POLYCHLORINATED BIPHENYLS IN SERUM OF THE SIBERIAN YUPIK PEOPLE FROM ST. LAWRENCE ISLAND, ALASKA

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ABSTRACT

Objectives. To determine serum levels of polychlorinated biphenyls (PCBs) in Siberian Yupik adults from St. Lawrence Island, Alaska, and to determine the relative contribution of atmospheric transport of PCBs and local contamination to body burdens.
Study Design. Siberian Yupiks of various ages were recruited from three populations: residents of the village of Gambell, residents of the village of Savoonga who did not have family hunting camps near the Northeast Cape (NEC), a Formerly Used Defense Site (FUDS) known to be contaminated with PCBs, and residents of Savoonga whose families had a hunting camp at the NEC.
Methods. Levels of PCBs were measured in serum samples from 130 people, ages 19-76. These Alaska Natives follow a traditional diet high in marine mammals and fish, which bioconcentrate organochlorine compounds that migrate to the Arctic via global air transport and ocean currents.
Results. The lipid-adjusted serum PCB levels of those members of families with hunting camps at the NEC had a mean lipid-adjusted PCB concentration of 1,143 ppb, whereas other residents of Savoonga had values of 847 ppb and residents of Gambell had values of 785 ppb.
Conclusions. Our observations suggest that atmospheric transport of PCBs contributes to levels in the Yupik people, but that the abandoned military site at the NEC may also contribute to the human body burden in those individuals who have either spent substantial time or consumed food from there.
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Keywords: Alaska, Eskimos, FUDS, atmospheric transport

Abbreviations:
AMAP - Arctic Monitoring and Assessment Programme
NEC - Northeast Cape
PCBs - Polychlorinated Biphenyls
FUDS - Formerly Used Defense Site
USACOE - United States Army Corps of Engineers
QA/QC – Quality Assurance/Quality Control
ANOVA – Analysis of Variance
SEM – Standard Error of the Mean
ATSDR – Agency for Toxic Substances Disease Registry
ANCOVA – Analysis of Co-Variance
VIF – Variance Inflation Factor
ppb – Parts Per Billion
ppt – Parts Per Trillion

INTRODUCTION

Levels of PCBs are declining in most of the developed world since the manufacture and use of these substances has been curtailed (1, 2). This is also true for at least some Northern dwelling communities (3). However, the polar regions are reservoirs for atmospheric transport of persistent toxic substances, which are carried by air currents and then condense out of the vapor phase in the cold of the polar regions and are deposited in snow (4). This fact, plus the high fat diet of many indigenous communities in the Arctic, raises concern that the intake of organochlorine compounds, which include PCBs, dioxins/furans and persistent organochlorine pesticides, may pose serious health risks to these populations (5, 6). The variety of diseases known to be associated with exposure to PCBs include cancer, immune suppression, neurobehavioral decrements, endocrine disruption of sex steroid and thyroid function, cardiovascular disease and diabetes (1, 7).

St. Lawrence Island, Alaska, is an island 104 miles long and averaging 20-30 miles across. It is located 38 miles off the Russian coast, about 150 miles below the Arctic Circle and about 130 miles west of Nome, Alaska. The population of St. Lawrence Island consists of about 1,400 Siberian Yupiks, living in two villages, Gambell and Savoonga. The Siberian Yupik people follow a traditional life-style, which includes significant consumption of marine mammals and fish, bird eggs, as well as local greens and berries. Storage of meats is primarily either by drying in the brief summer, freezing or fermenting in pits in the ground. The villages have electricity and most homes have indoor plumbing.

Two US military bases were constructed on St. Lawrence Island because of its strategic location. The military established a base at Gambell during World War II, and the Air Force and Army came in the early 1950s and operated there until the early 1980's. Little is known about activities at Gambell, since data regarding activities there is still classified. Gambell is built on coarse gravel, and fuels, oils and other hydrocarbons that spilled have settled in a layer above the permafrost, some 8-10 feet below the surface. There is no documented history of the use of PCBs at Gambell, although some use is likely in generators, transformers and paint.

The other military base was located at the opposite end of the island, at the Northeast Cape (NEC) during the Cold War. While there is no permanent settlement at the NEC, the region has a number of hunting and fishing camps where members of some Savoonga families spend several months in the spring and early summer to hunt seal, walrus and whale, as well as to catch fish from the local rivers and streams and near shore areas and collect greens. When the military base at the

NEC was closed in 1972, most of the supplies and materials present at the site, including buildings, heavy equipment and generating facilities, as well as fuel containers, were abandoned, or buried on-site.

In addition to abandoned buildings, radar stations and air strips, the military left a range of contaminants, including fuels, PCBs and various trace metals, which had a severe impact on the local environment. The military complex established at the NEC is located along the Bering Sea. The soils are typical of tundra-covered areas, with numerous wetlands, ephemeral ponds and small streams draining from the granitic mountains. There was a documented diesel fuel spill of 160,000 gallons in the late 1960s that killed fish and other animals in the Suqitughneq (Suqi) River. The area around the power generating station and the soils and plants down-gradient of the main complex are highly contaminated with PCBs and volatile organics, as determined as a part of the ongoing remediation of the site under the direction of the United States Army Corps of Engineers (USACOE) and their contractors. While a multi-million dollar remediation of the NEC is currently being conducted by the USACOE, significant contamination remains (8).

The perception in the Yupik community is that, in recent years, there has been a significant increase in the levels of various diseases, especially cancer and diabetes, and that this has occurred particularly among those individuals who have spent significant time at the NEC. The concern in the community is that these increases in disease have resulted from environmental contamination originating from the former military sites. One woman, Annie Alowa, whose family had a camp at the NEC and who was dying of cancer, established contact with the Alaska Community Action on Toxics, an advocacy organization based in Anchorage. This contact ultimately resulted in an NIEHS Environmental Justice grant for St. Lawrence Island, which has supported this project.

The residents of St. Lawrence Island have at least two possible sources of exposure to environmental contaminants. Certainly, the abandoned military sites comprise one of these. Although relatively localized, they are in areas of human activity and food collection. In addition, many organochlorines, including PCBs, dioxins/furans and persistent pesticides, travel to and concentrate in the polar regions by vapor phase transport followed by precipitation in the cold climate (global distillation), or by ocean currents (9). These lipophilic compounds then bioconcentrate in the food chain and are ultimately consumed by humans. Native Yupik people, whose diet includes the significant consumption of marine mammal fats, are susceptible to major exposure via this route. In addition, the consumption of polar bear is not uncommon among the Yupik people and, since seal blubber is a major food for the polar bear, PCB levels in polar bear meat, fat and organs are much higher than in the marine mammals.

At the request of the community, we initiated a study of serum levels of PCBs in 2001. We analyzed blood from residents of Gambell, residents of Savoonga who did not have family camps at the NEC, and residents of Savoonga who did have such camps. The hypothesis to be tested was that the results would allow us to distinguish contributions to the PCB body burden of global transport of these compounds from those arising from proximity to the military sites.

MATERIAL AND METHODS

Recruitment of the study population

The study population consisted of 40 residents of Gambell, 44 residents of Savoonga who had spent little or no time at the NEC, and 46 residents of Savoonga whose families had camps at the NEC and spent time there. Figure 1 shows a map of the island, and the relative distances between these sites. For those with family camps at the NEC, the duration of time spent there varied significantly, and not all family members went there every year. However, those who went frequently spent several months at the camp, and returned with food harvested from the vicinity of the NEC. Food in this culture is traditionally shared with the larger family members.

Subjects ages were between 19-75 years, with approximately equal numbers of men and women. Subjects were not randomly selected, but individuals were recruited by Yupik staff from willing participants balanced for age and gender. This should not have resulted in significant bias, given that diets and behaviors are very uniform in this population. There were no exclusion criteria. After signing an informed consent, subjects filled out a brief questionnaire (those who did not speak English were interviewed) documenting residential history, occupational history and time spent at the NEC. Subjects also provided an 8-hr fasting blood sample (two 10-ml specimens, collected in glass specimen tubes). Blood samples were obtained during August 2001, and between August and October in 2003. A few individuals who showed transient PCB congeners in their bloods in 2001 were asked to provide a second sample for analysis in 2003. All results were reported to the person who gave the blood by written communication, and most subjects also had private meetings with Dr. Carpenter during the summer of 2004 to discuss their personal blood results. The study was reviewed and approved by the Institution Review Board of the University at Albany. Detailed dietary information is currently being collected through other funding, but is not available at present.

Serum PCBs were determined as previously described (10). In brief, serum was

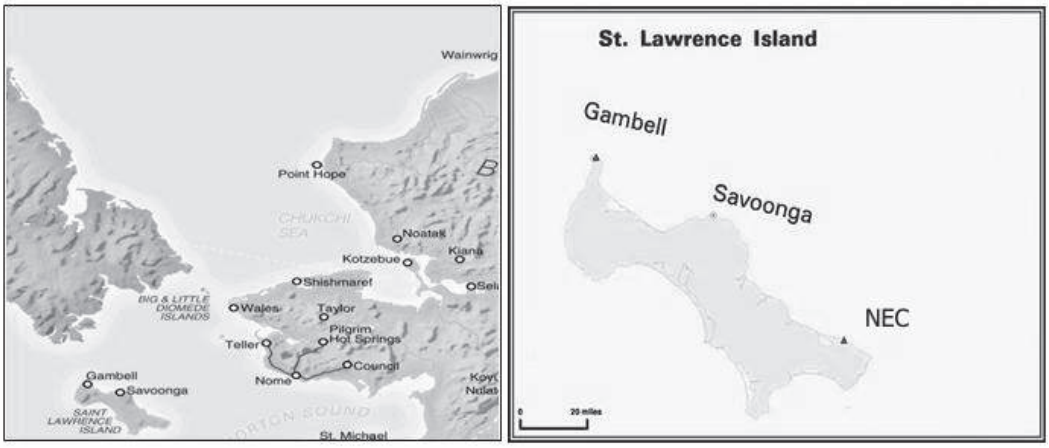

Figure 1. Maps of St. Lawrence Island and vicinity, showing the location of the villages of Gambell and Savoonga and the FUDS site at NEC.

separated from clotted cells and extracted three times with diethylether/hexane. Polar lipids and other interferents were removed by adsorption onto Florisil, and 83 individual PCB congeners and 18 congeners co-eluting as pairs or triplets were identified and quantitated by simultaneous parallel dual-column gas chromatography with electron capture detection. Calibration was performed using a 1:1:1:1 mixture of Aroclors 1221, 1016, 1254 and 1260 (AccuStandard, Inc.), with internal standard-based quantitation. Values for individual congeners that were below the method detection limit (MDL) were given a value of zero. Total serum lipid concentration was determined by drying and weighing the residual of a hexane extract. A rigorous QA/QC program was applied as previously described (10).

Statistical procedures

Two-way ANOVA and Multiple Regression were used to analyze the data. For the regression model, the error terms were assumed to be independent, normal random variables with a mean of zero and with constant variance (Homogeneity of Variance). If the model is appropriate for the data at hand, the observed residuals should then reflect the properties assumed for error terms. The appropriateness of linear function for the data was analyzed from residual plots against the predictor variable (age). The residuals fell within a horizontal band around zero, displaying no systematic tendencies to be positive or negative. This indicates that there is no pattern of the residuals when plotted against the fitted values. Whether a linear function is appropriate for the data being analyzed can be studied from a residual plot against the fitted values to test the linear regression assumption that the variance of the error terms is constant. If the error variance increases with the predictor, this will give a megaphone-type plot. In our case, the error variance was constant, and we did not find any megaphone-type structure when we plotted the residuals against the fitted values.

RESULTS

The serum PCB levels of the 130 Yupik adults of St. Lawrence Island, aged from 19 to 75 years, ranged from 0.6 to 17.8 ng/g (ppb) wet weight, with a mean concentration of 4.6 ppb. After lipid adjustment, the mean value was 933 ppb. Table I shows the mean level of total PCBs (wet weight and lipid-adjusted) in serum from female and male residents of Gambell, residents of Savoonga that have family hunting camps near the NEC, and residents of Savoonga who rarely, if ever, go to the NEC. The lowest PCB levels were found in residents of Gambell, where the mean lipid-adjusted PCB level was 785 ppb. In contrast, residents of Savoonga had a mean lipid-adjusted serum PCB concentration of 847 ppb, while residents of Savoonga who had spent time at the NEC had the highest total serum PCB level of 1,143 ppb. In the two-way ANOVA, there is a marginally statistically significant difference between Gambell and NEC in serum PCB values ($p < 0.06$, SEM = 1.26), but the NEC levels were not significantly different from those in Savoonga ($p < 0.16$). In all groups, the mean levels were higher for males than females. This result was statistically significant ($p < 0.0014$, SEM = 2.25).

Figure 2 shows serum PCB level (wet weight) plotted against age for each of the

three Yupik subgroups. Serum levels of PCBs were generally positively correlated with age, while there is obvious variability. This is consistent with previous observations indicating that levels generally increase with age (1), but also may reflect a greater exposure to these very persistent compounds in past years. We have modeled this data by transforming it to a log-normal distribution. When modeled in a multiple regression analysis, we find that, for each one year increase in age, there is a predicted increase in serum PCB levels of 0.47 ppt wet weight after adjusting for all other variables (residence site and sex).

Table I. Serum PCB levels (wet weight and lipid-adjusted in ppb) for female and male residents of Gambell, NE Cape and Savoonga.

	Gambell			NE Cape			Savoonga		
	Female	Male	All	Female	Male	All	Female	Male	All
n	22	18	40	19	27	46	25	19	44
Age (mean)	39	47	43	44	46	45	40	42	41
Wet Weight Total PCB									
Mean	2.642	5.726	4.030	4.758	5.826	5.385	3.745	4.748	4.178
Min	0.619	1.572	0.619	1.176	1.044	1.044	0.899	0.636	0.636
Max	7.651	11.053	11.053	13.552	17.794	17.794	9.788	14.388	14.388
Median	2.119	5.841	2.844	3.586	5.485	4.457	2.888	3.617	3.523
Lipid-Adjusted Total PCB									
Mean	628	977	785	859	1343	1143	794	918	847
Min	124	291	124	295	218	218	166	138	138
Max	2816	2632	2816	2222	4963	4963	1882	1845	1882
Median	370	972	706	814	1088	878	760	822	773

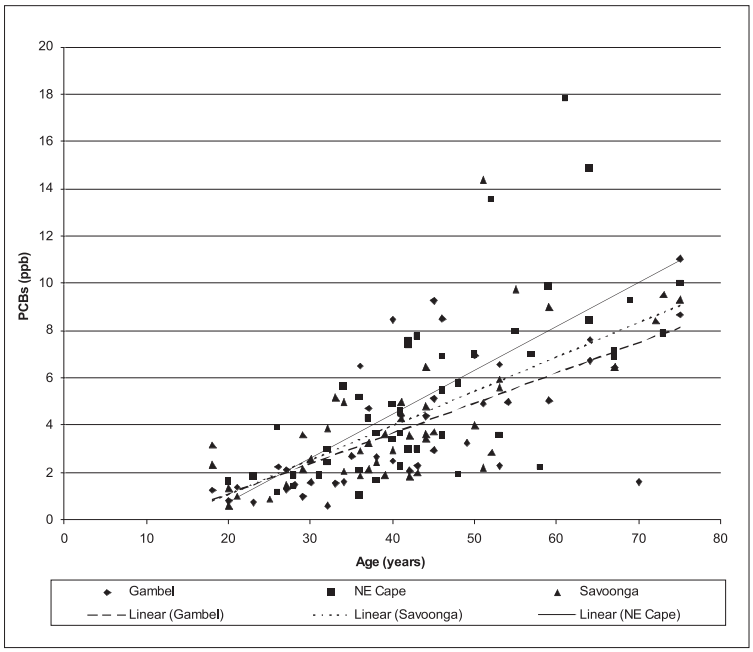

Figure 2. Serum PCB (wet weight) as a function of age for residents of Gambell, Savoonga and those with family camps at the NEC. The data from each individual in the study is plotted, as well as the linear regression best fit for each of the three populations. For Gambell the R^2 = 0.4696, for NEC R^2 = 0.4713 and for Savoonga R^2 = 0.5134.

Analysis of covariance (ANCOVA) was carried out by adding the term "age" to the model. The Pearson correlation between age and serum PCB levels for females was 0.56 ($p < 0.0001$), while for males it was 0.63 ($p < 0.0001$). For running ANCOVA we tested the assumption that there should be no interaction between the continuous variable "age" at different locations, and we found no significant interaction, consistent with the selection of age ranges to be nearly the same at the three sites.

By use of the main effects model, using age as a continuous variable and location and sex as categorical variables, we found that the overall F statistic for the model is significant ($p < 0.0001$) and the adjusted R^2 is 59% for the full model. The means of serum PCB levels in Gambell is marginally significantly different from those at the NEC [$p < 0.06$ (CL = .025, 0.16)] with a Variance Inflation Factor (VIF) of 1.3, indicating no multicolinearity between predictors after adjusting for all other variables in the model. As in the two-way ANOVA, there was not a significant difference between the means from Savoonga and those from the NEC. Serum PCBs from males were significantly greater than those from females [$p < 0.0028$ (CL = -0.43, -0.01), VIF = 1.31]. As above, age, as a continuous variable, was significantly related to mean PCB levels [$p < 0.0001$ (CL = 1.21, 1.71), VIF = 1.03].

In the model with two-way interaction terms, the overall F is 20.10, with a p value of 0.0001 and an R^2 of 61%. The model explains about 61% of the variation in the data. The other measure of the fit of the model is residual analysis, where assumptions of homogeneity of variance of error terms was not violated. Age was found to be statistically significant [$\beta = 1.53$, $p < 0.0001$, degree of freedom = 1, SEM = 0.24, (CI = 1.06, 2.10), VIF = 4].

Table II lists each of the 101 PCB congeners that were measured, the MDL for each congener, as well as the average lipid-adjusted level and the number of individuals with levels above the MDL. The table also provides this information among persons in the age ranges 18-34, 35-50 and 51-75 years. Figure 3a shows the median pattern of the major PCB congeners detected in the Yupik samples. The higher chlorinated, persistent PCB congeners 153, 138(+163+164), 118, 170, and 180 dominate. Most of the congeners detected are relatively persistent, although the more labile PCBs 52, 95, 101(+90), and 110 are also present, consistent with recent and/or ongoing exposure. Figure 3(b) shows PCB patterns from three individual Yupik subjects, each of whom has a similar overall pattern, but with a greater contribution from lower chlorinated congeners. Since, in general, the lower chlorinated congeners are more transient, this is evidence of recent exposure. Another striking anomaly (not shown in this Figure, but seen in Figure 4) was the detection of PCB 22 (2,3,4'-triCB) from the NEC at concentrations ranging from 86 to 375 ppt in eight individuals. Four of these subjects had serum levels of this congener >300 ppt, while it was not detected in any of the subjects from the other two locations. This labile congener is not often noted in human samples, but has been previously reported in environmental media, such as soil and air at a PCB contaminated landfill (11, 12). The presence of this congener in serum is also consistent with recent PCB exposure.

Figure 4 shows results obtained from a single individual (a 35-year-old male from

Table II. Presence of individual congeners (levels greater than the MDL) in Yupik bloods [lipid-adjusted, ng/g (ppb)] in the full population and in three age groups. Values for hexachlorobenzene (HCB), DDE and mirex are also presented.

			All age groups		Age 18-34		Age 35-50		Age 51-75	
Structure	IUPAC#	MDL	Average	n	Average	n	Average	n	Average	n
TOTAL PCB			1031	130	496	37	912	57	1704	36
2	1	16.5		0		0		0		0
4	3	8.2		0		0		0		0
2/2+3	4+2	6.3		0		0		0		0
2/6	10	0.4		0		0		0		0
24	7	0.6		0		0		0		0
25	9	0.2		0		0		0		0
2/3	6	1.1		0		0		0		0
2/4	8	2.5	6.7	7		0	4.0	3	8.7	4
HCB		0.8	102	130	65	37	93	57	155	36
26/2	19	3.3		0		0		0		0
3/4	13	1.1		0		0		0		0
25/2	18	1.3		0		0		0		0
4/4	15	0.4		0		0		0		0
24/2	17	4.2		0		0		0		0
236+26/3	24+27	0.2	2.4	1		0	2.4	1		0
26/4+23/2	32+16	2.7		0		0		0		0
245	29	0.2	2.2	2		0	2.3	1	2.2	1
25/3	26	0.2	4.7	2		0	2.4	1	6.9	1
24/3	25	0.6		0		0		0		0
25/4	31	0.4	5.3	11	6.5	5	4.3	6		0
24/4	28	1.5	6.3	103	6.0	32	6.7	42	5.8	29
34/2	33	0.8		0		0		0		0
25/26	53	0.8	1.5	3		0	1.6	1	1.4	2
24/26	51	1.0		0		0		0		0
23/4	22	0.4	65	7	100	1	61	1	59	5
236/2	45	1.0		0		0		0		0
23/26	46	1.0	1.7	4	1.6	1	1.3	1	1.8	2
25/25	52	1.0	12	124	11	36	12	52	13	36
24/25	49	2.3	8.8	17	15	2	7.8	12	8.4	3
24/24+236/3	47+59	1.3	9.8	63	7.5	13	11	27	9.5	23
23/25	44	1.9		0		0		0		0
23/24	42	0.2	2.2	2	4.1	1	0.3	1		0
26/34	71	0.4	13	1	13	1		0		0
236/4	64	0.2		0		0		0		0
23/23	40	16.1		0		0		0		0
245/3	67	0.2	2.0	9	0.9	2	0.3	2	3.2	5
235/4	63	0.2	1.4	7	1.1	1	1.2	2	1.6	4
245/4	74	0.8	27	130	19	37	24	57	41	36
25/34	70	1.1	6.7	56	7.7	30	5.6	25	8.1	1
24/34	66	0.8	4.4	102	4.7	30	3.8	41	4.9	31
236/25	95	0.4	12	103	11	35	12	41	13	27
236/24	91	0.4	6.8	4	7.8	3	3.5	1		0
23/34	56	0.2	5.1	10	1.2	1	4.5	5	6.8	4
235/25	92	0.4	7.9	40		0	4.4	16	10	24
236/23	84	0.6	6.3	38	14.3	1	2.5	15	8.6	22
235/24+245/25	90+101	1.3	12	130	14	37	11	57	13	36

Table II continues to next page

Table II continues from previous page

Structure	IUPAC#	MDL	All age groups		Age 18-34		Age 35-50		Age 51-75	
			Average	n	Average	n	Average	n	Average	n
245/24	99	1.3	36	128	20	35	32	57	59	36
235/23	83	0.8	3.6	33	2.8	3	1.9	11	4.6	19
245/23	97	1.0	3.4	49	3.5	26	3.3	22	3.4	1
234/25	87	1.7	7.8	125	7.6	37	6.4	53	10	35
DDE+234/24	DDE+85	1.3	458	130	323	37	439	57	627	36
236/236	136	0.8	10	35	4.9	4	4.9	13	15	18
236/34	110	2.7	11	66	8.0	18	7.1	30	20	18
34/34	77	1.3	2.7	4	0		0	2.7	4	
2356/25	151	1.1	34	32	6.9	1	17.0	16	55	15
2346/25	144	0.4	1.8	34	1.0	6	1.5	11	2.3	17
2356/24+235/34	147+109	0.8	16	52		0	9.8	26	22	26
345/24+236/245	123+149	1.9	9.0	80	11.2	37	7.5	38	5.2	5
245/34	118	1.3	49	130	34	37	41	57	76	36
2356/23	134	1.7	8.2	30	8.9	1	12.6	12	5.0	17
2345/4	114	0.2	3.4	62	0.9	16	1.7	28	8.3	18
235/245	146	4.2	35	127	23	34	31	57	55	36
245/245	153	4.6	236	130	115	37	211	57	400	36
234/236	132	4.4	6.8	57.4	3	5.9	2		0	
234/34	105	0.4	8.8	128	7.6	37	8.6	55	10	36
2345/25	141	1.1	3.1	27	4.3	6	3.0	13	2.3	8
2356/236	179	0.6	4.9	31	1.7	1	2.4	16	8.0	14
2345/24	137	0.4	6.0	120	2.9	28	5.4	57	9.5	35
2346/236	176	0.2	1.6	11	0.2	1	1.8	8	1.6	2
234/235	130	0.2	4.9	62	2.3	3	3.4	25	6.3	34
236/345+234/245+2356/34	164+163+138	2.1	115	130	60	37	104	57	189	36
2346/34	158	0.2	2.3	91	2.2	25	2.5	42	2.2	24
2345/23	129	0.2	1.0	33	0.7	16	1.8	11	0.4	6
2356/245	187	1.0	43	128	23	37	40	57	71	34
2346/245	183	0.6	12	123	3.1	35	7.8	55	29	33
234/234	128	0.2	9.4	108	5.5	30	6.3	46	17	32
23456/25	185	0.2	1.4	74	2.1	21	0.7	31	1.5	22
2345/236	174	1.1	4.5	61	4.3	17	4.3	27	5.0	17
2356/234	177	1.1	7.0	113	5.9	22	6.6	56	8.3	35
2346/234	171	1.0	14	75	9.9	12	13	43	20	20
2345/34	156	0.6	16	126	7.8	33	14	57	27	36
2346/2356	201	1.0	10	66	7.0	5	6.7	27	14	34
2345/235	172	0.4	8.8	113	6.0	22	7.5	56	13	35
2345/245	180	3.3	98	130	36	37	85	57	181	36
23456/236	200	0.2	14	12	5.0	3	34	4	3.9	5
MIREX		5.0	35	117	18	26	30	56	56	35
2345/234	170	1.9	26	129	11	36	23	57	47	36
23456/34	190	0.4	5.9	128	5.3	35	4.8	57	8.4	36
2345/2356	199	0.4	28	129	14	37	25	57	47	35
23456/245	203	0.6	11	126	4.3	34	11	57	18	35
2345/2346	196	0.4	4.2	112	2.7	20	3.5	57	6.2	35
23456/234	195	0.4	5.2	97	3.3	12	4.0	51	7.5	34
2345/2345	194	0.6	29	78	14	4	21	39	39	35
23456/2345	206	0.4	8.6	109	3.4	22	7.3	54	14	33

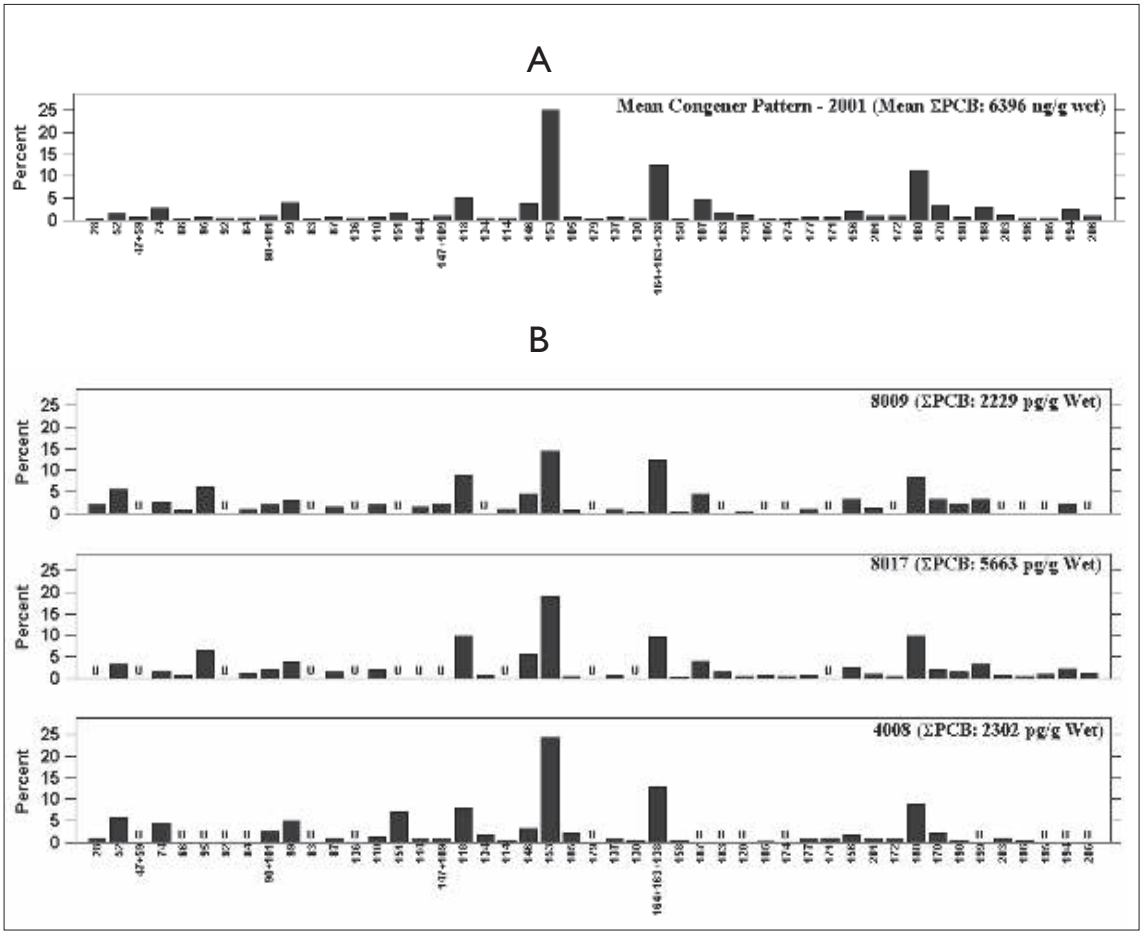

Figure 3. Mean PCB congener pattern in blood from 59 Yupiks aged 35 and over, analyzed in 2001 (A), with data normalized as percentages of total PCBs, and congener patterns from three individuals with elevated levels of transient PCB congeners (B). The mean pattern is very similar to that reported for the average US population (19), but the three individuals shown in B demonstrate the presence of a much higher proportion of lower chlorinated, transient congeners, indicative of recent exposure.

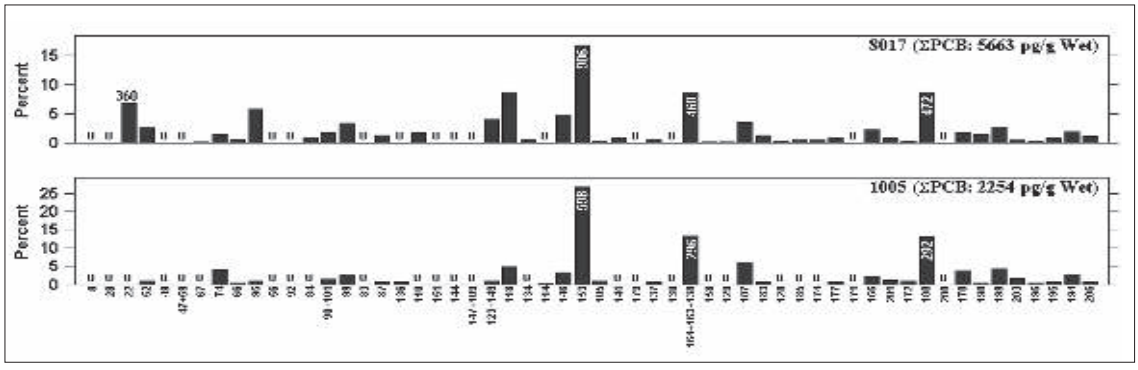

Figure 4. PCB congener pattern in blood taken from one individual (male, age 35, from the NEC group) in 2001 (upper) and from a repeated blood sample in 2003 (lower). Note the decrease in serum levels over time, and the shift in the PCB congener pattern.

the NEC group) who gave two blood samples, one obtained in 2001 and the other in 2003. His wet weight concentration was 5.7 ppb in 2001, but only 2.3 ppb in 2003, in spite of the general tendency for levels to increase with age. There was a decrease of between 34-36% in each of the three most persistent congeners (PCBs 138, 153 and 180) over this period of time. However, his congener profile also changed significantly over this period, with a significant reduction in the percentage of transient PCB congeners. This suggests significant recent exposure before the blood sample was drawn in 2001, followed by significant metabolism of the transient congeners. There was also some reduction in the more persistent congeners over time. This individual was selected for repeat analysis because of his high blood PCB 22 levels in 2001, but it was not present in any significant amount in 2003.

DISCUSSION

While there have been a number of studies of indigenous populations in many of the northern countries, there has been relatively little study in Alaska. The Arctic Monitoring and Assessment Programme (AMAP) was created in 1991 to begin monitoring human health in the Arctic. Hansen (13) reported lipid-adjusted levels of 14 PCB congeners and DDE in maternal plasma of Arctic residents of Canada, Greenland, Sweden, Norway, Iceland and Russia. The PCB values ranged from 167 μg/kg (ppb lipid) in Canada, to 571 ppb in Greenland. The AMAP (14) reported on PCB levels in several different districts of Greenland, finding an average total, lipid-adjusted PCB level of 2,160 ppb. They noted significant variation between different districts, with greater levels on the east than west coast. Thus, the level of PCBs in the Yupiks are within the ranges reported for other Arctic people, although there is considerable variation among the various groups studied.

One of the few reports from Alaska is that of Rubin *et al*. (15), who studied Alaska Native women in samples collected between 1980 and 1987. The mean total PCB level (sum of 28 congeners) was 7.56 ppb (1,153 ppb lipid-adjusted). They reported total PCB levels to be higher in the northern and southwestern parts of Alaska than in the interior or central south, perhaps reflecting a greater consumption of marine mammals in these regions. In the northwestern part, (which would include St. Lawrence Island, although residents here were not subjects in the study), the mean total PCB level was 9.48 ppb. Our PCB results are somewhat lower than those reported by Rubin et al. (15), perhaps reflecting a decrease in PCB levels over time. However, our results indicate that the Yupik people have significantly larger body burdens of PCBs than the background US and Canadian population.

PCB levels generally increase with age and, in the Yupiks over the age of 30, the mean PCB values were 7.5 ppb wet weight (1,506 ppb lipid-adjusted). The levels of PCBs in individuals from the general US population without unusual exposure was reported by the ATSDR (1) to be 0.9-1.5 ppb (wet weight). On average, fasting human serum contains about 0.6% fat, which means that a total PCB level of 1.5 ppb wet weight is equivalent to 250 ppb lipid. Thus, on average, the Yupik population of St. Lawrence Island shows elevated levels of total PCBs as compared to the general North American background.

Another comparison population, which we studied using identical analytical methods, is a sample of 753 adult Mohawk Native Americans from Akwesasne, located at the New York, Ontario and Quebec junction. While the Mohawks are traditionally fish eaters, the local fish are contaminated with PCBs from releases from aluminum foundries (16). Upon advice from tribal leaders some, but not all, of the Mohawks have reduced their consumption of local fish. We found that the Mohawks (30 years of age and older) had a mean PCB concentration somewhat lower than that of the Yupiks [3.2 ppb wet weight (706 ppb lipid-adjusted)], but also peresented a much larger range of values (0.29- 48.3 ppb) (17), probably reflecting the greater variability in diet.

Our study is not without limitations. Subjects were not randomly recruited, but were invited to participate by the project staff on the Island based on their age and whether, or not, their families had camps at the NEC. We did not obtain medical histories, nor information on medications, such as lipid-lowering drugs, as this was not a health effects study. We also do not, at present, have detailed dietary histories on the individuals studied. However, we do not believe that the procedures used are likely to have introduced significant bias in providing a profile of serum PCB levels as a function of age and residence.

The results provide some support for the community belief that the FUDS at the NEC contributes to the body burden of contaminants among those individuals who spend significant time at camps near the site. The mean serum PCB levels in those persons whose families have camps at the NEC tended to be higher than those of the other Yupiks, although the overall difference did not quite reach the level of statistical significance. Although ingestion of food is a likely route and source of exposure, it is not clear what is the dominant exposure pathway among these individuals. While detailed dietary information is currently being gathered, it is not available at present. A number of the men were employed at the military site during its operation and during the remediation of the site. Insofar as is known, PCBs were used primarily at the electrical generating facilities and are also known to be associated with the paint used at the sites. It is clear that contamination from metals and polyaromatic hydrocarbons has spread into the drainage basin of the Suqi River and into the Suqi estuary (8), although the extent of this spread is unclear. At present, there is little data on the spread of PCBs. Some fish collected from the Suqi River have shown measurable levels of PCBs (8), but most fish in the river are primarily anadromous, and would not be expected to be highly contaminated. The marine mammals would also not be expected to be contaminated from this site to any great extent, since none of them remain at the site for extended periods. Reindeer graze in the vicinity, but they are highly mobile and it is unlikely that they are the major source of contamination. Other produce from the NEC includes greens and berries. It is possible that contaminated particulates, including significant dust and suspended particles from the recent remedial activities being conducted, could contribute to the exposure if the produce were not carefully washed.

The presence of relatively high levels of transient, lower chlorinated congeners in a subset of Yupiks is an indication of recent exposure (18). From the data in Table II, one can get a good indication of how transient a

congener is by comparing levels in persons of different ages. For the more persistent congeners (PCBs 118, 138, 153, 180) the average levels clearly increase with age, whereas there is little, or no, age-dependence for the more transient congeners. The rather high amounts of PCB 22, a transient congener, in 8 of the 20 people with ties to the NEC is significant, as is the fact that the highest levels of PCB 22 were found in the youngest age group. However, in spite of personal interviews with most of the individuals with this congener, it was not possible to determine a common source of exposure. These individuals with PCB 22 were primarily members of three families. Some, while having spent significant periods of time at the NEC, reported that they had not been there for several years. However, all of them reported that relatives and friends who did go to the NEC brought back foodstuffs which were shared, most commonly salmon berries, greens, or reindeer. Thus, it is not certain that this exposure was tied to the NEC FUDS, even though no one in either of the other two groups showed this transient congener.

There is also a FUDS at the community of Gambell. While there is significant metal and volatile organic contamination at Gambell, there is little evidence for PCBs. The Gambell geology and geography are significantly different from those of the NEC. The FUDS and community of Gambell is situated on a highly permeable cobble spit and any spilled or released contaminants quickly migrate to the underlying permafrost, whereas at the NEC, the relatively impermeable soils retain the contaminants near the surface. It seems likely that the major source of PCBs for the residents of Gambell is global and regional atmospheric transport of these substances, which then bioconcentrate after depositing in the snow, soils and water. The mean PCB concentration of about 4 ppb (785 ng/g lipid) is somewhat lower than the wet weight values reported for Inuits of Greenland (13.3 ppb) (15), probably secondary to the fact that the levels of contaminants in marine mammals in the north Atlantic is greater than that in the north Pacific. The predominant air currents in far Western Alaska come primarily from Russia, Japan and China, whereas the northern Atlantic receives sources from the highly industrialized US, Canada and Western Europe.

The levels of PCBs were non-significantly greater at Savoonga than at Gambell, even though the mean age of the subjects was 2 years higher in Gambell. It is likely that the Yupik peoples tradition of sharing food is a factor here. Those residents with camps at the NEC live principally in Savoonga, and probably shared enough of the foods they brought back to Savoonga to raise the levels of other inhabitants.

In summary, our results suggest that the former military site located at the NEC on St. Lawrence Island may contribute to the PCB exposure of the native residents, but that the predominant source is global transport, deposition and bioconcentration in foodstuffs.

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