Prenatal Exposure of the Northern Québec Inuit Infants to Environmental Contaminants

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The Inuit population residing in Nunavik (northern Québec, Canada) relies on species from the marine food web for subsistence and is therefore exposed to high doses of environmental contaminants such as polychlorinated biphenyls and methylmercury and to a lesser extent lead. In view of the neurotoxic properties of these substances following developmental exposure, we initiated a study on infant development in this remote coastal population. Here we report the magnitude of prenatal exposure to these contaminants and to selective nutrients in Inuit mothers and their newborns who were recruited on the Hudson Bay coast. We conducted interviews during the women's pregnancies and at 1 and 11 months postpartum and collected biological samples for mercury, lead, polychlorinated biphenyls (PCBs), and chlorinated pesticides analyses as well as selenium and N-3 polyunsaturated fatty acids (n3-PUFA). Cord blood, maternal blood, and maternal hair mercury concentrations averaged 18.5 μg/L, 10.4 μg/L, and 3.7 μg/g, respectively, and are similar to those found in the Faroe Islands but lower than those documented in the Seychelles Islands and New Zealand cohorts. Concentrations of PCB congener 153 averaged 86.9, 105.3, and 131.6 μg/kg (lipids) in cord plasma, maternal plasma, and maternal milk, respectively; prenatal exposure to PCBs in the Nunavik cohort is similar to that reported in the Dutch but much lower than those in other Arctic cohorts. Levels of n3-PUFA in plasma phospholipids and selenium in blood are relatively high. The relatively low correlations observed between organochlorine and methylmercury concentrations may make it easier to identify the specific developmental deficits attributable to each toxicant. Similarly, the weak correlations noted between environmental contaminants and nutrients will facilitate the documentation of possible protective effects afforded by either n3-PUFA or selenium against neurotoxic contaminants. *Key words*: Canada, chlorinated pesticides, environmental contaminants, human exposure, Inuit, lead, mercury, polychlorinated biphenyls, polyunsaturated fatty acids, selenium. *Environ Health Perspect* 109:1291–1299 (2001). [Online 30 November 2001]
http://ehpnet1.niehs.nih.gov/docs/2001/109p1291-1299muckle/abstract.html

Mercury is a heavy metal that enters the environment from both natural and anthropogenic sources. A natural element in the earth's crust, Hg is converted by bacteria to methylmercury (MeHg) in lakes and oceans and bioaccumulates in the marine food web. Hg is also released into the environment through human activities, mainly burning of fossil fuels and waste incineration. Polychlorinated biphenyls (PCBs) and chlorinated pesticides are organochlorine compounds (OCs), a family of lipophilic compounds used extensively in North American and European industry and agriculture from 1930 to the mid-1980s (*1,2*). OCs have been dispersed widely in the environment. Even in industrialized countries where they are no longer being manufactured, they are still detectable in the environment because they resist degradation, are released into the environment by inadvertent spills and careless disposal, and in some countries are still in use (*3*). The PCBs used for industrial purposes were complex mixtures of various congeners, each with its own unique molecular structure and potentially different toxicological effects.

OCs and heavy metals are carried from industrialized countries to the Arctic by long-range atmospheric transport, waterways, and oceanic currents (*4*). Due to their high lipophilicity and resistance to biodegradation, OCs bioaccumulate in fatty tissues of organisms and are biomagnified through the food chain, producing relatively high concentrations in the fat of predator species (*5*). In lakes and oceans, Hg is converted by bacteria to methylmercury (MeHg) and bioaccumulates in fish and in the meat of sea mammals who eat MeHg-contaminated fish. Because fish and marine mammals represent an important part of the diet of the Inuit, exposure to OCs and Hg are of particular interest for public health authorities in the Arctic regions. Elevated levels of PCBs and Hg in Inuit adults have been reported by Dewailly et al. (*6,7*) in northern Québec and by Bjerregaard et al. (*8*) in Greenland. High PCB and Hg concentrations have been reported by Bjerregaard and Hansen (*9*) among Greenlandic Inuit mothers and newborns.

The developmental neurotoxicity of MeHg first became evident during the 1950s at Minimata Bay, Japan, which was heavily contaminated with Hg from industrial effluent entering the bay. A second well-documented MeHg poisoning occurred in Iraq in the 1970s when seed grain contaminated with a MeHg fungicide was used to make homemade bread (*10*). The neurodevelopmental effects seen in children exposed *in utero* in both Japan and Iraq included severe sensory and central nervous system impairments (*11,12*). Three well-designed, prospective, longitudinal studies that examined the effects of prenatal exposure to lower doses of MeHg on childhood cognitive function were performed in New Zealand, Faroe Islands, and Seychelles Islands (*13–17*). In the Faroe Islands study, MeHg exposure was found to be related to poorer performance in the domains of fine motor function, attention, language, visual–spatial abilities, and verbal memory (*15,18*). Although no adverse effects were found in the Seychelles study (*16,19,20*), the New Zealand study, which was similar in exposure and research design, found

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We are grateful to the Nunavik population for their participation in this research. We thank the medical and health care professionals from the Inuulitsivik Health Center and the nursing stations in Puvirnituq, Inukjuaq, and Kuujjuaraapik for their assistance in recruiting this cohort. We gratefully acknowledge the support of the Nunavik Nutrition and Health Committee, the Municipal Councils of Puvirnituq, Inukjuaq, and Kuujjuaraapik, the Pauktuutit Inuit Women's Association, and the Nunalituqait Ikaluqatigiitut Association. The technical assistance of the professionals from the *Centre de Toxicologie du Québec* regarding laboratory analysis is acknowledged. We are grateful to G. Lebel for his involvement in the management of the exposure data, and to C. Bouffard, L. Chiodo, J. Gagnon, E. Lachance, K. Poitras, B. Tuttle, and C. Vézina for their committed involvement in all phases of the data collection and instrument coding processes.

This study was made possible by grant number R01-ES07902 from the National Institute of Environmental Health and Sciences/NIH, and grants from Indian and Northern Affairs Canada (Northern Contaminants Program), Health Canada, and Hydro-Québec (Environmental Child Health Initiative).

Received 16 March 2001; accepted 1 June 2001.

poorer performance in domains similar to those observed in the Faroe study (*13,14*).

The developmental toxicity of heat-degraded PCBs was first recognized in Japan in the late 1960s and in Taiwan in the late 1970s. In both countries, infants born to women who had consumed rice oil contaminated with mixtures of PCBs and polychlorinated dibenzofurans (PCDFs) exhibited skin rashes and poorer intellectual functioning during infancy and childhood (*21,22*). The effects of prenatal exposure to background levels of PCBs and other OCs from environmental sources have been studied since the 1980s in prospective longitudinal studies. In Michigan, prenatal PCB exposure was associated with poorer visual recognition memory in infancy (*23–25*), an effect recently confirmed in the Oswego study (*26*). In North Carolina, deficits in psychomotor development were seen in the most highly exposed children through 24 months of age (*27,28*). In Michigan, prenatal PCB exposure was linked to poorer intellectual function at 4 and at 11 years (*24,29*), a finding confirmed at 42 months in the Netherlands (*30*).

Low levels of postnatal lead exposure have been linked to poor childhood cognitive performance in several studies (*31,32*). Although prenatal lead exposure at background levels is associated with adverse effects on cognitive function during infancy, these effects have generally been transient and are no longer evident during childhood (*33*).

Neurotoxic effects of MeHg might be attenuated by protective effects of nutrients such as selenium, and adverse effects from OCs might be attenuated by a high intake of N-3 polyunsaturated fatty acids (n3-PUFA). Increased intake of Se and n3-PUFA would be expected in a population who consume relatively large quantities of fish and marine mammals. Although the effects of Se on MeHg toxicity have not been well documented in humans, there is evidence from over 40 animal studies that Se can influence the deposition of Hg in the body and protect against its toxicity (*34*). n3-PUFA, especially DHA, are essential for brain development (*35*). DHA deficiency impairs learning and memory in rats (*36*), and rodents and nonhuman primates fed diets severely deficient in n3-PUFA show altered visual function and behavioral problems (*37*). Supplementation of n3-PUFA can enhance visual acuity and brain development in preterm human infants (*38,39*), although it is not clear whether increased levels of these nutrients can benefit full-term infants (*40*). Therefore, n3-PUFA may protect against neurotoxicity associated with prenatal exposure to environmental contaminants.

We are currently conducting a prospective longitudinal study to examine the effects of pre- and postnatal exposure to OCs and MeHg on cognitive and behavioral development in a sample of Inuit infants in northern Québec (Nunavik). Whereas Dewailly et al. (*6,7*) examined contaminant exposure in Nunavik Inuit adults, here we focus specifically on levels of exposure in infants during the period of development when humans appear to be most vulnerable. We report on the concentrations of OCs, Hg, and lead in biological samples from our Nunavik cohort of mothers and newborns and compare their levels with those found in other developmental studies. In addition, we examine the degree to which exposure to neurotoxicants tends to be elevated in the same individuals. Finally, in view of the unique source of exposure to OCs and heavy metals in this population (marine food web), we document circulating levels of Se and n3-PUFA, which may afford protection against exposure to neurotoxicants.

Materials and Methods

Population. Pregnant Inuit women from Nunavik were invited to participate in a study focusing on infant health and development. The Nunavik region is located north of the 55th parallel, about 1,500 km from Montreal and 2,000 km from the Great Lakes in the United States (Figure 1). About 7,660 Inuit live in 14 villages scattered along a 2,000-km seashore line along Hudson Bay, Hudson Strait, and Ungava Bay. The study participants were living in Puvirnituq (50%), Inukjuaq (37%), and Kuujjuaraapik 13%), the three largest communities on the Hudson Bay coast.

Procedures and variables. From November 1995 to March 2001, a midwife or nurse in each of three targeted communities gave our research assistant the name of each pregnant woman shortly after her first prenatal visit. Our research assistant then contacted the potential participant by telephone and invited her to meet at the community nursing station to learn about the study's objectives and procedures. Women without telephones (24% of the sample) were contacted by an announcement on the community's FM radio station asking them to contact our research assistant. A detailed informed consent was obtained from each participating mother. The research procedures were approved by the human subjects committees of Laval University and Wayne State University. Interviews were conducted in the community's nursing station at midpregnancy and at 1, 6, and 11 months postpartum by trained research assistants to assess the mothers' socioeconomic and personal characteristics. Among the 333 Nunavik women invited to participate in this study through April 2000, 13.5% were excluded because a newborn from the same mother had been previously recruited, 2.4% could not be contacted by our research assistants, and 18.5% refused to participate. Among the women interviewed prenatally, 4.5% were subsequently excluded for miscarriage or perinatal or postnatal mortality; 5.6% for failure to obtain the biological samples needed to document maternal PCB and Hg body burden; 3.4% for relocation to another village; and 2.8% for the adoption of the newborn by residents of another village; 3% chose to withdraw from the study.

A 30-mL blood sample was obtained from the umbilical cord after it was severed. A 12.5-mL blood sample was obtained from each participating mother at delivery or within a few weeks thereafter [median = 6 days; interquartile range (IQR) = 0–6.6 weeks]. Two 5-mm diameter hair samples were collected from the mother, one at the prenatal interview (median = 21 weeks of pregnancy; IQR = 17–28 weeks) and one at the 1-month postnatal interview (median = 35 days; IQR = 17–59 days). A 10-mL milk sample was collected from breast-feeding mothers at the 1-month postnatal interview (median= 35 days; IQR = 17–59 days). PCB congener and chlorinated pesticide concentrations were measured in cord and maternal plasma and breast milk. Hg concentrations were determined in cord and maternal whole blood, as well as in the hair sample collected postnatally, which was cut into three segments of 3 cm in length, with each segment corresponding to a trimester of pregnancy. The hair samples were long enough to represent the whole pregnancy (≥ 9 cm) for all participants except one for whom the sample collected prenatally was used in addition to the postnatal sample. Lead concentrations were measured in cord

Figure 1. Nunavik Region in northern Québec, Canada.

blood, Se concentrations in cord and maternal blood, and n3-PUFA in cord plasma.

Laboratory procedures. Analyses of OCs, Hg, lead, and Se were performed at the laboratory of the *Centre de Toxicologie du Québec*, which is accredited by the Canadian Association for Environmental Analytical Laboratories. Blood samples containing EDTA as the anticoagulant were centrifuged and the plasma was collected in glass vials prewashed with hexane. Plasma samples were stored at –80°C until analysis. A 1:1:3 mixture of ammonium sulfate:ethanol:hexane was first added to the plasma to extract OCs. The extracts were then concentrated and purified on two Florisil columns (60–100 mesh; Fisher Scientific, Nepean, Ontario, Canada). The 14 most prevalent PCB congeners (IUPAC nos. 28, 52, 99, 101, 105, 118, 128, 138, 153, 156, 170, 180, 183, and 187) and 11 chlorinated pesticides or their metabolites [aldrin, α-chlordane, γ-chlordane, *p,p´*-dichlorodiphenyltrichloroethane (DDT), *p,p´*-dichlorodiphenyldichloroethene (DDE), hexachlorobenzene (HCB), β-hexachlorocyclohexane (HCH), mirex, *cis*-nonachlor, *trans*-nonachlor, oxychlordane] were measured in the purified extracts with an HP 5890 high-resolution gas chromatograph equipped with dual-capillary columns (HP Ultra I and Ultra II) and dual Ni-63 electron capture detectors (Hewlett-Packard, Palo Alto, CA, USA). Quality control procedures were described previously (*41*). Percent recovery ranged from 89% to 100%, and the detection limit was approximately 0.02 µg/L for all compounds. Coefficients of variation (n = 20, different days) ranged from 2.1% to 9.1%. Biases—the difference between the concentration of the reference material and the concentration found using the analytic method—ranged from –10.9% to 3.8%.

The same OCs were measured in milk samples using a similar procedure. Compounds were initially extracted from milk using a mixture of acetone/hexane, followed by a second extraction with hexane alone. Combined organic phases were washed with deionized water, concentrated, and purified on activated Florisil columns. A mixture of dichloromethane/hexane was used to elute the compounds, which were separated and quantified by HRGC as described above. Detection limits vary from 0.6 to 2.0 µg/kg lipids for the various OCs. We used two certified milk reference materials (CRM 188 and 450) to assess precision and accuracy of the method. Coefficients of variation varied from 10% to 20% and biases from 5% to 15%, depending on the specific organochlorine. Because OCs distribute mainly in body fat, concentrations in plasma and milk samples are reported in micrograms per kilogram of lipids. We measured total cholesterol, free cholesterol, and triglycerides in plasma samples by standard enzymatic procedures, but determined phospholipids according to the enzymatic method of Takayama et al. (*42*), using a commercial kit (Wako Pure Chemical Industries, Richmond, VA, USA). We estimated the concentration of total plasma lipids according to the formula developed by Phillips et al. (*43*). We weighed an aliquot of the milk fat extract to determine the concentration of lipids in milk samples.

We determined total mercury concentrations in samples of cord and maternal blood and maternal hair by cold vapor atomic absorption spectrometry. Samples were digested with nitric acid and mercury was reduced by adding anhydrous stannous chloride ($SnCl_2$) and cadmium chloride ($CdCl_2$). Metallic mercury was volatilized and detected by atomic absorption spectrometry (Model 120; Pharmacia, Piscataway, NJ, USA). The detection limit for blood mercury analysis was 1.0 nmol/L. Quality control procedures were described previously (*41*). Coefficients of variation (n = 50, different days) at levels of 40 and 90 nmol/L (in-house reference materials) were 5% and 5.5%, respectively. Relative biases were 2.4% and –0.4%, respectively. The detection limit for hair mercury analysis was 1 nmol/g. We obtained accuracy and precision data using certified reference material through Health Canada's hair mercury inter-laboratory comparison program. Coefficients of variation (n = 50, different days) were 4.8% for the 12.3 µg/g reference specimen (CRM 397) (*44*) and 4.3% for the 4.42 µg/g reference specimen (CRM 13) (*45*). The relative biases were –2.2% and +1.9%, respectively.

We diluted an aliquot of whole blood with a mixture of nitric acid, ammonium phosphate, and Triton X-100 and analyzed it for lead by graphite furnace atomic absorption with Zeeman background correction (model ZL 4100; Perkin Elmer, Norwalk, CT, USA). The detection limit of the method is 50 nmol/L. We used four reference specimens of 2.8, 2.1, 1.2, and 0.3 µmol/L to calibrate the analytic method for lead; the corresponding coefficients of variation were 2.4%, 2.9%, 2.3%, and 5.0%, and relative biases were +2.0%, +2.2%, –0.8%, and –0.2%, respectively (n = 10).

We determined blood Se concentrations with inductively coupled plasma mass spectrometry (ICP-MS) using state-of-the-art instrumentation (PE Elan 6000; Perkin Elmer). Samples were diluted and aspirated into the instrument. We performed matrix-matched calibration using a pool of normal blood. We obtained accuracy and precision data using reference material from our ICP-MS comparison program. The detection limit was 0.1 µmol/L. The coefficient of variation (n = 37, different days) at a level of 2.7 µmol/L was 5.9%, and the bias was –0.4%.

The fatty acid composition of plasma phospholipids was determined by the Lipid Analytical Laboratory at the University of Guelph (B.J. Holub). A 200-µL aliquot of plasma was extracted following the addition of chloroform:methanol (2:1, v/v), in the presence of a known amount of internal standard (diheptadecanoyl phospholipid).

Table 1. Characteristics of participants.

Characteristics	Total no.	Mean	SD	Range	No.	Percent
Marital status (% single)	175				53	30.3
Age	175	24.6	5.67	14.1–40.7		
Education	175	8.8	1.62	6.0–14.0		
Socioeconomic status[a]	172	25.6	10.39	8.0–50.0		
Unskilled laborers					55	32.0
Semiskilled workers					51	29.7
Skilled craftsmen, clerical, and sales					52	30.2
Technical, small business					14	8.1
Language of interview	175					
English					121	69.2
French					23	13.1
Inuktitut					31	17.7
Breast-feeding status (% breast-fed)[b]	146				140	95.9

[a]Hollingshead Index (*46*) for the mother and her partner or, if she was not self-supporting, for her primary source of support (usually her parents). [b]Among nonadopted infants.

Table 2. Concentrations of mercury in blood and hair.

Mercury concentrations	No.	Arithmetic mean	Geometric mean	SD	Range	IQR
Cord blood (µg/L)	95	22.7	18.5	0.4	2.8–97.0	12.0–27.2
Maternal blood (µg/L)	130	12.6	10.4	0.4	2.6–44.2	6.6–17.0
Maternal hair (µg/g)[a]	123	4.5	3.7	1.9	0.3–14.0	2.5–6.2
Maternal hair, first trimester (µg/g)	124	4.4	3.5	2.0	0.2–18.5	2.2–6.1
Maternal hair, second trimester (µg/g)	124	4.6	3.6	2.1	0.4–16.3	2.3–6.6
Maternal hair, third trimester (µg/g)	125	4.4	3.7	1.9	0.3–12.8	2.4–6.0

[a]Average of concentrations found at first, second, and third trimesters of pregnancy.

Total phospholipids were isolated from the lipid extract by thin-layer chromatography using heptane:isopropyl ether:acetic acid (60:40:3, v/v/v) as the developing solvent. After transmethylation using BF3/methanol, the fatty acid profile was determined by capillary gas-liquid chromatography. Fatty acid concentrations in plasma phospholipids were expressed as percentages of the total area of all fatty acid peaks from C14:0 to C24:1 (percent weight).

Results

Sample sociodemographic characteristics are summarized in Table 1. A large proportion of women were single, 15% were younger than 18 years, and 5% were older than 35. Only 17% of participants had obtained their high-school diploma. Twenty-three percent of the participating women were primiparous, and 32% had already delivered three or more children. Most of the interviews were conducted in English. Most women (90%) smoked during pregnancy (data not shown). Descriptive statistics for the blood and hair Hg analyses are presented in Table 2. The average Hg concentration is 1.8 times higher in cord blood than in maternal blood, and the average hair Hg concentrations are similar during all three trimesters of pregnancy. The intercorrelations among blood and hair Hg concentrations are presented in Table 3. The cord blood–maternal blood correlation is very high, and even a little higher when only maternal blood samples collected within 1 month of delivery are considered (n = 51, r = 0.93). Cord blood Hg concentrations are moderately related to maternal hair Hg concentrations. Given that the cord blood Hg concentration primarily reflect recent exposure, it is not surprising that the cord blood Hg concentrations are more strongly related to third-trimester hair Hg concentrations than to those measured in samples corresponding to earlier trimesters. Cord blood lead concentrations average 0.2 µmol/L, which corresponds to 41.4 µg/L [n = 95, geometric mean = 0.2 µmol/L, geometric standard deviation (SD) = 2.0, range = 0.0-0.9, IQR = 0.1–0.3 (data not shown)].

Tables 4, 5, and 6 show the descriptive statistics for the 14 PCB congeners and 11 chlorinated pesticides in cord plasma, maternal plasma, and breast milk, respectively. The most prevalent congeners in all three media are 153, 138, and 180. These three congeners represent about 66% of the total concentration of the 14 PCB congeners in all three media. The next most prevalent congeners are 99, 118, 170, and 187, and the least prevalent are 52, 101, 105, 156, 183, and 187. The intercorrelations among congeners detected in at least 70% of cord plasma and breast milk samples are presented in Table 7. These intercorrelations are very high in cord plasma, ranging from 0.71 to 0.98 (median r = 0.90). The intercorrelations in maternal plasma are similar [median r = 0.90; range = 0.62–0.99 (data not shown)]. The magnitude of the intercorrelations among the seven congeners that are readily detected in cord and maternal plasma is similar in breast milk, but the intercorrelations with the lowest chlorinated congeners (52, 101, and 105) are somewhat weaker. On the basis of these data, it seems reasonable to use PCB congener 153, the most prevalent congener, as a marker for exposure to the environmental PCB mixture in the Arctic.

The predominant chlorinated pesticides are *p,p′*-DDE, HCB, oxychlordane, and *trans*-nonachlor (Tables 4, 5, and 6). The pesticide *p,p′*-DDT, which is much less persistent than its main metabolite, *p,p′*-DDE, constitutes a very small proportion (< 8%) of the total DDT (*p,p′*-DDT + *p,p′*-DDE) concentrations in biologic samples. The intercorrelations among the chlorinated pesticides detected in at least 70% of samples are presented in Table 8 for the cord plasma and breast milk samples. These intercorrelations are strong in both cord plasma (median r = 0.76) and breast milk (median r = 0.79). The chlorinated pesticides measured in both media are strongly associated with PCB congener 153, except for *p,p′*-DDT where the association is moderate, presumably because the *p,p′*-DDT concentration is low, close to the detection limit, and is more transitory and more specifically reflective of recent exposure.

PCB and chlorinated pesticide concentrations are lowest in cord plasma and highest in breast milk. For example, the average cord plasma concentration of congener 153 is 84.4% of its average concentration in maternal plasma, and its average concentration in maternal plasma is 83.6% of that in breast milk. Although concentrations differed among the three media, correlations

Table 3. Intercorrelations among blood and hair mercury concentrations.

Source	Cord blood	Maternal blood	Hair, averaged	Hair, first trimester	Hair, second trimester	Hair, third trimester
Cord blood		0.88* (61)	0.64* (72)	0.42* (73)	0.55* (72)	0.80* (73)
Maternal blood			0.71* (95)	0.60* (96)	0.63* (96)	0.74* (97)
Maternal hair, averaged[a]				0.94* (123)	0.98* (123)	0.92* (123)
Maternal hair, first trimester					0.91* (123)	0.74* (124)
Maternal hair, second trimester						0.87* (124)

Values shown are Pearson r (n).
[a]Average of the total mercury concentrations found at first, second, and third trimesters of pregnancy. *$p \le 0.000$.

Table 4. Descriptive statistics for PCB congeners and chlorinated pesticides concentrations detected in at least 70% of cord plasma samples (n = 98).

	Percent detected	Arithmetic mean	Geometric mean	SD	Range	IQR	Total PCBs
PCBs (µg/kg)							
Congener 28	6.1						
Congener 52	24.5						
Congener 99	94.9	22.1	17.2	2.0	2.8–116.8	11.2–26.0	6.3
Congener 101	18.4						
Congener 105	14.3						
Congener 118	86.7	17.1	13.0	2.1	2.8–97.4	8.5–20.8	4.89
Congener 128	0						
Congener 138	100	70.7	54.8	2.0	10.1–313.1	34.0–92.4	20.2
Congener 153	100	116.0	86.9	2.2	13.4–550.9	51.8–148.7	33.1
Congener 156	38.8						
Congener 170	76.5	17.5	12.3	2.3	2.8–65.3	5.9–23.1	5.0
Congener 180	100	45.0	33.4	2.2	6.1–164.2	19.8–55.8	12.8
Congener 183	36.7						
Congener 187	93.9	20.6	16.7	1.9	3.8–65.3	11.6–27.8	5.9
Σ 14 congeners[a]		350.3	279.9	1.9	70.8–1420.1	180.4–436.1	
Chlorinated pesticides (µg/kg)							
Aldrin	0						
β-HCH	21.4						
p,p′-DDE	100	387.9	305.2	2.0	55.7–1773.4	208.2–467.3	
p,p′-DDT	71.4	16.6	13.6	1.9	4.2–58.2	7.5–21.2	
Mirex	31.6						
HCB	100	55.6	45.6	1.9	10.6–233.6	29.9–69.0	
α-Chlordane	0						
γ-Chlordane	0						
cis-Nonachlor	73.5	13.7	10.6	2.1	2.8–43.7	5.3–18.0	
trans-Nonachlor	100	60.6	48.2	2.0	7.4–196.0	33.0–77.8	
Oxychlordane	95.9	39.0	28.6	2.3	2.8–191.3	19.0–53.1	

[a]Sum of all 14 congeners including congeners not detected in at least 70% of samples.

among PCB congener 153 concentrations in cord plasma, maternal plasma, and breast milk are very high (cord plasma–maternal plasma, $r = 0.93$; cord plasma–breast milk, $r = 0.91$; maternal plasma–breast milk, $r = 0.95$). The strength of these associations does not change when the same Pearson correlation analyses are performed using only the maternal plasma samples collected within 1 month after delivery (data not shown).

The intercorrelations between PCB congener 153 and Hg are modest: cord PCB–cord Hg, $r = 0.24$; cord PCB–average hair Hg, $r = 0.34$; maternal PCB–average hair Hg, $r = 0.17$. The associations between concentrations of lead and Hg in cord blood are also low (0.21–0.29). The intercorrelations between cord blood lead and OC concentrations are even weaker, whether OCs are measured in cord plasma, maternal plasma, or breast milk (0.06–0.16).

Cord blood Se concentrations average 3.8 µmol/L (geometric mean = 3.5, SD = 1.4, range = 1.9–11.6, IQR = 2.8–4.3, $n = 93$). Maternal blood Se concentrations average 4.5 µmol/L (geometric mean = 4.1, SD = 1.4, range = 1.9–15.6, IQR = 3.2–5.0, $n = 130$). Docosahexaenoic acid (DHA) average 3.6% of total phospholipids in cord plasma (geometric mean = 3.5, SD = 1.4, range = 1.1–7.5, IQR = 2.7–4.3, $n = 97$). The intercorrelations among the environmental contaminants, Se and DHA are presented in Table 9. Cord blood Se concentrations are weakly associated with cord plasma PCB 153 but moderately associated with cord blood, maternal blood, and hair Hg concentrations. DHA is weakly correlated with PCB 153 and moderately associated with Hg concentrations. None of these nutrients are associated with cord lead concentrations.

Discussion

These data confirm that prenatal exposure to Hg among the Inuit of Nunavik is higher than that observed in general population samples in Canada and the United States (*41,47*). Hg concentrations reported in other cohorts are presented in Table 10. When compared with cohorts with relatively high concentrations that were selected to examine the neurobehavioral effects of prenatal Hg exposure, the Hg exposure in Nunavik Inuit is similar to that observed in the Faroe Islands first and second cohorts (*18,48*), slightly lower than in the Seychelles Islands cohorts (*17,20*), and substantially lower than in the highest exposed group in the New Zealand study (*14*). Hg exposure in the Inuit is also markedly lower than in another northern Québec aboriginal population, the Cree, in 1977–1978, but slightly higher than the average concentration observed in the same population more recently in 1992 (*49,50*). Compared with Greenlandic Inuit from the Disko Bay region (*9*), the Nunavik Hg exposure is lower. Because the intercorrelation between cord Hg and cord OC concentrations is low in the Nunavik cohort, it

Table 5. Descriptive statistics for PCB congeners and chlorinated pesticides concentrations detected in at least 70% of maternal plasma samples ($n = 159$).

	Percent detected	Arithmetic mean	Geometric mean	SD	Range	IQR	Total PCBs
PCBs (µg/kg)							
Congener 28	17.6						
Congener 52	56.6						
Congener 99	100	24.4	19.1	2.0	3.3–124.8	12.1–29.1	6.1
Congener 101	62.3						
Congener 105	74.2	4.4	3.4	2.0	0.95–25.8	2.0–5.4	1.1
Congener 118	98.7	18.1	14.3	2.0	1.3–100.9	8.9–19.9	4.7
Congener 128	15.1						
Congener 138	100	73.8	57.8	2.0	10.2–387.1	36.8–93.9	18.6
Congener 153	100	137.4	105.3	2.1	18.9–709.0	64.5–166.7	34.6
Congener 156	93.7	8.5	6.4	2.1	1.1–44.6	3.5–10.6	2.1
Congener 170	99.4	23.3	16.9	2.2	1.3–148.3	9.1–29.8	5.9
Congener 180	100	58.9	43.8	2.1	7.6–383.5	25.3–72.8	14.8
Congener 183	96.9	9.4	7.4	2.0	1.3–44.8	4.7–11.5	2.4
Congener 187	100	26.6	21.3	1.9	3.3–127.8	13.7–32.9	6.7
Σ 14 congeners[a]		397.3	313.2	2.0	71.3–1951.3	197.9–489.2	
Chlorinated pesticides (µg/kg)							
Aldrin	0.6						
β-HCH	74.2	7.0	5.6	1.9	1.3–31.2	3.6–8.9	
p,p´-DDE	100	386.3	307.3	1.9	58.8–2268.1	198.1–485.5	
p,p´-DDT	93.1	18.8	14.0	2.2	1.9–133.8	8.8–22.9	
Mirex	93.7	11.7	8.8	2.2	1.0–60.2	5.4–14.5	
HCB	100	51.1	42.0	1.9	6.7–352.6	28.6–63.6	
α-Chlordane	0						
γ-Chlordane	5.0						
cis-Nonachlor	96.2	16.9	13.2	2.0	1.3–114.4	9.4–20.0	
trans-Nonachlor	100	83.1	65.1	2.0	9.4–578.2	44.9–94.7	
Oxychlordane	100	57.6	42.5	2.1	6.1–390.1	26.3–66.8	

[a]Sum of all 14 congeners including congeners not detected in at least 70% of samples.

Table 6. Descriptive statistics for PCB congeners and chlorinated pesticides concentrations detected in at least 70% of breast milk samples ($n = 116$).

	Percent detected	Arithmetic mean	Geometric mean	SD	Range	IQR	Total PCBs
PCBs (µg/kg)							
Congener 28	41.0						
Congener 52	83.8	7.1	4.2	3.0	0.4–45.1	2.7–9.0	1.5
Congener 99	98.3	35.5	27.4	2.1	2.7–166.8	18.1–41.2	7.5
Congener 101	88.9	6.4	4.3	2.6	0.3–38.2	2.8–7.7	1.3
Congener 105	85.5	4.9	3.2	2.5	0.3–42.6	1.9–5.9	1.0
Congener 118	100	23.1	18.6	1.9	3.7–108.1	12.6–26.0	4.9
Congener 128	56.4						
Congener 138	99.1	96.7	78.2	1.9	14.0–408.9	50.6–121.8	20.4
Congener 153	100	164.4	131.6	1.9	21.7–727.9	83.1–207.5	34.6
Congener 156	92.3	12.0	8.3	2.6	0.3–53.5	5.4–15.8	2.5
Congener 170	97.4	25.3	18.5	2.3	0.6–100.3	11.4–34.9	5.3
Congener 180	99.1	61.1	48.0	2.0	10.5–214.2	29.7–82.9	12.9
Congener 183	99.1	10.9	8.8	1.9	1.7–43.8	5.5–13.6	2.3
Congener 187	100	30.7	25.6	1.8	6.2–97.8	17.5–38.1	6.5
Σ 14 congeners[a]		474.5	385.9	1.9	75.7–1915.8	253.7–579.4	
Chlorinated pesticides (µg/kg)							
Aldrin	0						
β-HCH	96.6	13.4	11.0	1.9	1.3–60.0	7.2–16.9	
p,p´-DDE	100	514.9	419.7	1.9	85.9–2295.4	273.8–639.4	
p,p´-DDT	96.6	37.8	29.9	2.1	1.0 –161.1	20.3–48.9	
Mirex	94.0	8.4	5.8	2.5	0.4–35.2	3.1–10.5	
HCB	99.1	59.0	50.2	1.8	7.6–225.8	37.8–72.8	
α-Chlordane	3.4						
γ-Chlordane	66.7						
cis-Nonachlor	99.1	28.3	23.3	1.9	3.2–117.3	16.5–34.0	
trans-Nonachlor	99.1	139.0	112.6	1.9	15.3–546.6	77.2–169.1	
Oxychlordane	99.1	109.4	81.4	2.1	10.5–642.2	49.8–122.1	

[a]Sum of all 14 congeners including congeners not detected in at least 70% of samples.

should be possible to identify the specific deficits attributable to each of these environmental contaminants in this cohort.

The intercorrelations among the Hg measures reflecting the third-trimester exposure—the cord blood, maternal blood, and maternal third-trimester hair Hg concentrations—are high, suggesting that all three measures provide reliable assessments of third-trimester fetal exposure. A similar high cord–maternal blood intercorrelation was recently reported for the Greenlandic Inuit (*9*). The cord and maternal blood Hg measures are less strongly related to the first- and second-trimester hair Hg values. Hair Hg is approximately 90% MeHg, the most toxic form of Hg, and has the advantage of providing a historical record of MeHg exposure (*34*). These data suggest that potential neuropsychological deficits caused by the impact of Hg on third-trimester brain development may be detected more easily using cord blood or third-trimester hair Hg rather than hair Hg concentrations averaged across pregnancy. Conversely, deficits attributable to Hg exposure early in pregnancy might well be more readily detected by the first-trimester hair Hg measure. The average lead concentration obtained in the Nunavik cohort is two times higher than that found in the general population from southern Québec (*41*) but about 2.0, 1.5, and 2.0 times lower than those obtained in the developmental lead studies conducted in Boston, Massachusetts, Cincinnati, Ohio, and Port Pirie, Australia, respectively (*51–53*). The Nunavik cord blood lead concentration is similar to that reported by Bjerregaard and Hansen (*9*) for the Greenlandic Inuit (32.6 µg/L). Because lead concentration is related neither to OCs nor to Hg exposure in this population, lead is not likely to be a confounder that will need to be controlled in analyses examining the developmental effects of prenatal OCs and Hg exposure.

Selenium is widely distributed in the environment, and exists naturally in the form of selenide, elemental Se, selenite, and selenate. Most Se compounds are water soluble. Data on Se in fish and marine mammals are available, especially for specimens collected in the Arctic regions (*54*). The average Se whole cord blood concentration found in this study is 50% higher than that observed in southern Québec between 1993 and 1998 (arithmetic mean = 2.4 µmol/L, geometric mean = 2.3 µmol/L, range = 1.3–4.3, n = 178) (*55*). It is 1.7 times higher than those found in the cohorts of marine mammal consumers from the Faroe Islands (*48,56*). These data indicate that we should be able to test hypotheses regarding protective effects of Se on neurodevelopmental end points because we observed elevated levels of this

Table 7. Intercorrelations among PCB congeners detected in at least 70% of cord blood and breast milk samples.

PCB congeners (µg/kg)	PCB 52	PCB 99	PCB 101	PCB 105	PCB 118	PCB 138	PCB 153	PCB 156	PCB 170	PCB 180	PCB 183	PCB 187
Cord blood (n = 98)												
PCB 99					0.91*	0.92*	0.90*		0.76*	0.81*		0.82*
PCB 118						0.90*	0.86*		0.71*	0.76*		0.84*
PCB 138							0.98*		0.89*	0.93*		0.95*
PCB 153									0.91*	0.94*		0.93*
PCB 170										0.96*		0.88*
PCB 180												0.93*
PCB 187												
Breast milk (n = 116)												
PCB 52		0.59*	0.68*	0.57*	0.51*	0.53*	0.51*	0.42*	0.43*	0.41*	0.54*	0.47*
PCB 99			0.64*	0.75*	0.86*	0.91*	0.91*	0.64*	0.80*	0.77*	0.87*	0.79*
PCB 101				0.61*	0.57*	0.51*	0.49*	0.27*	0.33*	0.36*	0.53*	0.46*
PCB 105					0.86*	0.69*	0.68*	0.51*	0.54*	0.54*	0.72*	0.62*
PCB 118						0.87*	0.88*	0.61*	0.71*	0.73*	0.86*	0.80*
PCB 138							0.99*	0.79*	0.90*	0.93*	0.96*	0.94*
PCB 153								0.78*	0.91*	0.94*	0.96*	0.93*
PCB 156									0.86*	0.83*	0.74*	0.74*
PCB 170										0.94*	0.86*	0.87*
PCB 180											0.92*	0.94*
PCB 183												0.96*
PCB 187												

Values shown are Pearson r.
*$p \leq 0.000$.

Table 8. Intercorrelations among chlorinated pesticides and PCBs detected in at least 70% of cord plasma and breast milk samples.

Pesticides (µg/kg)	β-HCH	*cis*-Nonachlor	*p,p´*-DDE	*p,p´*-DDT	Mirex	HBC	Oxychlordane	*trans*-Nonachlor	PCB 153
Cord blood (n = 98)									
cis-Nonachlor			0.73*	0.73*		0.76*	0.68*	0.83*	0.65*
p,p´-DDE				0.71*		0.76*	0.79*	0.86*	0.89*
p,p´-DDT						0.71*	0.56*	0.71*	0.55*
HCB							0.79*	0.89*	0.72*
Oxychlordane								0.91*	0.87*
trans-Nonachlor									0.85*
Breast milk (n = 116)									
β-HCH		0.74*	0.85*	0.65*	0.45*	0.78*	0.82*	0.80*	0.75*
cis-Nonachlor			0.82*	0.79*	0.55*	0.90*	0.86*	0.95*	0.70*
p,p´-DDE				0.76*	0.60*	0.81*	0.88*	0.88*	0.87*
p,p´-DDT					0.52*	0.74*	0.70*	0.76*	0.63*
Mirex						0.54*	0.62*	0.62*	0.79*
HCB							0.86*	0.91*	0.71*
Oxychlordane								0.95*	0.86*
trans-Nonachlor									0.80*

Values shown are Pearson r.
*$p \leq 0.000$.

antineurotoxicant and only moderate intercorrelations with Hg. The strength of the cord Se–cord Hg association observed in the Nunavik cohort underscores the importance of measuring and controlling Se in further analysis examining the developmental effects of Hg. A significant but somewhat weaker cord Se–cord Hg association (r = 0.35) was observed in the Faroe Islands cohort by Grandjean et al. (*56*).

With regard to OC exposure, it is difficult to compare the data in the present study with those from early PCB neurobehavioral studies conducted in Michigan (*29*) and North Carolina (*57*), which used packed column gas chromatography for OC determination. In Table 11, OC concentrations observed in the present sample are compared with those from the general Canadian and American populations and with more recent cohort studies using contemporary analytic methods for PCB determination (congener specific analysis). For each comparison, we recalculated the Nunavik OC concentrations according to the method used in the comparison study. For example, to compare our data with those of the Faroe cohort, where total PCB exposure was calculated as two times the sum of congeners 138, 153, and 180, we performed a similar calculation using the Nunavik data. Comparison of breast milk and cord plasma PCB and pesticides concentrations show that the prenatal OC exposure among the Nunavik Inuit is two to three times higher than that observed in general populations in southern Québec and in New Bedford, Massachusetts (*58–60*). PCB concentrations in Nunavik are similar to those found in cord and maternal plasma samples of the Netherlands study (*61*); the Nunavik breast milk PCB concentrations, however, are somewhat lower. Concentrations of OCs in cord plasma and breast milk samples from Nunavik are about two to three times lower than those found in the groups of marine mammal consumers from the Greenland and Faroe Islands cohorts (*9,48*). This result suggests that marine mammal consumption may be less frequent in Nunavik women than in those Arctic groups.

PCB concentrations in plasma and milk are highly correlated, but levels in milk are somewhat higher than those in plasma. The difference in PCB accumulation between plasma and breast milk lipids could be caused by a difference in lipid polarity between plasma and milk. Alternatively, this discrepancy may result from differences in the analytic methods used to quantify lipids (gravimetric in milk vs. enzymatic in plasma). The lower concentrations in cord plasma relative to maternal plasma are more difficult to explain because these contaminants are believed to partition between fat compartment on a 1:1 ratio; however, a similar cord–maternal plasma ratio (0.87) has been reported by Bjerregaard and Hansen (*9*).

OC contaminants are detected more easily in breast milk because it provides a larger quantity of fat for analysis; therefore, we measured certain lower chlorinated congeners that could not be detected in the other two media. However, these low chlorinated congeners constitute a very small proportion (only 4%) of the total PCB body burden as indicated in maternal milk. Similarly, *p,p′*-DDT, which breaks down relatively rapidly in the environment, constitutes a very small proportion (only 4%) of the total DDT body burden (*p,p′*-DDT + *p,p′*-DDE), indicating that the Arctic exposure consists primarily of the more persistent forms of these pesticides. By contrast, half the total DDT (52%) exposure in the Michigan cohort in the early 1980s consisted of *p,p′*-DDT, indicating that the source of that exposure was more recent pesticide use and/or that there was a local source of DDT (*62*).

The high intercorrelations of PCB congener 153 with all of the moderate-to-heavily chlorinated congeners and with most pesticides except *p,p′*-DDT suggest that congener 153 can be considered a marker for exposure to most OCs in the Arctic region. Although several different OC mixtures were introduced into the environment in industrial countries between the 1930s and 1970s, most of the lower chlorinated congeners have biodegraded. These data show that, generally speaking, the mixture of OC contaminants persisting in the Arctic today is quite homogeneous, so much so that it seems unlikely that the neurobehavioral effects associated with

Table 9. Intercorrelations between contaminants and nutrients.

Contaminants	Cord blood Se	Cord blood DHA
Cord blood PCB 153 (μg/kg lipid basis)	0.19 (92)	0.27* (96)
Cord blood mercury (μg/L)	0.51** (92)	0.34** (93)
Hair mercury, averaged[a] (μg/g)	0.37* (69)	0.51** (72)
Hair mercury, third trimester (μg/g)	0.45** (70)	0.49** (73)
Cord blood lead (μg/L)	0.08 (92)	0.15 (93)

DHA, docosahexaenoic acid. Values shown are Pearson r (n).
[a]Average of the total mercury concentrations found at first, second, and third trimesters of pregnancy. *$p \le 0.05$. **$p \le 0.001$.

Table 10. Comparison of mercury concentrations in Nunavik with those observed in other cohorts.

Cohort	Medium	Years	No.	Geometric mean	Range	IQR
Canada						
Nunavik Inuit	Cord blood (μg/L)	1996–2000	95	18.5	2.8–97.0	12.0–27.2
	Maternal blood (μg/L)		130	10.4	2.6–44.2	6.6–17.0
	Maternal hair (μg/g)		123	3.7	0.3–14.0	2.5–6.2
Southern Québec (*41*)	Cord blood (μg/L)[a]	1993–1995	1,108	1.0	0.9–1.0[b]	
James Bay Cree (*50*)	Women's hair, not pregnant (μg/g)[c]	1992	70	2.5	Maximum = 19.0	
Northern Québec Cree (*49*)	Maternal hair (μg/g)	1977–1978	215	6.0[d]	5.2[e]	
United States (*47*)	Women's hair, not pregnant (μg/g)	1981	1,274	0.36[f]	0.14–0.90	
			1,546	0.24[g]	0.09–0.62	
Faroe Islands						
First cohort (*18*)	Cord blood (μg/L)	1986–1987	894	22.9		13.4–41.3
	Maternal hair (μg/g)		914	4.3		2.6–7.7
Second cohort (*48*)	Cord blood (μg/L)	1994–1995	163	20.4	1.9–102.0	11.8–40.0
	Maternal hair (μg/g)		144	4.1	0.4–16.3	2.5–7.4
Seychelles Island						
Main study (*20*)	Maternal hair (μg/g)	1989–1990	740	5.9[h]	0–25	
Pilot study (*17*)	Maternal hair (μg/g)		789	6.6[h]	0.6–36.4	
New Zealand (*14*)	Maternal hair (μg/g)	1978–1984	935[i]	8.3[d]	6.0–86.0	
Greenland, Disko Bay (*9*)	Cord blood (μg/L)	1994–1996	178	25.3	2.4–181.0	
	Maternal blood (μg/L)	1994–1996	180	12.8	1.9–75.6	

[a]The average Hg concentration was reported in nmol/L; this concentration was divided by 5 to convert to μg/L. [b]95% confidence interval. [c]Women 15–39 years old. [d]Arithmetic mean. [e]SD. [f]Among seafood consumers. [g]Among nonseafood consumers. [h]Median. [i]In the high Hg group.

Table 11. Comparison of OC concentrations in Nunavik with those observed in other cohorts.

	Comparison cohorts				Nunavik cohort (1996–2000)[a]			
Years	No.	PCB congener or pesticide	Arithmetic mean	Range	No.	Arithmetic mean	Range	Reference
Canada, southern Québec, 1988–1990								(*58*)
Breast milk (mg/kg)	536	138	0.05	0.01–0.18	116	0.10	0.01–0.41	
		153	0.05	0.01–0.20		0.16	0.02–0.73	
		180	0.03	0.01–0.09		0.06	0.01–0.21	
		p,p´-DDE	0.34	0.02–2.9		0.51	0.09–2.3	
Cord plasma (µg/L), 1993–1995								(*59*)
	656	Aroclor 1260	0.51[b]	0.49–0.54[c]	98	1.9[b]	0.57–6.2[c]	
		p,p´-DDE	0.41[b]	0.39–0.44[c]		1.0[b]	0.25–2.36[c]	
United States, New Bedford, MA, 1993–1998								(*60*)
Cord serum (µg/L)	751	99	0.03	0–1.42	98[d]	0.06	0.01–0.33	
		118	0.06	0–2.05		0.04	0.01–0.24	
		138	0.06	0–0.90		0.18	0.02–1.1	
		153	0.09	0–1.34		0.30	0.04–2.4	
		180	0.04	0–0.40		0.12	0.02–1.1	
		p,p´-DDE	0.48	0–15.0		0.97	0.13–4.0	
		HCB	0.03	0–0.66		0.15	0.02–0.83	
Netherlands, 1990–1992								(*61*)
Cord plasma (µg/L)	382	118	0.04	0.01–0.16	98	0.04	0.01–0.24	
		138	0.13	0.01–0.59		0.18	0.02–1.1	
		153	0.18	0.02–0.85		0.30	0.04–2.4	
		180	0.10	0.01–0.76		0.12	0.02–1.1	
Maternal plasma (µg/L)	415	118	0.16	0.02–0.60	159	0.14	0.01–0.84	
		138	0.60	0.13–1.60		0.59	0.06–3.1	
		153	0.91	0.18–2.50		1.09	0.14–6.1	
		180	0.54	0.08–3.10		0.47	0.06–2.2	
Breast milk (µg/kg)	195	118	35.5	9.7–94.0	116	23.1	3.7–108.1	
		138	129.9	43.8–314.3		96.7	14.0–408.9	
		153	186.3	59.9–475.7		164.4	21.7–727.9	
		180	76.8	2.5–418.8		61.1	10.5–29.7	
Faroe Islands, 1994–1995								(*48*)
Maternal serum (µg/g)	173	PCB	1.12[b]	0.04–18.4	159	0.42[b]	0.1–2.8	
		p,p´-DDE	0.72[b]	0.18–8.0		0.31[b]	0.1–2.3	
Breast milk (µg/g)	168	PCB	1.52[b]	0.07–18.5	116	0.52[b]	0.1–2.7	
		p,p´-DDE	0.87[b]	0.05–13.7		0.42[b]	0.1–2.3	
Greenland, Disko Bay, 1994–1996								(*9*)
Maternal plasma (µg/L)	180	Aroclor 1260	14.2[b]	3.0–95.3	159	6.3[b]	1.0–47.9	
		Σ 14 PCB	5.2[b]	1.1–34.0		2.3[b]	0.4–15.8	
		Total DDT	3.8[b]	0.5–30.8		2.4[b]	0.1–2.8	
		HCB	0.9[b]	0.1–7.0		0.3[b]	0.4–18.9	

Abbreviations: Aroclor 1260, 5.2 times the sum of PCB congeners 138 and 153; PCB, 2 times the sum of PCB congeners 138, 153 and 180; Σ14 PCB, sum of PCB congeners IUPAC # 28, 52, 99, 101, 105, 118, 128, 138 153, 156, 170, 180, 183, 187; Total DDT, sum of *p,p´*-DDE and *p,p´*-DDT.
[a]PCB values calculated using the same approach as the comparison cohort. [b]Geometric mean. [c]95% confidence interval. [d]PCBs were measured in cord plasma.

individual congeners and pesticides can be evaluated in this population.

Dietary fish oils are particularly high in eicosapentaenoic acid (EPA) and docosahexaenioc (DHA) acid, which are n3-PUFAs (*63*). High intake of marine mammals is also associated with increased plasma concentrations of n3-PUFA (*64*). Concentrations of n3-PUFA are not easily compared between studies because there are important measurement differences in laboratory procedures and quantification methods. When compared with data from the southern Québec cohort analyzed in the same laboratory as those from Nunavik, DHA concentrations were three times higher in Nunavik (*65*). In our cohort, DHA is weakly correlated with PCB 153 but moderately associated with Hg concentrations. Dewailly (*6*) also reported a moderate association ($r = 0.56$) between n3-PUFA and Hg concentrations in Nunavik Inuit adults. These data suggest that we will be able to test hypotheses regarding protective effects of n3-PUFA.

The very high OC intercorrelations in the three media assessed in this data set indicate that the measurement of PCB and pesticide concentrations in these specimens are very reliable. These associations are lower on a wet weight basis (data not shown), which may explain the lower maternal plasma–breast milk associations found in the Netherlands study (*61*). The very high correlations obtained using the dual capillary column method in the present study contrast dramatically with the more modest intercorrelations obtained in the Michigan study (*66*) (cord blood–maternal blood, $r = 0.42$; cord blood–maternal milk, $r = 0.16$; maternal blood–maternal milk, $r = 0.35$). The use of the more reliable measures in the present study increases the likelihood of detecting developmental deficits associated with those exposures. These high intercorrelations will also enable us to assess reliably the prenatal exposure from any one of these measures for individuals with incomplete data.

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