Concentration of Organochlorines in Human Brain, Liver, and Adipose Tissue Autopsy Samples from Greenland

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Organochlorines are persistent lipophilic compounds that accumulate in Inuit people living in circumpolar countries. Organochlorines accumulate as a result of the Inuits' large consumption of sea mammal fat; however, available data are limited to blood lipids, milk fat, and adipose tissue. We report results of organochlorine determination in liver, brain, omental fat, and subcutaneous abdominal fat samples collected from deceased Greenlanders between 1992 and 1994. Eleven chlorinated pesticides and 14 polychlorinated biphenyl congeners were measured in tissue lipid extracts by high-resolution gas chromatography with electron capture detection. Mean concentrations of polychlorinated biphenyls, 2,2′-bis(4-chlorophenyl)-1,1-dichloroethylene, β-hexachlorocyclohexane, hexachlorobenzene, mirex, *trans*-nonachlor, and oxychlordane in adipose tissue samples from Greenlanders were 3–34-fold higher than those measured using the same analytical method in samples from Canadians in Quebec City, Quebec. Brain lipids contained lower concentrations of all organochlorines than lipids extracted from other tissues. Organochlorine residue levels in lipid extracts from liver, omental fat, and subcutaneous abdominal fat samples were similar, with the exception of β-hexachlorocyclohexane, which reached a greater concentration in liver lipids than in lipids from both adipose tissues (4-fold; $p < 0.05$). Comparisons with available international data on adipose tissue levels reveal that the organochlorine body burden in the Inuit population of Greenland is presently among the highest resulting from environmental exposure.
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Although they reside far from pollution sources, subsistence populations living in remote northern regions often display a greater body burden of organochlorine compounds (OCs) than people living in industrialized regions (*1–10*). OCs include agricultural compounds (e.g., chlordane, HCB, mirex), industrial compounds [polychlorinated biphenyls (PCBs)], and by-products of combustion and various industrial processes (polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans). Although the use of most organochlorines was severely restricted or banned in North America and Western Europe during the 1970s, these compounds are still released into the environment because of ongoing use in developing countries and improper storage or disposal in developed countries.

OCs are released at middle and lower latitudes and reach the Arctic through long-range atmospheric transport, waterways, and ocean currents (*11*). Because of their lipophilic nature and chemical stability, OCs are subject to biomagnification in the marine food web; their concentrations reach several parts per million in fatty tissues of high-rank predators (ringed seal, beluga, polar bear) (*12–14*). Mean PCB concentrations ranging from 100 to 1,500 µg/kg (wet weight) were measured in blubber (subcutaneous fat) samples collected in 1994 from ringed seals (*Phoca hispida*) along the west coast of Greenland (*14*). Higher concentrations, ranging from 900 to 5,600 µg/kg (wet weight) were found in blubber samples collected from belugas (*Delphinapterus leucas*) at the same location during 1989–1990.

The traditional diet of Inuit populations includes large amounts of fatty tissues from these sea mammal species, and results in relatively large daily intakes. Using data collected during the course of the Inuit Heath Survey conducted in Nunavik (arctic Quebec, Canada) in 1992, we previously estimated that the mean PCB intake of Inuit women resulting from their traditional diet was 13.8 µg/day; the consumption of ringed seal fat, beluga skin, and beluga fat represented 79% of this dose (*7*). In comparison, Newsome et al. (*15*) reported a mean dietary intake of 5.7 ng PCB/kg body weight for Canadians during 1992–1996; this corresponds to a 0.34-µg daily intake, assuming a 60-kg body weight. This value is 40 times lower than that resulting from sea mammal fat consumption in the Inuit population. In fact, Inuits receive a relatively high dose of several OCs as compared to general populations living in North America or Western Europe (*5,14*).

Biological half-lives of several years have been documented in humans for the most persistent organochlorines (*16,17*), resulting in their accumulation with age in body fat, including adipose tissue (*18*), blood lipids (*19*), and milk fat (*20*). Limited information is available regarding OC body burden in Inuits living in circumpolar countries [Alaska (United States), Canada, Russia, and Greenland]. During the early 1960s, when DDT was extensively used in the United States, Durham and colleagues (*21*) measured DDT and DDE concentrations in body fat samples collected from 20 Alaskan natives and reported concentrations of 1.4 and 3.8 ppm, respectively, in lipid extracts (a spectrophotometric method was used and the identity of the isomers was not specified). Analyses performed at that time on body fat samples collected from 61 hospitalized patients from the general U.S. population revealed mean concentrations of 6.8 and 8.6 ppm for DDT and DDE, respectively (*21*).

Studies conducted more recently, after the use of most organochlorines was banned or limited in North America and Western Europe, revealed strikingly different results. For instance, Jensen and Clausen (*8*) determined the concentrations of several OCs in subcutaneous fat samples of 33 Inuits from Greenland and 17 Danes from southern Denmark. Although concentrations of aldrin, dieldrin, lindane, heptachlor, heptachlor epoxide, and PCBs were similar in both groups, significantly higher concentrations of 2,2′-bis(4-chlorophenyl)-1,1-trichloroethylene (*p,p′*-DDT) and 2,2′-bis(4-chlorophenyl)-1,1-dichloroethylene (*p,p′*-DDE) were measured in samples from Greenlanders (median concentrations of 0.9 and 3.1 ppm lipid weight, respectively) than in Danes (0.3 and 1.8 ppm, respectively).

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Results from a large breast milk survey conducted during 1989–1990 in Nunavik revealed an even greater gap between the body burden of the Inuit population and that of the general population living closer to industrial sources (*3,5*). One hundred seven women participated in a breast milk survey that involved all Inuit communities in Quebec. The authors reported mean levels of PCBs (Aroclor 1260) and *p,p′*-DDE of 2.9 and 2.2 mg/kg milk fat (ppm), respectively, as compared to 0.52 and 0.38 mg/kg in 536 Quebec women from the rest of the province. Mean concentrations of other OCs [*trans*-chlordane, dieldrin, endrin, heptachlor epoxide, hexachlorobenzene (HCB), mirex] were 2–10 times higher than those measured in the reference group.

Although data have been obtained on OC residue levels in milk, plasma, and adipose tissue samples of Inuits, no information is available regarding concentrations in organs such as the liver and brain, which accumulate OCs. There is a need to improve our knowledge on the body burden and distribution of these compounds in highly exposed populations because some OCs, most notably PCBs, reportedly cause reproductive as well as developmental disorders at relatively low doses in laboratory animals and humans (*22,23*). The present study aims to measure the concentration of 25 OCs in four tissues from Inuit Greenlanders collected during autopsies: brain, liver, omental fat, and subcutaneous abdominal fat. Preliminary results on organochlorine concentrations in maternal blood plasma samples collected from 10 regions of the Arctic (*14*) suggest that the Inuit population of Greenland is the most exposed population residing in the Arctic.

Materials and Methods

Population. The population of Greenland totals approximately 55,000, of which 16% are nonnatives, primarily Danes. The population is spread along the coast in 16 towns and 60 minor settlements. Autopsies, except for forensic cases in which a pathologist is brought in from Denmark especially for the case, are uncommon in Greenland. As part of a cooperative study of atherosclerosis in Alaska and Greenland, three physician investigators in Greenland elected to learn the standardized procedure for specimen collection at autopsy. Specimen collection began in fall 1990 and continued through fall 1994; specimens from 105 autopsy cases were collected. This autopsy rate represents approximately 10% of the total number of deaths that occurred in Greenland during this period. The cases are proportionally representative of the age, sex, and death classification (violent/nonviolent) of all deaths during this period. Case subjects were from the west coast region of Greenland, between Ilulissat and Nuuk.

Tissue samples for organochlorine analysis were collected during a series of 41 consecutive autopsies performed between November 1992 and mid-October 1994, during the course of the atherosclerosis study. These samples were frozen immediately after collection and stored at -80°C until time of analysis. Forty-one omental fat, 26 subcutaneous abdominal fat, 26 liver (upper part of the right lobe), and 17 brain (hippocampus, frontal cortex, substantia nigra, or putamen) samples were available in sufficient amounts to perform OC analysis. The mean age of the subgroup was 60 years (women: 61 years, n = 22; men: 58 years, n = 19). Causes of death included cancer (n = 11), violent deaths (n = 8), cardiovascular diseases (n = 7), chronic bronchitis (n = 2), and various causes (n = 13).

Chemical analysis. Fourteen PCB congeners (International Union of Pure and Applied Chemistry numbers: 28, 52, 99, 101, 105, 118, 128, 138, 153, 156, 170, 180, 183, 187) and 10 chlorinated pesticides or their metabolites [α-chlordane, γ-chlordane, oxychlordane, *cis*-nonachlor, *trans*-nonachlor, HCB, *p,p′*-DDT, *p,p′*-DDE, β-hexachlorocyclohexane (β-HCH), and mirex] were determined in tissue samples.

Extraction and purification steps were performed according to a modification of the procedure described by Ryan and colleagues (*24*). Samples (~ 1 g) were spiked with

Table 1. Mean OC concentrations (microgram per kilogram lipid basis) in autopsy tissue samples from Greenlanders.

	Subcutaneous fat (n = 26)				Omental fat (n = 41)				Brain (n = 17)				Liver (n = 26)			
OCs	Mean[a]	CI	Range	%[b]	Mean	CI	Range	%	Mean	CI	Range	%	Mean	CI	Range	%
β-HCH	114	(91–142)	(20–334)	100	96	(81–114)	(29–260)	100	43	(33–56)	(16–105)	100	395	(312–501)	(67–1,000)	100
p,p′-DDT	142	(109–187)	(45–415)	100	116	(91–148)	(9–316)	100	7	(4–11)	(1.6–44)	53	33	(19–58)	(2–301)	77
p,p′-DDE	3,194	(2,486–4,103)	(889–11,280)	100	3,290	(2,708–3,998)	(790–9,300)	100	319	(236–429)	(77–732)	100	2,909	(2,268–3,731)	(885–10,270)	100
Mirex	116	(89–151)	(21–444)	100	126	(101–157)	(24–450)	100	32	(23–44)	(7–62)	100	101	(78–131)	(18–237)	100
α-Chlordane	0.5	(0.3–0.8)	(0.1–6.5)	24	0.4	(0.3–0.6)	(0.1–8)	35	2.4	(1.6–3.8)	(0.8–12)	29	4	(3–6)	(0.6–48)	42
γ-Chlordane	7[c]	(4–13)	(0.1–41)	90	6	(4–10)	(0.1–37)	95	1.0	(0.8–1.4)	(0.3–5.3)	6	18	(10–31)	(0.5–139)	81
HCB	594	(476–742)	(164–1,892)	100	588	(491–704)	(156–1,890)	100	260	(175–387)	(41–757)	100	754	(603–943)	(166–1,986)	100
Oxychlordane	743	(581–949)	(162–2,240)	100	698	(562–866)	(130–3,080)	100	149	(105–211)	(26–486)	100	1,086	(827–1,425)	(268–3,830)	100
cis-Nonachlor	256	(202–325)	(60–788)	100	271	(225–325)	(67–795)	100	26	(16–40)	(2–91)	94	318	(248–408)	(91–911)	100
trans-Nonachlor	1291	(1,031–1,618)	(357–3,437)	100	1,241	(1,021–1,507)	(260–3,455)	100	138	(101–189)	(36–379)	100	1,502	(1,171–1,927)	(431–3,880)	100
PCB congeners (IUPAC no.)																
28	10	(6–17)	(0.2–185)	100	8	(6–10)	(2.3–156)	96	2.4	(1.3–4.3)	(0.5–33)	41	4	(2–6)	(0.5–79)	57
52	10	(7–15)	(2–150)	100	13	(10–17)	(1.9–200)	100	1.8	(0.9–3.3)	(0.3–19)	29	8[c]	(4–13)	(0.5–92)	65
99	238	(180–317)	(32–857)	100	215	(178–259)	(33–620)	100	31	(25–39)	(15–74)	100	154	(119–201)	(21–486)	100
101	26	(19–35)	(7–100)	100	18	(15–23)	(4–90)	100	8	(6–11)	(2–24)	94	19	(14–26)	(3–92)	92
105	47	(36–60)	(10–152)	100	50	(41–61)	(7–140)	100	3	(2–6)	(0.5–29)	53	18	(11–32)	(0.9–124)	77
118	257	(198–335)	(41–811)	100	267	(219–326)	(46–764)	100	38	(27–54)	(8–127)	100	209	(163–267)	(32–478)	100
128	9	(6–14)	(0.8–70)	85	3	(2–4)	(0.1–27)	100	1.0	(0.8–1.3)	(0.5–2.4)	6	2.1	(1.5–2.9)	(0.6–15)	15
138	1,103	(878–1,386)	(273–3,870)	100	1,098	(927–1,300)	(190–2,450)	100	134	(99–182)	(34–296)	100	855	(677–1,080)	(161–2,120)	100
153	1,689	(1,355–2,106)	(531–5,580)	100	1,582	(1,331–1,879)	(280–3,800)	100	198	(149–263)	(53–397)	100	1,177	(912–1,518)	(242–3,770)	100
156	173	(139–215)	(57–625)	100	195	(160–236)	(27–497)	100	30	(21–43)	(5–88)	100	143	(116–175)	(51–270)	100
170	385	(308–482)	(112–1,550)	100	422	(347–513)	(61–1,100)	100	46	(31–68)	(7–154)	100	327	(263–408)	(105–886)	100
180	1,147	(908–1,449)	(239–4,420)	100	1,136	(939–1,375)	(170–3,000)	100	145	(105–201)	(27–378)	100	791	(621–1,007)	(234–2,310)	100
183	92	(71–118)	(14–413)	100	93	(78–110)	(19–318)	100	10	(6–17)	(0.5–29)	88	69	(55–87)	(11–241)	100
187	499	(398–626)	(113–2,200)	100	507	(428–601)	(99–1,330)	100	82	(59–114)	(14–175)	100	445	(355–559)	(110–1,030)	100

Abbreviations: CI, 95% confidence interval; *p,p′*-DDE, 2,2′-bis(4-chlorophenyl)-1,1-dichloroethylene; p,p′-DDT, 2,2′-bis(4-chlorophenyl)-1,1-trichloroethylene; HCB, hexachlorobenzene; β-HCH, β-hexachlorocyclohexane; IUPAC, International Union of Pure and Applied Chemistry; OC, organochlorine; PCB, polychlorinated biphenyl.
[a]Geometric mean; in calculating mean values, results not detected were attributed a value equal to half of the detection limit. [b]Percentage of analyzed samples in which the substance was detected (see "Materials and Methods" for detection limits). [c]n = 21 due to analytical interference.

the internal standard (PCB congener no. 198), homogenized in hexane:acetone (2:1, v/v), and the resulting organic phase was washed with water to remove the bulk of the acetone. An aliquot of the hexane extract was used for lipid determination by gravimetry and the rest of the extract was defatted with concentrated sulfuric acid. The defatted hexane extract was successively washed with water and aqueous potassium hydroxide prior to filtration through anhydrous sodium sulfate. The filtrate was then concentrated and cleaned up by chromatography on an acidic silica gel column and a deactivated (0.5%) Florisil (U.S. Silica Co., Berkeley Springs, WV) column. OCs were eluted from the columns using methylene chloride: hexane (25:75, v/v) and analyzed on an HP-5890 gas chromatograph (Hewlett Packard, Palo Alto, CA) equipped with dual capillary columns (Ultra-1 and Ultra-2; Hewlett Packard) and dual ^{63}Ni electron detectors (simultaneous injection in both columns). Depending on the lipid content and the available quantity of tissues, detection limits ranged in omental fat from 0.3 to 3.6 µg/kg, in subcutaneous fat from 0.3 to 0.9 µg/kg, in liver from 3 to 14 µg/kg, and in brain from 3 to 8 µg/kg. Average percentage recoveries of organochlorines extracted from adipose tissue and brain samples ranged from 74 to 106% for PCB congeners and from 60 to 117% for chlorinated pesticides. In liver samples the percentage recoveries varied between 80 and 110% for PCBs and between 85 and 120% for chlorinated pesticides. The between-day precision ranged from 3.7 to 18.3% and from 6.9 to 16.8% for PCB congeners and chlorinated pesticides, respectively.

All concentrations are presented on a lipid weight basis because OCs are lipophilic substances that distribute mainly in body fat. A nonparametric Kruskal-Wallis test followed by a Tukey-type multiple comparison test (*25*) were used to compare OC concentration ratios for the various tissues (α = 0.05). Simple correlation analyses (Pearson correlation coefficient) were performed to evaluate associations between OC levels in different autopsy tissues and to assess the influence of age on omental fat OC concentrations. Parametric statistical analyses were performed on log-transformed values because OC concentrations in autopsy tissues follow a log-normal distribution. All statistical procedures were performed using the SPSS 8.0 for Windows statistical package (SPSS, Inc., Chicago, IL).

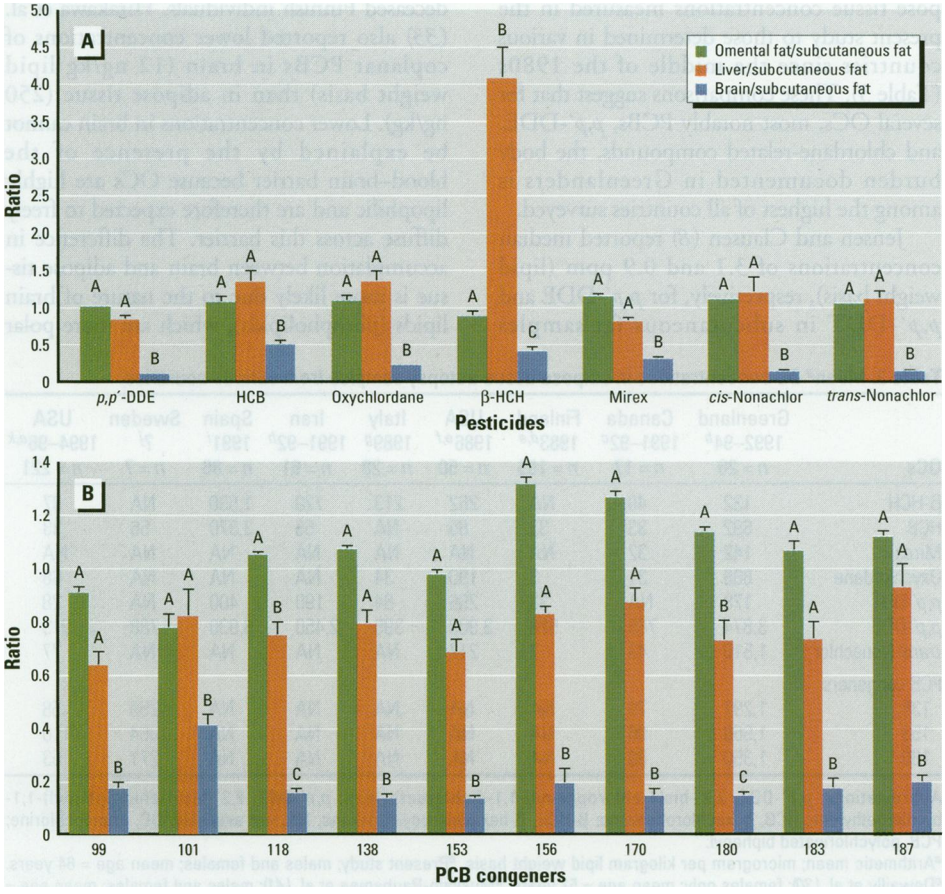

Figure 1. Ratios of organochlorine concentrations for omental fat, liver, and brain samples relative to subcutaneous fat samples. Abbreviations: *p,p′*-DDE, 2,2′-bis(4-chlorophenyl)-1,1-dichloroethylene; HCB, hexachlorobenzene; β-HCH, β-hexachlorocyclohexane; PCB, polychlorinated biphenyl. Each bar represents the arithmetic mean ± standard error for 17 individuals for whom all four tissues were collected. Mean values for columns topped by different letters are statistically different ($p < 0.05$).

Results

Concentrations of OCs in brain, liver, subcutaneous abdominal fat, and omental fat samples are presented in Table 1. Adipose tissue and liver samples from Inuits contained detectable amounts of most substances; only α-chlordane and PCB congener no. 128 were detected in less than 50% of these tissue samples. In contrast, several compounds (PCB congener numbers 28, 52, and 128; α-chlordane; γ-chlordane) were detected in less than half of the brain samples. Compounds found in < 85% of tissue samples were excluded from further statistical analyses. *p,p′*-DDE, *trans*-nonachlor, oxychlordane, and HCB were the most abundant pesticides in all four tissues, whereas PCB congeners that showed the highest concentrations were PCBs 138, 153, 170, 180, and 187. The sum of the three most abundant PCB congeners (PCBs 138, 153, and 180) represented 63–68% of total PCB congener concentrations in tissue samples. Mean lipid contents were 62.0% in subcutaneous fat, 59.6% in omental fat, 8.3% in brain, and 4.5% in liver.

To study possible differences in OC accumulation between the tissues, statistical analyses were restricted to data for 17 people with complete information on residue levels in all four tissues (Figure 1). Brain to subcutaneous fat concentration ratios were lower than 1 for all OCs ($p < 0.05$). For example, mean *p,p′*-DDE concentration in brain lipids was 10-fold lower than that measured in adipose tissue lipids. Strong correlations were nevertheless noted between concentrations of *p,p′*-DDE in brain and those in subcutaneous abdominal fat (Pearson's $r = 0.86$; $p < 0.0001$), omental fat ($r = 0.89$; $p < 0.0001$), or liver ($r = 0.94$; $p < 0.0001$). Similar correlations ($r > 0.65$; $p < 0.005$) were also noted for the other OCs, with the exception of PCB congeners 101 and 183.

Liver, omental fat, and subcutaneous fat contained similar concentrations of chlorinated pesticides and their metabolites, with one notable exception, β-HCH, showing a 4-fold greater concentration in liver lipids than in fatty tissue lipids ($p = 0.0001$). PCB congener concentrations were also similar in omental fat and subcutaneous abdominal fat, and although mean hepatic concentrations of most PCB congeners appeared lower than those in omental fat or subcutaneous fat (by approximately 20% on average), ratios were statistically different than 1 only for PCB congeners 118 and 180 (Figure 1).

Mean omental fat concentration of ΣDDT (the sum of *p,p'*-DDT and *p,p'*-DDE concentrations), Σchlordane (the sum of α-chlordane, γ-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane concentrations), and ΣPCB (the total concentration of 14 PCB congeners) according to gender and age groups are presented in Table 2. Data are presented only for omental fat because of the small number of samples available for other tissues. Concentrations of ΣPCB, ΣDDT, and Σchlordane in males were not statistically different from those in females. Age was correlated with ΣPCB concentrations ($r = 0.43$; $p = 0.005$) but not with ΣDDT ($r = 0.19$; $p = 0.23$) or Σchlordane concentrations ($r = 0.27$; $p = 0.09$).

Discussion

The traditional diet of Inuits living in circumpolar countries is their major source of exposure to organochlorines (*5,8,9,26–29*). Determination of OCs in human tissue samples collected during autopsies performed on 41 Greenlanders revealed a relatively high body burden of several of these persistent compounds in this population as compared to those encountered in populations living in industrialized regions. This is best exemplified by comparing concentrations measured in the present study with those quantified by the same laboratory, using the same analytical method in mammary adipose tissue collected from 17 women living in the Quebec City region and undergoing surgery for benign breast disease during 1991–1992 (*30*). These 17 women (mean age = 51 years) showed mean organochlorine concentrations below those of Greenlanders by factors varying between 3 and 34 (Table 3). In particular, the total concentration of the three most abundant PCB congeners (numbers 138, 153, and 180) in adipose tissue samples from Inuit women in the present study was 4,615 μg/kg (lipid weight basis), a value 18-fold greater than that of 252 μg/kg determined in samples from Quebec City women. Furthermore, most of the autopsy samples collected in the present study were from residents of the town of Nuuk, where exposure to organochlorines is probably lower than in other towns or settlements because of a greater prevalence of western-lifestyle habits (the consumption of imported foods).

Comparisons with data obtained in other studies should be made with caution because of the differences in analytical methods between laboratories and over time. With these limitations in mind, we compared adipose tissue concentrations measured in the present study to those determined in various countries since the middle of the 1980s (Table 3). These comparisons suggest that for several OCs, most notably PCBs, *p,p'*-DDE, and chlordane-related compounds, the body burden documented in Greenlanders is among the highest of all countries surveyed.

Jensen and Clausen (*8*) reported median concentrations of 3.1 and 0.9 ppm (lipid weight basis), respectively, for *p,p'*-DDE and *p,p'*-DDT in subcutaneous fat samples collected from 33 Greenlanders (25 women) between 25 and 70 years of age, who were admitted during 1974 for acute operations. Therefore, although the body burden of *p,p'*-DDE in the 26 Greenlanders of the present study is similar to that measured 20 years ago, the body burden of *p,p'*-DDT has apparently decreased by a factor of 5 during this period. This downward trend has also been observed in breast milk surveys conducted in developed countries and is probably the result of the ban or restrictions on the use of DDT introduced in these countries during the early 1970s (*31*). Given the greater persistence of *p,p'*-DDE as compared to *p,p'*-DDT, the decrease in *p,p'*-DDE body burden occurs at a much slower rate than that of the parent compound (*31*).

In the present study, mean concentrations of OCs in brain lipid extracts were 2–10 times lower than those in adipose tissue extracts. Other studies reported OC concentrations in several tissues, including brain, of deceased individuals. Similar to our study, Hattula et al. (*32*) found lower PCB concentrations (expressed as Clophen 60; lipid weight basis) in brain (1,190 μg/kg) than in adipose tissue (2,800 μg/kg) of deceased Finnish individuals. Hirakawa et al. (*33*) also reported lower concentrations of coplanar PCBs in brain (12 ng/kg lipid weight basis) than in adipose tissue (250 ng/kg). Lower concentrations in brain cannot be explained by the presence of the blood–brain barrier because OCs are highly lipophilic and are therefore expected to freely diffuse across this barrier. The difference in accumulation between brain and adipose tissue is more likely due to the nature of brain lipids (phospholipids), which are more polar

Table 2. Mean concentrations (microgram per kilogram lipid basis) of selected OC subgroups in omental fat samples from Greenlanders, according to sex and age.

OCs	Mean[a] (*n*)	CI	Range
ΣDDT[b]	3,430 (41)	2,830–4,158	867–9,610
Σchlordane[c]	2,241 (41)	1,843–2,725	494–6,212
ΣPCB[d]	5,719 (41)	4,825–6,779	1,019–12,716
ΣDDT			
Females	3,483 (22)	2,716–4,465	867–6,600
Males	3,371 (19)	2,482–4,578	1,246–9,610
Σchlordane			
Females	1,977 (22)	1,508–2,592	494–6,212
Males	2,592 (19)	1,968–3,414	897–6,189
ΣPCB			
Females	5,342 (22)	4,087–6,983	1,019–12,716
Males	6,189 (19)	5,076–7,546	2,229–11,877
ΣDDT			
41–54 years	3,497 (16)	2,538–4,817	867–8,200
55–69 years	2,764 (12)	1,879–4,067	1,246–7,920
≥70 years	4,089 (13)	3,077–5,435	1,429–9,610
Σchlordane			
41–54 years	2,084 (16)	1,423–3,052	494–6,189
55–69 years	2,016 (12)	1,448–2,807	897–6,212
≥ 70 years	2,704 (13)	2,081–3,513	1,095–6,141
ΣPCB			
41–54 years	4,909 (16)	3,517–6,851	1,019–10,252
55–69 years	5,337 (12)	3,964–7,186	2,229–12,716
≥ 70 years	7,357 (13)	6,237–8,678	3,717–12,195

Abbreviations: CI, 95% confidence interval; OC, organochlorine; PCB, polychlorinated biphenyl.
[a]Geometric mean; in calculating mean values, results not detected were attributed a value equal to half the detection limit. [b]*p,p'*-DDT + *p,p'*-DDE. [c]α-Chlordane + γ-chlordane + *cis*-nonachlor + *trans*-nonachlor + oxychlordane. [d]Sum of the 14 PCB congeners.

Table 3. Mean[a] OC concentrations in adipose tissue autopsy samples from various countries.

OCs	Greenland 1992–94[b] *n* = 26	Canada 1991–92[c] *n* = 17	Finland 1983[d,e] *n* = 105	USA 1986[e,f] *n* = 50	Italy 1989[g] *n* = 28	Iran 1991–92[h] *n* = 61	Spain 1991[i] *n* = 86	Sweden ?[j] *n* = 7	USA 1994–96[e,k] *n* = 221
β-HCH	132	40	NA	262	213	728	1,530	NA	37
HCB	692	33	33	85	NA	55	3,370	56	33
Mirex	142	32	NA	NA	NA	NA	NA	NA	NA
Oxychlordane	888	31	3	190	34	NA	NA	NA	68
p,p'-DDT	178	NA	33	296	64	190	400	NA	28
p,p'-DDE	3,874	765	518	3,908	395	2,450	3,930	788	913
trans-Nonachlor	1,510	43	7	217	NA	NA	NA	NA	77
PCB congeners									
138	1,297	70	NA	NA	NA	NA	NA	259	58
153	1,968	96	NA	NA	NA	NA	NA	354	110
180	1,350	86	NA	NA	NA	NA	NA	271	53

Abbreviations: *p,p'*-DDE, 2,2'-bis(4-chlorophenyl)-1,1-dichloroethylene; *p,p'*-DDT, 2,2'-bis(4-chlorophenyl)-1,1-trichloroethylene; HCB, hexachlorobenzene; β-HCH, β-hexachlorocyclohexane; NA, not available; OC, organochlorine; PCB, polychlorinated biphenyl.
[a]Arithmetic mean; microgram per kilogram lipid weight basis. [b]Present study; males and females; mean age = 64 years. [c]Dewailly et al. (*30*); females only; mean age = 51 years. [d]Mussalo-Rauhamaa et al. (*41*); males and females; mean age = 54 years. [e]Concentrations on a lipid weight basis estimated from wet weight values, assuming a 60% lipid content in adipose tissue. [f]Lordo et al. (*18*); males and females; mean age = unknown; 50 composite samples formulated from 671 specimens collected nationwide. [g]Gallelli et al. (*39*); males and females; mean age = 56 years. [h]Burgaz et al. (*42*); males and females; mean age = 37 years. [i]Gómez-Catalán et al. (*44*); males and females; mean age = unknown. [j]Weistrand and Norén (*36*); males and females; mean age = 47–80 years. [k]Stellman et al. (*49*); females (breast cancer study controls); mean age = 50 years.

than adipose tissue lipids (triglycerides), the very lipophilic compounds partitioning to a greater extent in the latter tissues (*34*).

Mean OC concentrations in liver and adipose tissue lipid extracts were not markedly different, with the exception of β-HCH. In most previous studies involving the analyses of multiple human autopsy tissues, no marked differences were found between liver and adipose tissue with regard to the residue levels of PCB, HCB, and *p,p'*-DDE (*32,35, 36*). No data were located in the literature regarding the tissue distribution of β-HCH in humans. The higher concentration of β-HCH in liver lipids as compared to that in fatty tissue lipids suggests a specific binding of this compound to liver proteins.

There was no difference between males and females with regard to OC residue levels in the various tissues. This lack of a gender effect was previously reported by several investigators (*18,37–41*). In the present study, the age of the subject was associated with the concentration of PCBs (sum of congeners) in omental fat. Several researchers have reported a relationship between age and OC body burden (*18,37,39–44*) in different populations, indicating that these persistent chemicals accumulate in the body throughout the lifetime.

The high organochlorine body burden displayed by Greenlanders may bear public health consequences. Although the database is limited, results from studies involving workers in the capacitor industry indicate that chloracne or liver changes may occur when PCB concentrations in the blood of workers exceed 200 µg/L (*45,46*). However, exposure to polychlorinated dibenzofurans might have contributed to the adverse effects encountered in the workplace (*46*). The 200-µg/L whole blood concentration corresponds to a 270-µg/L plasma concentration and a 45-mg/kg lipid concentration, assuming a plasma/whole blood PCB concentration ratio of 1.35 (*47*) and a 6-g/L total lipid concentration in the plasma of workers. The mean concentration of PCBs (Aroclor 1260) in lipids extracted from omental fat samples of 41 individuals in the present study was 14.1 mg/kg (range = 2.4–31.7). Therefore, although obvious differences exist between PCB mixtures found in workers and in Inuit people in the present study, we tentatively conclude that PCB exposure in the adult Greenland population is too low to induce skin or liver problems.

Of more recent interest is the possibility that prenatal exposure to OCs might induce a variety of adverse health effects (immune and thyroid function, hormone-dependent cancers, disorders of male and female reproductive tracts, developmental deficits) as a result of endocrine modulation. Several recent reviews have addressed this controversial issue (*22,23,48–51*) and it is not clear at the present time whether exposure to PCBs and other OCs represents a real threat for Inuit populations. Studies are underway to characterize the body burden of women of reproductive age and to measure developmental end points in Inuit infants during the first year of life. Notwithstanding these potentially adverse health effects, the traditional diet is of great importance for the health of the Inuit people (*7,9*). More specifically, marine mammal fat, in addition to being the largest source of OCs in the traditional Inuit diet, is also rich in polyunsaturated omega-3 fatty acids, which protect against atherosclerosis and perhaps cancer. Local health authorities in the Arctic must evaluate the social, economic, cultural, and health impacts before deciding whether to suggest dietary modifications or not (*7*). Concomitantly to addressing this difficult question, we believe that the high body burden displayed by the Inuit people justifies major international efforts to reduce the input of OCs and other persistent organic pollutants into the Arctic environment.

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