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Body burden of metals and persistent organic pollutants among Inuit in the Canadian Arctic

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ABSTRACT

Inuit living in the Arctic are exposed to elevated levels of environmental contaminants primarily due to long-range atmospheric transport. Blood sampling and contaminant biomonitoring was conducted as part of the International Polar Year Inuit Health Survey in 2007-2008. The body burden of metals (e.g. Cd, Pb) and persistent organic pollutants (e.g. PCBs, DDT & DDE, toxaphene, chlordane, PBDEs) were measured for Inuit participants (n = 2172) from 36 communities in Nunavut, Nunatsiavut, and the Inuvialuit Settlement Region, in Canada. The geometric mean of blood concentrations for Cd, Pb, PCBs, DDE & DDT, toxaphene, and chlordane were higher than those in the Canadian general population. A total of 9% of study participants exceeded the intervention guideline of 100 μg L^{-1} for Pb, 11% of participants exceeded the trigger guideline of 5 μg L^{-1} for Cd, and 1% exceeded the intervention guideline of 100 μg L^{-1} for PCBs. Also, 3% of women of child-bearing age exceeded blood Pb of 100 μg L^{-1} while 28% of women of child-bearing age exceeded 5 μg L^{-1} of PCBs. This work showed that most Inuit Health Survey participants were below blood contaminant guidelines set by Health Canada but that metal and POP body burdens commonly exceed exposures observed in the general population of Canada.

1. Introduction

Long-term elevated exposure to metals and Persistent Organic Pollutants (POPs) is associated with health risks from chronic disease (AMAP, 2004, 2005). For example, exposure to POPs can result in adverse effects to the neurological, immune, and endocrine systems and can potentially cause birth defects and cancer while elevated exposure to metals can result in neurological (Pb), bone (Cd), and kidney (Cd) problems (ATSDR, 2003, 2007, 2008). The POPs included in this report, which can be transported globally and bioaccumulate in Arctic marine food webs (Muir et al., 1999), include: polychlorinated biphenyls (PCBs), chlordane, toxaphene, polybrominated diphenyl ethers (PBDEs), and dichlorodiphenyldichloroethylene (p,p-DDT) & dichlorodiphenyldichloroethylene (p,p-DDE). Chlordane, toxaphene, and DDT are all organochlorine pesticides with DDE being the primary metabolite of DDT (Muir et al., 1992). In contrast, PCBs and PBDEs are industrial chemicals once used in dielectric fluids and flame-retardants, respectively. Of these POPs, all but PBDEs were included in the initial "Dirty Dozen" of the Stockholm Convention resulting in their ban (Annex A) or strict restriction (Annex B); PBDEs were added to Annex A of the Stockholm Convention in 2009 (UNEP, 2012).

Previous contaminant biomonitoring studies have indicated that Inuit face elevated exposures to metals and POPs. For example, the concentration of POPs (e.g. DDE, PCBs, chlordane) in the breast milk of Nunavik Inuit mothers was between 4 and 10-fold higher than in breast milk collected from mothers in southern Canada (AMAP, 1998). Similarly, maternal plasma concentrations of several POPs were consistently higher (up to 10-fold) among Inuit than among non-Indigenous people in Arctic Canada (AMAP, 2003). Further, blood Pb concentrations were elevated in Inuit populations relative to other ethnic groups living in the Canadian Arctic (AMAP, 2003). In contrast, blood Cd levels of non-smoking Inuit are similar to concentrations observed in non-smoking southern Canadians. However, the Cd content of tobacco, as well as the high Inuit smoking rate, dictated that average Cd concentrations in the blood of Inuit are approximately twice that of southern Canadians (AMAP, 1998, 2003). There are 160,000 Inuit living in Canada, Alaska, Greenland and Russia (ICC Canada, 2011).

In Canada, the Inuit homeland stretches across 4 regions (*2006 Inuit population size*): Nunavik (10,000), Nunavut (25,000), the Inuvialuit Settlement Region (3100) and Nunatsiavut (2200)

Abbreviations: AMAP, Arctic Monitoring and Assessment Programme; CHMS, Canadian Health Measures Survey; DDE, Dichlorodiphenyldichloroethylene; DDT, Dichlorodiphenyltrichloroethane; IPY, International Polar Year; ISR, Inuvialuit Settlement Region; OC, Organochlorine; OHSA, Occupational Safety and Health Administration; PBDE, Polybrominated diphenyl ether; PCB, Polychlorinated biphenyl; POP, Persistent Organic Pollutant; QAQC, Quality Assurance Quality Control.

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(Statistics Canada, 2008). There have been extensive biomonitoring programs conducted in Nunavik (Fontaine et al., 2008). However, no representative biomonitoring initiatives have been conducted in the other 3 regions. The International Polar Year (IPY) Inuit Health Survey was undertaken to provide the first comprehensive cross-sectional study of Inuit health in the Inuvialuit Settlement Region (ISR), Nunatsiavut, and Nunavut (Egeland et al., 2011a, 2011b; Zienczuk and Egeland, 2012). The survey randomly selected households in each of the thirty-three coastal and three inland communities in the Canadian Arctic. The contaminant biomonitoring component of the survey, which recruited 2595 Inuit participants in 36 Canadian Arctic communities in 2007 and 2008, was designed to address the data gap posed by the small sample sizes of previous studies.

The primary objective of this study was to conduct blood sampling in order to determine the current exposure levels of metals (e.g. Cd, Pb) and POPs (e.g. PCBs, PBDEs, toxaphene, chlordane, and DDE & DDT) for Inuit in Nunavut, Nunatsiavut, and the ISR. The secondary objectives were to: (i) establish the percent of study participants who exceeded contaminant blood guidelines, and (ii) compare the current biomonitoring results to those of previous studies in the Arctic, and (iii) compare the contaminant results to the Canadian general population collected from Cycle 1 of the Canadian Health Measures Survey (CHMS) (Health Canada, 2011).

2. Material and Methods

2.1. Population and Study Design

Steering Committees were established in each of the three participating jurisdictions to provide guidance and oversight for the design, implementation, and communication of the study (Saudny et al., 2012). Households were approached to recruit participants through a random selection from community lists provided by each municipality. Individuals aged 18 years and older who self-identified as Inuit were invited to participate in the clinical assessments (Saudny et al., 2012). Pregnant women were excluded. From 2796 approached households, 1901 households (68%) agreed to take part with a total of 2796 adults interested in participating. However, 201 individuals were excluded due to missed appointments leaving 2595 study participant overall. Of the 2595 study participants, 2172 provided blood samples for contaminant biomonitoring. The IPY Inuit Health Survey 2007–2008 also included a detailed assessment of Inuit nutrition, chronic disease risk, mental health, socio-economic status, household overcrowding, and food security. The results for many of these other endpoints have been previously published elsewhere (Egeland et al., 2011a; Huet et al., 2012; Rosol et al., 2011).

2.2. Blood Sampling and Chemical Analyses

Blood was collected from the median antecubital vein of 2172 participants with aged 18 and older for contaminant biomonitoring. For serum samples, blood was collected in 8.5 mL Becton–Dickinson (B–D) plastic vacutainers with clot activators and gel for serum separation. For whole blood, plasma and erythrocytes, blood was collected into 10 mL B-D plastic vacutainers coated with K_2-EDTA as anticoagulant. Within 2 hours of collection, aliquots of whole blood were removed and stored at −80 °C until analysis. All remaining blood was centrifuged at 4 °C and serum, plasma and erythrocyte samples were stored at −80 °C until analysis.

Quantification of metals in whole blood was performed by ICP-MS on an ELAN DRC II instrument for Cd and an ELAN 6000 instrument for Pb (Perkin-Elmer SCIEX, Concord, Canada). Prior to analysis, whole blood samples were diluted 20-fold in an ammonia solution. Limits of detection (in nmol L^{-1}) for Cd and Pb were 0.44 and 4.6, respectively, and each run of samples included a standard. Between-day coefficients of variation for blood concentrations of Cd and Pb measurements were 3.5% and 3.4%, respectively. For POP analysis, plasma samples were enriched with internal labelled standards and proteins were denatured with reagent grade alcohol. Organohalogenated compounds were extracted with hexane from the aqueous matrix using a liquid–liquid extraction. Extracts were passed through florisil columns before analysis by GC-MS using a DB-XLB column (60 m × 0.25 mm × 0.25 μm). Ions were measured after negative chemical ionization. After this analysis, 125 μL of hexane was added to each sample to analyze separately the PBDEs on a shorter analytical column (DB-XLB 15 m × 0.25 mm × 0.1 μm). Analyte concentrations were corrected according to the percent recovery of labelled internal standards. The ECD detector was used to quantify the PCB congeners 28 and 52 when the detection limit was not obtained with the mass detector. Total PCBs were calculated using the sum of 14 congeners (i.e. PCB-28, PCB-52, PCB-99, PCB-101, PCB-105, PCB-118, PCB-128, PCB-138, PCB-153, PCB-156, PCB-170, PCB-180, PCB-183 and PCB-187). Arochlor 1260 was measured for a subset (n = 1147) of the 2162 study participants. Linear regression analysis between the total PCB concentrations (sum of congeners) and Arochlor 1260 concentrations was performed on this subset. The Arochlor 1260 plasma concentrations for the other 1015 participants were estimated based on their total PCBs (sum of congeners) concentrations and the results of the linear equation. Total PBDEs were calculated from the sum of 3 PBDE congeners: PBDE-47, PBDE-99, and PBDE-100. Chlordane was calculated from the sum of *cis*-nonachlor, *trans*-nonachlor and oxychlordane while toxaphene was calculated from the sum of parlar-26 and parlar-50. Detection limits ranged 0.005 μg L^{-1} (oxychlordane) and 0.3 μg L^{-1} (PCB-52) (Table 1). Plasma concentrations of POPs are described per liter blood plasma and per kg plasma lipid. Analyses were performed by the Laboratoire de Toxicologie of the Institut National de Santé Publique du Québec, which is accredited ISO 17025 and participates in the QAQC program of the Canadian Northern Contaminants Program and the Arctic Monitoring Assessment Program.

2.3. Guideline Selection

Whenever possible, trigger and/or intervention guidelines (Table 2) established by Health Canada were used as threshold reference points for the biomonitoring component of the Inuit Health Survey (AMAP,

Table 1
Limits of detection per liter blood plasma for each persistent organic pollutant (POP).

Analyte	Detection limit (μg L^{-1})
PCB-28	0.05
PCB-52	0.3
PCB-99	0.03
PCB-101	0.01
PCB-105	0.01
PCB-118	0.01
PCB-128	0.01
PCB-138	0.01
PCB-153	0.01
PCB-156	0.01
PCB-170	0.01
PCB-180	0.01
PCB-183	0.01
PCB-187	0.01
Oxychlordane	0.005
Cis-nonachlor	0.005
Trans-nonachlor	0.01
Toxaphene, Parlar 26	0.005
Toxaphene, Parlar 50	0.005
p,p'-DDT	0.05
p,p'-DDE	0.02
PBDE-47	0.03
PBDE-99	0.02
PBDE-100	0.02