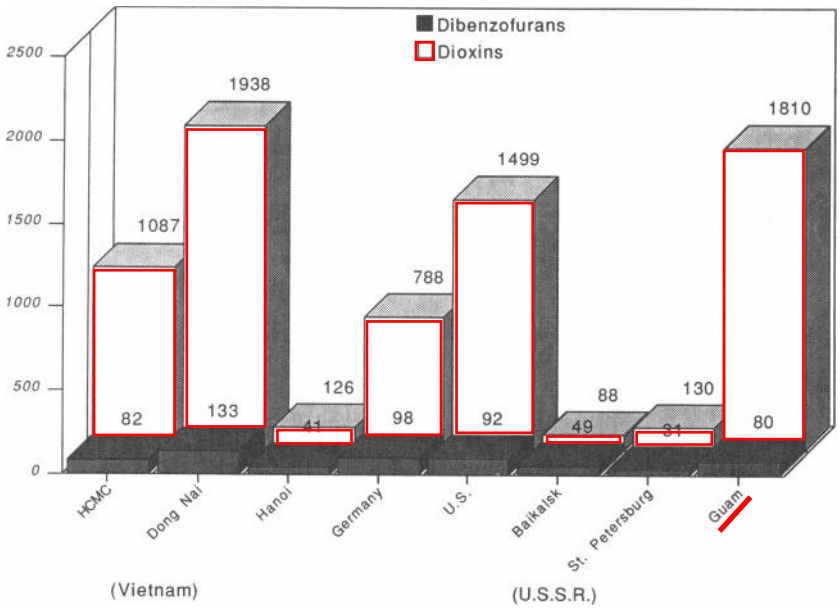

FIGURE 1. Dioxins and dibenzofurans in human blood from the general population (ppt, lipid). (HCMC) Ho Chi Minh City.

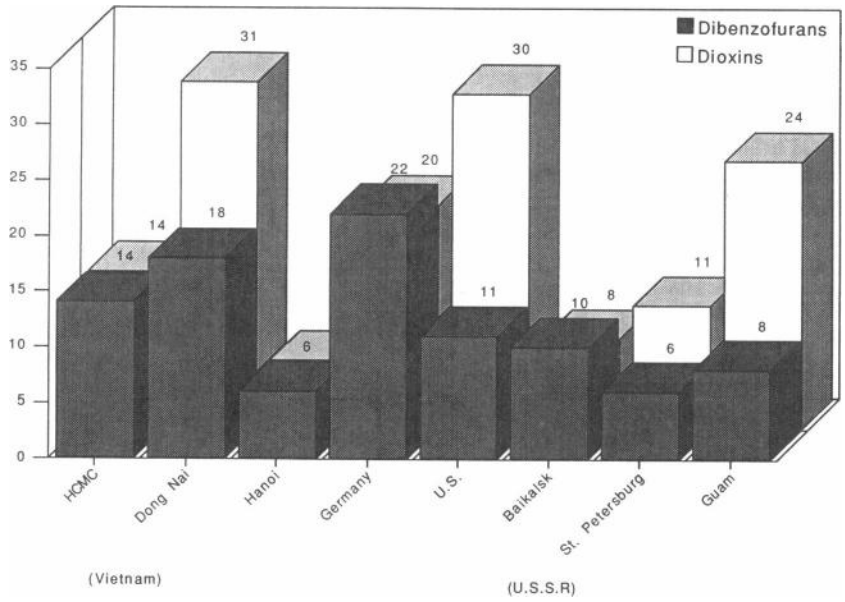

FIGURE 2. Dioxin and dibenzofuran toxic equivalents in human blood from the general population (ppt, lipid). (HCMC) Ho Chi Minh City.

a range of 1.8–13.7% contribution to the total PCDD/Fs and 6.2–18.6% to the TEqs. Both 2,3,4,6,7,8-hepta (HpCDD) and OCDD contribute a small amount to the total dioxin equivalents, ranging from 0.4 to 6%, despite their large percentage of contribution to absolute totals, which ranges from 8% in Siberia to 17% in the sample from black South Africans for HpCDD, and a particularly striking 49.7% for Siberia to 74.7% from Thailand for OCDD. For HpCDF and OCDF, the percent contribution is relatively small, 1–7.4%, and 0.1–1.24% for total PCDD/Fs and TEq, respectively, from HpCDF. OCDF contributes 0.38–2.9% to the total PCDD/F and 0.004–0.07% to TEq.

The findings from South Africa are of interest because of the difference in levels between the black population and the white population. The values are usually lower for the black population than the white. This is consistent with the idea of the white population having a dietary intake of higher quality and quantity consisting of more meat, fish, and milk products, thus having higher dioxin and dibenzofuran levels.

Table 3. Dioxin and dibenzofuran levels in pooled blood from south, central, and north Vietnam (ppt, lipid).

		South					Central				North
Congener	TEF	Ho Chi Minh City (*n*=50)	Dong Nai (*n*=33)	Tay Ninh (*n*=50)	Binh Hoa (*n*=50)	Ma Da Forest (*n*=50)	Quang Tri (*n*=50)	Hue (*n*=50)	Da Nang (*n*=50)	A Luoi (*n*=33)	Hanoi (*n*=32)
2,3,7,8-TCDD	1	3.4	12	6.8	28	12	9.5	11	18	15	<2.4
1,2,3,7,8-PeCDD	0.5	8.8	14	2.8	10	3.4	14	15	30	ND (2.2)	4.2
1,2,3,7,8,9-HxCDD	0.1	7.5	14	5.2	11	ND (2.2)	9	23	15	ND (1.8)	2.3
1,2,3,6,7,8-HxCDD	0.1	29	52	16	25	13	36	53	73	11	13
1,2,3,4,7,8-HxCDD	0.1	8.6	15	6.5	6.1	7.1	6.6	19	22	ND (4.1)	5.7
1,2,3,4,6,7,8-HpCDD	0.01	97	176	45	90	24	78	101	93	21	13
OCDD	0.001	933	1655	600	685	226	614	773	1278	127	87
2,3,7,8-TCDF	0.1	4.6	3.9	1.8	ND (1.2)	3	3	2.3	<6	<6.8	2.6
1,2,3,7,8-PeCDF	0.05	3.2	2.9	ND (1)	3	ND (1)	ND (1.8)	4.8	ND (3.1)	ND (2.1)	<1.1
2,3,4,7,8-PeCDF	0.5	21	22	3.7	8	2.1	8.5	20	24	3	8.6
1,2,3,7,8,9-HxCDF	0.1	14	27	7.5	23	8.9	36	89	108	21	6.5
2,3,4,6,7,8-HxCDF	0.1	11	27	5.3	13	3.8	21	61	57	11	6.4
1,2,3,6,7,8-HxCDF	0.1	ND (1.4)	ND (1.2)	ND (1)	ND (2.9)	ND (1)	ND (1.6)	ND (1)	ND (1.2)	ND (1.6)	ND (1.1)
1,2,3,4,7,8-HxCDF	0.1	3.3	5	ND (1.1)	ND (1.9)	ND (1)	ND (1.2)	3.6	6.3	ND (1)	1.8
1,2,3,4,6,7,8-HpCDF	0.01	22	31	8	28	11	61	84	117	23	12
1,2,3,4,7,8,9-HpCDF	0.01	2.6	2.7	ND (2.9)	ND (5.5)	ND (2)	ND (2.5)	ND (4.2)	ND (5.7)	ND (2.5)	<1.2
OCDF	0.001	ND (5.5)	11	ND (6.9)	ND (10)	ND (4)	ND (9.9)	ND (6.5)	ND (13)	ND (12)	<3
Total PCDD		1087	1938	682	855	286	767	995	1529	174	126
Total PCDF		82	133	26	75	29	130	265	315	61	41
Total PCDD/F		1169	2071	708	930	314	897	1260	1844	235	167
Total PCDD TEq		14	31	12	39	16	23	30	46	17	6
Total PCDF TEq		14	18	4	8	3	11	27	31	6	6
Total PCDD/F TEq		28	49	16	47	19	34	57	77	23	12

Abbreviations: TEF, toxic equivalent factor; CDD, chlorinated dibenzodioxin; CDF, chlorinated dibenzofuran; T, tetra; Pe, penta; Hx, hexa; p, nepta; O, octa; P, poly; TEq, toxic equivalent; ND, nondetectable.

Table 4. Dioxin and dibenzofuran percentage contribution to total PCDD/Fs and TEq human milk from various countries (ppt, lipid).

	Hanoi (*n*=30)[a]		Da Nang (*n*=11)[b]		Dong Nai (*n*=11)[b]		Cambodia (*n*=8)[b]		Thailand (*n*=10)[b]		Germany (*n*=185)[c]		USA (*n*=42)[b]		USSR-Siberia (*n*=23)[d]		S. Africa (White) (*n*=18)[b]		S. Africa (Black) (*n*=6)[b]	
Congeners	PCDD/Fs	TEq	PCDD/Fs	TEq	PCDD/Fs	TEq	PCDD/Fs	TEq	PCDD/Fs	TEq	PCDD/Fs	TEq	PCDD/Fs	TEq	PCDD/Fs	TEq	PCDD/Fs	TEq	PCDD/Fs	TEq
2378-TCDD	1.7	23.9	1	16.8	4.3	38.5	0.57	16	0.33	10	0.86	11.2	0.93	20	2.7	22.5	0.45	13.5	0.4	14.3
1,2,3,7,8-PeCDD	2.3	16.5	2.8	22.5	3.1	13.8	1.9	26.7	1.2	17.7	2.7	17.4	1.9	20	3.3	13.8	1.53	23	1.3	23.8
Total HxCDD	6.9	10	7.1	11.4	6.9	6.2	5.9	17	2.5	7.4	13.3	17.2	11.7	25	8.3	7	8.82	26.5	9.2	32.9
1,2,3,4,6,7,8-HpCDD	9.1	1.3	10.2	1.7	11.9	1.1	12.8	3.7	11	3.3	13.3	1.7	11.8	2.5	8	0.68	16	4.8	17	6.1
OCDD	61.7	0.89	54.2	0.88	50.6	0.46	68.6	2	74.7	2.2	53.3	0.69	65.4	1.4	49.7	0.4	67	2	65.3	2.3
2,3,7,8-TCDF	1.6	2.3	0.41	0.66	0.68	0.62	0.6	1.7	2	5.8	0.58	0.75	0.8	1.7	2.9	2.4	0.396	1.2	0.27	0.96
1,2,3,7,8-PeCDF	0.79	0.57	0.76	0.62	0.43	0.19	0.37	0.53	0.77	1.1	0.2	0.13	0.13	0.14	1.2	0.5	0.11	0.159	0.099	0.18
2,3,4,7,8-PeCDF	4.8	34.7	3.2	25.5	5.5	25.4	1.9	26.7	2.9	41.9	6.9	44.8	2	22	10.2	43	1.45	21.8	0.666	12
Total HxCDF	6.9	9.9	11.5	18.6	13.7	12.5	2.3	6.5	3	8.7	4.7	6.2	3	6.4	11.4	9.6	1.9	6.67	1.8	6.5
1,2,3,4,6,7,8-HpCDF	2.7	0.39	7.4	1.2	2.6	0.24	2.6	0.73	1	0.3	1.5	0.2	1.1	0.24	1.2	0.1	1.24	0.4	2	0.7
OCDF	1.7	0.022	1.4	0.02	0.38	0.004	2.8	2.8	0.66	0.03	2.9	0.04	1.2	0.02	1.2	0.008	0.74	0.022	2	0.07
Total[d] PCDDs[e]	82	53	75	53	77	61	90	90	90	42	83	48	92	69	72	44	94	70	93	80
Total PCDFs[e]	18	47	25	47	23	39	11	11	10	58	17	52	8	31	28	56	6	30	7	20

[a]Hanoi data are a pool of 28 from previously published data, plus 2 new samples
[b]Data from Schecter et al. (*49–51*).
[c]Totals are rounded. Mean value for 185 individual analyses.
[d]Siberian samples obtained from Baikalsk, Irkutsk, Kachug, and Novosibirsk.
Abbreviations: CDD, chlorinated dibenzodioxin; CDF, chlorinated dibenzofuran; TEq, toxic equivalent; T, tetra; Pe, penta; Hx, hexa; Hp, hepta; O, octa.

Dioxin Levels in Adipose Tissue

Because dioxins are lipid soluble, adipose tissue was frequently used for the early measurement of dioxins in human tissue and has become somewhat of a "gold standard." For ease of comparison, a pie graph presentation by individual countries of congener contribution to the total dioxin toxic equivalents in adipose tissue from general populations is shown in Figure 3. This is more representative of toxicity (rather than environmental contamination) than presentations of analytic data, but is subject to change

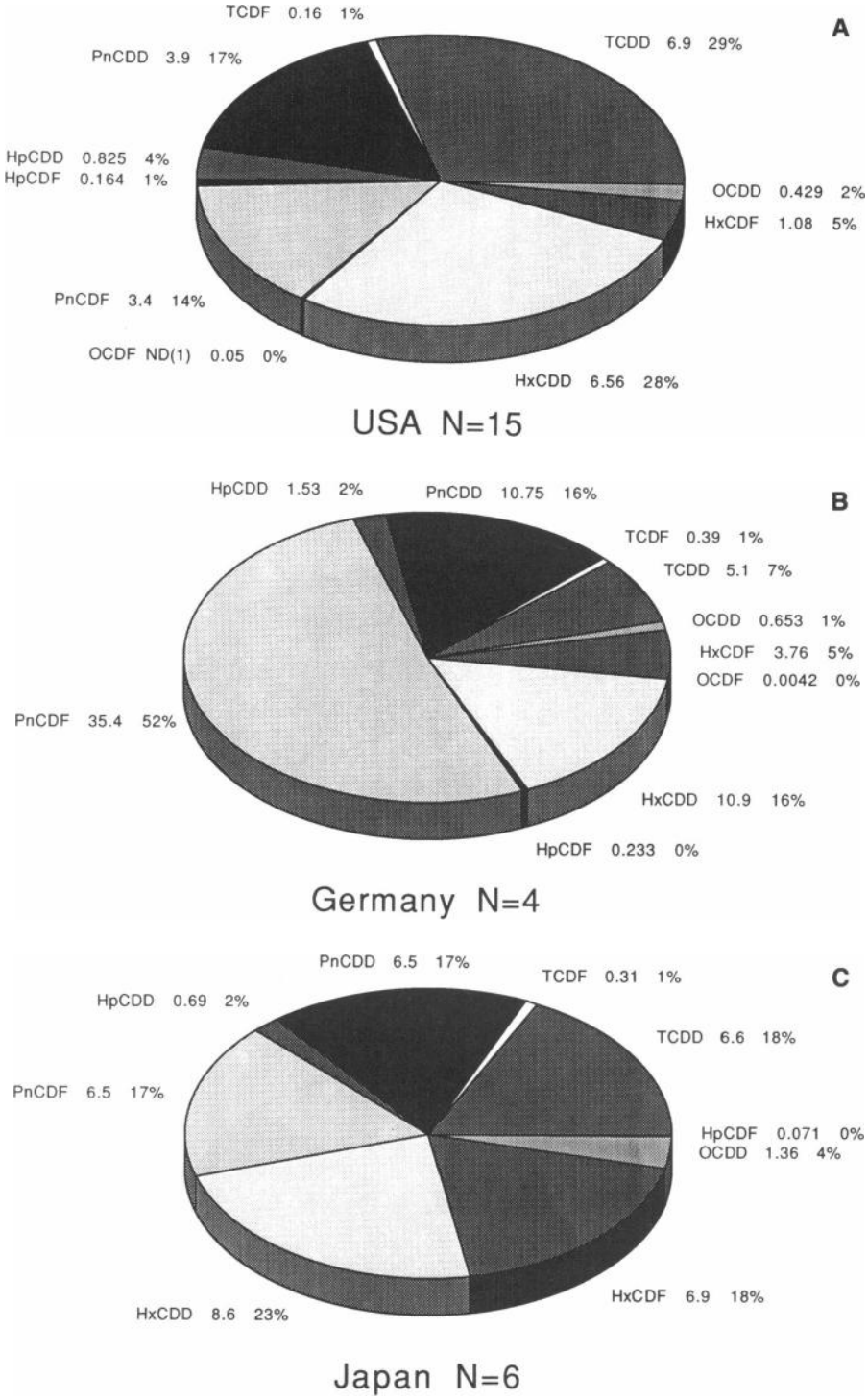

FIGURE 3. Dioxin and dibenzofuran congeners' TEq and percentage contribution (ppt, lipid) to total TEq in adipose tissue from the general population. (*A*) United States (*51*); (*B*) Germany (*51*); (*C*) Japan [TCDF not detected (*11*)]; (*D*) Canada [TCDF not detected (*11*)]; (*E*) south of Vietnam [PeCDF data not available; OCDF not detected (*52,53*); (*F*) north of Vietnam [PeCDF not available; OCDF not detected (*52,53*); and (*G*) China [TCDD, HpCDF, and OCDF not detected (*53*)].

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as dioxin and dibsnzofuran congeners are assigned different values when new information concerning toxicity, pharmacokinetics in humans, or toxicity for specific end points becomes available. It is useful, however, to give an approximation of human toxicity contributed by the congeners, just as previous data and presentation usually reflected total levels of chemicals and percentage of total PCDD/Fs in the environment.

These specimens were collected and analyzed between 1983 and 1991.

For the United States, we find 2,3,7,8-TCDD contributing 29%, HxCDD 28%, PeCDD 17%, and PeCDF 14%. In Germany, we see a somewhat different pattern, with PeCDF 52%, HxCDDs 16%, and TCDD 7% of total TEqs (*52*).

In Japan, we found TCDD contributing 18%, with 23% from

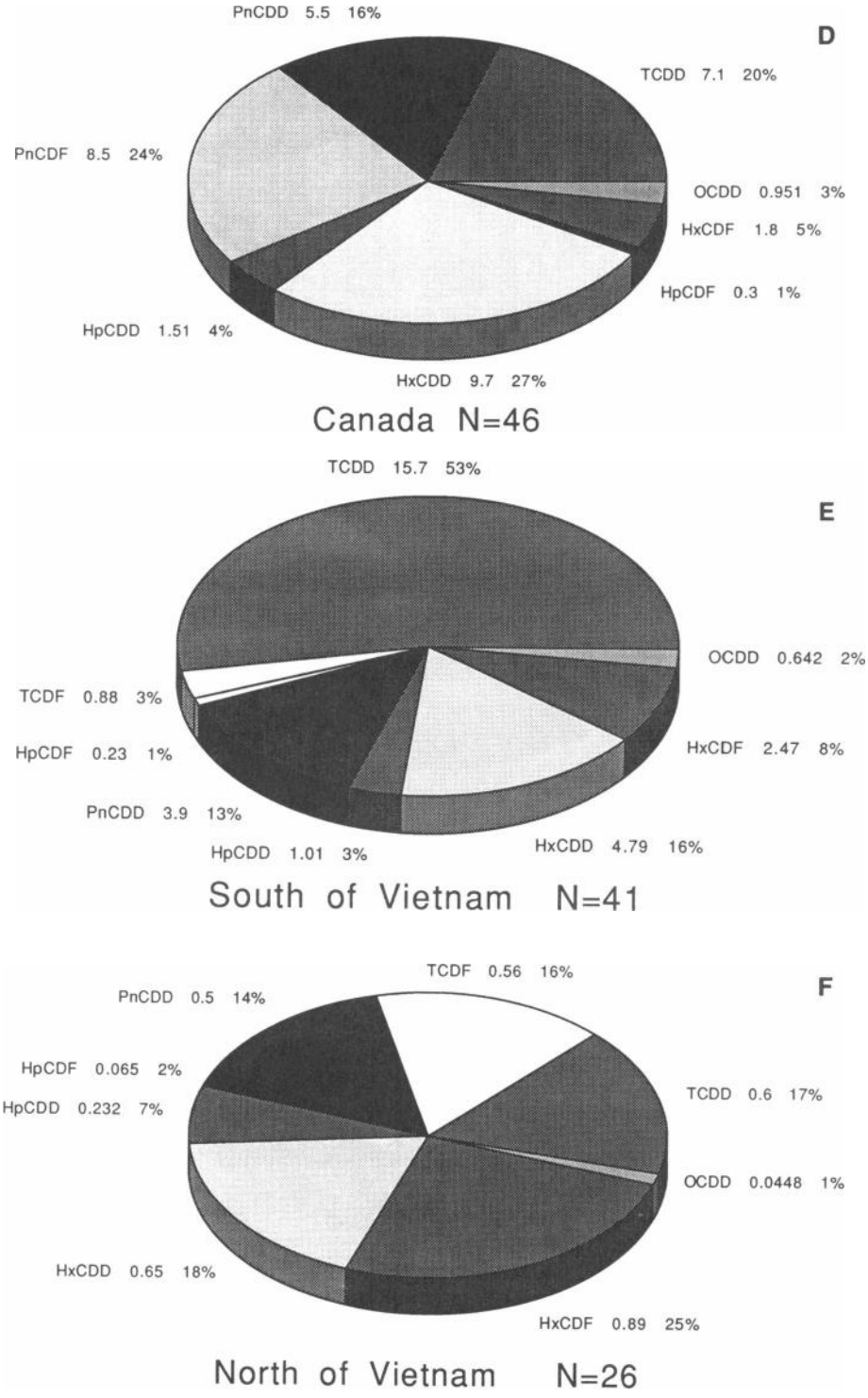

FIGURE 3. *Continued.*

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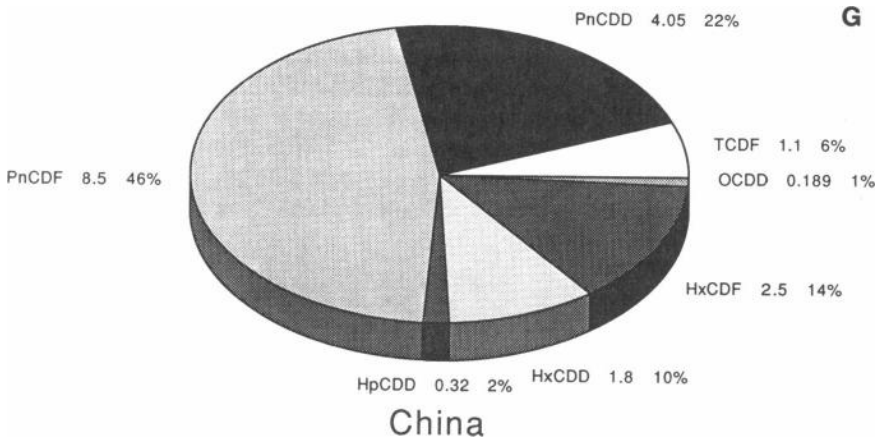

FIGURE 3. *Continued.*

HxCDDs, 18% from HxCDF, and 17% each from PeCDD and PeCDF. In Canada, the percentage is similar to the United States. TCDD contributes 20% of the TEqs, with HxCDD 27%, PeCDF 24%, PeCDD 16%, HpCDF 1% and OCDD, the most plentiful congener, contributes only 3% (*11*).

Results for Vietnam are presented for the north and south of that nation. The persons sampled from the south of Vietnam lived in provinces where Agent Orange spraying occurred in the past, but were otherwise selected from the general population. TCDD contributes 53% of the TEqs in this series, followed by 16% from HxCDD, 13% PeCDD, 8% HxCDF, 3% TCDF and HpCDD, and 2% from OCDD. In the north of Vietnam, by contrast, with its much lower levels of PCDD/Fs, TCDD contributes only 17% of total TEqs, whereas 25% is from HxCDF, 18% from HxCDD, a much higher than usual 16% is from TCDF, 14% is from PeCDD, 7% from HpCDD, and only 1% is from OCDD (*9,53,54*).

China, where total dioxin and dibenzofuran levels are quite low, has the largest TEq contribution of 46% from PeCDF, followed by 22% from PeCDD, 14% from HxCDF, 10% from HxCDD, 2% from HpCDD, and a low 1% from OCDD, the most plentiful but least toxic congener (*11*).

Dioxin Levels in Stillborn, Ancient, and Modern Human Livers

Figure 4*A* presents levels of total dioxins recently measured in livers of three stillborn infants (*55*), one ancient adult found frozen in Alaska (*32*), and three modern adults from the United States (*56*) in order to contrast the markedly higher levels of dioxins and dibenzofurans currently found in adults, primarily from industrial sources, and to highlight the increase in dioxin body burden seen in adults as compared to children at birth. Findings of low levels in stillborns reflects transplacental transfer due to unavoidable intake, so long as environmental contamination persists.

Figure 4*B* presents the same data converted to dioxin toxic equivalents to provide a reference from a toxicologic standpoint. It is interesting to note that the modern stillborn liver dioxin TEq of 10 is quite similar to that found in ancient adult livers, 14 ppt, on a lipid basis.

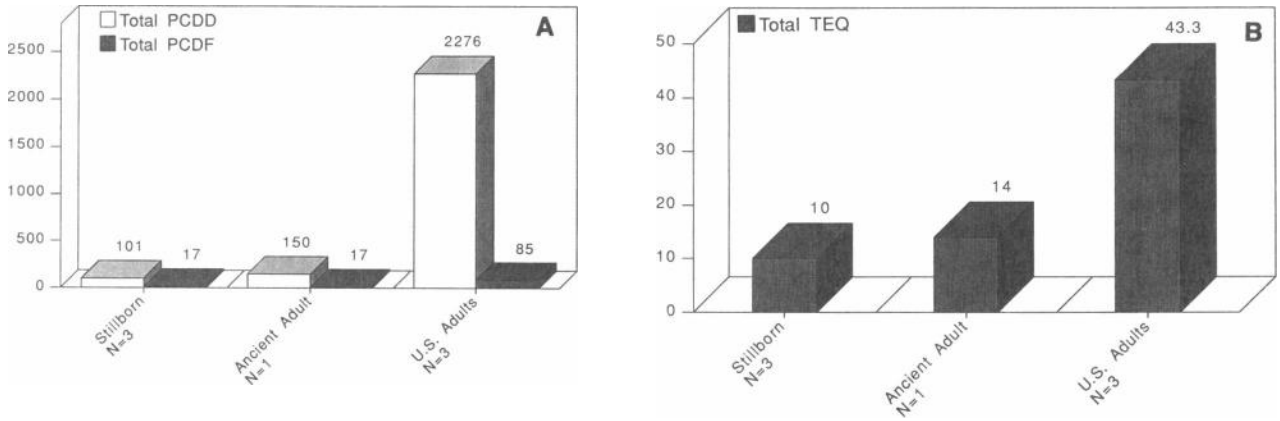

FIGURE 4. (*A*) Mean liver PCDD/Fs in U.S. adults, an ancient human adult, and stillborn infants (ppt, lipid). (*B*) Total mean liver TEq in U.S. adults, an ancient human adult, and stillborn infants (ppt, lipid).

Table 5. Mean percentage of congener contribution to total PCDD/F levels on a wet-weight basis in human autopsy tissue samples from two patients from New York.[a]

	Subcutaneous fat		Adrenal		Liver		Muscle		Spleen		Kidney	
Analyte	Level	% Contribution	Level	% Contribution	Level	% Contribution	Level	% Contribution	Level	% Contribution	Level	% Contribution
2,3,7,8-TCDD	4.9	0.6	3.8	0.7	2.5[b]	0.7[b]	ND	ND	1.3[b]	2.5	ND	ND
1,2,3,7,8-PeCDD	7.9	0.9	4	0.8	3.7[b]	1[b]	1.4	1	6.1	12	ND	ND
1,2,3,6,7,8-HxCDD	60.5	6.8	37	7.2	27.3	7.3	6.9	4.8	1.7	3.3	3.3	6.5
1,2,3,4,6,7,8-HpCDD	106.5	12	45.5	8.9	33	8.8	9.5	6.6	8.9	17.5	9.1	17.8
OCDD	645	72.5	405	78.8	285	76.4	123	85.4	33	64.7	35	68.6
2,3,4,7,8-PeCDF	16.5	1.9	5.2	1	5.4[b]	1.4[b]	1.1[b]	0.76[b]	ND	ND	ND	ND
Total HxCDF	30	3.4	9.8	1.9	10.6	2.8	2	1.3	ND	ND	2.6	5.1
1,2,3,4,6,7,8-HpCDF	18	2	4	0.8	4.9	1.3	ND	ND	ND	ND	1.7	3.3[b]
Total PCDD[c]	825	93	495	96	352	94	141	98	51	100	47	92
Total PCDF[c]	65	7	19	4	21	6	3	2	ND	ND	4	8
% Lipid	71	71	27	27	14	14	8	8	2	2	3	3

[a]Data from Ryan et al. (*9*) and Schecter et al. (*55*).
[b]Data value from one patient.
[c]Totals are rounded.
Abbreviations: CDD, chlorinated dibenzodioxin; CDF, chlorinated I dibenzofuran; T, tetra; P, poly; Pe, penta; Hx, hexa; Hp, hepta; O, octa; ND, nondetectable.

Dioxin Levels in Multiple Organs: Autopsy Specimen

It has recently become useful to estimate body burden and to make decisions as to exposure following special incidents, such as Agent Orange or industrial chemical contamination, by reporting adipose tissue or blood-lipid dioxin values. However, this does not provide target organ PCDD or PCDF levels. For this reason, congener contribution to total PCDD/F measurement and to total TEqs are presented in Tables 5 and 6, respectively, as mean values from two autopsies (*9,56*) performed on New York State residents in the 1980s. The values are presented on a wet-weight basis, but lipid values are provided to permit conversions. Further work is needed to increase the sample size to permit adequate tissue level characterization.

Comparison of Dioxin Levels in Blood, Milk, and Adipose Tissue

Data for human tissue dioxin levels are obtained primarily from human blood, adipose tissue, and human milk, as discussed in this paper. Table 7 presents a comparison of tissue levels from blood, adipose tissue, and milk from the general population of the United States (*48,49,52*). We found in these samples that blood has the highest total PCDD/F levels in absolute values and in TEq values. The levels are 1591, 590, and 356 ppt for absolute values for blood, adipose tissue, and milk, respectively and 41, 24, and 17 ppt, respectively, for TEq totals. It is also noteworthy that milk has the lowest levels in almost every instance except when it has the identical value with adipose of 5 ppt for total PCDF TEq. These observations have been made by others as well during the past few years. These data are from general population data, not from the same individuals. Figure 5 presents the same data in a graphical form for ease of visualization and comparison.

Particularly striking in our experience, as shown in the data presented here, is the observation that dioxin congeners frequently constitute approximately 90% of the total measured dioxins and dibenzofurans. But considering dioxin contribution to total toxic equivalents, they constitute approximately 61% of toxicity, with dibenzofuran contribution varying from nondetected to 39%, in the various tissues studied. In the case of OCDD, which contributes the most to the actual amounts measured, were OCDD to be given a more conservative TEq of 0.01 rather than 0.001, which could be justified using OCDDs highest toxic outcome (*57,58*), the TEq from dioxins as well as total TEq would be higher.

Summary and Conclusions

We have reviewed what we believe to be relatively representative data of that available from the general populations on dioxin and dibenzofuran levels in human blood, fat, milk, and other selected organ or tissue samples from a number of countries worldwide. Included in these data are ancient frozen human tissue and modern human tissue from stillborn infants as well as adult tissue for purposes of comparison.

The data have been manipulated, in some cases, to provide the percentage that a given congener, such as 2,3,7,8-TCDD, contributes to the total PCDD/Fs measured. In other cases, conversion to TEqs has been performed, followed by a numerical or graphical presentation of the contribution by congener to the total estimated toxicity of all measured congeners.

With present techniques, we can usually detect between 14 and 16 2,3,7,8 toxic chlorine-substituted congeners in human tissue. In some locations, as in less industrialized regions such as China, Thailand, Cambodia, and the north of Vietnam, we find relatively low levels of dioxins and dibenzofurans, in the range of 100 – 160 ppt on a lipid basis in blood or adipose tissue. Human tissue from more industrial areas usually has higher tissue dioxin levels, for example, the U.S. and German values of 1,591 and 886 ppt, respectively, for total PCDD/F. We are sometimes surprised by other levels: in remote Dong Nai Province in the south of Vietnam, total PCDD/F in blood lipid was found to be 2071 ppt, and in a remote South Pacific Ocean island, Guam, we found average levels of 1890 ppt, to a considerable extent due to high OCDD levels. The source of industrial contamination, which contributed to relatively elevated human tissue levels, presumably through consumption of contaminated meat, milk, fish, and their

Table 6. Mean percent congener contribution to total mean PCDD/F toxic equivalent (TEq) levels on a wet-weight basis in human autopsy tissue samples from two patients from New York.[a]

		Subcutaneous fat		Adrenal		Liver		Muscle		Spleen		Kidney	
Analyte	TEq	TEq	% Contribution	TEq	% Contribution	TEq	% Contribution	TEq	% Contribution	TEq	% Contribution	TEq	% Contribution
2,3,7,8-TCDD	1	4.9	17.5	3.8	27.1	2.5[b]	20.8[b]	ND	ND	1.3[b]	28.3[b]	ND	ND
1,2,3,7,8-PeCDD	0.5	3.95	14.1	2	14.3	1.85[b]	15.4[b]	0.7	29.8	3.05	66.3	ND	ND
1,2,3,6,7,8-HxCDD	0.1	6.05	21.6	3.7	26.4	2.73	22.8	0.69	29.4	0.17	3.7	0.33	41
1,2,3,4,6,7,8-HpCDD	0.01	1.07	3.8	0.46	3.3	0.33	2.8	0.09	4	0.09	1.9	0.09	11.4
OCDD	0.001	0.65	2.1	0.41	2.9	0.29	2.4	0.12	5.2	0.03	0.7	0.04	4.4
2,3,4,7,8-PeCDF	0.5	8.25	29.6	2.6	18.6	2.7[b]	22.5[b]	0.55[b]	13.4[b]	ND	ND	ND	ND
Total HxCDF	0.1	3	10.7	0.98	7	1.06	8.8	0.2	8.5	ND	ND	0.26	32.5
1,2,3,4,6,7,8-HpCDF	0.01	0.18	0.7	0.04	0.29	0.05	0.4	ND	ND	ND	ND	0.02[b]	2.1[b]
Total PCDD[c] TEq		17	60.7	10	71.4	8	66.7	1.6	68.4	4.6	100	0.5	0.6
Total PCDF[c] TEq		11	39.3	4	28.6	4	33.3	0.75	31.9	ND	ND	0.3	0.4
% Lipid			71		27		14		8		2		3

[a]Data from Ryan et al. (*9*) and Schecter et al. (*56*).
[b]Data value from one patient.
Abbreviations: CDD, chlorinated dibenzodioxin; CDF, chlorinated I dibenzofuran; T, tetra; P, poly; Pe, penta; Hx, hexa; Hp, hepta; O, octa; ND, nondetectable.

Table 7. Comparison of dioxin and furan levels in blood, milk, and adipose tissue from the United States (ppt, lipid).[a]

Congeners	Whole blood (n=100)	Adipose (n=15)	Milk (n=43)
2,3,7,8-TCDD	5.2	6.9	3.3
1,2,3,7,8-PnCDD	21	7.7	6.7
Total HxCDD	112	65.6	41.7
1,2,3,4,6,7,8-HpCDD	187	82.5	42
OCDD	1174	429	233
2,3,7,8-TCDF	3.1	1.6	2.85
1,2,3,7,8-PeCDF	2.8	ND	.45
2,3,4,7,8-PeCDF	13	6.8	7.3
Total HxCDF	32.6	10.8	10.6
Total HpCDF	36	16.4	4.05
OCDF	4.2	ND (1)	4.1
Total PCDD	1499	558	327
Total PCDF	92	32	29
Total PCDD/Fs	1591	590	356
Total PCDD TEq[b]	30	19	12
Total PCDF TEq[b]	11	5	5
Total PCDD/F TEq[b]	41	24	17
% Lipid	0.5%	85%	3.5%

[a]Data for blood, see Schecter et al. (*48*), for milk see Schecter et al. (*49*), and for adipose see Schecter et al. (*52*).
[b]Totals are rounded.
Abbreviations: CDD, chlorinated dibenzodioxin; CDF, chlorinated dibenzofuran; TEq, toxic equivalent; T, tetra; Pe, penta; Hx, hexa; Hp, hepta; O, octa.

products, is not known in these two latter remote and relatively nonindustrial areas. In remote Siberia, we found blood PCDD/F levels of only 137 ppt, and in European St. Petersburg, the level was only slightly higher, at 161 ppt. We have no explanation for the low level in St. Petersburg, which is lower than other European values. Although industrialization may not be prominent, environmental protection has not been notably strict in the former Eastern Block countries.

In many areas, the percentage of total PCDD/F from dibenzofurans was relatively low in absolute amount, but in some instances the toxic equivalents were higher from the PCDFs than from the PCDDs, as in Hanoi, Vietnam (53% compared to 47%) and Germany (52% versus 49%). Certain congeners, such as 2,3,4,7,8-PeCDF, with a relatively high TEq of 0.5, half that of 2,3,7,8-TCDD, contributed substantially to total TEqs (44% in Germany, 42% in Baikalsk, 38% in Ho Chi Minh City, and 36% in Hanoi).

Variations in general population dioxin levels appear to be greater than is the case for the dibenzofurans, which are usually present in markedly lower amounts. Shorter half-lives may account for lower levels for the dibenzofurans (*59–61*). In some cases, when there have been specific incidents of environmental

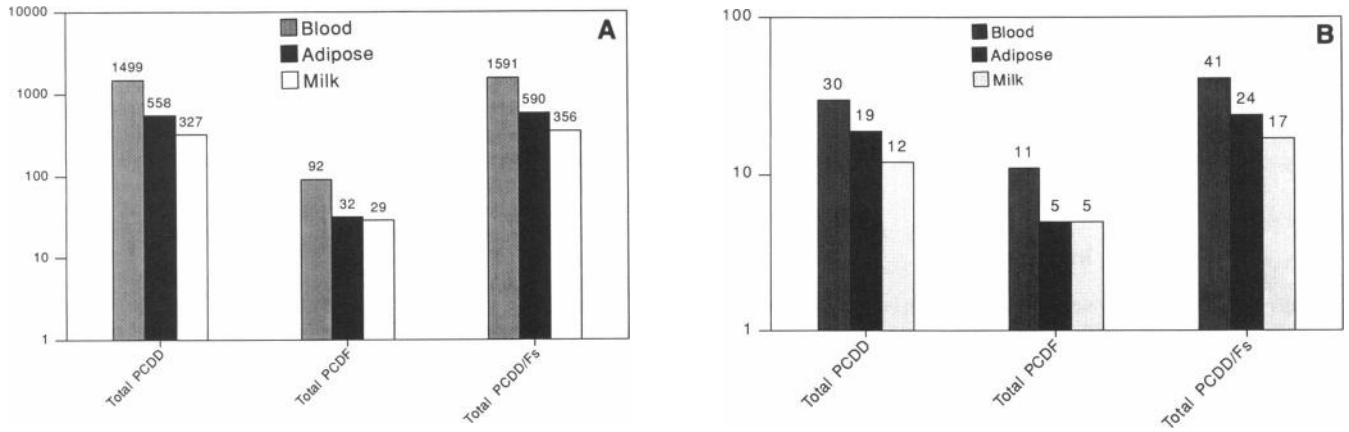

FIGURE 5. (*A*) Comparison of PCDD, PCDF, and PCDD/F levels in blood, milk, and adipose tissue from the United States (ppt, lipid). (*B*) Comparison of PCDD, PCDF, and PCDD/F TEq levels in blood, milk, and adipose tissue from the United States (ppt, lipid).

contamination in the past, such as the spraying of part of Vietnam with herbicide contaminated with 2,3,7,8-TCDD, elevated TCDD levels may be found in humans decades later. The source of most dioxins and dibenzofurans is not known at this time, so amounts of dioxins and dibenzofurans in globally different regions may vary without apparent explanation. Levels vary considerably in ash from municipal incinerators and in soot from PCB transformer fires, for example.

The question as to whether chlorinated dioxin and dibenzofurans existed before industrialization and formation of synthetic chemicals (*62*) is addressed in two ways by human tissue data. The higher levels of PCDD/Fs found in tissue from industrial countries and lower levels in samples from less industrial countries suggests industrial origin for most PCDD/Fs. Compared to present adult levels, the finding of quite low levels of PCDD/Fs in frozen ancient Eskimo tissue from the United States, similar to levels found in stillborns at the present time, is also consistent with an anthropogenic origin of almost all dioxins and dibenzofurans in the environment. This is also consistent with sediment data analyzed by time of deposition or by location (*26–29*).

Autopsy data are beginning to provide tissue-specific dioxin levels, which will make it possible to extrapolate blood dioxin levels, usually the tissue of choice for most patients, with target organ tissue levels. However, autopsy data are limited at this time (*9*). Another question of interpretation from blood dioxin measurements is the effect on blood, fat, and other organs of wasting, which occurs in terminal cancer patients, AIDS patients, and in certain other disease states. In a similar fashion, fasting may or may not mobilize body stores and increase blood dioxin levels. Answers to these questions require further study before body burden or target tissue dose can easily be determined from blood or fat measurement.

The past decade has witnessed an explosion of research on human tissue chlorinated dioxin and dibenzofuran levels. This has been driven by markedly improved chemical techniques. With these techniques and with an increase in capable laboratories and a decrease in costs, the next decade should provide a wealth of useful environmental and health data relating to the dioxins, especially regarding those dioxin levels in human tissue that are causally related to disease.

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2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN

CASRN: 1746-01-6

Polychlorinated dibenzo-p-dioxins occur as 75 different isomers. There are 22 possible tetrachlorodibenzo-p-dioxin isomers, but only one isomer that contains chlorines at the 2,3,7, and 8 positions. [WHO; Environmental Health Criteria 88. Polychlorinated dibenzo-p-dioxins and dibenzofurans. Available from, as of May 10th, 2004: http://www.inchem.org/pages/ehc.html]

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Synonyms :
Dioksyny (Polish)
PEER REVIEWED

In this study the people tested from Guam had a 16% higher dioxin blood level than the people from Ho Chi Minh City, Vietnam.

Body Burden :
The concn of 2,3,7,8-tetrachlorodibenzo-p-dioxin in whole blood samples were as follows (concn as parts per trillion lipid): Ho Chi Minh City, Vietnam, 3.4 (N=50); Don Nai, Vietnam (N=33), 12.0; Hanoi, Vietnam (N=32), <2.4; Germany, 3.6 (N=102); Baikalsk, Russia, 3.7 (N=8); St. Petersburg, Russia, 4.5; **Guam**, USA, 4.07(1). The concn of 2,3,7,8-tetrachlorodibenzo-p-dioxin in tissue and fluid samples from 5 mothers women living in Upstate NY were as follows (sample, concn in pg/g lipid): adipose tissue, 1.3; pre-delivery blood, 1.7; placenta, 2.7; cord blood, 1.3; post-pardum blood, 1.5; breast milk, 1.4(2). Concns of 2,3,7,8-tetrachlorodibenzo-p-dioxin in plasma lipids of individuals residing in Quebec on the North Shore of the St. Lawrence River (fishing people; N=25) and in urban centers (N=30) were 13.8 and 2.2 ng/kg, respectively(3). Mean levels of 2,3,7,8-tetrachlorodibenzo-p-dioxin in blood plasma from subjects living in Tarragona, Spain (non-occupationally exposed) were 1.9 pg I-TEQ (International toxicity equivilants)/g lipid (N=20; range, 0.9-5.3 pg I-TEQ/g lipid)(4). Blood levels of 2,3,7,8-tetrachlorodibenzo-p-dioxin in residents of Mataro, Spain (North of Barcelona) were 1.6 and 1.5 parts per trillion/g fat wt in male and female residents, respectively, for samples collected in March-June 1995(5). Blood sampled in 1993 from men and women (non-occupationally exposed) living in the vicinity of a municipal waste incincerator (MWI) in Schwandorf, Germany contained 2,3,7,8-tetrachlorodibenzo-p-dioxin at concns ranging from <0.3-3.6 (mean, 1.3) and 0.4-3.3 (mean, 1.4) pg/g lipid, respectively(6). Human milk from women in this study had 2,3,7,8-tetrachlorodibenzo-p-dioxin levels ranging from 0.6-2.0 pg/g milk fat (avg, 1.1 pg/g milk fat)(6). Whole blood samples collected from German individuals in 1994 contain 2,3,7,8-tetrachlorodibenzo-p-dioxin at a mean concn of 2.9 pg/g lipid (N=134; range, 1.0-7.8 pg/g lipid)(7). Blood samples from 3 groups of men living in Norway (Fjord area) contained 2,3,7,8-tetrachlorodibenzo-p-dioxin at avg concns as follows (group, concn in pg/g fat): reference, 3.6 (N=10; range, 0.2-7.0); moderate crab intake, 7.7 (N=15; range, 3-13.6); high crab intake, 11.0 (N=9; range, 6.3-22.4)(8). Between the period of 1989-1990, 2,3,7,8-tetrachlorodibenzo-p-dioxin mean levels in plasma samples from Finish workers were reported as follows (industry group; concns in pg/g lipid): control 4.1 (N=14; 1.3-10); bleaching

plant, 5.7 (N=14; range, 0.6-22); paper mill, 3.1 (N=20; range, 0.2-9.3)(9). The concn of 2,3,7,8-tetrachlorodibenzo-p-dioxin in blood samples collected between the years 1993-1994 from Japanese women (age, approx 20 yo) ranged from 0.77-3.4 pg/g lipid basis (N=50; avg, 1.8 pg/g lipid

basis)(10).

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