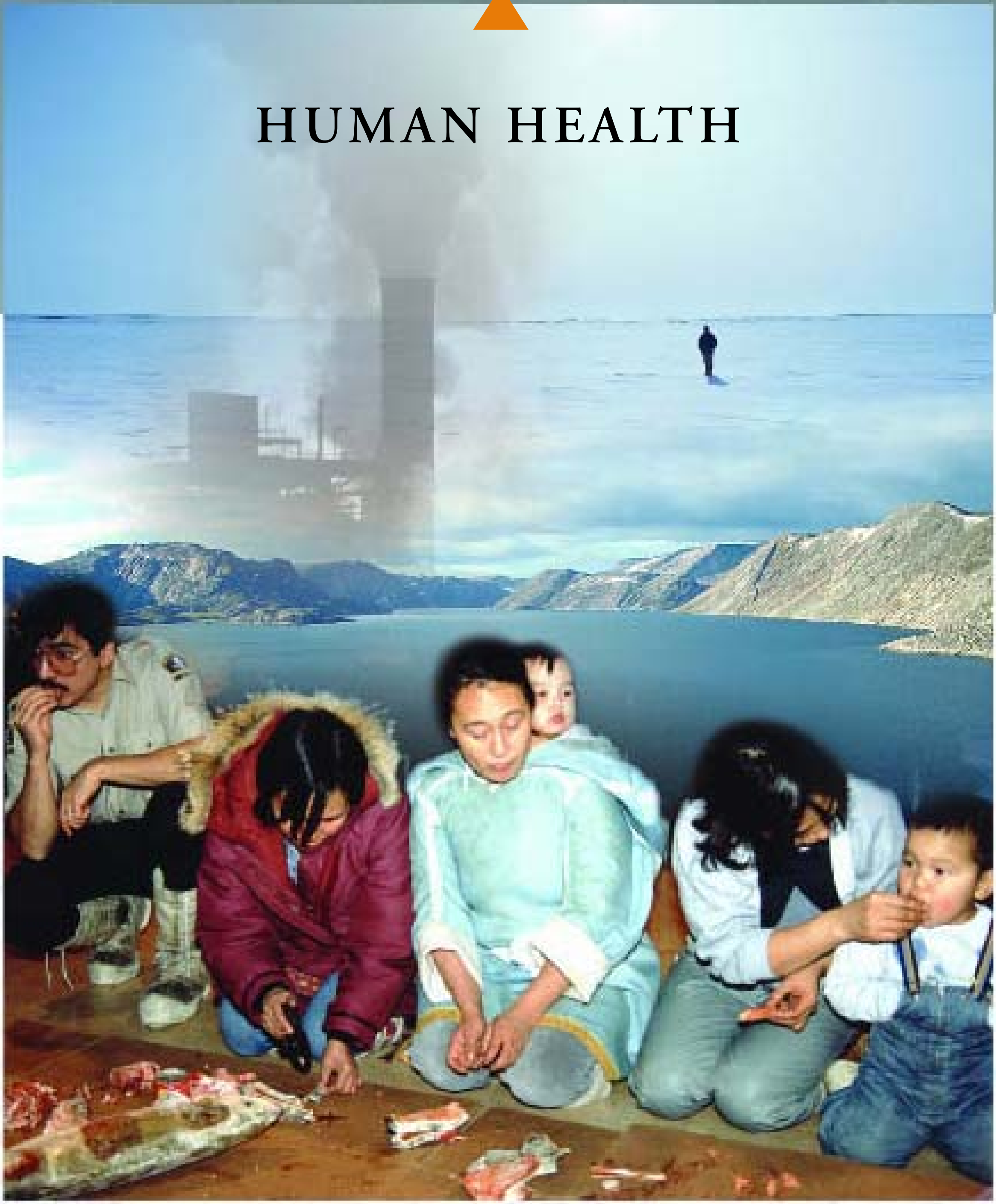
NORTHERN CONTAMINANTS PROGRAM

CANADIAN ARCTIC CONTAMINANTS ASSESSMENT REPORT II

HUMAN HEALTH



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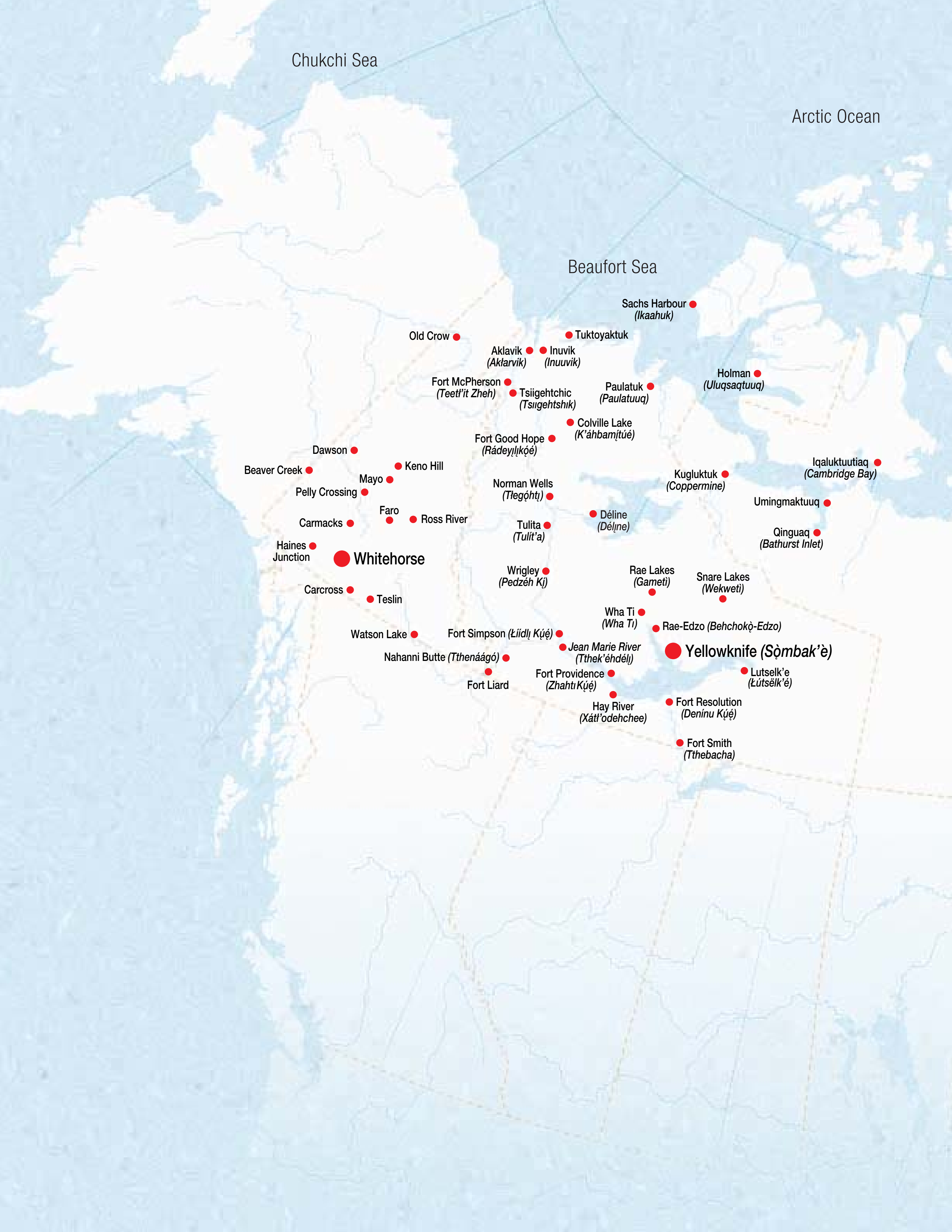

Chukchi Sea
Arctic Ocean
Beaufort Sea
Sachs Harbour
(Ikaahuk)
Old Crow
Tuktoyaktuk
Aklavik
(Akłarvik)
Inuvik
(Inuuvik)
Fort McPherson
(Teetł'it Zheh)
Tsiigehtchic
(Tsıigehtshık)
Paulatuk
(Paulatuuq)
Holman
(Uluqsaqtuuq)
Colville Lake
(K'áhbamı̨túé)
Fort Good Hope
(Rádeyı̨lı̨kóé)
Dawson
Beaver Creek
Keno Hill
Mayo
Pelly Crossing
Norman Wells
(Tłegóhtı̨)
Kugluktuk
(Coppermine)
Iqaluktuutiaq
(Cambridge Bay)
Umingmaktuuq
Faro
Carmacks
Ross River
Tulita
(Tulít'a)
Déline
(Délı̨ne)
Qinguaq
(Bathurst Inlet)
Haines
Junction
Whitehorse
Wrigley
(Pedzéh Kı̨)
Rae Lakes
(Gametì)
Snare Lakes
(Wekweètì)
Carcross
Teslin
Wha Ti
(Wha Tı)
Rae-Edzo (Behchokò-Edzo)
Watson Lake
Fort Simpson (Łíídlı̨ Kų́ę́)
Jean Marie River
(Tthek'éhdélı̨)
Yellowknife (Sòmbak'è)
Nahanni Butte (Tthenáágó)
Fort Liard
Fort Providence
(Zhahtı Kų́ę́)
Lutselk'e
(Łútsëlk'é)
Hay River
(Xát'l'odehchee)
Fort Resolution
(Denínu Kų́ę́)
Fort Smith
(Tthebacha)


Alert
Ausuittuq
(Grise Fiord)
Resolute
(Qausuittuq)
Ikpiarjuk/Tununirusiq
(Arctic Bay)
Mittimatalik
(Pond Inlet)
Kangiqtugaapik
(Clyde River)
Baffin Bay
Taloyoak
Igloolik
Sanirajak
(Hall Beach)
Uqsuqtuuq
(Gjoa Haven)
Kugaaruk
(Pelly Bay)
Qikiqtarjuaq
(Broughton Island)
Pangnirtung
Naujaat
(Repulse Bay)
Iqaluit
Kinngait
(Cape Dorset)
Qamanittuaq (Baker Lake)
Salliq
(Coral Harbour)
Kimmirut
(Lake Harbour)
Igluligaarjuk (Chesterfield Inlet)
Kangiqliniq (Rankin Inlet)
Tikirarjuaq (Whale Cove)
Ivujivik
Salluit
Kangiqsujuaq
Quaqtaq
Akulivik
Kangirsuk
Arviat
Puvirnituq
Aupaluk
Kangiqsualujjuaq
Tasiujaq
Nain
Kuujjuaq
Hudson Bay
Inukjuak
Hopedale
Makkovik
Postville
Rigolet
Umiujaq
Sanikiluaq
Happy Valley/Goose Bay
Kuujjuarapik

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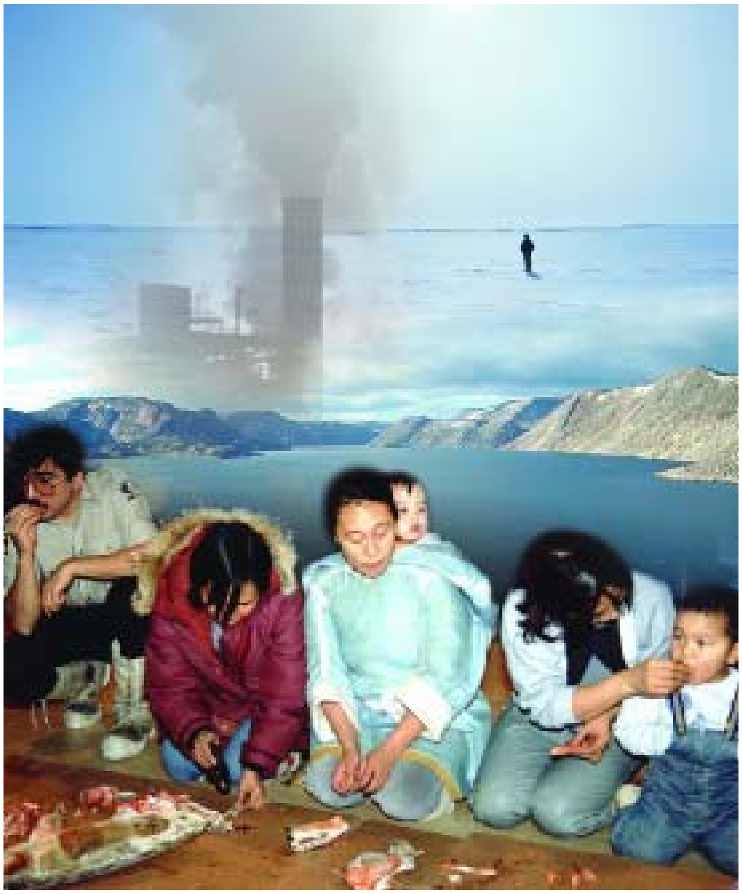
TOXIC SUBSTANCES IN THE ARCTIC AND ASSOCIATED EFFECTS - HUMAN HEALTH



Contributors:

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Executive Summary

The Northern Contaminants Program (NCP) was established in 1991 in response to concerns about human exposure to elevated levels of contaminants in fish and wildlife species that are important to the traditional diets of northern Aboriginal peoples. Early studies indicated that there was a wide spectrum of substances — persistent organic pollutants, heavy metals, and radionuclides — many of which had no Arctic or Canadian sources, but which were, nevertheless, reaching unexpectedly high levels in the Arctic ecosystem.

Under the first phase of the NCP (NCP-I), research was focussed on gathering the data required to determine the levels, geographic extent, and source of contaminants in the northern atmosphere, environment and its people, and the probable duration of the problem. Results generated through NCP-I were synthesized and published in 1997 in the first *Canadian Arctic Contaminants Assessment Report* (CACAR-I).

In 1998, the NCP began its second phase (NCP-II), which will continue until March 2003. NCP-II focussed upon questions about the impacts and risks to human health that may result from current levels of contamination in key Arctic food species as well as determining the temporal trends of contaminants of concern in key indicator Arctic species and air. It addressed these issues under a number of subprograms: human health; monitoring the health of Arctic peoples and ecosystems and the effectiveness of international controls; education and communications; and international policy.

The priority areas in the human health subprogram during NCP-II included: exposure assessment, toxicology, epidemiology, and risk and benefit characterization. The key objectives of this, the human health technical report in the CACAR-II series, are to summarize the knowledge produced since the first CACAR on human exposure to and possible health effects of current levels of environmental contaminants in the Canadian Arctic, and to identify the data and knowledge gaps that need to be filled by future human health research and monitoring. The CACAR-II series consists of a Highlights report and four technical reports: human health, biological environment, physical environment and knowledge in action.

Aboriginal perspectives on food and health

Traditional/country foods are an integral component of good health among Aboriginal peoples. The social, cultural, spiritual, nutritional and economic benefits of these foods must be considered in concert with the risks of exposure to environmental contaminants through their consumption of traditional/country foods. Traditional/country food is an economic necessity for many Aboriginal peoples. The hunting, fishing and gathering of traditional/country food and the subsequent sharing of these items with individuals throughout the community are social activities bringing together individuals, families and generations. In this way, traditional/country foods form and maintain an important social and cultural fabric among individuals which supports community health and well-being.

Health determinants

Determining the adverse human health effects due to the presence of contaminants in traditional/country foods is very difficult as many factors contribute to the health of an individual and in fact contaminants may only play a modest role in determining an individual's health status. Factors such as lifestyle (e.g., alcohol consumption, smoking, and substance abuse), diet, socioeconomic status and genetic predisposition are important health determinants that need to be considered when evaluating the results described herein.

Contaminant exposure

Persistent environmental contaminants such as PCBs, toxaphene, DDT and mercury biomagnify and bioaccumulate in the food chain. Levels of organochlorine contaminants in human tissue in the Arctic are considerably higher than those in southern Canadians, reflecting the greater consumption of food species at the top of long food chains.

Traditional/country food use by women and men 20–40 years of age is highest in Inuit communities, followed by Dene and Métis of the NWT and then First Nations people of the Yukon. Age and gender are factors influencing traditional/country food use, with men having higher average intakes than women, and traditional/country food consumption increasing with age. Continued monitoring and assessment of the frequency of consumption of traditional/country foods in a limited number of Dene and Métis, First Nations, and Inuit communities is needed to identify any significant changes in consumption patterns and those with highest exposures.

Human contaminant levels

Inuit mothers have oxychlordane and trans-nonachlor levels that are 6–12 times higher than those in Caucasians, Dene and Métis, or Other mothers, with Baffin Inuit mothers having the highest levels. Similar patterns were observed for PCBs, HCB, mirex and toxaphene. The monitoring of organochlorines in human tissues does not have a long history in the Canadian Arctic, and continued monitoring of tissue levels is needed to determine contaminant trends. Special attention should be given to oxychlordane, trans-nonachlor, HCB, mirex, toxaphene and PCBs, especially among the Inuit of Nunavut and Nunavik.

Recent research has revealed significantly higher levels of mercury in the maternal blood of Inuit women when compared to Caucasian, Dene and Métis or the Other group. Nunavik and Baffin Inuit have higher levels in maternal/cord blood than those seen in the Kitikmeot, Kivalliq and Inuvik regions. Mercury levels in the residents of one Nunavik community vary markedly from year-to-year due to variation in availability of traditional/country food, but recent tissue levels are similar to the levels found in the late 1970s. While there is a longer history of Arctic environmental monitoring of mercury compared to other contaminants (e.g., organochlorines), differences in sampling strategies have made any conclusions on trends very tenuous. Regular monitoring of tissue levels among communities with a range of exposures for mercury and selenium is advisable.

Research on lead isotope signatures has shown that the slightly elevated blood lead levels among some of the Inuit groups and the Dene and Métis are likely due to the use of lead shot in hunting traditional/country foods, and, therefore, its presence in wild game that is consumed. Blood cadmium levels are roughly 1.5 to 5 times higher among Inuit than in Dene and Métis, Caucasians, and Other. This difference is likely due to the high rate of smoking among Inuit mothers and the high cadmium content in Canadian tobacco.

Radiocesium entered the atmosphere as a result of atmospheric testing of nuclear weapons. Since the first CACAR (1997), measurements of radiocesium levels in Canadian caribou herds have shown that levels can now be considered insignificant. The radionuclides lead-210 and polonium-210 are naturally occurring and supply most of the radiation dose to consumers of traditional/country food. These radionuclides accumulate in the lichen → caribou → human food chain and have been present in the Arctic environment for thousands of years at more or less the same concentrations as found today. Current estimates of polonium exposure would give a radiation dose of 3–4 millisieverts/year (mSv/yr) to a high consumer of caribou meat over and above normal background radiation exposure of 2–3 mSv/yr.

Trends in traditional/country food dietary intakes and contaminant exposures

For Canadian Inuit, intakes of traditional/country food do not seem to have significantly changed in the last 20 years. Surveys of dietary intake in one Inuit community, Qikiqtarjuaq (Broughton Island), Nunavut have shown that mercury exposures were similar in 1987–1988 and 1999, thus implying little change in dietary pattern or mercury concentration in food. However, reported intakes of the organochlorines were somewhat higher in 1999, particularly among the highest users (95th percentile). Focussed monitoring of traditional/country food consumption in specific Arctic communities through surveys of dietary intakes of environmental contaminants, such as organochlorines (e.g., PCBs, chlordane, toxaphene) and mercury will help to provide more spatial and temporal data on changes in dietary patterns or contaminant concentrations in food.

Continued blood and hair monitoring and focussed dietary surveys in possible high exposure communities will guide northerners in their decisions on what, if any, dietary modifications are warranted.

Toxicology

In certain Arctic populations, toxaphene residues are within the same range as the experimental studies where effects on immune function and infant size have been observed. While more information is needed on the carcinogenic and endocrine-disruptive capacity of toxaphene, new and forthcoming information will be useful in a re-assessment of the toxicity and provisional tolerable daily intake (pTDI) of this chemical.

The pattern of chlordane-related residue accumulation in humans parallels that seen in the highest levels of the Arctic marine food chain. Estimated chlordane intake values for Arctic residents vary from levels less than the Health Canada pTDI to levels approaching or exceeding the higher US EPA TDI, depending on marine mammal fat consumption. Based on the latest rodent studies at Health Canada, a thorough risk assessment with the goal of re-assessing the TDI should take into account that the major chlordane metabolite oxychlordane is almost 10-fold more toxic than the parent chlordanes and nonachlors, and that *trans*-nonachlor and oxychlordane are among the more bioaccumulative chlordane contaminants.

Contaminant and dietary nutrient interactions

There is some evidence that dietary nutrients such as polyunsaturated fatty acids, fish protein, and selenium may interact with methylmercury toxicity at least on the mechanistic level. The two former nutrients may be protective against methylmercury (MeHg) neurotoxicity; however, there is no conclusive evidence of such an effect. It is clear that there is a need for more studies designed specifically to address the role of nutrition in the metabolism and detoxification of methylmercury.

Epidemiology

Neurobehavioural effects of perinatal exposure to environmental contaminants are best studied in prospective longitudinal cohort studies starting during pregnancy because there are numerous other determinants of infant and child development that need to be documented and are best assessed during pregnancy or at birth. Examples of these determinants are prenatal exposure to alcohol, drugs and tobacco; exposure to other environmental contaminants such as lead; and intake of nutrients such as selenium and omega-3 polyunsaturated fatty acids (PUFA) during pregnancy. The ongoing Nunavik cohort study should help shed more light on contaminant exposure and potential related health effects in the areas of neurodevelopment and immune function. With the establishment of this prospective Arctic birth-cohort, there will be opportunities to look at other contaminants which may have neurodevelopmental effects, as well as to study long-term effects that can only be documented at school age or later in the course of development.

Past research in Nunavik indicated that *otitis media* (middle ear infection) during the first year of life was associated with prenatal exposure to *p,p′*-DDE, HCB and dieldrin. Furthermore, the relative risk of recurrent *otitis media* increased with prenatal exposure to these compounds. To date, the ongoing Nunavik study supports the hypothesis that the high incidence of infections observed in Inuit children (mostly respiratory infections) may be due in part to high prenatal exposure to persistent organic pollutants (POPs).

Preliminary data from the Nunavik cohort indicate that the strength of the negative association of polychlorinated biphenyls (PCBs) on birth weight for newborns in northern Québec was comparable to the associations with prenatal exposure to alcohol and smoking during pregnancy. The negative effects of prenatal PCB exposure on birth weight and duration of pregnancy could still be demonstrated despite the beneficial effects of omega-3 fatty acids from the traditional/country diet.

Risk and benefit characterization, assessment and advice

Contaminant exposure risks

The primary contaminants of concern in the context of traditional/country food consumption in Arctic Canada are the persistent organic pollutants (POPs), PCBs, chlordane and toxaphene, the toxic metal mercury and naturally occurring radionuclides. The highest exposures to POPs and mercury are found in Inuit communities. In recent dietary surveys among five Inuit regions (Baffin, Inuvialuit, Kitikmeot, Kivalliq and Labrador), mean intakes by 20–40-year-old adults in Baffin, Kivalliq and Inuvialuit communities exceeded the pTDIs for chlordane and toxaphene. High consumers (95th percentile) of traditional/country foods are exceeding the pTDIs by many-fold for toxaphene, chlordane, and PCBs. The Inuit populations that had the greatest exceedance of the pTDIs also had the greatest exceedance of the PCB maternal blood guideline.

Mercury is the toxic metal of greatest concern in the Canadian Arctic. Dietary intakes of mercury were similar in the two surveys conducted in 1987–1988 and 1998–1999, indicating there has been little change in dietary pattern and/or mercury concentrations in traditional/country foods. Based on the exceedances of the provisional tolerable daily intake (pTDI) and of various blood guidelines, mercury, and to a lesser extent lead (from use of lead shot in hunting of game), may be a significant concern among Arctic peoples.

There is mounting evidence that a threshold may exist for radiation-induced cancer and this threshold may be equal to or greater than 100 mSv. This issue is of significance to northerners, who were exposed in the past to nuclear weapons fallout, or who have slightly higher exposures due to caribou meat consumption.

Nutritional benefits of traditional/country food diet

The nutritional benefits of traditional/country food and its contribution to the total diet are substantial, even though only 6–40% of total dietary energy may be from this food source. Research findings are consistent across the Canadian Arctic and confirm that decreasing traditional/country food in the diet is likely to have negative health consequences, in part through the corresponding increase in total fat, saturated fat and sucrose intakes above the recommended levels. Traditional/country food also contributes significantly more protein, iron and zinc to the diets of Inuit children than imported foods. The increase in diabetes, cardiovascular disease and obesity have been linked to this shift away from the traditional/country food diet. The substantial nutritional benefits of traditional/country food and its contribution to the total diet have been documented; however, further research is needed on the negative health consequences of not consuming traditional/country food.

Benefit and risk management and assessment framework

Benefit and risk assessment and management relating to contaminants in traditional/country food involves a consideration of the type and amount of food consumed and the sociocultural, nutritional, economic, and spiritual benefits associated with traditional/country foods. Benefit and risk management decisions must involve the community and must take all aspects into account to arrive at a decision that will be the most protective and least detrimental to the communities. Regardless of the decision taken, some health risks associated with exposure to contaminants may remain. In the Arctic, these risks are outweighed by the benefits of continued consumption of traditional/country foods. The uncertainty over risks and benefits will continue to pose a large and complex public, moral and political dilemma.

Benefit and risk communication

Effective communication is fundamental to the aims of the NCP. Communication efforts incorporate Aboriginal knowledge on the nutritional benefits and risks associated with the consumption of traditional/country foods and of imported foods, and on the importance of a traditional lifestyle to overall health and well-being. These efforts provide northerners with the appropriate information to make more informed decisions about harvesting and consumption of both traditional/country food and imported foods, and also to avoid some of the mistakes of earlier communication efforts related to environmental contaminants. No one method of communication is best, but what is needed is a variety of methods and materials appropriate to communities in different regions and specific to groups within each community, all aimed at providing opportunities for two-way exchanges of information and allowing an understanding of the issue to develop.

The practice of risk communication has changed over the past two decades, building upon lessons learned along the way. In place of one-way models of information distribution, NCP-II strove toward shared decision making through partnerships involving territorial Health Departments and regional contaminants/health committees, community representatives and representatives of Aboriginal organizations at all stages of the risk management and risk communication process.

ITK/Eric Loring

Résumé

Le Programme de lutte contre les contaminants dans le Nord (PLCN) a été créé en 1991 en réponse aux préoccupations concernant l'exposition des humains à des concentrations élevées de contaminants dans les poissons et des espèces sauvages qui sont importants dans l'alimentation traditionnelle des Autochtones du Nord. Les premières études avaient mis en évidence une vaste gamme de substances — les polluants organiques persistants, les métaux lourds et les radionucléides — dont beaucoup n'avait pas de sources dans l'Arctique ni au Canada mais qui se retrouvait néanmoins à des concentrations anormalement élevées dans l'écosystème de l'Arctique.

Dans la première phase du PLCN (PLCN-I), la recherche était concentrée sur la collecte des données nécessaires pour déterminer les concentrations, l'étendue géographique et les sources des contaminants dans l'atmosphère, l'environnement et ses habitants du Nord et la durée probable du problème. Les résultats de cette phase ont été colligés et publiés en 1997 dans le *Rapport d'évaluation des contaminants dans l'Arctique canadien* (RECAC).

En 1998, le PLCN a entrepris sa deuxième phase (PLCN-II), qui se poursuivra jusqu'en mars 2003. Cette phase se concentre sur les impacts et les risques pour la santé humaine que pourraient induire les concentrations actuelles de contaminants dans les espèces alimentaires clés de l'Arctique, et sur la détermination des tendances temporelles des contaminants dans les espèces arctiques qui sont des indicateurs clés, ainsi que dans l'air. Elle examine ces questions dans un certain nombre de sous-programmes : santé humaine, surveillance de la santé des populations et écosystèmes de l'Arctique et de l'efficacité des contrôles internationaux, éducation et communications, et politique internationale.

Les domaines d'étude prioritaires du sous-programme pour la santé humaine du PLCN-II étaient l'évaluation de l'exposition, la toxicologie, l'épidémiologie, et la caractérisation des risques et avantages. Le rapport technique sur la santé humaine de la série RECAC-II a pour objectif clé de résumer les connaissances recueillies depuis le premier RECAC sur l'exposition humaine aux niveaux actuels des contaminants environnementaux dans l'Arctique canadien et sur les effets possibles de ces contaminants sur la santé, et d'identifier les lacunes dans les données et les connaissances qui doivent être comblées par les recherches et la surveillance futures en matière de santé humaine. La série RECAC-II est constituée d'un rapport de synthèse et de quatre rapports techniques sur les sujets suivants : santé humaine, environnement biologique, environnement physique et application des connaissances.

Perspectives des Autochtones sur les aliments et la santé

Les aliments traditionnels sont une composante intégrante de la bonne santé chez les Autochtones. Les avantages sociaux, culturels, spirituels, nutritifs et économiques de ces aliments doivent être examinés conjointement avec les risques d'exposition aux contaminants environnementaux liés à la consommation d'aliments traditionnels. Ces derniers sont en effet une nécessité économique pour de nombreux Autochtones. La chasse, la pêche et la cueillette d'aliments traditionnels, et le partage dans la collectivité de ces produits de consommation est une activité sociale qui réunit les individus, les familles et les générations. Les aliments traditionnels créent et entretiennent donc entre les individus un tissu social et culturel important qui conforte la santé et le bien-être de la collectivité.

Facteurs déterminants pour la santé

Il est très difficile de déterminer les effets nuisibles pour la santé humaine de la présence de contaminants dans les aliments traditionnels car de nombreux facteurs contribuent à la santé d'un individu et, en fait, les contaminants pourraient n'y jouer qu'un rôle mineur. Des facteurs comme le mode de vie (p. ex., la consommation d'alcool, le tabagisme et l'usage de drogues), l'alimentation, la situation socio-économique et les prédispositions génétiques sont des facteurs importants pour la santé qui doivent être pris en considération dans l'évaluation des résultats du présent rapport.

Exposition aux contaminants

Les contaminants environnementaux persistants comme les BPC, le toxaphène, le DDT et le mercure se bioamplifient et se bioaccumulent dans la chaîne alimentaire. Dans l'Arctique, les concentrations de contaminants organochlorés dans les tissus humains sont beaucoup

plus élevées que dans le sud du Canada, ce qui reflète la plus grande consommation d'espèces situées au sommet de longues chaînes alimentaires.

La consommation d'aliments traditionnels par les femmes et les hommes de 20 à 40 ans est le plus élevée chez les Inuits, puis chez les Dénés et les Métis des T.N.-O., et ensuite chez les Premières nations du Yukon. L'âge et le sexe sont des facteurs qui influent sur la consommation des aliments traditionnels, la consommation moyenne étant plus élevée chez les hommes que chez les femmes, et plus élevée avec l'âge. Une surveillance et une évaluation continues de la fréquence de consommation des aliments traditionnels dans un nombre limité de collectivités dénées et métis, des Premières nations et inuites est nécessaire pour détecter tout changement significatif dans les habitudes de consommation et déterminer quelles sont les collectivités les plus exposées.

Niveaux de contamination des humains

Les mères inuites ont des concentrations d'oxychlordane et de trans-nonachlore de 6 à 12 fois plus élevées que les mères caucasiennes, dénées et métis ou autres, les mères inuites de l'île de Baffin ayant les plus fortes concentrations. On a constaté la même chose pour les BPC, l'hexachlorobenzène, le mirex et le toxaphène. La surveillance des substances organochlorées dans les tissus humains est récente dans l'Arctique canadien, et une surveillance continue des concentrations dans les tissus est nécessaire pour déterminer les tendances des contaminants. Une attention spéciale doit être portée à l'oxychlordane, au trans-nonachlore, à l'hexachlorobenzène, au mirex, au toxaphène et aux BPC, particulièrement chez les Inuits du Nunavut et du Nunavik.

Des recherches récentes ont révélé des concentrations nettement plus élevées de mercure dans le sang maternel des femmes inuites comparativement aux femmes caucasiennes, dénées et métis et autres. Les Inuits du Nunavik et de l'île de Baffin ont de plus fortes concentrations de contaminants dans le sang maternel ou le sang de cordon ombilical que ceux des régions de Kitikmeot, de Kivalliq et d'Inuvik. Les concentrations de mercure dans les résidents d'une collectivité du Nunavik présentent de grandes variations d'une année à l'autre, à cause des variations dans la disponibilité des aliments traditionnels, mais récemment les concentrations dans les tissus étaient voisines de celles observées vers la fin des années 1970. Bien que le mercure ait été surveillé dans l'environnement arctique plus longtemps que les autres contaminants (p. ex., les substances organochlorées), il est difficile de tirer des conclusions sur les tendances en raison des différences dans les stratégies d'échantillonnage. Une surveillance régulière des concentrations tissulaires dans les collectivités exposées à divers degrés au mercure et au sélénium est conseillée.

Des recherches sur les signatures des isotopes du plomb ont montré que les concentrations de plomb légèrement élevées dans le sang de certains groupes inuits ainsi que des Dénés et des Métis sont probablement dues à l'utilisation de plombs pour chasser les aliments traditionnels, d'où la présence de plomb dans le gibier consommé. Les concentrations de cadmium dans le sang sont de 1,5 à 5 fois plus élevées chez les Inuits que chez les Dénés et les Métis, les Caucasiens et autres. La différence est probablement due au niveau élevé de tabagisme des mères inuites et à la forte concentration de cadmium dans le tabac canadien.

Du radiocésium a été libéré dans l'atmosphère par les essais atmosphériques d'armes nucléaires. Depuis le premier RECAC (1997), les niveaux de radiocésium mesurés dans les troupeaux de caribous canadiens peuvent maintenant être considérés comme négligeables. Le plomb 210 et le polonium 210, qui sont radioactifs, sont naturellement présents dans l'environnement et sont les sources les plus importantes de rayonnement absorbé par les consommateurs d'aliments traditionnels. Ces radionucléides s'accumulent dans la chaîne alimentaire lichen → caribou → homme et sont présents dans l'environnement arctique depuis des milliers d'années à approximativement la même concentration qu'aujourd'hui. D'après les estimations actuelles, l'exposition au polonium transmettrait une dose de rayonnement de 3–4 millisieverts/ans (mSv/an) à un gros consommateur de viande de caribou en plus de l'exposition naturelle au rayonnement de 2–3 mSv/an.

Tendances des apports alimentaires traditionnels et des expositions aux contaminants

Chez les Inuits canadiens, les apports alimentaires traditionnels ne semblent pas avoir changé de façon importante au cours des 20 dernières années. Des relevés des apports alimentaires dans une collectivité inuite, Qikiqtarjuaq (Broughton Island, Nunavut), ont montré que les expositions au mercure étaient comparables en 1987–88 et 1999, de sorte qu'il n'y aurait que peu de changement dans les modes d'alimentation ou la concentration de mercure dans les aliments. Toutefois, l'ingestion constatée de substances organochlorées était un peu plus élevée en 1999, particulièrement chez les gros consommateurs (95^{e} percentile). Une surveillance concentrée sur la consommation d'aliments traditionnels dans des collectivités arctiques particulières au moyen de relevés des ingestions de contaminants présents dans l'environnement, comme les substances organochlorées (p. ex., BPC, chlordane, toxaphène) et le mercure, aidera à obtenir plus de données spatiales et temporelles sur les changements dans les modes d'alimentation ou les concentrations de contaminants dans les aliments.

Une surveillance continue du sang et des cheveux, et des relevés visant les habitudes alimentaires dans les collectivités susceptibles d'une grande exposition aux contaminants aideront les habitants du Nord à déterminer s'ils doivent modifier leurs habitudes alimentaires.

Toxicologie

Dans certaines populations arctiques, les résidus de toxaphène sont du même ordre de grandeur que ceux observés dans des études expérimentales où des effets ont été observés sur la fonction immunitaire et la taille des nouveau-nés. Bien qu'on ait besoin de plus d'information sur la capacité carcinogène et la capacité de perturbation endocrinienne du toxaphène, de nouvelles données prochainement disponibles seront utiles pour réévaluer la toxicité et la dose quotidienne admissible provisoire (DQAP) de cette substance.

L'accumulation de résidus liés au chlordane dans les humains ressemble à celle observée aux niveaux les plus élevés de la chaîne alimentaire marine arctique. Les ingestions estimées de chlordane par les résidents de l'Arctique varient entre un niveau inférieur au DQAP de Santé Canada et un niveau approchant ou dépassant la dose admissible provisoire de l'EPA des États-Unis, selon la quantité de graisse de mammifères marins consommée. D'après les plus récentes études sur les rongeurs effectuées par Santé Canada, une évaluation en profondeur du risque visant à réévaluer la dose admissible provisoire devrait tenir compte du fait que le principal métabolite du chlordane, l'oxychlordane, est presque 10 fois plus toxique que les chlordanes et les nonachlores connexes, et que le trans-nonachlore et l'oxychlordane sont parmi les chlordanes les plus bioaccumulatifs.

Interaction des contaminants et des éléments nutritifs

On a certaines raisons de croire que les éléments nutritifs comme les acides gras polyinsaturés, les protéines du poisson et le sélénium peuvent interagir avec la toxicité du méthylmercure, du moins au niveau mécaniste. Les deux premiers de ces éléments nutritifs peuvent offrir une protection contre la neurotoxicité du méthylmercure (MeHg), mais il n'en existe pas de preuve concluante. Il est évident qu'il faut mener d'autres études conçues spécifiquement pour examiner le rôle de la nutrition dans le métabolisme et la détoxification du méthylmercure.

Épidémiologie

Il est préférable d'étudier les effets neurologiques de l'exposition périnatale aux contaminants environnementaux dans les études des cohortes longitudinales futures en commençant pendant la grossesse parce qu'il y a de nombreux autres facteurs déterminants du développement des nouveau-nés et des enfants qui doivent être documentés, et qui peuvent être évalués le mieux durant la grossesse ou à la naissance. L'exposition prénatale à l'alcool, aux drogues et au tabac, l'exposition à d'autres contaminants environnementaux comme le plomb, et l'ingestion d'éléments nutritifs comme le sélénium et les acides gras polyinsaturés oméga-3 durant la grossesse sont des exemples de ces facteurs déterminants. L'étude en cours des cohortes du Nunavik devrait fournir de nouvelles données sur l'exposition aux contaminants et sur les effets connexes potentiels sur la santé dans les domaines du neurodéveloppement et de la fonction immunitaire. Avec la création de cette future cohorte de naissances arctique, on aura la possibilité d'examiner d'autres contaminants pouvant avoir des effets sur le neurodéveloppement, et d'étudier les effets à long terme qui ne peuvent être documentés qu'à l'âge scolaire ou plus tard dans le développement.

Dans les recherches antérieures effectuées au Nunavik, l'*otitis media* (infection de l'oreille moyenne) durant la première année de la vie a été associée à l'exposition prénatale au p,p.-DDE, à l'hexachlorobenzène et à la dieldrine. De plus, le risque de réapparition de l'*otitis media* augmente avec l'exposition prénatale à ces substances. Jusqu'ici, l'étude en cours au Nunavik confirme l'hypothèse que le taux d'infection élevé observé chez les enfants inuits (généralement des infections respiratoires) peut être la conséquence en partie d'une forte exposition prénatale aux polluants organiques persistants (POP).

D'après des données préliminaires provenant de la cohorte du Nunavik, l'ampleur de l'association négative des biphényles polychlorés (BPC) sur le poids des nouveau-nés à la naissance dans le nord du Québec est comparable aux associations avec l'exposition prénatale à l'alcool et au tabac durant la grossesse. Les effets négatifs de l'exposition prénatale aux BPC sur le poids à la naissance et la durée de la grossesse ont pu être mis en évidence malgré les effets bénéfiques des acides gras oméga-3 fournis par l'alimentation traditionnelle.

Caractérisation et évaluation des risques et des avantages, et conseils connexes

Risques de l'exposition aux contaminants

Les principaux contaminants préoccupants dans le contexte de la consommation d'aliments traditionnels dans l'Arctique canadien sont les polluants organiques persistants (POP), les BPC, le chlordane et le toxaphène, le mercure et les radionucléides naturels. Les plus grandes expositions aux POP et au mercure se trouvent dans les collectivités inuites. Dans de récents sondages sur les habitudes alimentaires dans cinq régions inuites (île de Baffin, Inuvialuit, Kitikmeot, Kivalliq et Labrador), les doses moyennes des adultes de 20 à 40 ans dans les collectivités de l'île de Baffin, de Kivalliq et d'Inuvialuit étaient supérieures à la DQAP pour le chlordane et le toxaphène. Chez les gros consommateurs (95^{e} percentile) d'aliments traditionnels, la dose est de plusieurs fois la DQAP pour le toxaphène, le chlordane et les BPC. Les populations inuites où la dose dépassait le plus la DQAP étaient également celles où la concentration de BPC dans le sang maternel dépassait le plus le maximum recommandé.

Le mercure est le métal toxique le plus préoccupant dans l'Arctique canadien. Les ingestions de mercure étaient comparables dans les deux sondages effectués en 1987–1988 et 1998–1999, ce qui signifie qu'il y a eu peu de changement dans le régime alimentaire et/ou les concentrations de mercure dans les aliments traditionnels. Sur la base de l'excédent par rapport à la dose quotidienne admissible provisoire (DQAP) et des diverses concentrations maximales recommandées dans le sang, le mercure et, à un degré moindre, le plomb (provenant des plombs utilisés pour chasser le gibier), peuvent être une préoccupation importante chez les peuples de l'Arctique.

On a de plus en plus d'indications qu'il peut exister un seuil pour les cancers provoqués par l'irradiation, et que ce seuil peut se situer à 100 mSv ou plus. Cette question est importante pour les habitants du Nord, qui ont été exposés par le passé aux retombées des explosions nucléaires, ou qui sont un peu plus exposés à cause de la consommation de la viande de caribou.

Avantages nutritifs des aliments traditionnels

Les avantages nutritifs des aliments traditionnels et la contribution de ces derniers à l'apport alimentaire total sont substantiels, même si de 6 à 40 % seulement de l'énergie alimentaire totale provient de cette source. Les résultats des recherches sont uniformes pour tout l'Arctique canadien et confirment que la baisse des aliments traditionnels dans le régime alimentaire aura probablement des conséquences négatives sur la santé, en partie en raison de l'augmentation correspondante de l'ingestion de graisses totales, de graisses saturées et de sucrose au-dessus des niveaux recommandés. Les aliments traditionnels constituent également un apport plus important en protéines, en fer et en zinc dans le régime alimentaire des enfants inuits que les aliments importés. L'augmentation des cas de diabète, de maladies cardiovasculaires et d'obésité a été liée à cet abandon partiel de l'alimentation traditionnelle. Les avantages nutritifs substantiels des aliments traditionnels et leur contribution à l'apport alimentaire total ont été documentés, mais d'autres recherches sont nécessaires sur les conséquences négatives pour la santé de la non-consommation des aliments traditionnels.

Gestion des avantages et des risques et cadre d'évaluation

Dans l'évaluation et la gestion des avantages et des risques liés aux contaminants dans les aliments traditionnels, il faut examiner le type et la quantité des aliments consommés ainsi que les avantages socioculturels, nutritifs, économiques et spirituels associés aux aliments traditionnels. Dans la gestion des avantages et des bénéfices, les décisions doivent se prendre avec la participation de la collectivité et tenir compte de tous les aspects pour la protéger le mieux possible et lui être le moins préjudiciable. Quelle que soit la décision prise, il peut rester des risques pour la santé liés à l'exposition aux contaminants. Dans l'Arctique, ces risques sont minimes comparativement aux avantages de la consommation des aliments traditionnels. L'incertitude par rapport aux risques et aux avantages continuera d'être un dilemme public, moral et politique considérable et complexe.

L'information sur les avantages et les risques

L'efficacité de la communication est fondamentale pour que soient atteints les buts du PLCN. Les informations communiquées comprennent les connaissances des Autochtones sur les avantages et les risques pour la nutrition de la consommation des aliments traditionnels et des aliments importés, et sur l'importance du mode de vie traditionnel pour la santé et le bien-être de la collectivité. Ces informations permettent aux habitants du Nord de prendre des décisions plus éclairées sur la récolte et la consommation des aliments traditionnels et des aliments importés, et d'éviter certaines des erreurs des précédentes activités d'information sur les contaminants environnementaux. Il n'y a pas de méthode de communication privilégiée; il faut disposer d'une variété de méthodes et de matériels appropriés aux collectivités de régions différentes, ainsi qu'aux divers groupes de chaque collectivité, le tout visant à offrir des possibilités d'échange d'information bidirectionnels, et de compréhension de la question à examiner.

La méthode d'information sur les risques a changé au cours des deux dernières décennies en s'appuyant sur les leçons apprises. Au lieu d'utiliser des modèles unidirectionnels de distribution d'informations, le PLCN-II s'est efforcé de prendre des décisions collectives par l'intermédiaire de partenariats avec les ministères de la Santé territoriaux et les comités régionaux sur les contaminants ou la santé, les représentants des collectivités et les représentants des organismes autochtones à toutes les étapes du processus de gestion des risques et du processus d'information connexe.

Table of Contents

List of Tables

List of Figures

ITK/Eric Loring

GNWT/NWT Archives/Tessa Macintosh

Introduction

1.1 Objectives and reason for concern

The Northern Contaminants Program (NCP) was established in 1991 in response to concerns about human exposure to elevated levels of contaminants in fish and wildlife species that are important to the traditional diets of northern Aboriginal peoples. Early studies indicated that there was a wide spectrum of substances – persistent organic pollutants, heavy metals, and radionuclides – many of which had no Arctic or Canadian sources, but which were, nevertheless, reaching unexpectedly high levels in the Arctic ecosystem.

Under the first phase of the NCP (NCP-I), which took place from 1991–1997, research was focussed on gathering the data required to determine the levels, geographic extent, and sources of contaminants in the northern atmosphere, environment and its people, and the probable duration of the problem. The data enabled us to understand the spatial patterns and temporal trends of contaminants in the North, and confirmed our suspicions that the major sources of contaminants were other countries. Information on the benefits from continued consumption of traditional/country foods was also used to carry out assessments of human health risks resulting from contaminants in those foods. Results generated through NCP-I were synthesized and published in 1997 in the first Canadian Arctic Contaminants Assessment Report (CACAR-I) (CACAR, 1997).

In 1998, the NCP began its second phase (NCP-II), which will continue until March 2003. NCP-II focusses upon questions about the impacts and risks to human health that may result from current levels of contamination in key Arctic food species as well as determining the temporal trends of contaminants of concern in key Arctic indicator species and air. A large amount of data on contaminants in the Canadian Arctic has been produced since the first CACAR report was published. The "legacy" POPs, as well as mercury, cadmium and selenium have continued to be the focal point of the measurement and monitoring of contaminants in the Canadian Arctic. However, new chemicals, such as polybrominated diphenyl ethers (PBDEs) have warranted significant attention. CACAR-II was prepared in parallel with the international Arctic Monitoring and Assessment Programme (AMAP) II Assessment.

The key objectives of this report are to summarize the knowledge on human exposure to and possible health effects of current levels of environmental contaminants in the Canadian Arctic, and to identify the data and knowledge gaps that need to be filled by future human health research and monitoring. This report presents new information that has been collected and evaluated in the intervening five years since the first CACAR was published.

From a human health perspective, the main purpose in conducting assessments of environmental contaminants in Arctic Canada is to address concerns about possible adverse health effects in people exposed to these toxic substances. These concerns are especially significant for northern Aboriginal peoples because of the high proportion of traditional/country foods in their diet. These food sources include marine mammals (e.g., whales, walrus, seals, fish, and terrestrial wild game. Bioaccumulation of lipophilic environmental contaminants contribute to the high concentrations of contaminants in the fatty tissues of some animal species. In turn, the frequent consumption of traditional/country foods typically results in higher tissue levels in individuals (see Section 1.4 for more detail).

Information gathering and analysis of data on contaminant intakes and exposure levels (Chapter 2), including toxicologic (Chapter 3) and epidemiologic data (Chapter 4) allows certain conclusions (Chapter 6) to be drawn regarding characterizing the risks posed by exposure to environmental contaminants (Chapter 5). However, the benefits of consuming traditional/country foods in Arctic Canada must also be weighed against these risks. In addition to their nutritional benefits (Section 5.2), traditional/country foods also have significant cultural, social, spiritual and economic importance and benefits (Sections 1.3 and 5.3) for Aboriginal peoples who rely on these foods. Appendix 1 provides a list of acronyms and selected symbols used throughout the report.

The benefits and risks of traditional/country food consumption are assessed during the risk assessment process where options for risk management are evaluated and selected. Benefit and risk communication (Chapter 5) is also important, and includes providing advice to northern people who are more exposed to environmental contaminants primarily through consumption of traditional/ country foods.

In addition, the research conducted on the previously mentioned areas is essential in identifying knowledge gaps (Chapter 8), and helps to highlight areas requiring further ongoing monitoring of exposure to and potential health effects of environmental contaminants.

- *The key objectives of this report are to assess the impact on human health of exposure to current levels of environmental contaminants in the Canadian Arctic, and to identify the data and knowledge gaps that need to be filled by future human health research and monitoring.*

1.2 Aboriginal peoples of northern Canada

"Aboriginal peoples" is the inclusive term normally used to describe the descendants of Canada's original inhabitants and is used throughout this report. The term "Indigenous peoples" is often used internationally.

Three groups of Aboriginal peoples are recognized by the Canadian Constitution: the Inuit, the Métis and the First Nations, who in the Arctic include the Dene and Yukon First Nations. All of these peoples are present in Canada's North. For statistical purposes, this section will describe the Inuit of Northwest Territories (NWT), Nunavut, Nunavik (northern Québec) and northern Labrador; the Dene and Métis of the NWT; and the 14 First Nations of the Yukon Territory. Métis are present in the Mackenzie Valley and southern Yukon (Figure 1.2.1).

FIGURE 1.2.1

General locations of Arctic cultural groups.

Source: Adapted from CACAR (1997)

About 56,000 (or 7.5%) of Canada's total Aboriginal population of 743,000 live in the country's Arctic region, where they comprise just over half (53%) of the combined population (Table 1.2.1). In Nunavut, the Aboriginal population accounts for approximately 84% of the total population of 24,665. A population breakdown by ethnicity in Nunavut shows the Inuit make up 83% of the population. The general pattern in Nunavik is similar, with about 88% of the population being Inuit and 11% non-Aboriginal. The corresponding figures for the NWT are about 28% First Nations, 10% Inuit, 9% Métis, and 52% non-Aboriginal, of the total NWT population of 39,455. Overall, an average 87% of people living in those areas defined as Inuit regions of Canada identified themselves as Inuit. In the Yukon, Aboriginal peoples comprise about 20% of the total population and consist mainly of First Nations and Métis peoples.

TABLE 1.2.1 Aboriginal peoples: population size and proportion of the total population in each region of Arctic Canada, 1996

Region	Total population	% Aboriginal peoples[1]
Nunavut	24,665	84 (20,695)
Northwest Territories	39,455	48 (19,010)
Nunavik (Northern Quebec)	8,700	89 (7,765)
Labrador (Arctic)	2,435	88 (2,145)
Yukon	30,650	20 (6,170)
Total Canadian Arctic Regions	105,905	53 (55,785)

Source: Statistics Canada (2002)

[1] Data presented in this table are for those who identify with one or more Aboriginal groups (Métis, Inuit, or First Nations).

Additional 1996 demographic data for Canada's Arctic regions reveals high proportions of the total population between the ages of 0 and 14 years (34%), and between the ages of 25 to 44 years (33%) (Figure 1.2.2), while the 65 years-and-over age group represents only 3% of the total population of Arctic Canada (Statistics Canada, 2002; based on 1996 data). In comparison, the overall population of Canada has an older age structure with smaller proportions in the younger age groups and greater proportions in the older age groups.

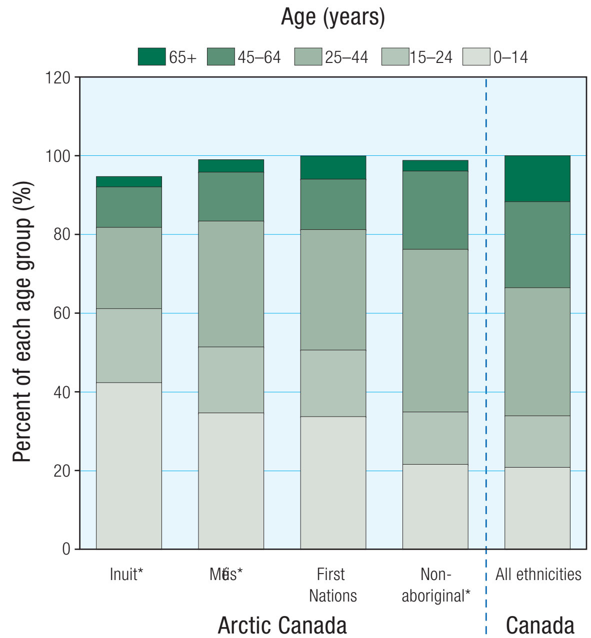


FIGURE 1.2.2

Age distribution of Canadian Arctic population by ethnicity.

Source: Statistics Canada (2002)

* Does not add up to 100% due to rounding errors.

In Arctic Canada the Inuit population has the highest percentage of people in the 0–14 age group (42%), and the non-Aboriginal population the lowest (22%). Approximately 19% of the Inuit population in Arctic Canada are between ages 15 and 24, versus roughly 13% of the non-Aboriginal population. Again, a similar pattern by ethnicity holds true in the rest of Canada. There are lower proportions of Inuit in the 25–44 and 45–64 age groups in Arctic Canada compared to the Arctic non-Aboriginal population (21% and 11%, versus 42% and 20%, respectively), and also when compared to the total Canadian population (33% and 22%, respectively).

In comparison to Arctic Canada, the total Canadian population shows an even age distribution, with a smaller population of young people (21% aged 0–14) and a larger population aged 65 years and over (12%), accounted for by the large non-Aboriginal population. Both the Aboriginal and non-Aboriginal populations of Arctic Canada have a lower percentage of people in the 65-and-over age group (range of 3–6% for the four ethnic groups of interest).

- *About 7.5% (or 56,000) of Canada's total population of 743,000 Aboriginal people live in the five major regions of Arctic Canada, where they comprise just over half (53%) of the total combined population of the Canadian Arctic.*

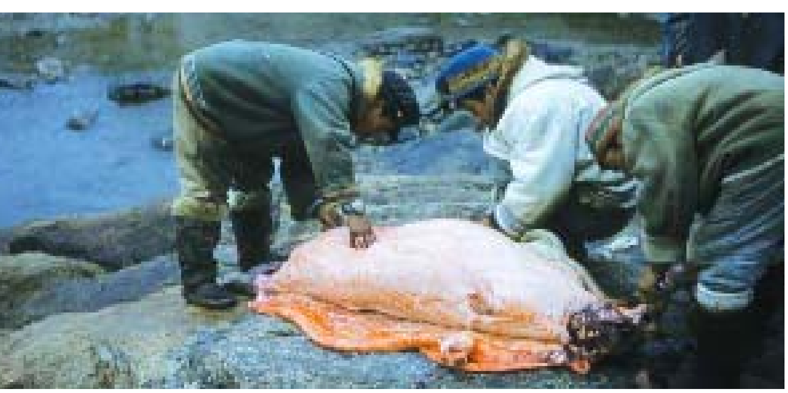
- *Demographic data from 1996 illustrate that Arctic populations, especially the Inuit are generally younger than the Canadian population, which has a more even age distribution.*

1.3 Aboriginal perspectives on food and health

In Aboriginal populations, food is perceived as an integral component of being healthy. While this chapter does not discuss this issue in full detail, it attempts to illustrate how Aboriginal perspectives on food and health differ from those in Western societies. Traditional/country foods play a vital role in the social, cultural, economic and spiritual well-being of Aboriginal peoples (Wheatley, 1996). Within many northern Aboriginal societies, exchanging traditional/country foods involves a complex set of socio-economic rules and procedures that relate to the structural organization of these societies.

Aboriginal peoples describe their food quite specifically as Inuit food, or Dene food, as the case may be. The term "traditional food" (or "country food") refers to the mammals, fish, plants, berries, and waterfowl/seabirds harvested from local stocks. Imported foods refer to all other foods which are bought mainly from the store.

For Inuit, traditional/country foods are directly associated with physical health and well-being. At Sanikiluaq, for example, people regard certain foods, such as seal, as being capable of generating bodily warmth and strength in a way that imported foods cannot. Such foods are therefore essential in the diet for Inuit activities such as hunting (Usher *et al.*, 1995). However, as Egede (1995) notes, traditional/country foods represent not only health in the physical sense, but also form an essential basis of personal and community well-being for Inuit and Dene. "Inuit foods give us health, well-being, and identity. Inuit foods are our way of life...Total health includes spiritual well-being. For us to be fully healthy, we must have our foods, recognizing the benefits they bring. Contaminants do not affect our souls. Avoiding our food from fear does" (Egede, 1995).



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Among Inuit, individual life is itself seen as a synthesis of two elements that can be roughly translated as: the body (the physical actuality and functionality of the human body), and the soul (spirit, mind, immediate emotional state, or even the expression of consciousness) (Borré, 1994). Traditional/country food is essentially important in contributing to the way individuals conceptualize their own well-being (Ridington, 1988). Among Inuit, this integration is accomplished through capturing, sharing, and consuming traditional/country food. The cultural aspects related to the harvesting of traditional/country foods such as sharing and communal processing of food are important to individual and community health.

These cultural aspects have been examined in survey-type studies in Arctic Canada. For example, information collected in interviews in three major dietary surveys demonstrated a similar agreement of selected cultural attributes of the harvesting and use of traditional/country food. Data for the five Inuit areas (n = 1,721 individual interviews) show that more than 80% of respondents agreed that harvesting and using traditional/country food by the family gives a wide range of cultural, nutritional and economic benefits (Kuhnlein *et al.*, 2000; 2002, in press).

- *Traditional/country foods are an integral component of good health among Aboriginal peoples, and their social, cultural, spiritual, nutritional and economic benefits must be considered in concert with the risks of exposure to environmental contaminants via consumption of traditional/country foods.*

1.4 Factors contributing to the exposure of Aboriginal peoples to environmental contaminants in traditional/country food

Food is a significant vector for contaminant exposure in all populations. A substantial proportion of the Aboriginal diet consists of traditional/country food; therefore, Aboriginal peoples have a higher risk of contaminant exposure than the non-Aboriginal populations in the North specifically, or in the rest of Canada.

Many of the traditionally harvested fish, and land and marine animals are long-lived and are from the higher trophic levels of the food chain, thereby providing an opportunity for considerable bioaccumulation and biomagnification of persistent contaminants (see Figure 1.4.1). Aboriginal peoples are especially likely to be exposed to environmental contaminants such as mercury and polychlorinated biphenyls (PCBs) through the consumption of fish and mammalian organ meats respectively, and of fats, especially those of marine mammals (Kinloch *et al.*, 1992; Kuhnlein *et al.*, 1995c).

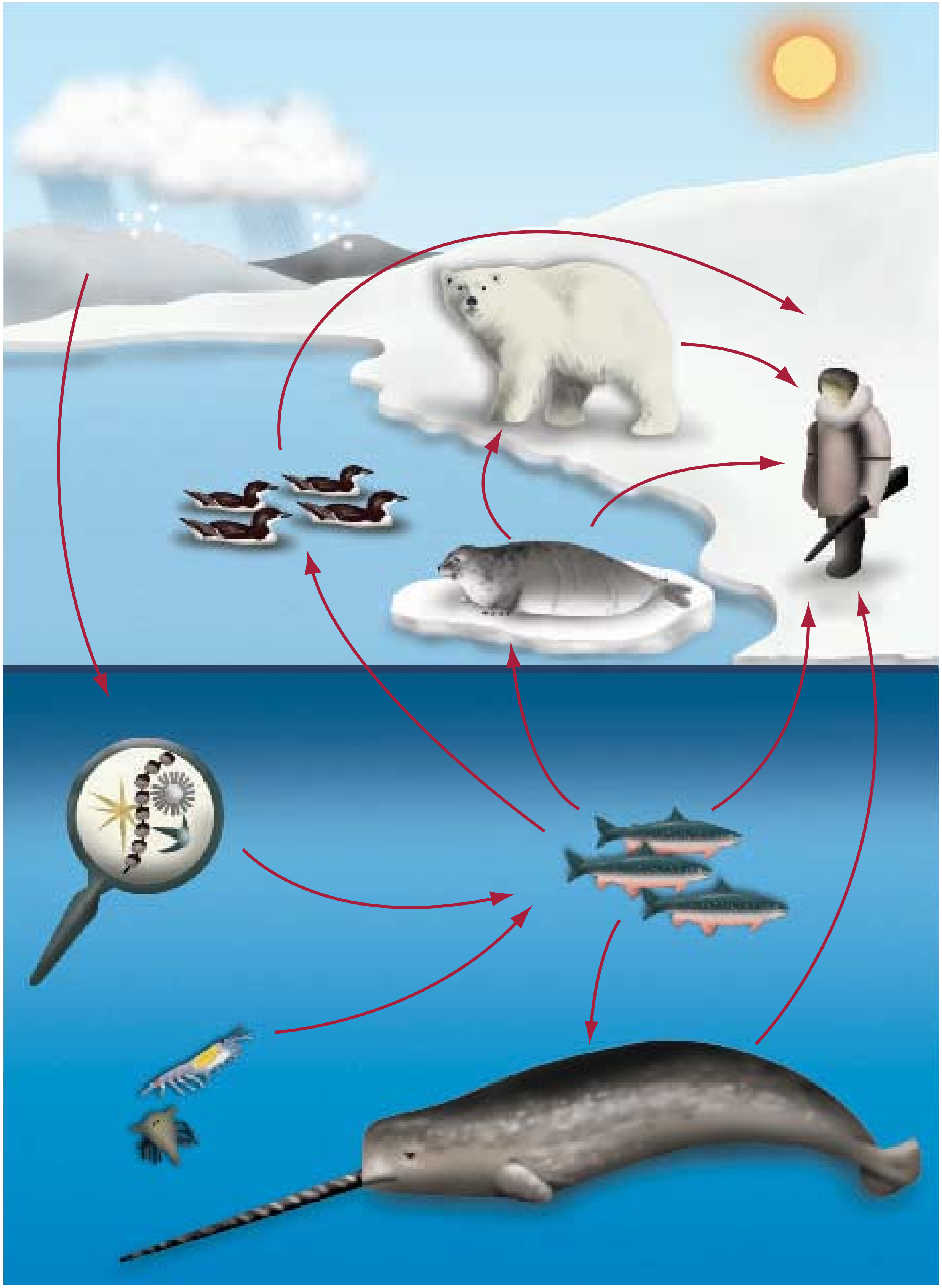

FIGURE 1.4.1

Movement of contaminants through the Arctic marine food chain.

Source: Adapted from CACAR (1997)

Health impact assessments must consider both exposure to contaminants through traditional/country foods and the many benefits of these foods (see Section 5.2 on the nutritional benefits of traditional/country food). As alluded to in Section 1.3, health impact assessments must also be considered in terms of the distinctive significance of traditional/country food to Aboriginal peoples. Hazard and risk, as social scientific studies have noted, are not merely "objective" categories, they are socially constructed. Vulnerability to a hazard is a function not only of the intrinsic nature of the hazard, but also of the geographic location and socio-economic conditions of people exposed to it, as well as their cultural perspective on the hazard (Hewitt, 1983; Douglas, 1992).

Dewailly *et al.* (2001d) conducted a study to better understand the socio-demographic factors that influence Nunavimmiut exposure to contaminants and the intake of certain nutrients found to be deficient among some sub-groups in this Nunavik population. These researchers re-analyzed 1992 Santé Québec data and identified a number of relationships between contaminant exposures, nutritional deficiencies, and various socio-demographic factors among residents in the region. Inuit couples appeared to have higher levels of traditional/country food consumption than those reporting to be divorced, widowed or single. Mean contaminant intake increased with age, with the geometric mean age-adjusted intake being higher among Inuit with fewer years of formal education completed, among those living in couples, and among those living in households of more than six individuals. For several nutrients, mean age-adjusted intake was higher among residents living in communities along the Ungava coast than among those residing in communities along the Hudson coast. Some nutritional deficiencies were more frequently associated with individuals less often employed in full-time work.

The results of the Dewailly *et al.* (2001d) study reflect the effects of some traditional socio-demographic factors (occupation, community of residence, marital status and household structure, age, gender, and level of education) on contaminant and nutrient intakes through traditional/country food consumption. These results are not surprising, as they identify sociological characteristics of individuals and their potential effects on such things as their geographical, social, and economic access to both traditional/country and imported foods in Nunavik. The findings are helpful to health officials, as they support the identification of potential "at-risk" groups for some contaminant exposures and nutritional deficiencies based on existing community variables that are commonly available. Further, it provides information as to the potential "why" question relating to individuals' exposure or lack of access to these foodstuffs. In general, this information supports the development and design of more effective promotion strategies for traditional/country foods and health.

Economic factors also affect exposure of Aboriginal peoples to contaminants in traditional/country food. Traditional/country food is an economic necessity for most Aboriginal peoples. In many northern communities, employment and incomes are low, and traditional/country food makes a significant addition to effective household income. The cost of a standard basket of imported food to provide a nutritionally adequate diet is prohibitively high in Arctic communities. For example, previous calculations of the cost to purchase equivalent amounts of imported meats in local stores have resulted in an estimated value of traditional/country food production in the NWT of about $55 million, or well over $10,000 per Aboriginal household per year (Usher and Wenzel, 1989). Although this estimate was published in 1989, and applied to the NWT when it still included Nunavut, the key message still holds true today. Moreover, such estimates apply only to the product itself, as a food commodity, and do not include any other values that Aboriginal peoples commonly attach to traditional/country foods such as the activity of hunting itself, or the collective cultural and social values of sharing and teaching.

Finally, there are health costs associated with not eating traditional/country food, which are borne both by Aboriginal peoples themselves and by public health programs. For example, reduced traditional/country food consumption in northern Aboriginal populations, coupled with decreasing physical activity, has been associated with obesity, dental caries, anemia, lowered resistance to infection, and diabetes (Szathmary *et al.*, 1987; Thouez *et al.*, 1989).

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Aspects relevant to these factors that contribute to Aboriginal people's exposure to contaminants through traditional/country food are discussed further in Sections 5.2 "*Nutritional benefits of traditional/country food*", 5.3 "*Social, cultural, spiritual, and economic benefits of traditional/country food*", and 5.5 "*Benefit and risk management framework for the Northern Contaminants Program*".

- *Persistent environmental contaminants such as PCBs, toxaphene, DDT and mercury biomagnify and bioaccumulate in the food chain. Because a substantial proportion of the Aboriginal diet consists of traditional/country food, Aboriginal peoples have a higher risk of contaminant exposure than the non-Aboriginal population in the North specifically, or in the rest of Canada.*
- *The health effects of traditional/country food consumption cannot be fully assessed by estimating exposure to contaminants alone, but must also be considered in terms of the distinctive significance of traditional/country food to Aboriginal peoples.*
- *Traditional/country food is an economic necessity for many Aboriginal peoples, and provides additional benefits in terms of the values commonly attached to traditional/country foods such as the activity of hunting itself, or the collective cultural and social values of sharing and teaching.*

1.5 Evaluation of research in CACAR and application to benefit and risk assessment/management

The Northern Contaminants Program (NCP) has generated a considerable body of knowledge on the human health implications of contaminants. This assessment report reviews this information and presents research that has been conducted or is relevant to Arctic contaminant issues. As with any scientific review caution should be used when interpreting the results of any single study. In assessing causal associations between findings in any epidemiological or toxicological study the following factors must be considered: strength and magnitude of the association, consistency of the association, dose-response relationship, temporally correct association, and biological plausibility of the association. Several studies are needed to draw any conclusions about factors such as consistency of the association. Many toxicological and epidemiological studies examining the issue from several perspectives may have to be reviewed to draw causal relationships between an environmental contaminant and a toxin. This assessment outlines where Arctic contaminant research supports or questions presently accepted causal associations between environmental contantaminants and human health effects and also points out new directions for research and evaluation.

The results from five to ten years of NCP research have been gathered from a wide variety of studies. For example, these studies have ranged from animal experiments on toxaphene which found immune effects at low doses, to laboratory tests of components and metabolites of chlordane which indicate that levels of oxychlordane and *trans*-nonachlor in highly exposed individuals may approach levels where physiological changes are seen in rodents. Animal experiments based on the mixture of contaminants found in Arctic marine mammals demonstrated effects on immune systems. Epidemiological studies in the Canadian Arctic have documented higher exposures to environmental contaminants among a number of Arctic populations. Initial results from an ongoing cohort study among the Inuit population of Nunavik have shown a decreased birth size possibly related to increasing PCB concentrations. Ongoing studies related to this birth cohort study have also found a possible link between contaminants and immune deficits in Inuit infants. Similar findings have also been seen on birth size and immunological effects in the Michigan fish-eater studies and the Netherlands population studies, respectively (see Chapter 4). Important results on neurobehavioural outcomes for the Nunavik cohort will soon be available.

As indicated previously, these results must be interpreted with caution. Some of the studies are the first analyses of data and have not yet been published and critiqued by the scientific community. Once published and subjected to full peer review, and available for comment in the scientific literature, the importance and validity of data and its interpretation will be confirmed. Other factors such as lifestyle (e.g., alcohol, cigarette consumption), diet, socio-economic status and genetic predisposition are important determinants of health. In fact contaminants may only play a modest role in determining many important health outcomes (e.g., birth size). All these factors need to be considered when evaluating the results described herein.

- *This assessment outlines Arctic human contaminant research that supports or questions presently accepted causal associations between environmental contaminants and human health effects and also points out new directions for research and evaluation.*
- *In assessing causal associations between findings in any epidemiological or toxicological study the following factors must be considered: strength and magnitude of the association, consistency of the association, dose-response relationship, temporally correct association, and biological plausibility of the association.*

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- *Determining the adverse human health effects due to the presence of contaminants in traditional/country foods is very difficult. Many factors contribute to the health of an individual and in fact contaminants may only play a modest role in determining an individual's health status. Factors such as lifestyle (e.g., alcohol consumption, smoking, and substance abuse), diet, socio-economic status and genetic predisposition need to be considered when evaluating the results described herein.*

1.6 Research ethics

A number of considerations must be taken when undertaking research in the Arctic. Communities must consent to the research within their jurisdiction and, when seeking informed consent, researchers should explain the potential benefits or harmful effects the research may have on individuals, communities and/or the environment. No undo pressure should be applied to obtain this consent and greater emphasis should be placed on the risks to cultural values than on the potential contributions of the research to knowledge.

To promote and ensure appropriate communications, the NCP has produced *Guidelines for Responsible Research* and set accompanying consultation requirements. The guidelines provide direction and set a framework for communities and researchers to agree upon their mutual obligations and to foster an equitable and beneficial relationship. Consultation requirements ensure that communities are fully aware and approve of the research to be conducted in or close to their community on a case-by-case basis. Together, and with the input of an NCP Social/Cultural committee, these guidelines and consultation requirements are used to effectively involve northern communities as partners in research activities right from the stage of project design, and to integrate communication in all stages of the research. Guidelines for responsible research can be found on the NCP website at: www.ainc-inac.gc.ca/NCP.

Communication and participation planning have become integral components of the research proposal development process for projects funded through the NCP. Methodologies and guidelines have been developed through the NCP to ensure an ethical and responsible approach to contaminants research in the Arctic. The purpose of these guidelines is to ensure researchers respect and appreciate their responsibilities to the communities in all aspects of their research from project design and research needs to communication of the final results and conclusions.

To improve the communication of information and to increase the capacity of communities to make informed decisions about their health, food consumption and wildlife with regard to contaminants, a number of initiatives were undertaken and supported by the communities and the NCP. There are now four Territorial Contaminants Committees and a number of Regional Contaminants Coordinators (RCC). The territorial contaminants committees' responsibilities included participating in the Social/Cultural review of research projects in their jurisdictions to help ensure communities receive the appropriate information, and to ensure the needs and issues of the communities are presented to the scientists. The RCCs are the front-line workers in the communities who are trained to liaise between the researchers and the communities and provide information on contaminants to the community members. The NCP produces a summary of the projects funded through the program. This plain language booklet, which describes the projects and provides contact information, is a valuable tool.

Other publications have been produced during previous phases of the NCP in response to the growing awareness of community needs. These publications are still relevant and include the following:

1. *Training Front-line Community Professionals for their Role as Contaminants Communicators and Research Liaison Professionals*

The northern frontline training course is designed for capacity building at the community level. Course participants acquire the knowledge to answer or to access information on the questions and concerns of local residents about contaminants. This document is a well-designed and tested curriculum package for a three-day contaminants course.

The objectives of the frontline training program are to:

a) provide information that assists decision making by individuals and communities in their food use;

b) develop materials to assist communication and interpretation of the technical aspects of the NCP to communities in northern Canada;

c) provide information and training that will assist front-line community professionals to develop skills that will enhance their ability to perform functions, which "default" to them as part of their regular jobs, relating to contaminant information and scientific research in their communities, including evaluation of proposals.

2. Contaminants Communication in Inuit Communities — Communicating about Contaminants in Traditional/Country Food: The Experience in Aboriginal Communities

The work undertaken through this project constitutes a crucial step in realizing key, long-term objectives for contaminants communications in Inuit communities. These are to:

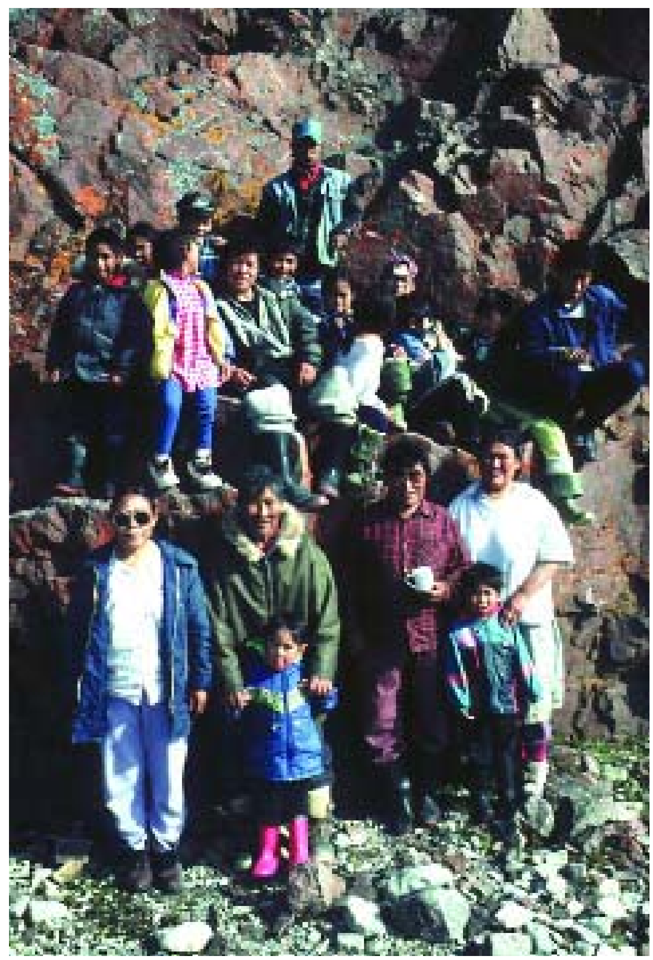
a) have relevant, complete, up-to-date and accessible information for Inuit to increase their control over contaminants-related issues and problems, and to assist them in making their own, informed lifestyle decisions. These may include, for example, more pressure on government and industry from the "grass-roots" for preventing the generation of contaminants at their sources; making choices about preparing and eating traditional/country food in certain ways; and educating others about contaminants.

b) develop the capacity among front-line communicators in Inuit communities to answer questions and serve as sources of knowledge and wisdom on contaminants-related matters.

3. A Guide to Making Presentations in Northern Communities for the Northern Aboriginal Contaminants Program

This guide was written for environmental scientists and health professionals who, in the course of their work on contaminants, are called upon to present information to groups of Aboriginal peoples from northern communities.

- *The NCP and Aboriginal communities have cooperated since 1993 to ensure that research efforts are approached in an ethical manner.*
- *Informed consent, including an explanation of the potential benefits and harmful effects of the research on individuals, must be obtained from communities, with an emphasis on the risks to cultural values rather than the potential contributions of the research to increase knowledge.*
- *Methodologies and guidelines have been developed through the NCP to ensure an ethical and responsible approach to NCP-funded contaminants research in the Arctic. These guidelines help to ensure that researchers respect and appreciate their responsibilities to the communities in all aspects of their research.*
- *Territorial Contaminants Committees and Regional Contaminants Coordinators have contributed to improving the communication of information on contaminants to community members and to increase the capacity of communities to make informed decisions about their health, food consumption and wildlife with regard to contaminants.*



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CHAPTER 2

Exposure Assessment

Key aspects of assessing exposure to environmental contaminants include evaluating sources of exposure and measuring human tissue levels of specific contaminants. In the context of Arctic Canada, consumption of contaminated traditional/country foods is a major vector of exposure to organochlorines, radionuclides and certain toxic metals such as mercury, cadmium, and lead. Accordingly, this chapter presents dietary information obtained from surveys in Inuit, and Dene and Métis communities (Section 2.1); data on contaminant levels in human tissues and their relationship to traditional/country food diets (Section 2.2); and linkages between dietary intakes and contaminant tissue levels (Section 2.3).

2.1 Dietary information

CACAR-I (CACAR, 1997) extensively documented the importance of traditional/country food as a source of nutrients. The cultural importance of this food as well as its economic value in Arctic communities where food insecurity is so prevalent were also emphasized. The information provided in 1997 is still relevant. Since CACAR-I, however, documentation of the Canadian Arctic food systems has vastly improved. The importance of traditional/country food in the diet of Nunavik Inuit (Blanchet *et al.*, 2000) and the diet of pregnant women in the Inuvik region (Tofflemire, 2000) have been better documented. The prevalence of food insecurity has been

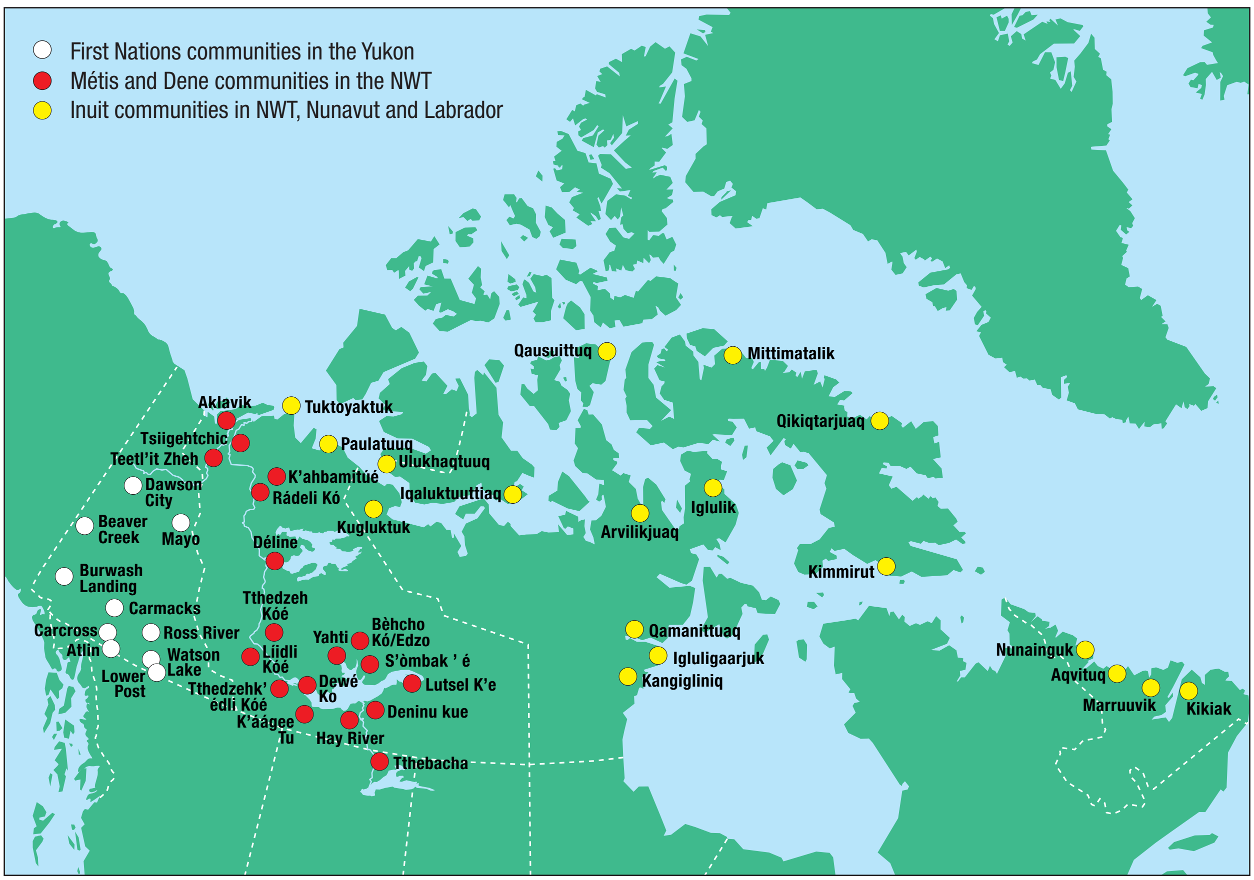


FIGURE 2.1.1

Communities participating in CINE dietary assessments.

Source: Kuhnlein and Receveur (2001)

the object of constant surveillance (Lawn and Hill, 1998; Lawn and Harvey, 2001), and three major studies of dietary intake in Arctic communities have been completed by the Centre for Indigenous Peoples' Nutrition and Environment (CINE).

Figure 2.1.1 shows the communities included in the three CINE surveys, identified as Yukon First Nations, Dene and Métis, and Inuit. At completion of CACAR-I (1997), partial results from the Dene and Métis survey were known, and the Yukon survey was underway. Data collection in Inuit communities ended in April 1999. Final reports from these three major dietary surveys are now available (Receveur *et al.*, 1996a; 1998a; Kuhnlein *et al.*, 2000), and additional peer-reviewed publications are forthcoming. Data from the Dene and Métis communities have led to several publications developing the points already reported in CACAR-I: how traditional/country food improves the nutritional quality of the diet (Receveur *et al.*, 1997); what levels of exposure are associated with traditional/country food consumption for organochlorines and heavy metals (Berti *et al.*, 1998a; Kim *et al.*, 1998) and radioactivity (Berti *et al.*, 1998b); and what are some of the social, cultural benefits (Receveur *et al.*, 1998a; 1998b) and determinants (Simoneau and Receveur, 2000) of traditional/country food use. Throughout this large participatory research effort, the objectives were to understand the patterns of traditional/country food use as well as the benefits and risks of using this food in the context of the total diet. Comparable methods were used in all three surveys whereby several types of interviews were conducted in two major seasons with individuals in randomly selected households. Food samples were collected for analysis of several contaminants and nutrients. In all, 24-hour recall interviews were conducted with 1,012 Dene and Métis, 802 Yukon First Nation residents, and 1,875 Inuit, and more than 700 food samples were contributed to the research during the study years.

2.1.1 Dietary survey results from Dene and Métis, Yukon, and Inuit communities

In Table 2.1.1, average weekly frequency of consumption of main traditional/country food items during late winter and fall in the major geographical areas is given. The most frequently mentioned traditional/country food items are caribou, moose, salmon, whitefish, grayling, trout, coney, scoter duck, cisco, walleye, spruce hen,

TABLE 2.1.1 Five traditional/country food items most often consumed (yearly average of days per week)

Region	Food item and yearly average of days per week consumed				
	1	2	3	4	5
Yukon	Moose 1.6	Caribou 0.7	Salmon 0.6	Grayling 0.4	Trout 0.1
Dene and Métis					
Gwich'in	Caribou 3.2	Whitefish 1.3	Coney 0.5	Moose 0.3	Scoter 0.2
Sahtu	Caribou 2.5	Moose 1.0	Trout 0.8	Whitefish 0.7	Cisco 0.3
Dogrib	Caribou 3.9	Whitefish 1.2	Trout 0.2	Moose 0.2	Walleye 0.2
Deh-cho	Moose 2.7	Whitefish 0.9	Caribou 0.8	Spruce Hen 0.4	Pike 0.3
South Slave	Moose 2.2	Caribou 1.9	Whitefish 1.8	Trout 0.4	Ptarmigan 0.2
Inuit					
Inuvialuit	Caribou 1.8	Char 0.5	Goose 0.2	Whitefish 0.2	Muskox 0.1
Kitikmeot	Caribou 1.2	Char 0.9	Muskox 0.3	Trout 0.3	Eider duck 0.2
Kivalliq	Caribou 1.9	Char 0.4	Crowberry 0.2	Beluga muktuk 0.2	Trout 0.1
Baffin	Caribou 1.3	Seal 1.0	Char 0.9	Narwal muktuk 0.2	Beluga muktuk 0.1
Labrador	Caribou 1.3	Trout 0.5	Partridge 0.3	Cloudberry 0.3	Char 0.2

Source: Kuhnlein (2002a)

pike, ptarmigan, Arctic char, Canada goose, muskox, eider duck, crowberry, beluga muktuk, ringed seal, narwhal muktuk, partridge, and cloudberry. More than 250 different species of wildlife, plants and animals were identified in workshops by community residents as forming the rich framework of the traditional/country food systems of Arctic peoples. Regional differences in species used most frequently are due to ecosystem variety and cultural preferences.

Results of 24-hour recall dietary interviews in the three areas (Yukon, Dene and Métis, and Inuit) demonstrated the extent of traditional/country food use. Figure 2.1.2 shows that traditional/country food use, as percent of total dietary energy in the three areas, varied from a low of 6% in communities close to urban centres, to a high of 40% in the more remote areas. In terms of grams per person per day (amount per capita calculated from averaging all 24-h recall data for fall and late winter combined), traditional/country food represents, for women 20–40 years of age, approximately 106 g in the Yukon, 144 g in Dene and Métis communities, and 194 g in Inuit communities; for men of the same age group the corresponding values were 169 g, 235 g, and 245 g for each region, respectively. Traditional/country food consumption increases with age so that in the age group 40 years and over, per capita daily consumption for women was: 193 g, 335 g, and 341 g in the Yukon, Dene and Métis, and Inuit communities respectively; and 236 g, 343 g, 440 g, respectively, for the men in each region.

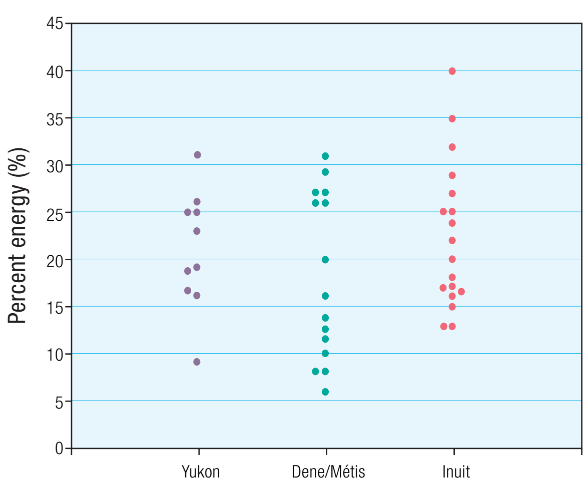


FIGURE 2.1.2

Percentage of energy from traditional/country foods in Yukon, Dene and Métis, and Inuit communities.
Source: Kuhnlein and Receveur (2001)

- *A recent assessment of the average weekly frequency of consumption of main traditional/country food items in Dene and Métis, Yukon, and Inuit communities has shown a very wide range of these foods, including more than 250 different species of wildlife, plants and animals. Regional differences in species used most frequently are due to ecosystem variety and cultural preferences.*
- *Traditional/country food use as a percent of total dietary energy in the three regions varies and is lower in communities close to urban centres versus those in more remote areas.*
- *Traditional/country food use for women and men 20–40 years of age is highest in Inuit communities, followed by Dene and Métis, and then Yukon First Nations. Age and sex are factors influencing traditional/country food use, with men having higher average intakes than women, and traditional/country food consumption increasing with age.*

2.2 Contaminant levels in people and their relationship to traditional/ country food diets

2.2.1 Levels of persistent organic pollutants in maternal and cord blood

The presence of organochlorine contaminants in the Arctic environment was noted by environmental researchers in the 1970s and summarized in the 1980s by Wong (1986). This led to human health studies in the 1980s to assess the possible exposure of Canada's northern peoples to organochlorine contaminants. In the mid-1980s, Kinloch *et al.* (1992) found elevated levels of PCBs in traditional/country foods (seals, whales) and elevated body burdens in Inuit mothers from Broughton Island, NWT. In the late 1980s, Dewailly *et al.* (1993) found similar elevated levels of PCBs and other contaminants among the Inuit people of Nunavik, Québec.

In response to these early studies, the government of the NWT undertook an assessment of contaminant levels in a range of population groups within the NWT. This was to establish a baseline upon which to make future comparisons. The government of Québec and the Nunavik health authorities have also undertaken a number of studies to assess exposure of southern and northern residents to environmental contaminants. This early research has led to one of the largest environmental contaminant research projects in Canada being undertaken in Nunavik by Dewailly, Muckle, Ayotte and colleagues to see if there are any detrimental effects on the children exposed to environmental contaminants such as mercury or PCBs.

Populations studied

A number of maternal/cord blood contaminant studies were done in the NWT, Nunavut and Nunavik between 1994 and 2000 (see Figure 2.2.1), and these studies have given an assessment of the spatial variation in contaminant levels. All of the studies in Nunavut took place before devolution and so all of these population groups are included in NWT/Nunavut. In the NWT and Nunavut there are four ethnic groups: Caucasian, Dene and Métis, Inuit, and Other (East Asian, African). Since Caucasians in the NWT consume mostly imported foods and their contaminant patterns are very similar to southern Canadian values, they provide a good comparison for northern peoples who consume northern traditional/country foods. The number of mothers in each region and ethnic group varied due to number of mothers available and the time of sampling. Populations sampled ranged from 175 Inuit mothers in Nunavik to 145 Inuit, 134 Caucasian, 93 Dene and Métis and 13 Other mothers in the NWT/Nunavut (Tables 2.2.1–2.2.7). The Caucasian and Dene and Métis mothers were from more than one region in the NWT/Nunavut but there were no significant differences in contaminant levels between these populations, so they were combined into their respective groups. Inuit came from four regions in NWT/Nunavut and there were significant differences between various groups, and so they are retained as separate groups. In Nunavik only 159 Inuit mothers were included in the population sampled.

Tissue levels of contaminants results

The results presented here for the NWT and Nunavut were supplied by Walker *et al.* (2001), who are preparing the NWT/Nunavut Environmental Contaminants Exposure Baseline report. The results for Nunavik were supplied by Muckle *et al.* (2001a; 2001b) in an upcoming paper and in some specific analyses for CACAR-II.

Residues of a number of organochlorine pesticides have been attributed to long-range atmospheric transport to the Arctic, and approximately 11 of these pesticides were included in the maternal/cord blood monitoring programs. The levels of eight of the major pesticides found most commonly in Canadian Arctic maternal blood samples

FIGURE 2.2.1

Contaminant studies in the Northwest Territories, Nunavut and Nunavik*.

Source: Walker et al. (2001)

*Boundaries are those of the Regional Health Boards in the NWT (prior to division).

are presented in Table 2.2.1. Oxychlordane and *trans*-nonachlor are components/metabolites of technical chlordane, an older generation insecticide no longer used in most of the developed world. It can be seen that Inuit have levels that are six to ten times higher than those seen in other population groups such as Caucasians, Dene and Métis, or Other (see Figure 2.2.2 for oxychlordane levels). When the Inuit groups in NWT/Nunavut/Nunavik are examined, the Inuit from Baffin have the highest oxychlordane and *trans*-nonachlor levels. Similar patterns are seen for HCB, mirex and toxaphene, as the Inuit mothers have markedly higher levels of these pesticides than those seen in rest of the groups (see Figures 2.2.3 and 2.2.4 for HCB and toxaphene levels, respectively).

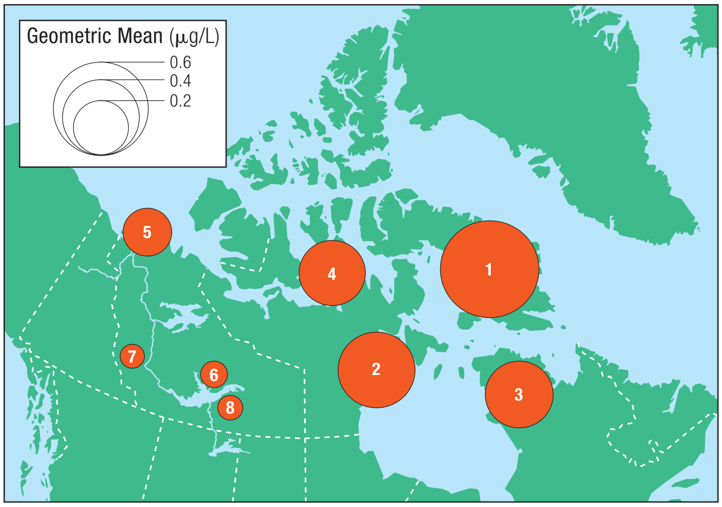
In contrast to the above pattern, the patterns demonstrated by β-HCH (beta-hexachlorocyclohexane) and DDE (dichlorodiphenyl dichloroethylene), a metabolite of the pesticide DDT, are quite different. Levels of β-HCH are five to twelve times higher among individuals in the Other group than levels seen in Inuit, Caucasians, or Dene and Métis (Figure 2.2.5). The levels of DDE in the Other group are also roughly three to six times higher than the levels observed in Inuit, Caucasian, or Dene and Métis (Figure 2.2.6). The Other group is made up of people with African and East Asian ancestry, and their exposure to these contaminants may have taken place in Africa or East Asia, or in foods imported from these regions, where β-HCH and DDE are still widely used.

TABLE 2.2.1 Mean levels of organochlorine pesticides in maternal blood, by region and ethnic group [geometric mean (range), μg/L plasma]

OC contaminant	Ethnicity/Region							
				Inuit				
	Caucasian[1] (n = 134)	Dene and Métis[1] (n = 93)	Other[1] (n = 13)	Baffin[1] (n = 30)	Inuvik[1] (n = 31)	Kitikmeot[1] (n = 63)	Kivalliq[1] (n = 17)	Nunavik[2] (n = 159)
Years of study	**1994–99**	**1994–99**	**1994–95**	**1996**	**1998–99**	**1994–95**	**1996–97**	**1995–2000**
Oxychlordane	0.05 (nd[7] – 0.22)	0.04 (nd – 0.23)	0.04 (nd – 0.21)	0.58 (0.09 – 2.4)	0.15 (0.03 – 1.1)	0.29 (nd – 2.9)	0.36 (nd – 6.2)	0.30 (0.01 – 3.9)
Trans-nonachlor	0.06 (0.02 – 0.26)	0.06 (nd – 0.37)	0.07 (0.02 – 0.30)	0.64 (0.16 – 2.5)	0.28 (0.05 – 1.8)	0.31 (nd – 3.0)	0.44 (0.03 – 3.7)	0.46 (0.01 – 4.6)
p, p′-DDT	0.05 (nd – 0.19)	0.03 (nd – 0.13)	0.22 (nd – 3.2)	0.14 (0.04 – 0.47)	0.07 (nd – 0.45)	0.08 (nd – 0.33)	0.09 (nd – 0.35)	0.09 (0.02 – 1.1)
p, p′-DDE	0.91 (0.22 – 11.2)	0.69 (0.15 – 5.3)	4.0 (0.51 – 34)	2.1 (0.55 – 6.0)	1.1 (0.40 – 3.8)	1.3 (0.12 – 7.8)	1.7 (0.21 – 7.2)	2.2 (0.14 – 18)
DDE:DDT	18 (nd – 75)	18 (nd – 89)	15 (nd – 31)	15 (7.1 – 43)	13 (nd – 51)	15 (nd – 53)	19 (nd – 52)	23 (2.8 – 209)
HCB	0.12 (0.04 – 0.61)	0.18 (0.02 – 1.7)	0.11 (0.02 – 0.40)	0.53 (0.14 – 1.5)	0.31 (0.06 – 1.2)	0.56 (0.05 – 4.5)	0.46 (0.07 – 1.8)	0.31 (0.05 – 2.8)
β-HCH	0.09 (nd – 0.55)	0.04 (nd – 0.13)	0.48 (0.04 – 39)	0.11 (nd – 0.44)	0.08 (nd – 0.25)	0.09 (nd – 0.44)	0.09 (nd – 0.30)	0.04 (0.02 – 0.25)
Mirex	0.02 (nd – 0.14)	0.02 (nd – 0.21)	0.01 (nd – 0.07)	0.06 (nd – 0.19)	0.03 (nd – 0.11)	0.05 (nd – 0.38)	0.06 (nd – 0.80)	0.07 (0.01 – 0.60)
Toxaphene (total)	0.05[3] (nd – 0.50)	0.07[4] (nd – 0.81)	n/a[5]	0.59 (nd – 6.4)	0.43 (nd – 3.6)	0.69[6]	0.74 (nd – 5.2)	n/a[5]
Parlar 26	0.01[3] (nd – 0.04)	0.01[4] (nd – 0.06)	n/a[5]	0.10 (0.02 – 0.57)	0.05 (nd – 0.36)	0.10[6]	0.08 (nd – 0.43)	n/a[5]
Parlar 50	0.01[3] (nd – 0.05)	0.01[4] (nd – 0.07)	n/a[5]	0.13 (0.03 – 0.66)	0.06 (nd – 0.43)	0.15[6]	0.10 (nd – 0.57)	n/a[5]

Sources: [1]Walker *et al.* (2001); [2]Muckle (2000), Muckle *et al.* (2001b)

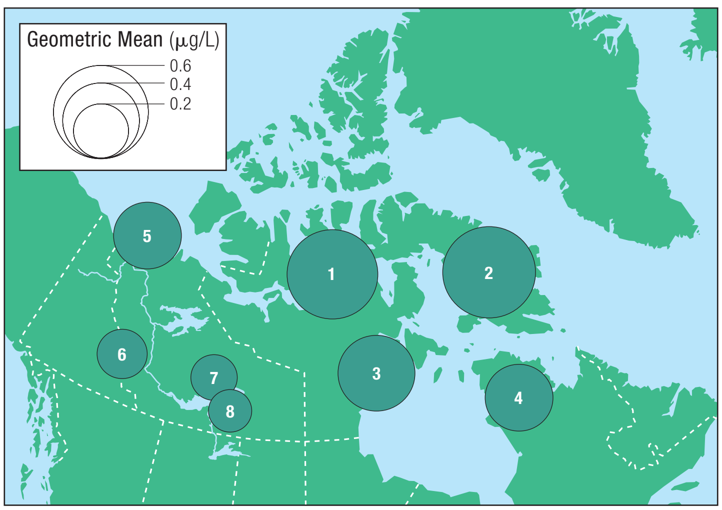
[3]n = 25; [4]n = 42; [5]not available; [6]four composites (n = 12, 12, 12 and 14); [7]nd = not detected.



1	**0.58** µg/L	Inuit – Baffin
2	**0.36** µg/L	Inuit – Kivalliq
3	**0.30** µg/L	Inuit – Nunavik
4	**0.29** µg/L	Inuit – Kitikmeot
5	**0.15** µg/L	Inuit – Inuvik
6	**0.05** µg/L	Caucasian
7	**0.04** µg/L	Dene/Métis
8	**0.04** µg/L	Other

FIGURE 2.2.2

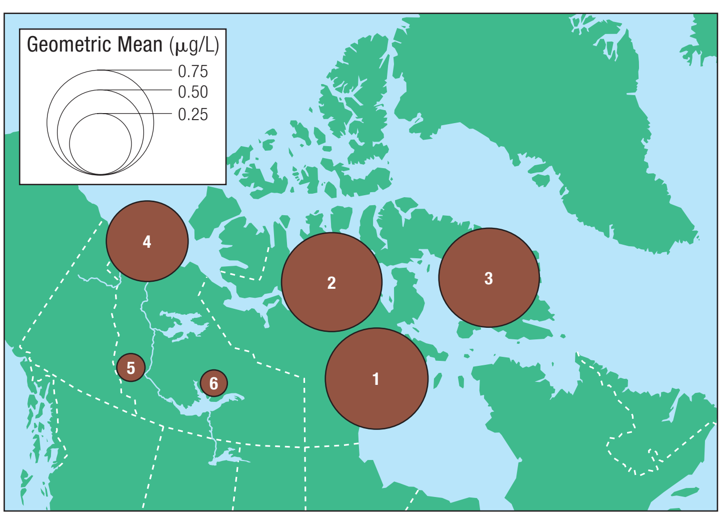
Maternal contaminant levels in Arctic Canada: Oxychlordane (µg/L plasma).
Source: Van Oostdam (2001)



1	**0.56** µg/L	Inuit – Kitikmeot
2	**0.53** µg/L	Inuit – Baffin
3	**0.46** µg/L	Inuit – Kivalliq
4	**0.31** µg/L	Inuit – Nunavik
5	**0.31** µg/L	Inuit – Inuvik
6	**0.18** µg/L	Dene/Métis
7	**0.12** µg/L	Caucasian
8	**0.11** µg/L	Other

FIGURE 2.2.3

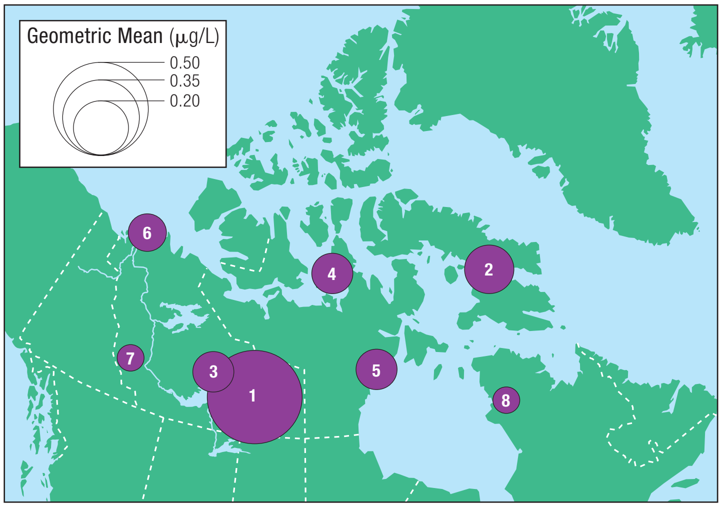
Maternal contaminant levels in Arctic Canada: Hexachlorobenzene (µg/L plasma).
Source: Van Oostdam (2001)



1	**0.74** µg/L	Inuit – Kivalliq
2	**0.68** µg/L	Inuit – Kitikmeot
3	**0.59** µg/L	Inuit – Baffin
4	**0.43** µg/L	Inuit – Inuvik
5	**0.07** µg/L	Dene/Métis
6	**0.05** µg/L	Caucasian

FIGURE 2.2.4

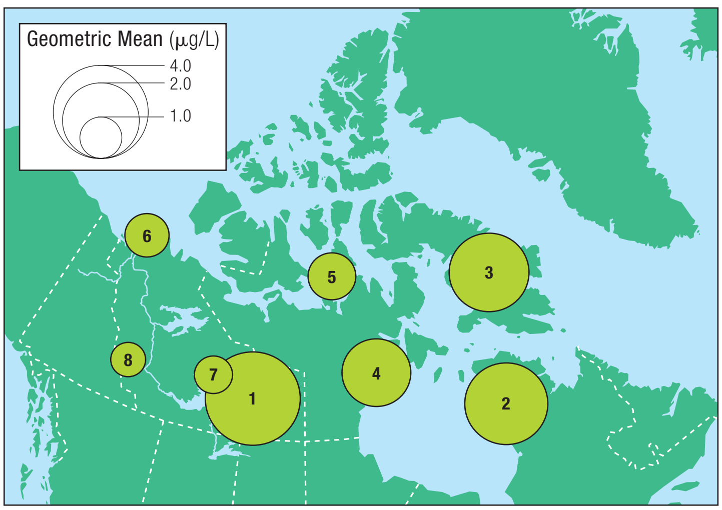
Maternal contaminant levels in Arctic Canada: Total toxaphene (µg/L plasma).
Source: Van Oostdam (2001)



1	**0.48** µg/L	Other
2	**0.11** µg/L	Inuit – Baffin
3	**0.09** µg/L	Caucasian
4	**0.09** µg/L	Inuit – Kitikmeot
5	**0.09** µg/L	Inuit – Kivalliq
6	**0.08** µg/L	Inuit – Inuvik
7	**0.04** µg/L	Dene/Métis
8	**0.04** µg/L	Inuit – Nunavik

FIGURE 2.2.5

Maternal contaminant levels in Arctic Canada: β-hexachlorocyclohexane (µg/L plasma).
Source: Van Oostdam (2001)



1	**4.0** µg/L	Other
2	**2.2** µg/L	Inuit – Nunavik
3	**2.1** µg/L	Inuit – Baffin
4	**1.7** µg/L	Inuit – Kivalliq
5	**1.3** µg/L	Inuit – Kitikmeot
6	**1.1** µg/L	Inuit – Inuvik
7	**0.9** µg/L	Caucasian
8	**0.7** µg/L	Dene/Métis

FIGURE 2.2.6

Maternal contaminant levels in Arctic Canada: p,p′-DDE (µg/L plasma).
Source: Van Oostdam (2001)

Polychlorinated biphenyls (PCBs) are a group of industrial compounds that were widely used in the 1950s, 1960s, and 1970s, and are now banned and being phased out but are still widespread in the environment. PCBs have been implicated in deleterious effects on the learning abilities of young children, and are a major contaminant of concern in the Arctic. Inuit mothers have the highest levels of PCBs measured as Aroclor 1260 compared to Caucasians, Dene and Métis, and the Other mothers (Table 2.2.2 and Figure 2.2.7). When the Inuit from all regions are compared, it can be seen the Baffin Inuit have the highest levels of PCBs (8.0 µg/L).

TABLE 2.2.2 Mean levels of PCBs in maternal blood, by region and ethnic group [geometric mean (range), µg/L plasma]

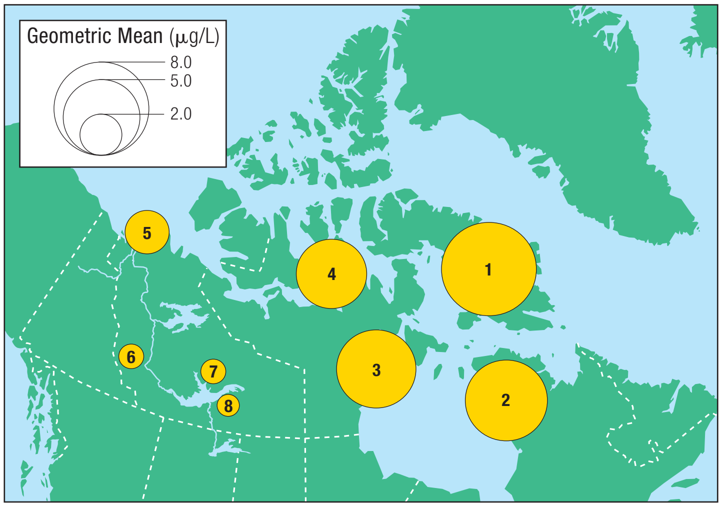
OC contaminant	Ethnicity/Region							
				Inuit				
	Caucasian[1] (n = 134)	Dene and Métis[1] (n = 93)	Other[1] (n = 13)	Baffin[1] (n = 30)	Inuvik[1] (n = 31)	Kitikmeot[1] (n = 63)	Kivalliq[1] (n = 17)	Nunavik[2] (n = 159)
Years of study	**1994–99**	**1994–99**	**1994–95**	**1996**	**1998–99**	**1994–95**	**1996–97**	**1995–2000**
Aroclor 1260[5]	1.3 (0.24 – 5.7)	1.3 (0.26 – 14)	1.1 (0.31 – 3.7)	8.0 (2.0 – 27)	2.4 (0.62 – 7.9)	4.5 (0.20 – 27)	5.6 (0.41 – 60)	6.0 (0.10 – 48)
PCB 28	0.02 (nd[4] – 0.10)	0.01 (nd – 0.06)	0.02 (nd – 0.04)	0.02 (nd – 0.05)	0.01 (nd – 0.09)	0.01 (nd – 0.06)	0.01 (nd – 0.07)	n/a[3]
PCB 52	0.01 (nd – 0.07)	0.01 (nd – 0.04)	0.01 (nd – 0.02)	0.03 (nd – 0.08)	0.02 (nd – 0.06)	0.02 (nd – 0.11)	0.02 (nd – 0.09)	n/a[3]
PCB 99	0.04 (nd – 0.19)	0.03 (nd – 0.28)	0.03 (nd – 0.09)	0.19 (0.04 – 0.73)	0.08 (0.02 – 0.28)	0.12 (nd – 0.81)	0.13 (nd – 1.3)	n/a[3]
PCB 101	0.01 (nd – 0.03)	0.01 (nd – 0.04)	0.01 (nd – 0.02)	0.02 (nd – 0.06)	0.02 (nd – 0.07)	0.02 (nd – 0.07)	0.02 (nd – 0.04)	n/a[3]
PCB 105	0.01 (nd – 0.05)	0.01 (nd – 0.06)	0.01 (nd – 0.02)	0.04 (nd – 0.15)	0.02 (nd – 0.07)	0.02 (nd – 0.09)	0.03 (nd – 0.22)	n/a[3]
PCB 118	0.04 (nd – 0.27)	0.04 (nd – 0.26)	0.03 (nd – 0.09)	0.14 (0.03 – 0.50)	0.07 (0.02 – 0.32)	0.09 (nd – 0.40)	0.09 (nd – 0.66)	0.10 (0.01-0.84)
PCB 128	nd	nd	nd	0.01 (nd – 0.05)	0.01 (nd – 0.03)	0.01 (nd – 0.06)	0.01 (nd – 0.02)	n/a[3]
PCB 138	0.11 (0.02 – 0.48)	0.10 (0.02 – 0.98)	0.10 (0.03 – 0.29)	0.51 (0.12 – 1.5)	0.19 (0.05 – 0.67)	0.30 (0.02 – 1.6)	0.37 (0.03 – 3.3)	0.42 (0.01 – 3.1)
PCB 153	0.14 (0.03 – 0.61)	0.16 (0.03 – 1.8)	0.12 (0.03 – 0.41)	1.0 (0.25 – 3.9)	0.26 (0.06 – 0.88)	0.56 (0.02 – 3.6)	0.70 (0.05 – 8.3)	0.75 (0.03 – 6.1)
PCB 156	0.02 (nd – 0.11)	0.02 (nd – 0.22)	0.02 (nd – 0.07)	0.06 (0.02 – 0.30)	0.02 (nd – 0.08)	0.05 (nd – 0.31)	0.05 (nd – 0.49)	n/a[3]
PCB 170	0.03 (nd – 0.16)	0.03 (nd – 0.39)	0.03 (nd – 0.10)	0.18 (0.04 – 0.95)	0.04 (nd – 0.13)	0.01 (nd – 0.67)	0.11 (nd – 2.3)	n/a[3]
PCB 180	0.09 (nd – 0.50)	0.08 (nd -0.12)	0.07 (0.02 – 0.29)	0.40 (0.07 – 1.8)	0.08 (0.02 – 0.30)	0.27 (0.02 – 1.7)	0.28 (0.03 – 4.2)	0.32 (0.02 – 2.3)
PCB 183	0.01 (nd – 0.05)	0.02 (nd – 0.14)	0.01 (nd – 0.03)	0.05 (nd – 0.16)	0.02 (nd – 0.07)	0.03 (nd – 0.11)	0.05 (nd – 0.44)	n/a[3]
PCB 187	0.03 (nd – 0.13)	0.05 (nd – 0.52)	0.03 (nd – 0.13)	0.18 (0.05 – 0.53)	0.06 (0.02 – 0.25)	0.01 (0.01 – 0.54)	0.13 (0.02 – 1.1)	n/a[3]
Sum of 14 PCBs	0.52 (0.11 – 2.2)	0.52 (0.12 – 5.5)	0.43 (0.13 – 1.4)	2.7 (0.70 – 9.4)	0.82 (0.23 – 2.7)	1.6 (0.12 – 9.4)	1.9 (0.17 – 22)	2.3 (0.17 – 16)

Sources: [1]Walker *et al.* (2001); [2]Muckle (2000), Muckle *et al.* (2001a; 2001b)

[3]not available; [4]nd = not detected; [5]Aroclor 1260 = 5.2 (PCB 153 + 138) (Weber, 2002a).

When PCBs are examined on a congener-specific basis, the more highly chlorinated congeners (PCBs 128–187) exhibit a similar pattern to that seen for PCBs as Aroclor 1260. Concentrations of PCB congeners are found in the following order: PCB 153>138>180>187, etc. There are no marked differences in congener patterns among the various ethnic groups. The Inuit have a slightly greater proportion of the most predominant PCB 153 when compared to the Caucasian and Dene and Métis groups, and also have slightly smaller proportions of PCBs 28, 52, 101 and 128 (see Table 2.2.2).

A number of studies have shown that some PCBs have dioxin-like activity. Twelve of the 209 PCBs share certain toxicological properties with dioxins and furans and have been assigned dioxin-like toxicity equivalency factors (TEFs) by the World Health Organization (Van den Berg *et al.*, 1998). The concentration of these "dioxin-like" PCBs can be multiplied by their TEF to calculate a PCB toxic equivalency (TCDD-TEQ) which is then added to the dioxin/furan component for a total TCDD-TEQ. There have not been many dioxin, furan and dioxin-like PCB analyses conducted under the Canadian Northern



1	**8.0** µg/L	Inuit – Baffin
2	**6.0** µg/L	Inuit – Nunavik
3	**5.6** µg/L	Inuit – Kivalliq
4	**4.5** µg/L	Inuit – Kitikmeot
5	**2.4** µg/L	Inuit – Inuvik
6	**1.3** µg/L	Dene/Métis
7	**1.3** µg/L	Caucasian
8	**1.1** µg/L	Other

FIGURE 2.2.7

Maternal contaminant levels in Arctic Canada: PCBs (as Aroclor 1260) (µg/L plasma).

Source: Van Oostdam (2001)

Contaminants Program maternal blood contaminant monitoring program due to the expense and large sample volumes needed for these analyses. Recently some analyses of composite samples were undertaken to assess the relative contributions of dioxins, furans and dioxin-like PCBs in Arctic Canadian populations (Van Oostdam and Feeley, 2002). In Table 2.2.3 the results are outlined for the 11 composite analyses for maternal blood from some of the mothers in the same groups previously described for organochlorines and PCBs. The Caucasian mothers had slightly higher levels of total TCDD-TEQs (dioxins and furans and dioxin-like PCBs 2,3,7,8-TCDD TEQs) than Inuit or Dene mothers (157 versus 148 and 121 pg/L, respectively) but the relative contributions of dioxin-like PCBs are very different in the three groups. Among Inuit mothers 80% of the total TCDD-TEQs are accounted for by dioxin-like PCBs while Caucasian mothers have only 27% of the total TCDD-TEQs coming from PCBs. The Dene mothers have a more equal contribution of dioxins and furans and dioxin-like PCBs in the overall total TCDD-TEQs. The main source of exposure for dioxins and furans, PCBs and many other organochlorine contaminants is through diet. Due to the expense and more difficult analyses there are few data on levels of dioxins, furans and dioxin-like PCBs in Arctic traditional/country foods. In spite of this, it seems reasonable to speculate that Caucasian mothers obtained their higher levels of dioxins and furans in their diet from imported foods while Inuit mothers likely obtained their higher levels of dioxin-like PCBs from traditional/country foods such as marine mammals which contain higher levels of PCBs (well-documented).

Comparisons can be also made based on contaminant levels found in cord blood. A similar pattern to that seen in the maternal data emerges for various contaminants, though the magnitude does vary in maternal and cord blood for contaminant data from the NWT and Nunavut (Van Oostdam *et al.*, 2001). Since lipid levels vary markedly between maternal and cord blood, cord-to-maternal comparisons are best made on a lipid weight (lw) basis. The strong correlation between cord and maternal blood levels can be seen in Table 2.2.4; correlations range from 0.87 to 0.96 and all are highly significant. These correlations indicate that either cord or maternal blood levels may be used in health impact studies of these contaminants. Some organochlorines (lipid weight basis) such as PCBs, oxychlordane, and DDE/DDT are found at lower levels in the cord blood than the maternal blood, thus resulting in cord-to-maternal blood ratios of 0.6 to 0.9. PCB congeners in cord blood were also 0.7 to 0.9 times the maternal concentration. Some organochlorines such as β-HCH, hexachlorobenzene, and heptachlorepoxide showed the opposite pattern, with 1.4 to 3.2 times higher levels being found in the cord blood compared to maternal blood. Similar patterns for a number of contaminants have been reported by Bjerregard *et al.* (2000) for Greenland Inuit. Though many researchers have taken the ratio between the cord and maternal blood concentrations to be a static relationship, recent work by Van Oostdam *et al.* (2001) has indicated that this ratio does vary by contaminant concentration, with the highest cord-to-maternal ratios being found at the lowest concentrations.

TABLE 2.2.3 Dioxins and furans and PCBs in maternal plasma (pg/L plasma)

	2,3,7,8, TCDD TEQs (ND = 0) (pg/L plasma)			
Ethnicity	**PCBs**	**D + F[1]**	**D + F + PCBs**	**% PCBs**
Inuit	117.8	29.8	147.7	80%
Caucasian	42.0	115.0	157.0	27%
Dene	54.0	67.0	121.0	45%

[1] D + F = Dioxins and Furans

TABLE 2.2.4 Cord and maternal contaminants (lw)

Contaminant	n[1]	Cord[2]	Maternal[2]	Ratio[3]	Correlation[4]	p Value[5]
β-HCH	116	68	59	1.4	0.87	0.0001
Hexachlorobenzene	335	37	40	1.1	0.95	0.0001
Oxychlordane	143	32	54	0.63	0.96	0.0001
PCBs (Aroclor 1260)	303	360	454	0.84	0.96	0.0001

Source: Van Oostdam (2001)

Abbreviations: β-HCH (*beta*-hexachlorocyclohexane); PCBs (polychlorinated biphenyls)

[1]Sample size: cord-maternal pairs; [2]Concentration (μg/kg lipid, arithmetic mean); [3]Cord/maternal blood (paired data only); [4]Pearson correlations; [5]Statistical significance of cord/maternal Pearson correlations.

Comparisons to other populations in the world can easily be made. No specific comparisons were made to the southern Canadian population, as the Caucasian population included in the NWT/Nunavut sampling has a similar diet and resulting similar contaminant levels as the southern Canadian population, which can serve as a useful benchmark for southern levels of contaminants. In comparison to Canadian Inuit mothers from Nunavik and Nunavut/NWT, Inuit from Greenland have markedly higher levels of PCBs as Aroclor 1260, i.e., 2.4–8.0 μg/L versus 6.4–36 μg/L, respectively (Table 2.2.5). This difference may result from consumption of more marine mammals in the traditional Greenland diet. Compared to Inuit mothers, lower levels of PCBs are seen in non-Indigenous people living in Arctic Russia. In contrast, levels of β-HCH are markedly higher in the mothers from India, followed by non-Indigenous mothers of Arctic Russia and then mothers in the Other group in the NWT/Nunavut (Table 2.2.5). This indicates that DDT must still be used in the Indian and Russian commercial food supply or used for insect control in the local environment. The markedly higher levels of β-HCH in mothers in India (127 μg/L) (Sharma and Bhatnagar, 1996) are likely due to the more extensive present-day use of β-HCH in the tropics to protect against insect vectors in the home and on crops.

Human environmental monitoring for organochlorines does not have a long history in the Canadian Arctic. In most cases there are only one or a few data points to assess contaminant trends — the late 1980s to the mid-1990s. Methodological differences in sampling strategies, and sampling high consumers versus general maternal samples make it difficult to compare the specific results of these two time points. It may be more useful to examine tissue levels of metals such as mercury which have a longer history of monitoring.

- *There were a number of maternal/cord blood contaminant studies in the NWT, Nunavut and Nunavik between 1994 and 2000, and these studies have given an assessment of the spatial variation in contaminant levels.*
- *Inuit mothers have oxychlordane and* trans-*nonachlor levels that are 6–12 times higher than those in Caucasians, Dene and Métis, or Other mothers, with Baffin Inuit mothers having the highest levels. Similar patterns were observed for PCBs, HCB, mirex and toxaphene.*

TABLE 2.2.5 Worldwide comparisons of maternal blood levels of PCBs (Aroclor 1260) and β-HCH (geometric means, μg/L plasma)

Contaminant	NWT/Nunavut/ Nunavik Inuit[1,2]	NWT other[1]	Greenland Inuit[3,4]	Arctic Russia (non-Indigenous)[5,6,7]	India (Indigenous)[8]
PCBs (Aroclor 1260)	2.4–8.0	1.1	6.4–36	3.3–4.3	
Beta-HCH	0.04–0.11	0.48	0.07–0.24	0.31–3.1	127

Sources: [1]Walker *et al.* (2001); [2]Muckle (2000), Muckle *et al.* (2001b); [3]Deutch (2000; 2001); [4]Deutch and Hansen (2000); [5]Klopov *et al.* (1998); [6]Klopov (2000), Klopov and Shepovalnikov (2000), Klopov and Tchachchine (2001); [7]Odland (2000); [8]Sharma and Bhatnagar (1996).

- *Levels of ß-HCH are 5–12 times higher among the Other group than in Inuit, Caucasians or Dene and Métis mothers, while DDE levels in the Other mothers are also roughly 3–6 times higher. This higher exposure may be due to the fact that the Other mothers group consists of people whose exposure may be related to their possible African or East Asian country of origin or foods imported from these regions.*
- *PCBs are a major contaminant of concern in the Arctic. Inuit mothers have the highest levels of PCBs measured as Aroclor 1260 compared to Caucasians, Dene and Métis and the Other mothers, with Baffin Inuit having the highest levels. There are no marked differences in congener patterns among the various ethnic groups.*
- *Caucasians mothers from the NWT have slightly higher levels of total dioxins and furans and dioxin-like PCBs, measured as TCDD-TEQs, than Inuit or Dene and Métis mothers. The relative contributions of dioxins and furans and dioxin-like PCBs to the total TCDD-TEQs are very different in the three groups. Among Inuit mothers, dioxin-like PCBs account for 80% of the total TCDD-TEQs, while for Caucasian mothers, these compounds account for only 27%; Dene and Métis mothers have a relatively equal contribution from both sources.*
- *Cord blood levels of contaminants show a pattern similar to that for the maternal data, though the magnitude does vary in maternal and cord blood for contaminant data from the NWT and Nunavut. These consistent correlations indicate that either cord or maternal blood levels may be used in health impact studies of these contaminants.*
- *Comparisons to other populations in the world can easily be made. In comparison to Canadian Inuit mothers from Nunavik and Nunavut/NWT, Inuit from Greenland have markedly higher levels of PCBs as Aroclor 1260. This difference may be due to consumption of more marine mammals in the traditional Greenland diet.*
- *The monitoring of organochlorines in human tissues does not have a long history in the Canadian Arctic, and there are insufficient data points to determine contaminant trends.*

ITK/Eric Loring

2.2.2 Levels of mercury in hair and blood

Traditional/country foods, such as fish and sea mammals, are considered the primary environmental pathway for mercury for Canadians living in the Arctic. Environmental and health concerns about mercury levels in human tissues in Canada were first identified in the early 1970s in two northern Ontario First Nations communities following contamination of fish due to effluents from chloralkali plants (Sherbin, 1979; Health Canada, 1979). Later on, these same concerns were raised in other Aboriginal communities across Canada (e.g., Nelson House, Manitoba; James Bay, Québec) affected by hydroelectric developments (McKeown–Eyssen and Ruedy, 1983).

Following these developments, the Medical Services Branch of Health Canada determined human tissue concentrations and regional distribution of mercury in Aboriginal peoples of Canada. These mercury determinations (total and organic mercury) have been done for adults, pregnant and reproductive-age women, and children including newborns. Up to 1998, the First Nations and Inuit Health Branch (FNIHB), formerly the Medical Services Branch of Health Canada, carried out community health risk assessments by analyzing hair and blood samples obtained from more than 40,000 residents in more than 500 First Nations and Inuit communities across Canada (CACAR, 1997). Since the mid-1980s, the mercury monitoring program among Cree First Nations of Québec has been continued by the Cree Board of Health and Social Services. A similar program has been undertaken by the Government of the Northwest Territories (GNWT) Department of Health and Social Services.

Population groups and studies

Specific population groups with exposure to mercury through consumption of traditional/country foods in NWT, Nunavut and northern Québec (Nunavik) include four ethnic groups: Caucasian, Dene and Métis, Inuit, and Other (East Asian, African). There are extensive data sets on patterns of exposure, including seasonal and temporal patterns, measured by hair and blood mercury levels as biomarkers and by eating pattern surveys, for First Nations and Inuit across Canada covering a 30-year period (Wheatley and Paradis, 1998; Health Canada, 1999). These data sets are maintained at Health Canada, the Cree Board of Health and Social Services of James Bay (for the James Bay Cree since 1988) (Dumont *et al.*, 1998), and the Department of Indian Affairs and Northern Development for data from the NCP over the past ten years (CACAR, 1997). The research and data on mercury from human tissue monitoring programs by the above-mentioned sources have led to one of the largest environmental contaminant research projects in Canada. It is being carried out in northern Canada by Dewailly and colleagues to examine detrimental effects on children exposed to dietary mercury and other contaminants. Recent maternal hair and maternal/cord blood contaminant studies in the NWT have given an assessment of the spatial variation in mercury levels (Tables 2.2.6, 2.2.7 and 2.2.8) (Snider and Gill, 2001; Dewailly *et al.*, 1999; Walker *et al.*, 2001). The number of mothers in each region and ethnic group varied due to the number of mothers eligible to be included in the sampling procedure.

Maternal hair

The Inuvik region is located in the MacKenzie Delta and Sahtu regions of the NWT. The cumulative mercury exposure as measured in hair (data for women of reproductive age) during 1976–1979 and 1998–1999 are summarized in Table 2.2.6. A total of 166 individuals were sampled during 1976–1979. The results revealed that 27% of the children between ages 3 and 14 years, and 34% of women of childbearing age (15–45 years old) had hair mercury concentrations greater than 6 µg/g [6 parts per million (ppm)], while 36% of all individuals tested (all ages and both genders) had concentrations greater than 6 µg/g hair (data not presented in table). Clearly, there are differences in mercury concentration distribution between various age groups. In Inuvik and Tuktoyaktuk, mercury measurements were made in hair in 1976–1979 and 1998–1999 (Table 2.2.6). Mercury levels in hair were lower in both communities in 1998–1999 than those seen in 1976–1979 and levels in the 1998–1999 sampling were approximately four times higher in Tuktoyaktuk than the Inuvik or any other women surveyed. In general, the observed factors that seem to influence hair mercury concentrations were age and place of residence. Mercury levels may now be lower in hair of women from some NWT communities but differences in sampling strategies may effect any conclusion on time trend. Some of the results reported by Wheatley and Paradis (1998) may be affected by resampling communities/residents with previously high mercury values.

TABLE 2.2.6 Current and historic levels of mercury in maternal hair[1,2] (µg/g)

Community	Year(s) tested	Age group (Yrs)	No. tested	Range		Geometric mean	GSD[3]
				Min.	Max.		
Inuvik + region	1976–79	15–45	70	0.5	41.4	4.16	2.91
Inuvik + region	1998–99	15–45	85	< LOD[5]	11.5	0.49	2.74
Tuktoyaktuk	1976–79	15–45	48	0.5	41.2	4.62	2.76
Tuktoyaktuk	1998–99	15–45	7	< LOD	11.5	2.29	5.69
Fort McPherson	1998–99	15–45	15	< LOD	0.4	0.37[6]	2.02[6]
Tsiigehtchic	1998–99	15–45	6	< LOD	1.3	0.58	1.92
Others[4]	1998–99	15–45	17	< LOD	4	0.62	2.63

Source: [1]Snider and Gill (2001)

[2]Peak exposure levels reported as parts per million (ppm) in hair; [3]GSD: Geometric mean standard deviation; [4]Eight communities from Western Northwest Territories: Aklavik, Colville Lake, Deline, Fort Good Hope, Norman Wells, Paulatuk, Sachs Harbour, and Tulita; [5]LOD: Below analytical method detection limits (0.4 µg/g); [6]Approximately 50% of samples were below detection limit; for statistical calculations results below detection limit were replaced by one-half the detection limit.

Similarly, Dewailly *et al.* (1999) in their studies in the Salluit region reported that the mean (geometric) mercury concentration in hair samples collected in 1999 was 5.7 µg/g, a value 2.5-fold lower than the 15.1 µg/g determined in a 1978 survey conducted by Health Canada. The mean mercury concentrations measured during 1999 in the 18–39 and the 40–59-year-old age groups were also five and four times lower ($p < 0.001$), respectively, than those documented during the 1978 survey. Dewailly *et al.* (2000a) has re-evaluated these data and reported that mercury levels in the Salluit residents' hair were five- to six-fold lower in 1979 and 1980 compared to 1978. It was pointed out that 1978 was also an exceptional for harvesting beluga and other species. Higher consumption related to a large traditional/country food harvest could explain why high mercury concentrations were found in hair samples in the 1978. The authors concluded that mercury levels in Salluit vary markedly from year to year due to variation in availability of traditional/country foods, but recent tissue levels are similar to the levels found in the late 1970s (Dewailly *et al.*, 2000a).

In the 1998–1999 study in Inuvik and 11 other communities in western NWT, the range of methylmercury (MeHg) concentrations in maternal hair (n = 85) was less than the detection limit (0.4 µg/g hair; i.e., 0.4 ppm) to 11.5 µg/g hair (Table 2.2.6). The average (geometric mean) maternal hair concentration was 0.49 µg/g. The results indicated that 97.7% of these women have peak mercury concentration levels below 6 ppm in maternal hair. Most (79%) participants had hair mercury concentrations that were ≤ 1.0 µg/g. A statistical difference ($p = 0.001$) was found between four communities, namely, Inuvik, Teetli'it Zheh (Fort McPherson), Tsiigehtchic and Tuktoyaktuk. The significant difference of a greater than 10-fold range was observed between the medians of these four communities. Again, inter-comparisons between these four communities showed that Tuktoyaktuk hair mercury levels were different from that for both Inuvik and Teetli'it Zheh (Fort McPherson).

Maternal/cord blood

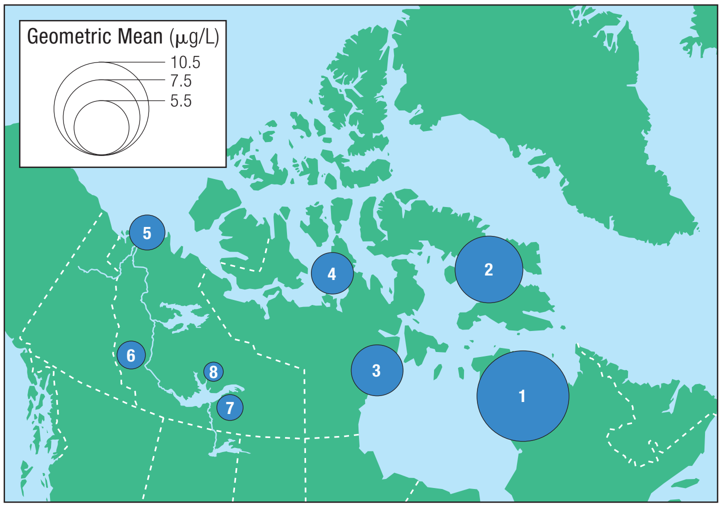
The Caucasian, and Dene and Métis mothers were from more than one region in the NWT/Nunavut, but there were no significant differences in contaminant levels between these populations, so they were combined into their respective groups. Inuit came from four regions in NWT/Nunavut, and there were significant differences among various groups, so they were retained as separate groups. In this data set, significantly higher levels of mercury were found in maternal blood from Inuit women compared to Caucasian, Dene and Métis, or mothers in the Other group (see Table 2.2.7 and Figure 2.2.8). In terms of geographic representation, among individuals tested in the program Inuit in the Baffin region had higher levels of mercury in maternal/cord blood than those seen in the Kitikmeot, Kivalliq and Inuvik regions. Markedly higher levels of mercury were observed in Inuit from Nunavik. Mercury has been noted to concentrate on the fetal side of the placental circulation, and cord blood mercury concentrations were 1.5 and 1.8 times greater than maternal concentrations in Nunavik and Nunavut, respectively. Similar patterns have been reported by Bjerregard *et al.* (2000) for Greenland Inuit.

TABLE 2.2.7 Mean concentrations of metals in maternal blood, by ethnicity and region, [geometric mean (range), µg/L whole blood]

	Ethnicity/Region							
				Inuit				
Metal	Caucasian[1] (n = 134)	Dene and Métis[1] (n = 92)	Other[1] (n = 13)	Baffin[1] (n = 31)	Inuvik[1] (n = 31)	Kitikmeot[1] (n = 63)	Kivalliq[1] (n = 17)	Nunavik[2] (n = 162)
Lead	21.2 (2.1 – 58)	31.1 (5.0 – 112)	22 (5.0 – 44)	42 (5.0 – 120)	19 (2.1 – 102)	36.1 (6.2 – 178)	29 (12 – 64)	50 (5.2 – 259)
Mercury (total)	0.9 (nd[4] – 4.2)	1.4 (nd – 6.0)	1.3 (0.20 – 3.4)	6.7 (nd – 34)	2.1 (0.60 – 24)	3.4 (nd – 13)	3.7 (0.60 – 12)	10.4 (2.6 – 44)
Mercury (organic)	0.69 (0.0 – 3.6)	0.80 (0.0 – 4.0)	1.2 (0.0 – 3.0)	6.0 (0.0 – 29)	1.8 (0.0 – 21)	2.9 (0.0 – 11)	2.7 (0.40 – 9.7)	n/a[3]
Selenium	123 (80 – 184)	117 (67 – 160)	128 (97 – 156)	118 (99 – 152)	118 (88 – 151)	122 (86 – 171)	106 (77 – 156)	318 (150 – 1232)
Cadmium	0.43 (nd – 8.5)	0.65 (nd – 5.9)	0.36 (nd – 3.2)	1.7 (0.03 – 6.2)	1.0 (nd – 7.1)	1.9 (0.01 – 7.8)	1.4 (0.11 – 7.7)	n/a[3]

Sources: [1]Walker *et al.* (2001); [2]Muckle *et al.* (2001b)

[3]not available; [4]nd = not detected.



1	**10.4** µg/L	Inuit – Nunavik
2	**6.7** µg/L	Inuit – Baffin
3	**3.7** µg/L	Inuit – Kivalliq
4	**3.4** µg/L	Inuit – Kitikmeot
5	**2.1** µg/L	Inuit – Inuvik
6	**1.4** µg/L	Dene/Métis
7	**1.3** µg/L	Other
8	**0.9** µg/L	Caucasian

FIGURE 2.2.8

Maternal contaminant levels in Arctic Canada: Total mercury (µg/L whole blood).

Source: Van Oostdam (2001)

Some of the recent data from Arctic countries on mercury levels in maternal blood are shown in Table 2.2.8. No specific comparisons were made to the southern Canadian population, as the Caucasian population included in the NWT/Nunavut sampling has a similar diet and therefore will have similar contaminant levels as the southern Canadian population, which serves as a useful benchmark for southern levels of contaminants. Maternal and cord blood mercury levels were low and similar in Norway, Iceland and Sweden and similar to levels in Caucasians, and Dene and Métis mothers in the NWT (Table 2.2.7). Mercury levels in Greenland Inuit mothers were higher than those seen in Inuit mothers from Nunavik and Nunavut/NWT (Table 2.2.7). These higher levels are likely due to the consumption of more marine mammals in the traditional Greenland diet.

TABLE 2.2.8 Worldwide comparisons of maternal blood mercury levels for women living in Arctic regions (µg/L whole blood)

Site	Year(s) collected	n	GM[3] (g/L)	GSD[4]
Greenland				
Disko Bay	1994–96[2]	180	12.8	
Iceland	1994–96[1]	40	2.9	1.3
Norway				
Kirkenes	1994[1]	40	3.4	1.2
Bergen	1994[1]	50	3.4	1.1
Hammerfest	1994[1]	57	2.5	0.8
Sweden	1994–96[1]	23	1.6	1.2

Sources: [1]AMAP (1998); [2]Bjerrgaard (2000)

[3]GM: geometric mean; [4]GSD: geometric standard deviation.

- *Recent maternal hair and maternal/cord blood contaminant studies in the NWT have given an assessment of the spatial variation in mercury levels.*
- *In general, the observed factors that seem to influence hair mercury concentrations were age and place of residence.*
- *Recent research reveals significantly higher levels of mercury in the maternal blood of Inuit women compared to Caucasian, Dene and Métis, or the Other group. Nunavik and Baffin Inuit have higher levels in maternal/cord blood than those seen in the Kitikmeot, Kivalliq and Inuvik regions.*
- *Mercury levels in Greenland Inuit mothers were higher than those seen in Inuit mothers from Nunavik and Nunavut/NWT. These differences may be due to many factors, including the consumption of more marine mammals in the traditional Greenland diet.*
- *Cord blood mercury levels were 1.5 and 1.8 times greater than maternal concentrations in Nunavik and Nunavut, respectively. Similar patterns have been reported for Greenland Inuit.*
- *Mercury levels in Salluit residents vary markedly from year-to-year due to variation in the availability of traditional/country foods, but recent tissue levels are similar to the levels found in the late 1970s. Mercury levels in some NWT communities are markedly lower than those in the 1970s and 1980s, but different sampling strategies may affect any conclusion on trend.*

2.2.3 Levels of selenium in maternal blood

Selenium levels in maternal serum are very similar among Caucasian, Dene and Métis, Other, and Inuit (Baffin, Inuvik, Kitikmeot, Kivalliq) peoples from the NWT/Nunavut (range of 117–128 µg/L) (see Table 2.2.7). Selenium levels were elevated (318 µg/L) only among Nunavik Inuit who had the highest levels of mercury. High concentrations of selenium are generally found in the traditional/country food diet of the Inuit of Canada (and Greenland), particularly marine mammals (e.g., whale skin). This element is a component of the glutathione peroxidases and it is believed that it may act as an antagonist to methylmercury, thereby offering some protection against potential adverse health effects due to methylmercury exposure; however, there is still much controversy over the role of selenium in methylmercury toxicity (AMAP, 1998).

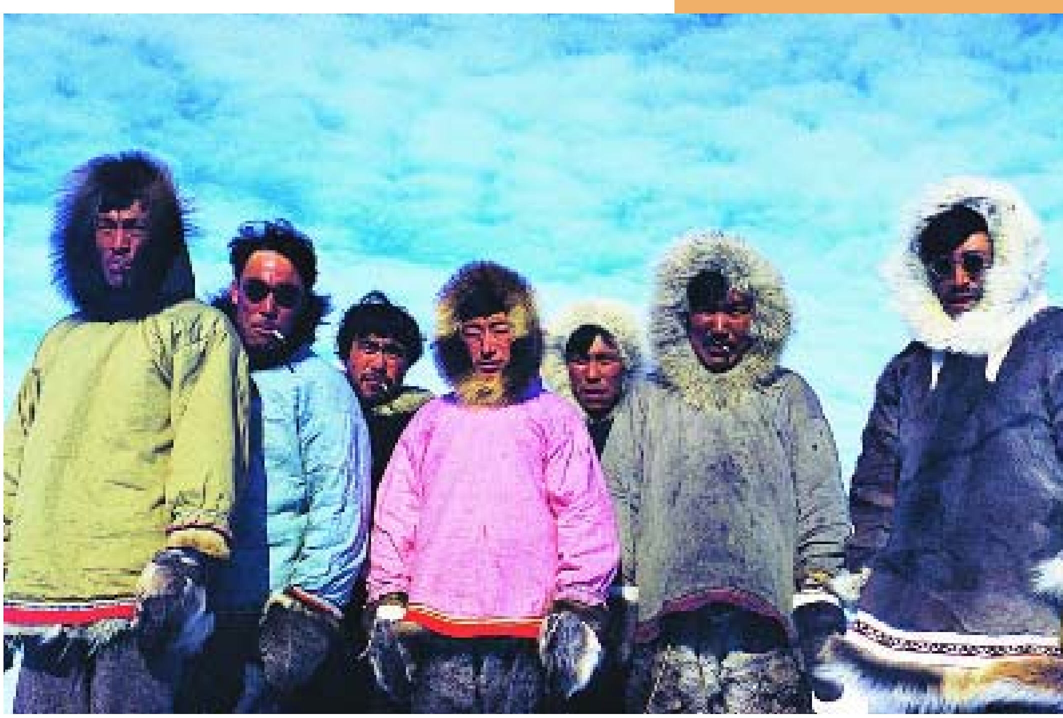
2.2.4 Levels of lead in maternal blood

Table 2.2.7 shows that lead levels in maternal blood are moderately elevated among some of the Inuit groups (Baffin, Kitikmeot, Kivalliq, Nunavik) and the Dene and Métis (range of 29–50 µg/L), while Caucasians, Other, and Inuvik Inuit have lower levels (range of 19–22 µg/L) (Walker *et al.*, 2001). Research on lead isotope signatures has indicated that these elevations of blood lead levels are likely due to the use of lead shot in the hunting of traditional/country foods, and thus its presence in the wild game consumed (Dewailly *et al.*, 2000b).

In an international context, lead levels are moderately elevated among some of the Inuit mothers from Greenland (range of 31–50 µg/L), and less so among women from Siberian Russia (range of 21–32 µg/L) compared to other circumpolar countries or regions.

2.2.5 Levels of cadmium in maternal blood

Table 2.2.7 shows that the Inuit have the highest mean levels of cadmium in maternal blood, ranging from 1.0 µg/L in Inuvik to 1.9 µg/L in Kitikmeot. Baffin and Kivalliq Inuit have levels of 1.7 µg/L and 1.4 µg/L, respectively. These values are roughly 1.5–5 times higher than blood cadmium levels of Dene and Métis (0.65), Caucasians (0.43), and Other (0.36). Note that of these three latter groups, blood cadmium levels were highest among the Dene and Métis, but still lower than any of the Inuit groups. This difference is likely due to the high rate of smoking among Inuit mothers and the high cadmium content in Canadian tobacco (Benedetti *et al.*, 1994). It may also result from the consumption of marine and terrestrial mammal liver and kidney. Though liver and kidney can contain significant amounts of cadmium, Elinder (1992) has shown that cadmium absorption from food is only 3 to 7% while the absorption of inhaled cadmium is from 10 to 60%.



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- *Research on lead isotope signatures has shown that the slightly elevated blood lead levels among some of the Inuit groups and the Dene and Métis are likely due to the use of lead shot in the hunting of traditional/country foods, and thus its presence in the wild game consumed.*
- *Blood cadmium levels are roughly 1.5 to 5 times higher among Inuit than in Dene and Métis, Caucasians, and Other. This difference is likely due to the high rate of smoking among Inuit mothers and the high cadmium content in Canadian tobacco.*
- *When compared with other circumpolar countries/regions, blood cadmium levels are highest among the Dene and Métis, and Inuit mothers from Arctic Canada, and Inuit mothers from Greenland. Again, these higher levels of cadmium are thought to be related to increased cigarette smoking among Aboriginal peoples and also to consumption of liver and kidney of traditionally hunted species.*

2.2.6 Radionuclide exposure

CACAR-I (CACAR, 1997) identified the lichen → caribou → human food chain as the most significant radiation exposure pathway for Arctic residents. Caribou are a major source of meat in many northern communities. These animals graze over wide areas on slowly growing lichens, which can accumulate deposited radionuclides and other contaminants over decades. CACAR-I showed that most of the radiation exposure received through this food chain resulted from anthropogenic radiocesium isotopes and from the naturally occurring lead-210 → polonium-210 decay chain.

ITK/Eric Loring

Radiocesium

The radiocesium isotopes — cesium-137 (^{137}Cs) and small traces of cesium-134 (^{134}Cs) — entered the environment as a result of atmospheric testing of nuclear weapons. The most intense period of testing occurred in the late 1950s and early 1960s. At that time ^{137}Cs was contributing a radiation dose as high as 5 mSv (millisieverts) per year to some northern residents (Tracy *et al.*, 1997), in addition to a normal radiation background dose of about 2.4 mSv/year (UNSCEAR, 1993). After the cessation of atmospheric testing by the major powers in 1963, levels of ^{137}Cs in the northern environment decreased dramatically but have persisted at lower concentrations right up to the present. This is due to the long half-life (30 years) of ^{137}Cs and to its slow turnover rate in Arctic ecosystems. Also, until 1980, there were small injections of radiocesium into the atmosphere from continued testing by non-signatories of the 1963 Limited Test Ban Treaty. On September 10, 1996 the General Assembly of the United Nations adopted a Comprehensive Test Ban Treaty banning the testing of all nuclear weapons in all environments for all time (Preparatory Commission, 1996). A number of nations have yet to ratify this Treaty and in 1998 India and Pakistan conducted several underground nuclear tests, although none of these tests were observed to have released any measurable radioactivity to the environment.

Large quantities of radiocesium (^{137}Cs and ^{134}Cs in a ratio of about 2 to 1) were released from the Chernobyl nuclear reactor accident in 1986. Although fallout from this accident had a major impact on reindeer herds in Scandinavia (Åhman and Åhman, 1994), the effect on Canadian caribou herds was to increase radiocesium levels by about only 20% above residual fallout levels (Marshall and Tracy, 1989; MacDonald, 2002). Because of its shorter half-life (2 years), ^{134}Cs disappears from the environment much more quickly than ^{137}Cs.

CACAR-I (CACAR, 1997) gave details on whole-body measurements of radiocesium carried out by Health Canada on northern peoples in 1989–1990 (Tracy *et al.*, 1997). The average radiation doses for northern communities at that time were all less than 0.1 mSv/year and the highest single dose was 0.4 mSv/year. These are insignificant compared to normal background radiation doses of 2 to 3 mSv/year. Since that report, recent measurements of radiocesium levels in Canadian caribou herds have shown that levels are decreasing further, with an ecological half-time of about 10 years (MacDonald *et al.*, 1996).

Lead-210 and polonium-210

Naturally occurring uranium in rocks and soils releases radon gas into the atmosphere. CACAR-I (CACAR, 1997) showed that radon gas itself is not a particular problem in the North. However, the decay of radon in air gives rise to the long-lived lead-210 (^{210}Pb; half life = 22.3 years), which in turn decays to the alpha-emitting radionuclide polonium-210 (^{210}Po; half life = 138 days). These radionuclides eventually settle onto lichens and other vegetation in more or less equal concentrations. When the lichens are eaten by caribou, ^{210}Pb is concentrated in bone and ^{210}Po accumulates in the meat and organs of the animal, which are in turn eaten by northern peoples. CACAR-I (CACAR, 1997) indicated ^{210}Po doses as high as 10 mSv/year for some northern communities consuming large amounts of caribou. The report recommended that more research be carried out to better characterize this source of radiation exposure.

The radionuclides ^{210}Pb and ^{210}Po are naturally occurring and have been present in the Arctic environment for thousands of years at more or less the same concentrations as found today. Local enhancements may have resulted from uranium mining, milling, and ore transport operations, although there is no evidence that any such contamination is widespread.

Since the publication of CACAR-I (CACAR, 1997), extensive dietary surveys have been carried out by CINE (see Section 2.1) which more accurately reflect the amount of polonium-210 ingested through caribou meat and other traditional/country foods. For example, in a 24-hour recall survey, Berti *et al.* (1998b) obtained a caribou consumption of 224 g/d for men and 178 g/d for women living in Gwich'in, NWT, who were over 40 years of age. These values have been corroborated independently by whole body surveys of ^{137}Cs in northern residents and in the meat they have been consuming (Tracy *et al.*, 2000). Concentrations of ^{210}Po in Canadian caribou meat are known to vary from 10 to 40 Bq/kg, with an average of about 20 Bq/kg (Thomas, 1994). Until recently, questions remained as to how much polonium is absorbed in the human intestine and how long it remains in the body. A study by Thomas *et al.* (2001) shows that intestinal absorption of polonium is indeed more than 50% and that the retention time in the human body is significantly longer than the previously accepted value of 50 days. All of these factors combined would give a radiation dose of 3 to 4 mSv/year to a high consumer of caribou meat, over and above normal background radiation.

Summary of radionuclide exposures

Information for the two most important radionuclides — ^{137}Cs and ^{210}Po — contributing to the radiation exposure of northern residents is summarized in Table 2.2.9. The table gives concentrations of the two radionuclides in caribou meat, concentrations in human tissues where available, and the radiation doses to humans consuming a traditional diet of caribou and other traditional/country foods. All of these doses must be interpreted in the context of a worldwide average exposure to natural background radiation of 2.4 mSv/year (UNSCEAR, 1993). The radiocesium doses have decreased to insignificant levels. Barring future inputs from another nuclear reactor accident or from a resumption of nuclear weapons testing, the radiocesium levels in northern food chains should be completely undetectable in a few years. The ^{210}Po doses remain somewhat elevated over and above normal background radiation (2.4 mSv/year).

TABLE 2.2.9 Radionuclide levels in caribou meat and people in the Canadian Arctic, and resulting radiation doses to people

Levels/Doses	Radionuclide	
	Cesium-137	Polonium-210
Levels in caribou meat (Bq/kg):		
mid-1960s	500 – 3,000	10 – 40
late 1980s	up to 700	10 – 40
late 1990s	up to 300	10 – 40
Levels in northern residents (Bq/kg):		
mid-1960s	up to 1,500	
late 1980s	up to 110	
Doses to northern residents (mSv/y):		
mid-1960s	up to 5[1]	9 – 12[2]
late 1980s	up to 0.4[1]	3 – 4[2]
late 1990s	up to 0.2[2]	3 – 4[2]

Source: Tracy and Kramer (2000)

[1]Doses based on measured whole-body concentrations of ^{137}Cs (Tracy *et al.*,1997).

[2]Doses based on estimated caribou consumption in a typical northern diet and on human metabolic parameters. The higher ^{210}Po doses in the 1960s are not based on any changes in environmental levels of ^{210}Po but on an estimated higher consumption of caribou meat at that time (Tracy and Kramer, 2000).

- *Caribou are a major source of meat in many northern communities, and the lichen → caribou → human food chain is the most significant pathway of exposure to radionuclides for Arctic residents. Most of the radiation exposure received through this food chain has resulted from anthropogenic radiocesium isotopes and from the naturally occurring lead-210 → polonium-210 decay chain.*
- *The average radiation doses of radiocesium from anthropogenic sources for northern communities in 1989–1990 were all less than 0.1 mSv/year and are insignificant compared to normal background radiation doses of 2–3 mSv/year.*
- *Radiocesium entered the atmosphere as a result of atmospheric testing of nuclear weapons. Since CACAR-I (CACAR, 1997), measurements of radiocesium levels in Canadian caribou herds have shown that levels are now considered insignificant and are continuing to decrease, with an ecological half-time of about 10 years.*
- *The radionuclides ^{210}Pb and ^{210}Po are naturally occurring and have been present in the Arctic environment for thousands of years at more or less the same concentrations as found today.*
- *CACAR-I (CACAR, 1997) indicated ^{210}Po doses as high as 10 mSv/year for some northern communities consuming large amounts of caribou. Current estimates of polonium exposure, taking into account a variety of factors, would give a radiation dose of 3–4 mSv/year to a high consumer of caribou meat, over and above normal background radiation.*
- *Radiocesium doses have decreased to insignificant levels. Barring future inputs from another nuclear reactor accident or from a resumption of nuclear weapons testing, the radiocesium levels in northern food chains should be completely undetectable in a few years. The ^{210}Po doses remain somewhat elevated over and above normal background radiation (2.4 mSv/year).*

GNWT/NWT Archives/Bob Decker

2.3 Trends in traditional/country food dietary intakes and contaminant exposures

Interview data from Inuit communities in 1999–2000 included questions about how individuals compared their intake of traditional/country food at that time to intake five years earlier. More than 50% of the entire sample from all Inuit communities reported that they were consuming the same or more than they did previously. When asked why more traditional/country food was not consumed by the family, most mentioned the expenses of hunting and other priorities for their time. Many individuals (42–68% of respondents in the five regions) expressed their wish to be able to purchase traditional/country food in the commercial food stores in their communities, because they did not have time to harvest these foods themselves (Kuhnlein *et al.*, 2000).

In addition to the studies conducted by CINE, a review of circumpolar Inuit dietary studies was conducted by Dewailly *et al.* (2000d). The study collected and reviewed all available dietary studies from the circumpolar Inuit regions to conduct an analysis of data coverage, and temporal and geographic trends in consumption, contaminant levels and nutrient status. Research conducted in Canada covered in this review included: the Santé Québec study in Nunavik (1995); Lawn and Langer (1994) surveys in Labrador and the NWT; a survey in Broughton Island by Kuhnlein *et al.* (1989); research conducted by Wein *et al.* (1998) in the Belcher Islands, NWT; and a study by Wein and Freeman (1992) in Aklavik, NWT.

Results obtained from recent studies for the Canadian North were compared to the Nutrition Canadian Eskimo Survey conducted in 1971. The analysis shows that in 1971, daily traditional/country food consumption varied between 191–219 g/day among women, while amounts today vary between 164–448 g/day. Among men, traditional/country food intakes varied between 277–646 g/day in 1971 and are now between 171–615 g/day, as reported in the more recent studies. In Canada, intakes of traditional/country food (by weight) do not seem to have changed significantly in the last 20 years. Changes in the Inuit diet are primarily related to an increase in the amount of imported foods consumed. More cereals, meats, fruits, vegetables and sugars are included today than before. Mean energy intakes among Inuit were lower in 1971 than today, and the contribution of protein to total energy intake has decreased in the last 30 years while the total lipid intake has increased on average. According to the Santé Québec study this is attributable in Nunavik to a higher consumption of market meats and prepared meals. This increase is also related to the degree of urbanization of Inuit communities (Shaefer and Steckle, 1980). Despite the fact that higher nutrient intakes are observed today compared to the last 20–30 years, several recent studies still show low intakes of vitamins A and C, and folic acid and calcium among Inuit populations (Dewailly *et al.*, 2000d).

Similar dietary intake measurements in Qikiqtarjuaq (Broughton Island), Nunavut were taken in 1987–1988 and 1999. The earlier study, however, was more intensive in that data were collected bi-monthly for the entire year, whereas in the latter study data were collected during two periods representing the estimated highest and lowest intake seasons. In both studies, measurements of mercury, chlordane, PCBs and toxaphene were made in foods eaten, for development of the food database. It was shown that mercury exposure data were similar in the two surveys, thus implying little change in dietary pattern or mercury concentration in food. However, reported intakes of the organochlorines were somewhat higher in the latter survey, particularly among the highest users (95th percentile). This was due to a higher reported consumption of narwhal muktuk and blubber in the community (Kuhnlein *et al.*, 1995c).

- *For Canadian Inuit, intakes of traditional/country food do not seem to have significantly changed in the last 20 years.*
- *Surveys of dietary intake in Qikiqtarjuaq (Broughton Island), Nunavut have shown that mercury exposures were similar in 1987–1988 and 1999, thus implying little change in dietary pattern or mercury concentration in food. Reported intakes of the organochlorines, however, were somewhat higher in 1999, particularly among the highest users (95th percentile). This was due to a higher reported consumption of narwhal muktuk and blubber in the community.*

INAC/Jennifer Baizana

Toxicology

CACAR-I (CACAR, 1997) describes in detail the toxicologic aspects of many of the environmental contaminants discussed herein, and this information will not be repeated here. Rather, this chapter focusses on new information on experimental dose-response studies on toxaphene and chlordane (Section 3.1), for which there are more limited human toxicologic data than for certain other contaminants; toxicologic studies of organochlorine mixtures (Section 3.2); and interactions between certain contaminants (primarily methylmercury) and dietary nutrients (Section 3.3).

3.1 Dose-response studies on priority contaminants for which there are limited data

3.1.1 Toxaphene

Background

Toxaphene is a broad-spectrum pesticide synthesized by the chlorination of technical camphene, wherein the final product contains 67–69% chlorine. The resulting product is a mixture of several hundred compounds (Parlar, 1985; Andrews *et al.*, 1993) that are not readily separated, even by high resolution GC due to the coelution of congeners (Hainzl *et al.*, 1994). Toxaphene manufactured by the Hercules Chemical Company was easily differentiated from toxaphenes prepared by other manufacturers (Saleh, 1991). Consequently, some have labelled Hercules' toxaphene as "Toxaphene®" and that produced by other manufacturers as "toxaphene" (Vetter and Oehme, 2000). As chromatographic techniques have improved, the estimated number of toxaphene congeners has increased steadily from ≥ 177 to ≥ 675 (Vetter and Oehme, 2000). These estimates are considerably less than the total number of theoretical toxaphene enantiomers of 32,256, plus the 512 optically inactive structures (Vetter 1993). Due to the coelution of toxaphene congeners, coupled with photodegradation, selective bioaccumulation and/or metabolism of toxaphene congeners by aquatic and terrestrial organisms including humans (Geyer *et al.*, 1999), however, the number of possible congeners present in "toxaphene" and in the environment will not be ascertainable for some time to come. A number of major congeners thought to account for most toxaphene-related residues have been identified in biota and humans (Stern *et al.*, 1992; Braekevelt *et al.*, 2001).

Regulatory aspects

Toxaphene became commercially important in the mid-1940s as a major agricultural insecticide and was also used more extensively when DDT was banned in the early 1970s (Schmitt *et al.*, 1981; Rice and Evans, 1984). The use of toxaphene was deregistered in Canada in 1980 (Agriculture Canada, 1980) and banned in the United States by 1982. Before being banned, toxaphene was the most heavily used insecticide in the U.S. and many other parts of the world (Saleh, 1991).

Toxaphene has been classified as an animal carcinogen (Reuber, 1979). Recently, a "peer review panel" reevaluated the United States Environmental Protection Agency's (EPA) cancer potency factor for toxaphene. They concluded that the EPA's current cancer potency factor of 1.1 $(mg/kg\ bw/day)^{-1}$ for toxaphene should be reduced to 0.1 $(mg/kg\ bw/day)^{-1}$ (Goodman *et al.*, 2000) indicating a possible lower risk from exposure to toxaphene. The panel's conclusion, which they indicate is "a highly conservative approach", was due, in large part, to a change in modelling methodology. In addition, toxaphene has been reported to be mutagenic in the Ames test (Hooper *et al.*, 1979), to induce hepatic enzymes (Chandra and Durairaj, 1993) and to be an immune suppressant (Allen *et al.*, 1983).

Health Canada has set a provisional Tolerable Daily Intake (pTDI) for toxaphene of 0.2 µg/kg bw/day. This pTDI is based on histopathology from a 90-day study in dogs and the use of a 1000-fold uncertainty factor to account for differences among individuals as well as between animals and humans, and the possibility that toxaphene is mutagenic and/or carcinogenic. Other regulatory agencies have determined other values for the tolerable daily intake of toxaphene. For example, the US Department of Health and Human Services has set an oral MRL (minimum risk level, which is equivalent to a TDI) of 1 µg/kg bw/day for intermediate duration exposure; however, this level is not meant for chronic exposure scenarios (ATSDR, 1996). The US EPA has not set a RfD (Reference Dose) for toxaphene, while the Nordic Council of Ministers (1997) has stated that if the carcinogenic effects of toxaphene were shown to be related to indirect mechanisms, a tolerable daily intake of 0.2 μg/kg bw/day could be set.

In view of the reports by Kinloch *et al.* (1992) and Kuhnlein *et al.* (1995c) that Aboriginal populations were ingesting toxaphene at levels that exceeded Health Canada's pTDI, it was decided that further experiments were required to clarify the potential toxicity of toxaphene.

Toxicology

The response of cynomolgus (*Macaca fascicularis*) monkeys to the effects of ingested technical grade toxaphene was examined in two recent studies (Arnold *et al.*, 2001; Bryce *et al.*, 2001). In a pilot study, groups of two males and two females ingested 0 or 1 mg of toxaphene/kg bw/day for approximately 52 weeks. An extensive variety of husbandry, clinical, biochemical and histopathological parameters were examined. The clinical findings included inflamation and/or enlargement of the tarsal (*Meibomian*) gland and impacted diverticulae in the upper and lower eye lids.

After the monkeys had been on test for 34 weeks, a total of seven tests were undertaken to ascertain the effects of toxaphene upon the immune system (Tryphonas *et al.*, 2000). While toxaphene affected some of these parameters, none of the differences were found to be statistically different from the control values. At the time of necropsy, the relative weights of the spleen and thymus were increased in the treated monkeys, but no histopathological lesions were evident. Toxaphene induced the cytochrome P450 enzymes responsible for the metabolism of aminopyrine and ethoxyresorufin, indicating that toxaphene was a "mixed function" inducer, i.e., having an ability to induce three methylcholanthrene and phenobarbital-like enzyme patterns. Previous studies with rodents have shown that toxaphene has characteristic phenobarbital-type induction patterns (Hedli *et al.*, 1998) but no reports were found linking toxaphene to three methylcholanthrene-type induction.

In a subsequent study, ten females per group ingested 0, 0.1, 0.4 or 0.8 mg of technical grade toxaphene/kg bw/day, while groups of five males ingested either 0 or 0.8 mg/kg bw/day. After 33 weeks on test, immunological testing was initiated. While some of the tests did not demonstrate a response to toxaphene, several tests did result in statistically significant effects at the dose levels of 0.4 and 0.8 mg/kg. The no-observed-effect-level (NOEL) for humoral effects upon the immune system of female cynomolgus monkeys was 0.1 mg/kg bw/day (Tryphonas *et al.*, 2001). During the 75 weeks prior to mating, the treated females' cholesterol serum levels decreased with increasing doses but only for week 63 was there a significant linear dose effect ($p = 0.0021$).

Beginning in study week 75, control males were mated with the test females. During the 26-week mating period, toxaphene did not affect: the number of matings needed to achieve impregnation ($p > 0.05$); the ability to maintain pregnancy ($p = 0.41$); gestation length ($p = 0.010$); sex ratios ($p = 0.85$); or birth weights ($p > 0.25$). However, toxaphene did result in an increased growth rate for neonatal females ($p = 0.0047$), and a decrease in the males' birth weight ($p = 0.047$) and growth rate ($p = 0.040$). This observation is not unique to toxaphene, as it has been observed with other halogenated hydrocarbons in both animal (Barsotti *et al.*, 1976; Chernoff and Kavlock, 1982; Barsotti and van Miller, 1984) and epidemiological studies (Kuratsune *et al.*, 1972; Yamashita, 1977; Fein *et al.*, 1984; Rogan *et al.*, 1988; Dar *et al.*, 1992; Guo *et al.*, 1994; 1995; Rylander *et al.*, 1995).

Discussion

From the results so far available from the Health Canada studies, wherein non-human primates were fed toxaphene, a NOEL of 0.1 mg toxaphene/kg bw/day was found regarding immunological effects. These immunological findings substantiate those seen in rodents where doses were 10 times higher (no NOEL was found in these studies). Although not yet available, the results from the histopathological investigations in monkeys will be important when comparing the results with those seen in rodents and dogs since the current Health Canada pTDI is based on histopathological findings in dogs.

Based on average toxaphene residues found in the monkeys' breast milk approximately four weeks after parturition, steady state toxaphene body burdens can be estimated at 2.9, 13.6 and 32.6 mg for the 0.1, 0.4 and 0.8 mg/kg bw/day dose groups, respectively. In comparison, average maternal toxaphene body burdens in Baffin and Kivalliq Inuit would be only 1.1 and 9.1 mg, or only three-fold lower than the current NOEL from the non-human primate studies. This would imply that in certain Arctic populations, toxaphene residues are within the same range as the experimental studies where effects on immune function and infant size have been seen (Arnold *et al.*, 2001).

Also in progress is work to determine toxaphene in tissues from the treated monkeys. This will be valuable information since the toxaphene tissue levels in monkeys can then be specifically related to the immunological and/or histopathological information as well as to the body burden data from people exposed to toxaphene, and for subsequent use in assessing their risk of developing health problems similar to those found in the monkeys.

While the monkey data involved non-carcinogenic endpoints, there is still some controversy regarding the mutagenicity and carcinogenicity of toxaphene. Both positive and negative results in terms of mutagenicity and genotoxicity have been noted for toxaphene in various assays. While toxaphene has been found to produce thyroid and liver tumours in exposed rodents, there has been some recent speculation that, at least for the thyroid tumours, their formation may be due to indirect mechanisms. Another area of recent interest is whether toxaphene may have endocrine-disrupting activity.

This new and forthcoming information will be used to re-assess the toxicity, and thus the pTDI for toxaphene. While more information is needed on the carcinogenic and endocrine-disruptive capacity of toxaphene, the new information will be useful for reassessing the toxicity and pTDI of this chemical.

- *From the results of the Health Canada experimental studies to clarify the potential toxicity of toxaphene, a NOEL of 0.1 mg toxaphene/kg bw/day was found for non-human primates based on immunological effects. These findings support those seen in rodents where doses were 10-times higher (no NOEL was found in these studies).*
- *In certain Arctic populations, toxaphene residues are within the same range as the experimental studies where effects on immune function and infant size have been observed.*
- *Both positive and negative results in terms of mutagenicity and genotoxicity have been noted for toxaphene in various assays. While toxaphene has been found to produce thyroid and liver tumours in exposed rodents, there has been some recent speculation that, at least for the thyroid tumours, their formation may be due to indirect mechanisms.*
- *While more information is needed on the carcinogenic and endocrine-disruptive capacity of toxaphene, new and forthcoming information will be useful for reassessing the toxicity and pTDI of this chemical.*

3.1.2 Chlordane compounds

Trans-*nonachlor,* cis-*nonachlor, oxychlordane and chlordane*

Chlordane is a mixture of over 120 structurally related organochlorine compounds, and was introduced as a broad spectrum insecticide in the 1940s and widely used in North America. In the late 1970s concerns about chlordane's persistence, toxicity and potential carcinogenicity curtailed many applications. Although chlordane is no longer registered in either Canada or the United States, various chlordane-related contaminants, distinct from the original mixture, persist in the environment. The tolerable daily intake (TDI) for chlordane-related contaminants ranges from 0.05 µg/kg bw/day [provisional TDI, Health Canada (Feeley, 2002)] to 0.5 µg/kg bw/day (WHO/FAO, 1986; US EPA, 1998). Estimated chlordane intake values for Arctic residents vary from levels below the Health Canada provisional TDI to levels approaching or exceeding the higher US EPA TDI, depending on marine mammal fat consumption. For example, estimated mean chlordane consumption by Broughton Island Inuit women ranged from 22–30 µg chlordane contaminants/day (0.32–0.43 µg/kg/day, assuming a mean body weight of 70 kg); whereas Sahtu Dene and Métis women consumed 0.66–1.43 µg chlordane contaminants/day (0.009 to 0.02 µg/kg/day, assuming a mean body weight of 70 kg) (Kuhnlein *et al.*, 1995b). In contrast, the most conservative estimate of Dougherty *et al.* (2000) is that the United States national average chlordane contaminant exposure in foods is approximately 0.01 µg/kg bw/day.

Together, *trans*-nonachlor and oxychlordane made up 76%–78% of chlordane-related residues in ringed seal blubber samples collected from the NWT in 1991, and 83% of chlordane-related residues in walrus blubber samples collected from Greenland in 1989 (Addison and Smith, 1998; Muir *et al.*, 2000). The pattern of chlordane-related residue accumulation in humans parallels that seen in the highest levels of the Arctic marine food chain. *Trans*-nonachlor and oxychlordane make up more than 90% of the total chlordane contaminants measured in breast milk from both northern and southern Canadians, with combined residues more than four-fold higher in the Arctic samples. The ratio of *trans*-nonachlor to oxychlordane (1:0.76) was similar for both groups (Newsome and Ryan, 1999).

Since most of the existing toxicology literature focusses on the technical or commercial chlordane mixture, recent Health Canada/NCP studies have addressed the lack of toxicity data for individual chlordane-related contaminants such as *trans*-nonachlor, *cis*-nonachlor and oxychlordane that are present at the highest levels in traditional/country foods and in human tissues and breast milk. All studies were designed according to guidelines published by the Organization for Economic Cooperation and Development (OECD, 1995). *Trans*-nonachlor, *cis*-nonachlor or technical chlordane were administered to male and female rats by oral gavage at doses of 0.25, 2.5 or 25 mg/kg bw/day for 28 days (Bondy *et al.*, 2000). Table 3.1.1 is a composite from several studies. In each study, dose groups with morbidity rates > 0 were included, as was the next lowest group. If the highest dose group had a morbidity of 0 only that group was included. In female rats *trans*-nonachlor was more toxic than *cis*-nonachlor or technical chlordane. In the highest dose group 43% of female rats treated with *trans*-nonachlor died; there were no deaths of female or male rats in any of the *cis*-nonachlor or technical chlordane treatment groups (Table 3.1.1).

TABLE 3.1.1 Summary of morbidity rates in female rats exposed to oxychlordane, *trans*-nonachlor, *cis*-nonachlor or technical chlordane by gavage

Test chemical	Dose (mg/kg body weight/ day)	Number of consecutive doses prior to the onset of illness[1]	Morbidity Incidence
Trans-nonachlor	25	17–20	43%
	2.5	> 28 [2]	0
Cis-nonachlor	25	> 28 [2]	0
Technical chlordane	25	> 28 [2]	0
Oxychlordane	10	1	100%
	2.5	26	4%
	1	> 28 [2]	0

Sources: Bondy (2000); Bondy *et al.* (2002; in press)

[1]Rats were exposed to test chemicals for 28 consecutive days by gavage. The pattern of illness was similar for all rats. At onset, affected rats lost weight rapidly, assumed a hunched posture and had an unkempt appearance. When handled they showed signs of abdominal tenderness.

[2]All animals were outwardly healthy at the time of necropsy.

Adipose tissue residue levels were higher in female rats than in males treated with *cis*-nonachlor, *trans*-nonachlor or technical chlordane. All three test chemicals caused thyroid lesions, liver microsomal enzyme induction, and increased the expression of markers for cellular proliferation and preneoplasia in various tissues, primarily at doses of 2.5 or 25 mg/kg bw/day (Curran and Mehta, 2002). Satellite immunotoxicity studies using female rats and *trans*-nonachlor and *cis*-nonachlor, but not technical chlordane, caused a statistically significant trend towards suppression of immune responses to a bacterium (*Listeria monocytogenes*) over the dose range 0.25–25 mg/kg bw for *cis*-nonachlor and 0.25–15 mg/kg bw for *trans*-nonachlor (Tryphonas *et al.*, 2002; submitted).

Since female rats were more sensitive to *trans*-nonachlor than males, 28-day oral toxicity studies with oxychlordane focussed on female rats. A pilot study indicated that oxychlordane caused 100% morbidity/mortality at a dose of 10 mg/kg bw/day after three days. Histopathological changes were observed in the liver, thymus and adrenals of affected rats. Based on these results, oxychlordane is substantially more toxic than *trans*-nonachlor (Table 3.1.1). Further oral toxicity studies were completed using oxychlordane doses ranging from 0.01–1 mg/kg bw/day. There were no clinical or histopathological signs of toxicity, including immunotoxicity, at these doses. Preliminary results indicate that female rats receiving oxychlordane by oral gavage at 2.5 mg/kg bw/day show signs of histopathological changes in the liver consistent with microsomal enzyme induction, similar to the effects of the nonachlors.

Based primarily on the incidence of morbidity and mortality in female rats, the comparative toxicity of the chlordane-related contaminants examined so far was (in order from most to least toxic): oxychlordane > *trans*-nonachlor > *cis*-nonachlor. The accumulation of chlordane-related residues in adipose tissues of treated rats followed a pattern similar to morbidity/mortality rates. Under identical dose and exposure conditions, residue levels were highest in rats treated with oxychlordane, followed by *trans*-nonachlor and finally *cis*-nonachlor (Table 3.1.2). The relative toxicity of individual chlordane contaminants, therefore, appears to be related to the amount of residue accumulation in adipose tissues.

TABLE 3.1.2 Comparison of adipose tissue residue levels in female rats exposed to oxychlordane, *trans*-nonachlor, *cis*-nonachlor or technical chlordane by gavage

Test chemical (2.5 mg/kg bw/for 28 days)	Adipose Tissue Residue Levels (μg/g lipid)[1]			Mean total adipose tissue residue levels
	Oxychlordane	*Trans*-nonachlor	*Cis*-nonachlor	
Oxychlordane	269.4	not detected	not detected	269.4
Trans-nonachlor	48.6	158.9	not detected	207.5
Cis-nonachlor	28.6	not detected	90.5	119.1

Sources: Bondy (2000); Bondy *et al.* (2002; in press)
[1]Data are mean adipose tissue residue levels for seven rats (*cis*-nonachlor and *trans*-nonachlor) or 10 rats (oxychlordane).

The toxicokinetic model proposed by Chan *et al.* (see Section 3.3.2), which addresses the issue of extrapolation from rodent studies to humans, indicates that chlordane at levels in the Inuit diet may pose an increased risk to humans. In rodent studies there was a significant trend towards suppressed immune responses to a bacterium (*Listeria monocytogenes*) in female rats treated with *trans*-nonachlor; concurrently, adipose tissue residue levels in the 0.25 mg/kg dose group were 36.5 μg/g of *trans*-nonachlor plus oxychlordane (Bondy *et al.*, 2000; Tryphonas *et al.*, 2002; submitted). In comparison, mean *trans*-nonachlor plus oxychlordane residue levels in omental fat from Greenland Inuit were 1.9 μg/g (Dewailly *et al.*, 2000c). Based on these data it is possible that a proportion of highly exposed Arctic residents could achieve tissue residue levels of chlordane-related contaminants approaching those associated with measurable physiological and immunological changes in rats.

- *The pattern of chlordane-related residue accumulation in humans parallels that seen in the highest levels of the Arctic marine food chain.*
- *Based on the latest rodent studies at Health Canada, a thorough risk assessment with the goal of re-assessing the TDI should take into account that (1) the major chlordane metabolite oxychlordane is almost 10-fold more toxic than the parent chlordanes and nonachlors, and (2)* trans-*nonachlor and oxychlordane are among the more bioaccumulative chlordane contaminants.*
- *In female rats, the comparative toxicity of the chlordane-related contaminants examined was: oxychlordane >* trans-*nonachlor >* cis-*nonachlor. The relative toxicity of individual chlordane contaminants appears to be related to the amount of residue accumulation in adipose tissues.*
- *The proposed toxicokinetic model, which addresses the issue of extrapolation from rodent studies to humans, indicates that chlordane at current levels in the Inuit diet may pose an increased risk to health.*
- *Based on the data presented, it is possible that a proportion of highly exposed humans would have tissue residue levels of chlordane-related contaminants approaching those associated with measurable physiological changes in rats.*

3.2 Toxicological effects induced by exposure to food-chain contaminant mixtures

3.2.1 Overview

Recognizing that environmental contaminants such as organochlorines in traditional/country food diets occur as complex mixtures, with possible interactions between compounds that may result in antagonism, additivity or synergism, one conclusion of CACAR-I (CACAR, 1997) was that animal studies be carried out to explore possible interactive effects of contaminants. It was also stated that emphasis should be placed on perinatal exposure and effects on neurobehavioural, immune or reproductive development. In most toxicological studies that investigated these effects, single compounds or technical/commercial mixtures were administered to laboratory animals (Giesy and Kannan, 1998). Because of the large number of compounds involved, this section focusses only on those studies which involved the administration of complex mixtures of food-chain contaminants. Only a few toxicological studies have been conducted on mixtures of food-chain contaminants relevant to the Arctic environment. These studies involved either the administration of a reconstituted mixture designed to approximate that found in sea mammal fat (Bilrha *et al.*, 2000), or lipids extracted from wildlife species that contained relatively high concentrations of organochlorines (Lapierre *et al.*, 1999; Fournier *et al.*, 2000).

An additional experimental and modelling study by Chan *et al.* (2000) was conducted to develop a framework for assessing the potential health risks associated with the consumption of contaminant mixtures in traditional/ country food.

3.2.2 Developmental toxicity study using the pig as the animal model

In the course of a developmental toxicity study funded in part by the NCP, researchers investigated the possible effects of pre- and postnatal exposure to an organochlorine mixture relevant to the Arctic ecosystem on male reproduction and the immune system using the pig as the animal model (Bérubé *et al.*, 2002; Guillemette *et al.*, 2002; Bilrha *et al.*, 2000). Sixteen Landrace-Yorkshire-Duroc sows were randomly allocated to four treatment groups. Animals in each group were administered different doses of an organochlorine mixture from four months of age until weaning of their first litter. The composition of the organochlorine mixture is described in Table 3.2.1 and was designed to approximate that found in the blubber of ringed seals from northern Québec (Muir, 2001).

TABLE 3.2.1 Composition of the organochlorine mixture

Compound	% Weight
PCB mixture[1]	32.59
Technical chlordane	21.3
p,p′-DDE	19.24
p,p′-DDT	6.79
Technical toxaphene	6.54
α-HCH	6.17
Aldrin	2.52
Dieldrin	2.09
1,2,4,5-Tetrachlorobenzene	0.86
p,p′-DDD	0.49
β-HCH	0.46
Hexachlorobenzene	0.35
Mirex	0.23
γ-HCH	0.20
Pentachlorobenzene	0.18

Source: Ayotte (2001)

[1] Mixture containing 2,4,4′-trichlorobiphenyl (320 mg), 2,2′,4,4′-tetrachlorobiphenyl (256 mg), 3,3′,4,4′-tetrachlorobiphenyl (1.4 mg), 3,3′,4,4′,5-pentachlorobiphenyl (6.7 mg), Aroclor 1254 (12.8 g), and Aroclor 1260 (19.2 g).

Organochlorines were dissolved in corn oil to reach the appropriate concentration and the resulting solution was placed in 2-mL gelatine capsules. The first group received 1 μg, the second group 10 μg and the third group 100 μg PCBs/kg bw/day. Animals in the fourth group (control group) were administered corn oil only. Treatment of females started at four months of age and lasted until the weaning of the F1 piglets. At puberty, females were inseminated with semen from an untreated boar (Duroc). Eight to ten male piglets per dose group were nursed by their sow during three weeks and after weaning received a standard diet without added OCs. Piglets were vaccinated against *Mycoplasma hyopneumoniae* at six weeks of age. Blood samples were collected monthly for organochlorines, hormonal and immunological measurements. Parameters of male reproductive function (numeration, motility, morphology) were also determined in sexually matured boars.

The weight gain of sows during treatment was similar in all groups and there were no signs of maternal toxicity. A dose-dependent decrease in body length at birth was noted when all piglets, males and females, were considered in the statistical analysis. Piglets from the high dose group showed a 7% reduction in mean length compared to the control group (36.7 versus 34.2 cm; $p < 0.05$). No other dose-response effects were noted with regard to the characteristics of piglets at birth (Bérubé *et al.*, 2002).

Some parameters of male reproductive system development and function were slightly modified by exposure to the organochlorine mixture. There was a marginally significant dose-related decrease in testis weight and sperm motility was slightly decreased in animals from the high dose group compared to controls ($p < 0.05$) (Guillemette *et al.*, 2002). With regard to immune system function, no difference between groups was observed for phagocytosis, surface markers, or C2 component activity measurements. Figure 3.2.1 shows the percentage of male piglets with plasma antibody levels against *Mycoplasma hyopneumoniae* equal to or greater than 7 mg/L. Exposure to OCs did not substantially modify the percentage of animals responding to the vaccine during the first months of life. However, starting at six months of age, a lower percentage of animals in the high dose group (100 μg/kg bw) reached a 7 mg/L antibody concentration (seroconversion level) compared to the other groups. At eight months of age, only 10% (1/10) of animals in the high dose group were above this level, compared to 80% (8/10) in the middle dose group ($p = 0.005$; Fisher exact test), 70% (7/10) in the low dose group ($p = 0.02$), and 50% (3/6) in the control group ($p = 0.12$) (Bilrha *et al.*, 2000).

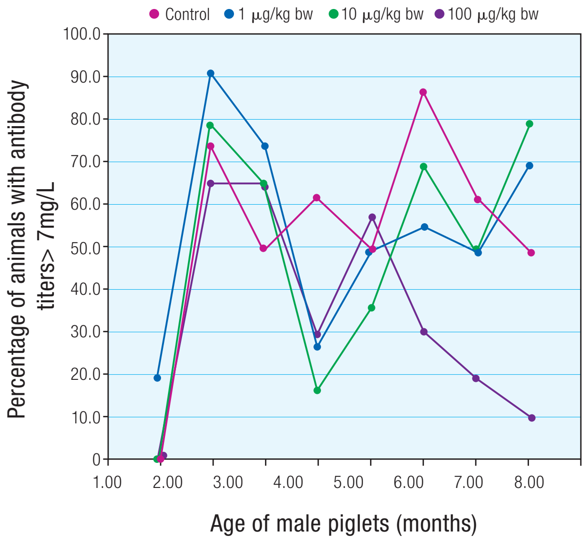

FIGURE 3.2.1

Percentage of male piglets showing plasma *Mycoplasma hyopnemoniae* antibody levels greater than 7 mg/L. The vaccine was administered at 6 weeks of age. Doses are for polychlorinated biphenyls. Doses of other compounds in the mixture can be calculated from proportions listed in Table 3.2.1.

Source: Ayotte (2002)

These results may indicate that the high dose of the organochlorine mixture can induce subtle effects, especially on *in utero* growth, and on the development of the male reproductive system. The former could be due to interference with thyroid hormones, while the latter could be the result of anti-androgenic or estrogenic effects related to exposure to the OC mixture. The mixture also appeared to interfere with immune system function in this animal model, as suggested by the low percentage of animals showing a sustained antibody response following vaccination in the high dose group. These results, however, must be interpreted with caution because of the large variability in antibody titres noted in piglets after four months of age.

While there appears to be no published studies on laboratory animals investigating the effects of a similar organochlorine mixture, Hany *et al.* (1999) treated female rats from 50 days prior to mating to postnatal day 0 with approximately 4 mg/kg daily doses of either Aroclor 1254 or a reconstituted mixture of the most prevalent PCB congeners found in human biological samples. Adult male offspring with *in utero* and lactational exposure to either PCB mixture showed markedly reduced testis weight and serum testosterone levels, thus demonstrating persistent anti-androgenic effects. Hence the results of Bérubé *et al.* (2002), in which there was a decrease in testis weight observed in the rat, may also be due to the PCB component of their complex mixture.

Other studies have investigated the effects on immune system function following subchronic administration of lipids from marine mammal fat to rats or mice (Lapierre *et al.*, 1999; Fournier *et al.*, 2000). In the first study, groups of rats were fed a diet containing lipids from either a highly contaminated St. Lawrence beluga (high dose), a 50:50 mixture of lipids from the St. Lawrence beluga and a relatively clean Arctic beluga (medium dose) or lipids from the Arctic beluga (control). After treating the animals for two months, various functions of the immune system were evaluated: lymphoblastic transformation, natural killer cell activity, plaque-forming cells, phagocytosis, oxidative burst and immunophenotyping. The authors reported no difference between experimental groups with regard to either of these immune function tests (Lapierre *et al.*, 1999).

A second study was conducted by Fournier *et al.* (2000) in which groups of mice were fed diets containing different ratios of both sources of lipids previously mentioned for 90 days. This experiment, however, incorporated a control group which was fed a diet containing beef oil. No differences were observed between experimental groups for most general parameters and immunological endpoints. Mice receiving diets containing lipids from beluga blubber, no matter what their contaminant levels, showed a decrease in CD8+ T cells in the spleen and in the ability of splenic cells to elicit humoral response against sheep red blood cells. Phagocytosis by peritoneal macrophages was also suppressed in all groups receiving lipids from beluga blubber compared to the control. It appears that the type of lipids fed to the animals (i.e., omega-3 fatty acids), rather than lipophilic contaminants contained in lipids, therefore, was responsible for the immunosuppressive effects noted in this experiment.

3.2.3 Experimental study in rats and a toxicokinetic modelling framework

An experimental and modelling study was conducted by researchers from McGill University, the University of Montreal and Health Canada between 1997 and 2000 (Chan *et al.*, 2000) to develop a framework for assessing the potential health risks to Arctic Inuit communities associated with the dietary intake of mixtures of chemical contaminants in traditional/country food. Based on the dietary intake data collected from Broughton Island in 1988 (Chan *et al.*, 1997), a mixture of organochlorines was designed to contain hexachlorobenzene, α-, β-, and γ-HCH, oxychlordane, *cis-* and *trans*-chlordane, *cis-* and *trans*-nonachlor, dieldrin, DDE, DDT, mirex, toxaphene and PCB congeners (28, 32, 101, 99, 118, 105, 153, 128, 138, 156, 187, 183, 180, 199). The dosages chosen were 10 times, 100 times, and 1000 times the mean daily intake level. Four groups of 12 female rats were administered the mixture in corn oil by gavage (three dose levels plus controls) for 28 days. There was no overt toxicity observed in any of the dose groups throughout the study, and no changes in body weights, food or water consumption. The highest dose was used as the no-observed-adverse-effect-level (NOAEL).

A physiologically based toxicokinetic (PBTK) modelling framework for organochlorine mixtures has been developed (Tardif *et al.*, 1997) and validated by the good agreement between the *a priori* independent predictions of the physiologically based pharmacokinetic (PBPK) model and the corresponding experimental data on adipose tissue concentrations in the exposed animals (Chan *et al.*, 2000).

The PBPK model was then applied to simulate the area under the curve and concentrations of chemicals in the target organ, i.e., the liver. The rat model was scaled to a human model by substituting the model parameters with the species-specific values. Hepatic and blood concentrations in the human model corresponding to the rat NOAEL and the equivalent Reference dose (RfD) in humans calculated using the PBPK model are presented in Table 3.2.2.

The RfD doses are compared to the current tolerable daily intake (TDI) used by Health Canada and the mean organochlorine intake levels estimated by the recent CINE dietary survey (Kuhnlein *et al.*, 2000). The RfD in general were higher than the TDI, except for DDT and chlordane, which were similar to the TDI. The mean daily intake of chlordane among the Inuit communities that participated in the CINE dietary survey was 20 times higher than RfD derived by the PBPK model.

This study is particularly relevant to the Arctic populations in that the chemical mixture used for the animal feeding experiment was prepared based on the concentrations of organochlorines found in an average Inuit diet reported in Broughton Island in 1988 (Chan *et al.*, 1997). Unlike the classical paradigm used to establish the current TDI, the inter-species extrapolation used in this study was performed without the use of any additional uncertainty factors. The results suggest that the presence of chlordane in the Inuit diet may pose an increased risk to the people consuming traditional/country foods contaminated with this organochlorine.

TABLE 3.2.2 Hepatic and blood concentrations in humans at steady-state corresponding to rat NOAEL and the equivalent reference dose in humans calculated using PBPK model

Organochlorine compound	Steady-state hepatic conc'n in humans (μg/L) (determined with PBPK model)	Steady-state blood conc'n in humans (μg/L) (determined with PBPK model)	Reference dose (RfD) in humans (μg/kg/day) (determined with PBPK model)	Current TDI (μg/kg/day)	Mean intake among Inuit communities (μg/kg/day)
Hexachlorobenzene	831	69.3	2.7	0.27	0.12
Sum of chlordanes	3.67	0.31	0.02	0.05	0.43
Sum of hexachlorocyclohexanes	721	60.1	4.4	0.3	0.03
Total DDT	4213	351	18	20	0.53
Mirex	66	5.5	0.21	0.07	0.01
Sum of PCBs	2692.9	224.4	17	1	0.66
Dieldrin	372	31	18.5	0.1	–

Source: Chan *et al.* (2000a)

Note: The Reference Doses are compared to the current TDI used by Health Canada and the mean organochlorine intake levels estimated by the recent CINE dietary survey.

- *The results of experimental studies using the pig as the animal model suggest that a high dose of an organochlorine mixture (a reconstituted mixture similar to that found in blubber samples from northern Québec seals) can induce subtle effects on development, especially on* in utero *growth and on the development of the male reproductive system.*
- *No clear-cut adverse effects on the immune system attributable to contaminants were noted in studies that investigated the toxicity of mixtures relevant to the Arctic environment.*
- *The rat-feeding experiment and the toxicokinetic modelling study are particularly relevant to the Arctic populations in that the chemical mixture used was prepared based on the concentrations of organochlorines found in an average Inuit diet and the mean daily intake of OCs reported in Broughton Island in 1988. Unlike the classical paradigm used to establish the current TDI, the inter-species extrapolation used in the study was performed without the use of any additional uncertainty factors. The results suggest that the presence of chlordane in the Inuit diet may pose an increased risk to the people consuming traditional/country foods contaminated with this organochlorine.*

ITK/Eric Loring

3.3 Contaminant and dietary nutrient interactions

3.3.1 Dietary nutrients and methylmercury toxicity

A recent report published by the United States National Research Council (UN NRC) on the toxicological effects of methylmercury concluded that dietary nutrients and supplements might protect against the toxicity of methylmercury (UN NRC, 2000). Moreover, intra-individual differences can be explained, in part, by nutritional factors that might exacerbate or attenuate the effects of mercury toxicity in the host (UN NRC, 2000). The main sources of mercury in the northern diet, such as fish and marine mammals, are also rich sources of fish protein, polyunsaturated fatty acids (PUFA), selenium (Se) and a range of other nutrients. Whether any of these nutrients offer protection against mercury toxicity has very direct relevance to several Inuit populations that have very high dietary intakes of mercury.

There is some evidence that these nutrients in the diet may interact with methylmercury toxicity at least on the mechanistic level. For example, a high-protein, low-fat diet decreased the retention of orally administered methylmercury in mice (Rowland *et al.*, 1984). Diets containing fish protein, a good source of both selenium and sulphur amino acids, decreased the toxicity of methylmercury in mice compared with diets containing casein (Ohi *et al.*, 1976). Hojbjerg *et al.* (1992) found that the wholebody retention of mercury was significantly reduced when mice were fed a diet containing 50% cod liver oil compared to mice fed with 50% coconut oil. The relative deposition of mercury, however, was significantly higher in all organs of mice fed a diet containing 20% energy from cod liver oil compared to mice fed a diet containing 20% energy from soya oil.

It is an intriguing thought that fish protein or polyunsaturated fatty acids (PUFA) that are commonly found in fish and marine mammal may protect against methylmercury neurotoxicity. The NCP has funded an animal feeding experiment testing the effects of fish protein or polyunsaturated fatty acids on methylmercury toxicity. The study is a collaboration between the Food Directorate of Health Canada and the Centre for Indigenous Peoples' Nutrition and Environment at McGill University (Chan, 2000a).

To study the effects of protein on methylmercury toxicity, 18 male Sprague-Dawley rats (Charles River, Canada — Montreal, Québec, Initial Body Weights: 150–170 grams) were fed one of three isocaloric, starch-based, semi-purified diets containing 20% by weight of either (a) casein, (b) fish protein, or (c) whey protein for four weeks before the dosing experiment. Methylmercury was administered for 14 days by gavage at three dose levels: (1) control, (2) 1 mg/kg/day; or (3) 3 mg/kg/day. There was no difference between the groups in the concentrations of total mercury in the brain and kidney and the amount of mercury excreted in the feces (data not shown). Thiobarbiturate reactive substances (TBARS) were measured as an indicator of oxidative stress and there were no differences between the concentrations of TBARS in the brains of rats fed the various diets. These results suggest that the amino acid composition of the diet may not be an important factor affecting the toxicokinetics of methylmercury or its toxicity in terms of lipid peroxidation.

To study the effects of dietary lipids on methylmercury toxicity, 30 male rats were fed one of five isocaloric, starch-based, semi-purified diets containing 20% by weight of either (a) seal oil, (b) fish oil, (c) Docosahexaenoic Acid (DHA) oil, d) soya oil, or e) lard, for four weeks before the dosing experiment. Methylmercury was administered for 14 days by gavage at three dose levels: (1) control, (2) 1 mg/kg/day; or (3) 3 mg/kg/day. There was no difference between the groups in the concentrations of total mercury in the brain and kidney and the amount of mercury excreted in the feces (data not shown); however, there was a significant dietary lipid effect on the concentrations of TBARs in the brain (Figure 3.3.1). Concentrations of TBARs increased with methylmercury dose in all dietary groups except for the group fed soya oil which had significantly lower ($p < 0.05$) TBARs than the other groups (Chan *et al.*, 2002). Since soya oil is rich in omega-6 fatty acids, these results suggest that omega-6 fatty acids play a more important role in protecting against methylmercury induced lipid peroxidation in the brain than saturated fat and omega-3 fatty acids.

- *There is some evidence that dietary nutrients such as polyunsaturated fatty acids, fish protein, and selenium may reduce methylmercury toxicity, at least on the mechanistic level. The two former nutrients commonly found in fish and marine mammals may protect against methylmercury neurotoxicity. However, there is no conclusive evidence or dose-response relationship available that can be incorporated either in the toxicokinetic model of methylmercury or the risk assessment paradigm.*
- *Research findings also suggest that omega-6 fatty acids found in soya oil may play a more important role in the protection against methylmercury-induced lipid peroxidation in the brain than saturated fat and omega-3 fatty acids.*

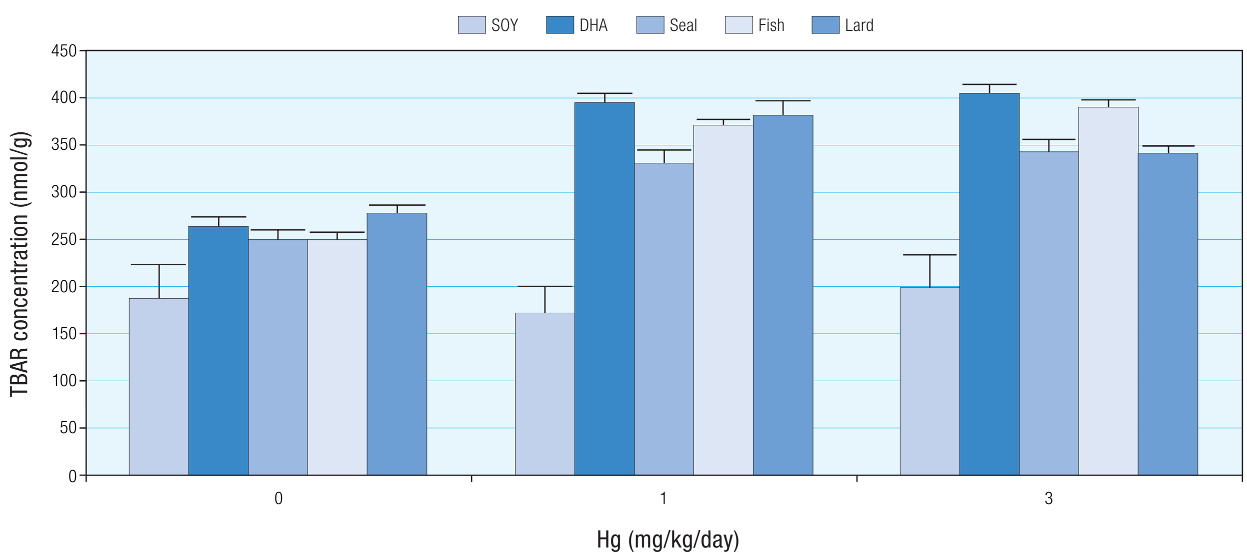

FIGURE 3.3.1

Concentrations of thiobarbiturate reactive substances (TBARS) in the brains of rats fed with different lipid diets and treated with methylmercury.

Source: Chan (2002)

3.3.2 Methylmercury and selenium interactions

Selenium has been the main nutritional factor considered by epidemiological and clinical studies of mercury to date. No epidemiological studies, however, have shown a correlation between selenium intake and the occurrence or absence of symptoms for methylmercury intoxication. There are also inconsistencies in the protective effects seen in animal studies (Magos, 1991). The role of selenium remains to be confirmed but selenium has been suggested to counteract the toxicity of several heavy metals including cadmium, Hg^{2+}, methylmercury, thallium and silver (Whanger, 1992). The protective effect of selenium against methylmercury intoxication, however, is less dramatic than that against inorganic mercury intoxication (Magos, 1991) and selenium in food at best delays, but does not prevent methylmercury intoxication (Magos, 1991). For both inorganic mercury and organic mercury, selenium has been implicated in the formation of the mercury-selenium complexes, glutathione-selenium-mercury and *bis* (methylmercuric) selenide, respectively (Gailer *et al.*, 2000). The protective effect of selenium against methylmercury toxicity does not appear to involve mercury absorption in the intestine or excretion of mercury in the urine or feces, and selenium also does not appear to affect the rate of methylmercury demethylation (Magos, 1991). Sumino *et al.* (1977) suggested that selenium modifies the form of methylmercury, thus altering its distribution by freeing methylmercury from blood proteins.

Various animal models have been used to show the potential benefits of selenium to counteract the developmental toxicity induced by methylmercury. For example, Nishikido *et al.* (1987) fed selenium to female mice 5–7 weeks before mating and prior to methylmercury subcutaneous administration on gestation day (GD) 13–15 and showed that selenium decreased fetal mortality. The same group of researchers gave selenium and methylmercury together by subcutaneous injection on GD 9 to mated female mice and this improved the performance of the righting reflex and the activity of the pups. Fredriksson *et al.* (1993), administered selenium to female rats eight weeks before mating and prior to oral gavage methylmercury administration on GDs 6–9 and showed an improvement in pup activity. Watanabe *et al.* (1999) fed female mice a diet either deficient or adequate in selenium and showed that a deficiency resulted in altered pup neurobehavioural outcome, as concurrent methylmercury exposure potentiated the neurobehavioural deficits of the selenium-deficient diet.

The chemical speciation of selenium is also an important factor in determining its efficacy. Nielsen and Andersen (1992) observed that compared to selenite, selenomethionine fed to mice (3 µg/mL drinking water) only slightly affected the toxicokinetics of MeHgCl in offspring.

Ringed seal (*Phoca hispida*) is the most abundant marine mammal species in the Canadian Arctic. Ringed seal tissues, particularly the liver, is the major source of methylmercury in the Inuit traditional/country food diet (Chan *et al.*, 1995). The chemical form of the mercury or selenium in ringed seal liver has never been characterized. Chan (2000b) used extensive chromatographic techniques and mass spectrophotometry to isolate and characterize the mercury and selenium ligands in ringed seal liver. Only about 20% of mercury and selenium was cytosolic and the remaining 80% was bound to cell membranes. Moreover, mercury and selenium were found to bind to ligands within the cell membranes of ringed seal liver. The proportion of mercury and selenium bound to ligands increased with the concentrations of the mercury in the liver. The mercury-selenium binding protein has a molecular size of about 65,000 Daltons (Da) and mercury and selenium had a 1:1 molecular ratio. The mercury-selenium binding protein may contain three major polypeptides with molecular sizes of 6,510.8, 14,305.1 and 14,353.1 Da, respectively.

The toxicokinetics of mercury in seal liver were studied using a rodent model (Chan, 2000b). Three groups ($n = 6$) of adult Sprague-Dawley rats were fed rat chow with the addition of one of the following for 14 days: 20% seal liver containing 20 µg/g mercury (final concentration in the chow was 4 µg/g); 20% seal liver containing 115 µg/g mercury (final concentration in the chow was 23 µg/g); or 20% veal liver spiked with $HgCl_2$ to make up a final concentration of 23 µg/g. The absorption rate and distribution in brain, liver and kidney are shown in Table 3.3.1. The results show that when mercury concentrations in the seal liver were low [i.e., around 10 µg/g dry weight (dw)], the absorption rate was 16%, which is lower than the approximately 90% reported for methylmercury, but higher than the approximately 5% absorption rate reported for inorganic mercury (WHO, 1990). In contrast, when the mercury concentrations in seal liver were high, i.e., higher than 100 µg/g dw, the absorption rate decreased to 3%, which is similar to that reported for inorganic mercury. Unlike inorganic mercury, however, the species of mercury found in seal liver can cross from the blood into the brain and a higher percentage (2% versus 0%) ($p < 0.05$) of mercury is accumulated in the brain compared to inorganic mercury. This toxicokinetics information can be incorporated into the risk assessment process when the source and form of mercury (organic, inorganic, selenomercury complex) is known.

TABLE 3.3.1 Absorption rate and distribution of mercury in brain, liver and kidney in rats fed with 20% seal liver containing two levels of mercury or veal liver spiked with mercuric chloride

Group	Absorption rate	% in brain	% in liver	% in kidney
Seal liver (4 µg/g Hg)	16	2	48	50
Seal liver (23 µg/g Hg)	3	2	30	68
Veal liver (23 µg/g Hg)	3	0	8	92

Source: Chan (2002)

To study the dietary effects of selenium and vitamin E on *in utero* exposure to methylmercury, groups of 15 female Sprague-Dawley rats were fed either a basal rodent diet or the same diet fortified with additional selenium as selenomethionine (1 ppm), Vitamin E (225 ppm), or a combination of these two nutrients, commencing eight weeks prior to mating and continuing up until gestation day 20 (Beyrouty, 2002). Treatment with the vehicle alone (control group) or methylmercury by gavage at 1.25 mg/kg bw/day was initiated four weeks prior to mating. These females were then mated with untreated males, and methylmercury treatment of the females continued up until gestation day 20. The mated females were allowed to deliver and the pups were evaluated daily.

All mated females in the control group gave birth to live healthy litters. In contrast, dams in the groups treated with methylmercury showed decreased pup survival following birth (Table 3.3.2). The magnitude of the pup mortality was highest in the methylmercury-treated groups receiving the basal diet alone or the basal diet fortified with selenium, and was lowest in the group that received the combination of additional selenium and Vitamin E.

TABLE 3.3.2 Survival of pups after treatment of selenium (Se) and/or vitamin E and methylmercury (MeHg)

	Control	MeHg (basal diet)	MeHg + Se	MeHg + Vitamin E	MeHg + Se/Vitamin E
No. of females at start	15	15	15	15	15
No. of females mated	15	15	13	15	14
No. of live litters at birth	15	12	11	13	13
No. of live litters at PND 7	15	4	3	9	11

Source: Chan (2002)

This indicates that selenium alone did not provide protection against fetal mortality caused by *in utero* methylmercury treatment, while vitamin E alone and the combination of vitamin E and selenium treatments did. The potential protective effect of vitamin E needs to be further investigated.

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- *Selenium has been the main nutritional factor considered by epidemiological and clinical studies to date. No epidemiological studies, however, have ever shown a correlation between selenium intake and the occurrence or absence of symptoms for methylmercury intoxication. There are also inconsistencies in the protective effects seen in animal studies, and the role of selenium remains to be confirmed.*
- *Information from toxicokinetic studies on laboratory rodents can be incorporated into the risk assessment process when the source and the form of mercury (organic, inorganic, selenomercury complex) is known.*
- *In animal studies, selenium alone did not provide protection against fetal mortality caused by* in utero *methylmercury treatment, while vitamin E alone and the combination of vitamin E and selenium treatments did. The potential protective effect of vitamin E needs to be further investigated.*

3.3.3 Other contaminants and dietary nutrient interactions

There are very few data on the potential effects of diet on the toxicity of other contaminants such as organochlorines. Slim *et al.* (1999) showed that vitamin E completely blocked PCB-mediated endothelial barrier dysfunction. This protective effect by vitamin E was associated with a decrease in both oxidative stress and decreased PCB-mediated production of the inflammatory cytokine IL-6. A recent study showed that PCBs can induce CYP 1A1 and DT-diaphorase activities in rat liver (Twaroski *et al.*, 2001). In addition, the DNA-binding activity of the transcription factor AP-1 was increased and *alpha*-tocopheryl quinone within the lipid fraction was significantly increased. These results suggest that PCBs may cause lipid peroxidation, and antioxidants such as vitamin E may have a protective role.

It has been shown that exposure to PCBs can trigger diseases of the vasculature, e.g., cardiovascular disease (Toborek *et al.*, 1995). In addition, high-fat diets may potentiate and diets high in antioxidant nutrients may protect against PCB-mediated endothelial cell dysfunction (Henning *et al.*, 1999; Slim *et al.*, 1999). Henning *et al.* (1999) have shown that the omega-6 parent fatty acid, linoleic acid, or 3,3′,4,4′-tetrachlorobiphenyl (PCB 77), an aryl hydrocarbon (Ah) receptor agonist, independently can cause disruption of endothelial barrier function.

Furthermore, cellular enrichment with linoleic acid can amplify PCB-induced endothelial cell dysfunction. Selected dietary lipids, therefore, may increase the atherogenic effects of environmental chemicals, such as PCBs, by cross-amplifying mechanisms leading to dysfunction of the vascular endothelium. In a more recent study, Slim *et al.* (2001) show that cytotoxic epoxide metabolites of linoleic acid can play a critical role in linoleic acid-induced endothelial cell dysfunction. In addition, the severe toxicity of PCBs in the presence of linoleic acid may be due in part to the generation of epoxide and diol metabolites.

These findings have implications in understanding interactive mechanisms of how dietary fats can modulate dysfunction of the vascular endothelium mediated by certain environmental contaminants. Omega-6 unsaturated fat seems to show protective effects against methylmercury toxicity in the brain but potentiates PCB toxicity in vascular tissues. The exact effective dose *in vivo* and the relevance in human populations remains unclear.

- *Recent research suggests that PCBs may cause lipid peroxidation, and antioxidants such as vitamin E may have a protective role.*
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Epidemiology and Biomarkers

In addition to exposure assessment (Chapter 2) and the toxicology of various contaminants (Chapter 3), epidemiological studies are an important part of toxic contaminant evaluation in the Arctic. Over the past decade most research efforts in Arctic Canada were focussed on the characterization of exposure of northerners. Epidemiological studies are now in place or in preparation. In order to detect early biological changes preceding overt diseases, biological markers of effects were also validated and introduced in epidemiological studies.

CACAR-I (CACAR, 1997) identified areas with knowledge gaps where research programs should be oriented. Under epidemiology, the following priorities were listed:

1. evaluate the developmental status (neurobehavioural, immunological, reproductive, etc.) of newborns in the Arctic;
2. evaluate fetal effects of mercury; and
3. evaluate kidney function among people exposed to cadmium (via liver and kidney consumption, or smoking).

In this chapter, the discussion is limited to methylmercury and POPs. Other contaminants such as cadmium and lead are now considered of low priority since major sources are local point sources (smoking for cadmium and lead shot for lead), and information on their toxicity is already available, validated, and widely used by regional/national/international health organizations. Furthermore, most health risk uncertainty related to the presence of contaminants in the Arctic food chain is due to methylmercury and POPs. Most of this chapter is devoted to prenatal exposure and adverse developmental effects resulting in altered immune and nervous system function early in life. In addition, since oxidation is one of the possible mechanisms of mercury toxicity, biomarkers of oxidative stress are being investigated as biomarkers of effects in the adult Inuit population.

Since Inuit constitute the most exposed group in the Canadian Arctic, this assessment is focussed on this group. However, conducting epidemiological studies in the Arctic is difficult and should take into account the following specific considerations.

Mixtures of contaminants found in the Arctic

Multi-chemical interactions of ecologically relevant mixtures (at relevant concentrations) can have an effect different from the sum of the effects of each component of the mixture. Arctic seafood contains a mixture of contaminants which may differ from those found in other parts of the world. How important these differences are is not known. The PCB congener profile found in human tissues in the Arctic, however, is similar to that found in southern Canada. Effects of mixtures need to be better understood.

Population size

The small size of the populations living in the Arctic limits the use of epidemiology. The number of disease cases is small and case control studies are extremely difficult to conduct. Only cross-sectional and cohort designs are possible. Health outcomes most amenable to epidemiological research in the Arctic are those with a range of stages from normal to abnormal, and which can be measured in all individuals (e.g., neurodevelopment, immune parameters, bone density, fertility parameters), and are not based on a stochastic distribution (having the disease or not, e.g., cancer). It is probably possible to avoid this limitation by implementing circumpolar studies.

Toxicant — nutrient interactions

The possibility that nutrients present in seafood could modify or counteract the toxicity of contaminants is highly probable and specific to fish-eating populations. These interactions need to be better understood.

Genetic factors

It is important to recognize that genetic variability may affect the susceptibility of individuals or populations to the effects of pollutants. Gene/environment interactions could also explain why some populations or individuals are more susceptible than others. Since few genetic studies have been conducted in the Arctic, and considering that Aboriginal peoples have their own genetic background, the impact of genetic polymorphisms that are involved in xenobiotics metabolism and toxicity in the Arctic should be evaluated.

Confounders

Many health endpoints are multifactorial and environmental stressors can contribute in varying degrees to the etiology of these diseases. Compared to the role that lifestyle and genetic factors play in the etiology of most diseases, contaminants likely play a modest role.

Health priorities

Health outcomes considered in Arctic epidemiology should be of public health importance (high incidence, severity, etc.). Few surveillance systems are available (e.g., mortality, cancer incidence, declared infectious diseases) and any changes in the burden of diseases should therefore rely on health professionals and elders. The high turnover of health workers limits trend observations.

4.1 Immune system function

In children and young adults accidentally exposed to large doses of PCBs and polychlorinated dibenzofurans (PCDFs) in Taiwan ("Yu-Cheng disease"), serum IgA and IgM concentrations as well as percentages of total T cells, active T cells and suppressor T cells decreased compared to values of age- and sex-matched controls (Chang *et al.*, 1981). The investigation of delayed-type hypersensitivity responses further indicated that cell-mediated immune system dysfunction was more frequent among patients than controls. Infants born to Yu-Cheng mothers had more episodes of bronchitis or pneumonia during their first six months of life than unexposed infants from the same neighbourhoods (Rogan *et al.*, 1988). The authors speculated that the increased frequency of pulmonary diseases could result from a generalized immune disorder induced by transplacental or breast milk exposure to dioxin-like compounds, more likely PCDFs (Rogan *et al.*, 1988). Eight to 14-year-old children born to Yu-Cheng mothers were shown to be more prone to middle ear diseases than were matched controls (Chao *et al.*, 1997).

In Dutch preschool children the effects of perinatal background exposure to PCBs and dioxins persist into childhood and were associated with a greater susceptibility to infectious diseases. Levels of PCB exposure, based on serum PCB congener 153 values of this cohort from two Dutch cities, were comparable with those found among northern Québec Inuit (Figure 4.1.1). Common infections acquired early in life may prevent the development of allergies, so PCB exposure might be associated with the lower prevalence of allergic diseases found in this study (Weisglas-Kuperus *et al.*, 2000). It should also be noted that Canadian Inuit from northern Québec have higher levels of PCB 153 than modern US populations (1990s) studied but similar to historical levels in the US (1960s and 1970s), and lower levels than those seen in the Faroe Islands (Figure 4.1.1).

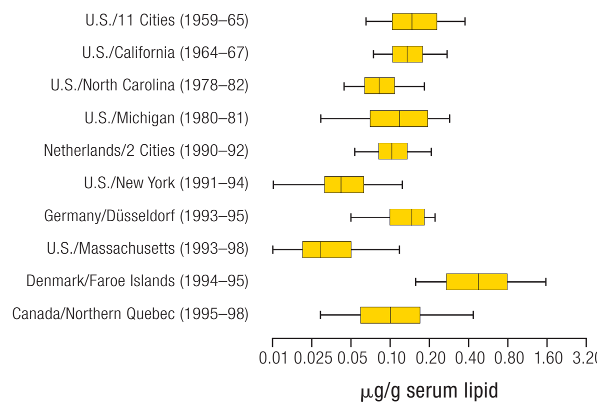

FIGURE 4.1.1

Distribution of PCB 153 concentration in cord or serum plasma, 10 studies.

Source: Longnecker *et al.* (2002b)

Most of the data presented in Section 2 on human exposure have relied on summary measures such as PCBs as Aroclor 1260. It should be noted that PCB 153 on average was found at the highest concentrations in all populations sampled (Table 2.2.2) and is one of the key PCBs that determines overall concentration of PCBs measured as Aroclor 1260.

Organic or inorganic mercury has cytotoxic activities for cellular components of the immune system in several species of rodents. Methylmercury, a form of organic mercury, can alter non-specific defence mechanisms, such as the inhibition of natural killer (NK) cell activity in rats and mice. It also decreases the expression of certain activation markers of T-cells (HLA-Dr, IL-2R) (NRC, 1992). Moreover, it has been well demonstrated that methylmercury can affect the function of B-cells and therefore reduce the humoral-mediated response (Daum, 1993).

4.1.1 Clinical outcomes

In Nunavik, an epidemiological study conducted during 1989–1991 investigated whether organochlorine exposure is associated with the incidence of infectious diseases and immune dysfunction in Inuit infants (Dewailly *et al.*, 2000c). The number of infectious disease episodes during the first year of life of 98 breast-fed and 73 bottle-fed infants was determined. Concentrations of organochlorines (OCs) were measured in early breast milk samples and used as surrogates to prenatal exposure levels. *Otitis media* (middle ear infection) was the most frequent disease, with 80% of breast-fed and 81% of bottle-fed infants experiencing at least one episode during the first year of life. During the second follow-up period, the risk of *otitis media* increased with prenatal exposure to p,p′-DDE, HCB and dieldrin. The relative risk (RR) for 4- to

7-month old infants in the highest tertile of p,p′-DDE exposure compared to infants in the lowest was 1.87 [95 % confidence interval (CI), 1.07–3.26]. The lowest tertile had a breast milk concentration of p,p′-DDE of < 730 versus > 1320 μg/kg lipid in the third or highest tertile. The relative risk of *otitis media* over the entire first year of life also increased with prenatal exposure to p,p′-DDE (RR, 1.52; 95% CI, 1.05–2.22) and HCB (RR, 1.49; 95% CI, 1.10–2.03). Furthermore, the relative risk of recurrent *otitis media* (≥ 3 episodes) increased with prenatal exposure to these compounds. No clinically relevant differences were noted between breast-fed and bottle-fed infants with regard to biomarkers of immune function, and prenatal OC exposure was not associated with these biomarkers. In this study, the potential confounders were not fully controlled i.e., omega-3 fatty acids, vitamin A and smoking. For this reason, studies were designed and initiated to address these issues.

In Nunavik, there are two ongoing studies on the effect of OCs on immune function and infectious disease incidence. The first one is a component of the cohort study, where infectious diseases are monitored during the first year of life (Dewailly *et al.*, 2001a). The second study is a review of all the medical files of 400 preschool children who participated in the Nunavik umbilical cord blood monitoring program in 1993–1996 (Dallaire, 2002). In a preliminary analysis of the first study, the risk of experiencing frequent infectious diseases episodes was assessed in 93 children exposed to PCBs and DDT during their first year of life (Dallaire *et al.*, 2002a). The risks were determined in relation to maternal PCB and DDT blood levels during pregnancy. Odds ratios were estimated using logistic regression analysis and the results were adjusted for a number of factors: maternal smoking during pregnancy, the number of smokers in the house, crowding, breastfeeding duration, and sex of the child. Maternal blood PCB congener 153 concentration was used as a surrogate of prenatal PCB exposure. Infants whose prenatal PCB exposure was above the median were put in the high-exposure group and those below the median were put in the low-exposure group. The following odd ratios [and 95% confidence intervals] denote the relative risk of children in the high-exposure group compared to the ones in the low-exposure group: upper respiratory tract infection 1.8 [0.7–4.7]; bronchitis 3.0 [0.9–9.5]; pneumonia 2.9 [1.1–7.8]; *otitis media* 1.1 [0.4–3.3]; and gastrointestinal infections 2.1 [0.7–7.0]. Results were similar for DDT + DDE maternal levels and are preliminary; 75 more infants will be added to the analysis. This study might support the hypothesis that the high incidence of infections observed in Inuit children (mostly respiratory infections) is due in part to high prenatal exposure to POPs. It should also be noted, however, that some studies have not found a link between pre- or post-natal PCB or dioxin exposure in infants and respiratory tract symptoms but did find shifts in various types of white blood cells related to contaminant levels (Weisglass-Kuperus *et al.*, 1995). Other factors such as vitamin A and omega-3 fatty acids can also modulate immune function and vitamin A has been found to be deficient in some Canadian Inuit populations (Blanchet *et al.*, 2000). It will be important to see the full results of the Nunavik studies when it will be possible to address a number of the important determinants of immune status.

4.1.2 Biomarkers

In 1997, an international symposium was held in Bilthoven (Netherlands) to discuss the most appropriate biomarkers of effects that could be used in epidemiological studies investigating the effects of contaminants on immune function (Van Loveren *et al.*, 1999). One of the stronger conclusions was to use antibody responses to vaccination with an antigen having no prior exposure.

Lymphocyte subsets and immunoglobulins

In the course of the 1990 cohort conducted in Nunavik, biomarkers of immune system function (lymphocyte subsets, plasma immunoglobulins) were determined in venous blood samples collected from breast-fed and bottle-fed infants at 3, 7 and 12 months of age. Results showed that at age 3 months, concentrations of white blood cells (lymphocytes, more specifically those of the CD4 subtype), were lower ($p \leq 0.05$) in blood samples from breast-fed babies when compared to those in the bottle-fed group. At 7 and 12 months of age, IgA concentrations were lower ($p \leq 0.05$) in breast-fed infants than in bottle-fed infants. This also appeared to be the case for CD4/CD8 ratios, although differences were not statistically significant. None of the immunological parameters was associated with prenatal OC exposure (Dewailly 2000c).

In the scope of the ongoing cohort study on neurodevelopmental effects of Arctic contaminants (Muckle *et al.*, 2001a), an immune component was added in 1998. The following immune function biomarkers have been selected: antibody response following vaccination; complement system; cytokine production by Th1/Th2 cells; and vitamin A status.

Antibody response following vaccination

Antibody response to vaccination is an intermediate marker of the competence of the adaptive immunity to infections. Vaccination programs include essentially three types of products: 1) killed vaccine (influenza, whole-cell pertussis, inactivated polio); 2) protein-conjugated or protein-based vaccine (Haemophilus influenza type b, diphtheria, tetanus, acellular pertussis vaccine, hepatitis B); and 3) attenuated live vaccine (measles-mumps-rubella, varicella, BCG). The antibody response to conjugated Haemophilus influenza type b (Hib) is of great interest. This vaccine is important in Inuit children because, prior to immunization, Hib was the most frequent cause of bacterial meningitis in Inuit children, which was 5–10 times more frequent than in Caucasian children (Ward, 1986).

Complement system

The complement (C′) system plays an important role in natural immunity against infectious agents. It is particularly essential in young children for whom the acquired immune system is not yet fully developed. Deficiency of many of the C′ components is associated with increased susceptibility to infections, generally of the upper respiratory tract. In a murine model, exposure to OC compounds increased the susceptibility to *Streptococcus pneumoniae* infections, decreased C3 levels, and lowered total C′ hemolytic activity (White, 1986).

Cytokine production by Th1/Th2 cells

Organochlorines and heavy metals could modulate the production of Th1/Th2-type cytokines. Along with their effects on Th1/Th2-type cytokines, OCs and metal ions are known to alter B-cell activity and to impair host resistance to several bacterial and viral infections (Heo, 1996). High levels of OCs and metal ions in blood and tissues are frequently related to fish consumption. Fish oil-supplemented diets (rich in omega-3 fatty acids) have generally been shown to reduce plasma levels of some cytokines. Most human studies have shown decreased plasma levels or diminished production of IL-1 and TNF. Both contaminants and omega-3 fatty acids alter the balance between Th1 and Th2-type cytokines, and could impair host resistance to infections. One of the principal limitations of using cytokines is their high variability due to minor infections (usually non-detected). The extremely high incidence of minor infections in the Arctic strongly limits the use of cytokines in epidemiological studies.

Vitamin A status

Vitamin A influences the expression of over 300 genes and thus plays a major role in cellular differentiation, including that of cells related to immune response (Sommer and West, 1996; Semba, 1994). Results from different animal and human studies vary; however, almost all studies revealed that lymphopoiesis and/or maturation of lymphocytes are altered (generally reduced) with vitamin A deficiency (Sommer and West, 1996; Olson, 1994; Semba, 1994). Vitamin A deficiency could increase the frequency, severity, and duration of infections. Lower respiratory disease was associated with vitamin A deficiency in many cross-sectional clinical and population-based studies. Also, *otitis media* was among the first infections to be associated with vitamin A deficiency in humans (Sommer and West, 1996; Bloem, 1990; Semba, 1994).

Vitamin A clinical deficiency has never been documented in Canadian Arctic populations. However, numerous studies have documented inadequate intakes of vitamin A (Receveur *et al.*, 1998a). A more recent report suggests that the daily vitamin A intake in Nunavik falls below the recommended intake (Blanchet *et al.*, 2000). Furthermore, persistent organic pollutants such as OCs have been shown to alter vitamin A homeostasis in many species, including primates [reviewed by Zile (1992)]. It is important, therefore, to gain a better understanding of the relationships between vitamin A, OC levels, and infectious disease incidence in Arctic populations.

In a recent pilot study, plasma concentrations of retinol were measured in cord blood samples to assess the vitamin A status of 135 Inuit newborns from Arctic Québec and 22 newborns from the general population of southern Québec. Mean retinol concentrations were 148.2 ng/mL and 242.8 ng/mL, respectively (Dallaire *et al.*, 2002b). Vitamin A levels of more than 200 ng/mL have been considered as normal vitamin A status, those between 100–200 ng/mL as low, and those lower than 100 ng/mL as deficient (Sommer and West, 1996). The difficulty of using vitamin A as an effect biomarker of PCB exposure is related to: 1) the variability of vitamin A intake among individuals; and 2) non-systematic supplementation programs in infants. Vitamin A status is being measured in the preschool and the newborn studies currently underway in Nunavik.

4.2 Neurodevelopment

4.2.1 Clinical outcomes

Polychlorinated biphenyls (PCBs)

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, North Carolina, the Netherlands and Oswego, New York. The principal source of PCB exposure was Great Lakes fish consumption in both the Michigan (Schwartz *et al.*, 1983) and the Oswego (Stewart *et al.*, 1999) studies, and consumption of dairy products in the Netherlands (Koopman–Esseboom *et al.*, 1994a). Newborns from the North Carolina cohort were exposed to background levels of PCBs, and there was no specific source of exposure (Rogan *et al.*, 1986b). Comparison of exposure levels between these different cohort studies is presented in Figure 4.1.1.

General development

The effects of prenatal exposure to PCBs and other OC compounds from environmental sources on birth size and duration of pregnancy have been investigated in the Michigan, North Carolina and Netherlands studies (Jacobson *et al.*, 1990a; Rogan *et al.*, 1986a; Koopman-Esseboom *et al.*, 1994c). In Michigan, higher cord serum PCB concentrations were associated at birth with lower weight, smaller head circumference, and shorter gestation (Jacobson *et al.*, 1990a). Similar effects were observed in the Netherlands study where the PCB cord and maternal plasma concentrations were associated with reduced birth weight and decreased growth rate (weight, length and head circumference) up to three months of age. Prenatal PCB exposure was not associated with birth size or growth at one year of age in North Carolina, the cohort with the lowest PCB exposure (Rogan *et al.*, 1986a).

A recent study on infant development was conducted in northern Québec (Muckle, 2002; in preparation). Prenatal PCB exposure in this cohort is 2–3 times higher than that observed in general populations in southern Québec and in Massachusetts (USA); is similar to that found in Michigan and the Netherlands; and is about 2–3 times lower than found in Greenland and the Faroe Islands. After controlling for potential confounders ($p \leq 0.10$) with the studied outcomes, higher cord plasma PCB 153 concentrations were associated with lower birth weight and marginally related to shorter duration of pregnancy. The strength of the association of the negative effect of PCBs on birth weight was comparable to the effects of exposure to alcohol and smoking during pregnancy. Cord plasma PCB 153 concentrations were marginally associated ($p = 0.07$) with shorter length at birth in girls and were not related to head circumference. These findings are consistent with the results of previous epidemiological studies conducted in populations exposed to PCBs through the consumption of PCB-contaminated food. The hypothesis of omega-3 fatty acids protecting against the negative effects of PCB exposure on birth outcomes was examined for the first time in this study. The results indicate that the negative effects of prenatal PCB exposure on birth weight and duration of pregnancy remained significant despite the significant protective effects of omega-3 fatty acids on these same endpoints (Muckle, 2002; in preparation).

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Neurodevelopment

Exposure to PCBs was associated with less optimal newborn behavioural function (e.g., reflexes, tonicity and activity levels) in three of the four studies previously described (Huisman *et al.*, 1995a; Rogan *et al.*, 1986a; Stewart *et al.*, 2000). Adverse neurological effects of exposure to PCBs have been found in infants up to 18 months of age in the Netherlands study (Huisman *et al.*, 1995b). In Michigan and the Netherlands, higher cord serum PCBs concentrations were associated with lower birth weight and slower growth rate (Fein *et al.*, 1984; Jacobson *et al.*, 1990b; Patandin *et al.*, 1998). In Michigan, prenatal PCB exposure was associated with poorer visual recognition memory in infancy (Jacobson *et al.*, 1985; 1990a; 1992), an effect that was recently confirmed in the Oswego study (Darvill *et al.*, 2000). In North Carolina, deficits in psychomotor development up to 24 months were seen in the most highly exposed children (Gladen *et al.*, 1988; Rogan and Gladen, 1991). In Michigan, prenatal PCB exposure was linked to poorer intellectual function at 4 and 11 years of age (Jacobson *et al.*, 1990a; Jacobson and Jacobson, 1996), a finding recently confirmed in the Netherlands at 42 months (Patandin *et al.*, 1999). Although much larger quantities of PCBs are transferred to nursing infants by breast-feeding than prenatally across the placenta (Jacobson *et al.*, 1984), virtually all the adverse neurobehavioural effects reported to date were linked specifically to prenatal exposure, indicating that the embryo and fetus are particularly vulnerable to these substances.

One prospective, longitudinal study, performed in the Faroe Islands, examined the effects of prenatal exposure to low doses of methylmercury resulting from fish and pilot whale consumption (Grandjean *et al.*, 1992; 1997). Because pilot whale tissues contain other neurotoxicants, this cohort was also exposed to PCBs and, as such, is the only cohort studied to date where the main source of PCB exposure was consumption of marine mammals, as is the case for the Inuit. Further analysis provides some evidence that the effects of methylmercury identified in this study are not the consequence of exposure to PCBs. Again, PCB concentrations in cord serum in these different studies are presented in Figure 4.1.1.

Methylmercury

Three well-designed, prospective, longitudinal studies that examined the effects of prenatal exposure to low doses of methylmercury were performed in New Zealand, the Faroe Islands, and the Seychelles Islands (Crump *et al.*, 1998; Davidson *et al.*, 1998; Grandjean *et al.*, 1997; Kjellström *et al.*, 1986; Myers *et al.*, 1995a). High methylmercury exposure in the Faroe population results from fish and pilot whale consumption (Grandjean *et al.*, 1992); deep-sea and reef fish consumption is the source of exposure for the Seychelles population (Myers *et al.*, 1995b); and fish consumption is the source of exposure for the New Zealand population (Kjellström *et al.*, 1986). Two other studies that aimed to examine the effects of prenatal mercury exposure resulting from fish consumption include one in Canada studying the James Bay Cree population (McKeown-Eyssen *et al.*, 1983) and one in Peru (Marsh, 1995). Neurobehavioural outcomes, however, were not assessed in these studies.

Comparisons between mercury concentrations in newborns are shown in Table 4.2.1. This table shows that the Inuit populations from Greenland have the highest levels of maternal and cord blood mercury. High and quite similar levels of mercury are also seen in the Faroe Islands, Seychelles and New Zealand studies and lower levels are found in the southern Québec and US populations cited (Muckle et al, 2001b).

The Faroe Islands study reported associations between maternal hair mercury concentrations corresponding to the pregnancy period and children's performance on neurobehavioural tests, particularly in the domains of fine motor function, attention, language, visual-spatial abilities, and verbal memory (Grandjean *et al.*, 1997). Subsequently, those effects were also found to be associated with cord blood mercury concentrations (Grandjean *et al.*, 1999). In contrast, prenatal methylmercury exposure was not related to neurobehavioural effects in the Seychelles Islands study (Davidson *et al.*, 1995; Davidson *et al.*, 1998; Myers *et al.*, 1995b). The New Zealand study, in which the exposure and research design were similar to the Seychelles study, also found adverse effects of prenatal methylmercury exposure (Crump *et al.*, 1998; Kjellström *et al.*, 1986). More specifically, higher hair mercury levels were associated with poorer neurodevelopmental test scores in similar domains to those observed in the Faroe study. Prenatal methylmercury exposure via fish consumption was associated with neurobehavioural deficits in the Faroe Islands study but not in the Seychelles Islands study. Little attention has been paid to the New Zealand study because, until recently, it had not been subjected to peer review.

Differences between the Faroe and the Seychelles Islands studies in the marker for mercury exposure, the test battery administered, age at testing, and source of exposure have been suggested to account for the differences in the findings. The New Zealand study, in which the exposure and research design were similar to the Seychelles Islands study, also found neurobehavioural effects, as did the pilot study conducted in the Seychelles Islands population (NRC, 2000). However, it should also be noted that the

TABLE 4.2.1 Comparison of mercury concentrations in Nunavik with those observed in other cohorts

Cohort	Medium	Years	n	Geometric mean	Range	Interquartile range
Canada						
Nunavik Inuit	Cord blood (µg/L) Maternal blood (µg/L) Maternal hair (µg/g)	1996–2000 1993–1995 1992	95 130 123	18.5 10.4 3.7	2.8–97.0 2.6–44.2 0.3–14.0	12.0–27.2 6.6–17.0 2.5–6.2
Southern Quebec	Cord blood (µg/L)[1]	1977–1978	1,108	1.0	0.9–1.0[2]	
James Bay Cree	Women hair, not pregnant (µg/g)[3]	1981	70	2.5	Max = 19.0	
Northern Quebec Cree	Maternal hair (µg/g)		215	6.0[4]	5.2[5]	
USA	Women hair, not pregnant (µg/g)	1981	1,274 1,546	0.36[6] 0.24[7]	0.14–0.90 0.09–0.62	
Faroe Islands						
First cohort	Cord blood (µg/L) Maternal hair (µg/g)	1986–1987 1994–1995	894 914	22.9 4.3		13.4–41.3 2.6–7.7
Second cohort	Cord blood (µg/L) Maternal hair (µg/g)		163 144	20.4 4.1	1.9–102.0 0.4–16.3	11.8–40.0 2.5–7.4
Seychelles Island						
Main study	Maternal hair (µg/g)	1989–1990	740	5.9	0–25	6.0
Pilot study	Maternal hair (µg/g)		789	6.6	0.6–36.4	6.1
New Zealand	Maternal hair (µg/g)	1978–1984	935	8.3[4]	6.0–86.0	
Greenland, Disko Bay	Cord blood (µg/L) Maternal blood (µg/L)	1994–1996 1994–1996	178 180	25.3 12.8	2.4–181.0 1.9–75.6	

Source: Muckle *et al.* (2001b)

[1]The average Hg concentration was reported in nmol/L; this concentration was divided by five to transform to µg/L; [2]95% confidence interval; [3]Women 15–39 years old; [4]Arithmetic mean; [5]Standard deviation; [6]Among seafood consumers; [7]Among non-seafood.

patterns of neurobehavioural damage produced by developmental mercury exposure in animals resemble those found in humans and include sensory system effects, motor or sensorimotor system effects, and cognitive effects.

Since 1997, Nunavik mothers and infants have been observed in a prospective longitudinal study funded by the National Institute of Health (US) and the NCP. Statistical analysis of data is ongoing and results on the neurobehavioural effects of perinatal exposure to PCBs, other OC compounds, and methylmercury will be published in 2002–2003. Results on exposure data were published recently (Muckle *et al.*, 2001a; 2001b) and are outlined in Chapter 3.

In addition, a subsample of the newborns who participated in the Nunavik cord blood monitoring program in 1993–1996 was evaluated at preschool age in 2000 and 2001 using a battery of sensitive tests designed to assess fine motor, gross motor, neurological, and neurophysiological functions. Results will be available in 2003.

4.2.2 Biomarkers of developmental effects

Cytochrome P450 1A1 Induction

Cytochrome P450 1A1 (CYP1A1) is a phase 1 biotransformation enzyme expressed in hepatic (liver) and extrahepatic tissues in humans. Its regulation is mediated by the Ah receptor. Induction of CYP1A1 was reported in laboratory animals treated with 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) or dioxin-like PCB congeners (Okey *et al.*, 1994). Placental CYP1A1 induction was reported in women who smoked during pregnancy, and the newborns of smokers showing a high placental aryl hydrocarbon hydroxylase (AHH) activity weighed less than newborns of smokers with lower AHH activity (Pelkonen *et al.*, 1979). Placental homogenates from Taiwanese mothers who developed Yu-Cheng disease (highly exposed to PCBs and PCDFs) had 100-fold greater CYP1A1-related AHH activity levels than those measured in homogenates from non-exposed mothers (Wong *et al.*, 1985). This enzyme induction was significantly associated with low birth weights (Lucier *et al.*, 1987).

Hydroxylation of toxicants by P450s leads to the formation of reactive intermediates that may damage DNA. PCBs were shown to form such reactive intermediates *in vitro* and to form DNA adducts following their bio-activation in hepatic (liver) microsomal systems containing high levels of P450s (Oakley, 1996; McLean, 1996).

CYP1A1 induction and DNA adducts were tested as possible markers of early biological effects related to OC exposure in Inuit women from Nunavik (Lageux *et al.*, 1999). CYP1A1-dependent ethoxyresorufin-O-deethylase activity (EROD) and DNA adducts were measured in placenta samples obtained from 22 Inuit women from Nunavik. These biomarkers were also assessed in 30 women from a Québec urban centre (Sept-Îles) who served as a reference group. Prenatal OC exposure was determined by measuring these compounds in umbilical cord plasma. Placental EROD activity and the amount of DNA adducts thought to be induced by OC exposure were significantly higher in the Nunavik group than in the reference group. For both biomarkers, smoking was found to be an important confounding factor, but OC exposure was significantly associated with EROD activity and DNA-adduct levels when controlling for self-declared smoking status. It was then concluded that CYP1A1 induction and DNA adducts in placental tissue could constitute useful biomarkers of early effects induced by environmental exposure to OCs (Lagueux *et al.*, 1999). In the latter study, however, there were very few Inuit women who did not smoke during pregnancy, the smoker and non-smoker groups were not balanced, and the smoking status was not ascertained with a biomarker. Therefore, a second study was conducted to determine if environmental exposure to PCBs induces placental CYP1A1 in Inuit women. This more recent study was designed to control the confounding effects of smoking better. The use of cotinine concentration in meconium and of cadmium concentrations in placenta as markers of prenatal exposure to tobacco smoke was previously validated (Pereg *et al.*, 2001). Placenta, cord blood and meconium samples were obtained from 35 Inuit women in Nunavik and 30 women in Sept-Îles (reference population). Efforts were made to sample more smokers in the Sept-Îles population and more non-smokers in the Nunavik population in order to balance the smokers and non-smokers groups. Smoking status was ascertained with the use of cotinine concentration in the meconium and, when necessary, individuals were reassigned to the proper smoking category based on this marker.

PCB concentrations were measured in cord plasma and CYP1A1 activity (EROD) was assessed in placental tissue. Despite the higher PCB exposure of the Inuit population, both groups showed similar EROD activities when data were stratified according to the smoking status ascertained by the cotinine concentration. In the Nunavik population, EROD activity was correlated with 2,2′,4,4′,5,5′-hexachlorobiphenyl (PCB 153) plasma concentration (a marker of exposure to the environmental PCB mixture). However, cotinine concentrations in meconium were also significantly correlated with PCB 153 plasma concentrations, and multivariate analyses failed to demonstrate a significant contribution of PCB exposure to placental CYP1A1 activity when tobacco smoking (as estimated with cotinine concentration in the meconium) was included in the analysis. Results from this study, therefore, showed that low-level environmental PCB exposure does not induce any increase in CYP1A1 activity in the placenta, leaving tobacco smoking as the major modulating factor (Pereg *et al.*, 2002). Exposure of Inuit from Nunavik to PCBs was much lower than the PCBs/PCDFs exposure in Taiwanese children. This could explain these contradictory results.

Thyroid hormones

Although many theories exist on how PCBs affect neurodevelopment, the main hypothesis involves the effect of PCBs on thyroid hormone homeostasis (Porterfield, 1998). Thyroid hormones regulate neuronal proliferation, cell migration and differentiation, including control of when differentiation begins and when cell proliferation ends (Hamburgh, 1969).

One hundred and eighty-two singleton term births were evaluated in the Faroe Islands, where marine food includes pilot whales (Steuerwald, 2000). Maternal serum, hair, milk and umbilical cord blood were analyzed for contaminants. Levels of essential fatty acids, selenium, and thyroid hormones were determined in cord blood. Each infant's neurologic optimality score was determined at two weeks of age, adjusted for gestational age, and predictors were assessed by regression analysis. Thyroid function was normal and not associated with PCB exposure.

In the Netherlands study, 418 mother-infant pairs were enrolled. Thyroid hormone levels were in the normal range, but higher dioxin and PCB-TEQ levels in human milk were significantly correlated with lower thyroid T3 (triiodothyronine) and T4 (thyroxine) levels and with higher levels of thyroid stimulating hormone (TSH) in the infants' plasma at the age of two weeks and three months. Thyroid hormone level alterations detected in this study, however, were not directly associated with neurological dysfunction (Koopman-Esseboom *et al.*, 1994b).

In Nunavik, 466 measurements were taken of thyroid hormones in Inuit newborns' umbilical cord blood samples in the cord blood monitoring program that took place between 1993 and 1996. Free T4 (thyroxine), total T3 (triiodothyronine), TBG (thyroxin-binding globulin) and TSH were measured. Hydroxylated metabolites of PCBs (OH-PCBs) and other phenolic compounds were also measured in a subsample (n = 10). As expected, birth weight was positively associated with thyroid hormones (thyroxine, TBG). For this reason, further analyses were adjusted for birth weight. After adjustment, TBG and TSH levels were significantly and negatively associated with PCB congener levels (Dewailly *et al.*, 1998)

The main transport mechanism of thyroid hormones to the brain requires passing through the blood/brain barrier via a thyroid hormone transport protein called transthyretin (TTR) (Chanoine and Braverman, 1992). Although PCBs show some binding affinity for TTR (Chauhan, 2000), OH-PCBs have much higher *in vitro* binding affinities — as high as 12 times the binding affinity of the natural ligand, thyroxine (T4) (Lans, 1994; Cheek, 1999; Brouwer, 1991). Binding to TTR is not limited to OH-PCBs — other chlorinated phenolic compounds such as pentachlorophenol (PCP), halogenated phenols, and brominated flame retardants (Van den Berg *et al.*, 1991; Van den Berg, 1990; Meerts, 2001) also have strong affinities for TTR. Recently, PCP was found to be the dominant phenolic compound determined in Inuit whole blood (Sandau *et al.*, 2000). Other halogenated phenolic compounds may also be important contaminants in plasma, as they have been found to exhibit toxicological properties similar to those of OH-PCBs (Van den Berg *et al.*, 1991; Schuur *et al.*, 1998).

PCBs have been previously measured in umbilical cord plasma; however, few studies have examined levels of hydroxylated metabolites in blood, especially in humans. OH-PCBs have been quantified recently in Canadian Inuit whole blood (Sandau *et al.*, 2000) and in Swedish and Latvian fish-eaters (Sjödin *et al.*, 2000). Sandau *et al.* (2000) examined chlorinated phenolic compounds in umbilical cord plasma of newborns in three populations with different PCB exposures, including the Inuit population. Retinol and thyroid hormone status [triiodothyronine (T3), free thyroxine (T4), thyroid-stimulating hormone (TSH), and thyroxin-binding globulin (TBG)] were determined in most samples. The authors found an inverse association (r = -0.47; p = 0.01) between log-normalized free thyroxine and log-normalized total phenolic compounds (ΣPCP and OH-PCBs). Total chlorinated phenolic compounds were also negatively associated with T3 (r = -0.48, p = 0.03) (Sandau *et al.*, 2002).

4.3 Sex hormone disruption

The development and maintenance of reproductive tissues are to a large extent controlled by steroid hormones. Some environmental chemicals mimic, while others antagonize natural hormone activity when tested with *in vitro* assays or in whole animal models. Studies dating back to the late sixties identified *o,p'*-DDT, a minor constituent of technical DDT, as a weak estrogenic compound capable of causing an increase in rat uterine weight in the classic immature female rat model (Bitman and Cecil, 1970). This compound and a few others sharing estrogenic properties have been implicated in abnormal sexual development in birds (Fry and Toone, 1981), and in feminized responses in male fish (Jobling *et al.*, 1995).

Certain male reproductive tract disorders (cryptorchidism, hypospadiasis, testicular cancer) have been reported to be increasing in parallel with the introduction of xenoestrogens such as DDT into the environment. Reduced semen quality was also reported in certain regions of the world during the last half of the 20th century (Carlsen *et al.*, 1992; Auger *et al.*, 1995). Although these alterations are thought to be mediated by the estrogen receptor, they are also consistent with inhibition of androgen receptor-mediated events. Kelce *et al.* (1995) identified the major and persistent DDT metabolite, *p,p'*-DDE, as a potent anti-androgenic agent in male rats. In addition to inhibiting androgen binding to the androgen receptor, this compound, when administered to pregnant dams, also induced characteristic anti-androgenic effects in male pups (reduced ano-genital distance; presence of thoracic nipples). Treatment with *p,p'*-DDE at weaning delayed the onset of puberty, while treatment of adult rats resulted in reduced seminal vesicle and ventral prostate weights.

2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) is yet another OC which has been shown to alter sexual development in male rats (Mably *et al.*, 1992). Decreases in epididymis and caudal epididymis weights, and in daily sperm production and caudal epididymal sperm number were observed at day 120 and at most earlier times, when a dose as little as 64 ng/kg was administered to dams on day 15 of gestation. A number of compounds structurally related to TCDD, including other 2,3,7,8-chloro-substituted dibenzo-*p*-dioxins, dibenzofurans, as well as non-*ortho* and mono-*ortho* substituted PCB congeners, bind to the Ah receptor and display similar toxicological properties.

Typical OC mixtures found in highly exposed human populations contain a large variety of OC compounds, including substances with estrogenic, anti-estrogenic, or anti-androgenic capacities. It may therefore be anticipated that complex real life mixtures, composed of numerous compounds that can interact with different receptors involved in cell differentiation and growth, could affect reproduction and development, and be involved in the pathogenesis of hormonally responsive cancers.

4.3.1 Clinical outcomes

Sexual maturation of newborn males

DDE was recently found to inhibit binding of androgen to its receptor and to block androgen action in rodents. Normal development of male genitalia in mammals depends on androgen action. Recently, Longnecker *et al.* (2002a) used stored serum samples to examine the relationship between maternal DDE levels during pregnancy and adjusted odds of cryptorchidism (n = 219), hypospadias (n = 199), and polythelia (extra nipples) (n = 167) among male offspring, using a nested case-control design with one control group (n = 552). Subjects were selected from a United States birth cohort study begun in 1959–1966, when DDE levels were much higher than they are at present. Compared with boys whose mothers' recovery-adjusted serum DDE level was less than 21.4 μg/L, boys with maternal levels greater than or equal to 85.6 μg/L had adjusted odds ratios of 1.3 [95% confidence interval (CI): 0.7, 2.4] for cryptorchidism, 1.2 [95% CI: 0.6, 2.4] for hypospadias, and 1.9 (95% CI: 0.9, 4.0) for polythelia. For cryptorchidism and polythelia, the results were consistent with a modest-to-moderate association, but in no instance was the estimate very precise. The results were inconclusive. In this cohort, DDE concentrations in umbilical cord serum were much higher than in Nunavik (geometric mean — 2.2, range 0.14 to 18 μg/L, Table 2.2.1)

Sexual maturation of newborn males is examined within the on-going cohort study conducted in Nunavik, and ano-genital distance and penis length are recorded. In adults, no study on hormone-associated diseases (breast cancer, endometriosis, male fertility) has been conducted in the Canadian Arctic.

Environmental risk factors for osteoporosis

POPs have recently been associated with an increased risk of osteoporosis in humans. The relationship between DDE and bone mineral density was recently examined in 68 sedentary Australian women who reported adequate dietary intake of calcium (Beard *et al.*, 2000). Reduced bone mineral density was correlated significantly with age (r = -0.36, p = 0.004), as well as with increases in the log of DDE levels in serum (r = -0.27, p = 0.03). The authors also used multiple-regression analysis to examine the influence of other predictor variables on the relationship between log DDE and bone mineral density. The strongest model (p = 0.002) included log DDE (p = 0.018), age (p = 0.002), and years on hormone replacement therapy (p = 0.10) as predictor variables, and this model afforded a prediction of 21% of bone mineral density variation. These results suggest that past community exposures to DDT may be associated with reduced bone mineral density in women. As a potent androgen receptor antagonist, DDE may reduce the inhibitory effect on cytokines and result in the inappropriate

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turnover of osteoclasts or inadequate production of osteoblasts within bone marrow, thus leading to reduced bone density (Beard *et al.*, 2000). These are interesting results, but they must not be overinterpreted as this was a small study and the menopausal status and time since menopause, two important determinants of osteoporosis, were not included in the analyses.

A study was conducted in Nuuk, Greenland in September 2000 to evaluate the prevalence of risk factors for osteoporosis fracture and more particularly environmental factors and their association with bone mass in menopausal women (Dodin, 2002). The risk of osteoporosis fracture was assessed using an ultrasound bone densitometer. The three ultrasound parameters measured were broadband ultrasound attenuation (BUA, dB/MHz), speed of sound (SOS, m/s), and stiffness index (SI). The study population consisted of 153 menopausal women aged 49 to 65 years (mean: 55.3, SD: 4.4). The mean body mass index (BMI; kg/m^2) was 27.9 (SD: 6.1). Seventy-five percent of the Inuit women were smokers, 49% had a BMI higher than the guideline, 28% were sedentary, 9% took calcium supplements, and 9% were currently on hormone replacement therapy. Mean stiffness, BUA, and SOS were respectively 107.7 SD: 11.0%, 1522.9 SD: 6.1 dB/MHz, and 78.5, SD: 13.6 m/s. All three ultrasound parameters adjusted for age were lower in this Inuit population compared with the women of Québec (Dodin, 2002).

Fourteen PCB congeners and 11 chlorinated pesticides were quantified in the Nuuk women's plasma samples. As PCB congeners and chlorinated pesticide concentrations were highly correlated, statistical analyses were done using the following integrative exposure indices: the sum of plasma concentrations for the 14 PCB congeners, the sum of plasma concentrations for chlordanes, and the sum of DDTs. A total concentration of mono-*ortho* congeners (dioxin-like compounds), expressed as 2,3,7,8-TCDD toxic equivalents (TEQ), was computed by summing the weighed concentrations of congeners according to each one's respective toxic equivalency factor (TEF: 0.0001 for PCB 105 and PCB 118; 0.0005 for PCB 156). Cadmium urinary concentrations were determined by atomic absorption (Dodin, 2002; in preparation)

The study found that 19% of the Inuit women had a high risk of osteoporosis fracture compared to 7.2% for the women of southern Québec. To identify which risk factors were associated with ultrasound parameters, a multiple linear regression model involving the stepwise removal of non-significant independent variables was used. The independent predictors of stiffness were age ($p = 0.018$), BMI ($p = 0.018$), former users of oral contraceptives ($p = 0.003$), current hormone replacement therapy users ($p = 0.005$), and the sum of log of mono-*ortho* PCB TEQs ($p = 0.004$). These variables accounted for 36% of the variance in the stiffness ($r^2 = 0.359$). Similar models were built with BUA and SOS as dependent variables. Mono-*ortho* substituted congeners (IUPAC numbers 105, 118 and 156) share some structural similarities with TCDD and can bind to the aryl hydrocarbon receptor (AhR). No significant association was found with DDE even though Greenlandic Inuit women were more exposed than Australian women (11.6 µg/L versus 3.9 µg/L). The consequences of activation of the AhR pathway on osteoporosis, however, are not clear. One possible explanation is that dioxin-like compounds elicit a broad spectrum of anti-estrogenic activities and may reduce bone density through this mechanism. In summary, mono-*ortho* PCB concentrations were associated with a low bone density, and this association remained significant after controlling for potential confounding factors (Dodin, 2002; in preparation).

4.3.2 Hormonal biomarkers

Hormone profiles

To obtain a steroid profile of androgens for both precursors and metabolites of dihydrotestosterone (DHT), a series of steroids, including DHT, could be measured: dehydroepiandrosterone (DHEA), androst-5-ene-3 eta, 17-diol, androstenedione, testosterone, DHT, estrone, estradiol, DHEA sulfate, androstane-3, 17-diol glucuronide, and androsterone glucuronide. These steroid levels help explain alteration in steroidogenic enzymes in classical steroidogenic tissues such as adrenals and the testis, and for steroidogenic transforming enzymes localized in peripheral tissues (prostate and skin).

In the Arctic, no study has been conducted to determine hormone profiles. A pilot study was recently performed in Greenland (n = 48 males) and the following male hormones were measured: DHEA, delta5-diol, delta4, testosterone, DHT, E1 and E2. These hormone levels will be correlated with POPs levels after adjustment for age, BMI and smoking (Dewailly, 2002).

4.4 Oxidative stress

Although oxidative stress has been associated with many chronic diseases (e.g., cancer, cardiovascular disease (CVD), neuro-degenerative disorders, etc.), no specific epidemiological study of these outcomes has been conducted in the Arctic to assess the role of oxidants and antioxidants. Results reported by Salonen *et al.* (1995) suggest the high CVD mortality observed among fish-eaters from Finland could be explained by the high mercury content of the fish (mainly non-fatty freshwater species), which could counteract the beneficial effect of fish consumption. This group noted a significant association between mercury concentration in the hair of eastern Finnish men and the risk of coronary heart disease (CHD). Mercury can promote the peroxidation of lipids, resulting in more oxidized low-density lipoprotein (LDL), which has been implicated as an initiator of atherosclerosis. In the same population, Salonen *et al.* (1982) previously observed an enhanced risk of CHD death in subjects with low serum selenium concentrations, an antioxidant which may possibly block the mercury-induced lipid peroxidation.

That both mercury and selenium can modulate CHD risk is also suggested by observations in fish-eating coastal populations such as Inuit living in Arctic regions. Inuit consume large amounts of fish and marine mammals, and consequently receive large doses of mercury. Contrary to the situation in eastern Finland, however, the mortality rate from CHD in Inuit is extremely low (e.g., 13 per 100,000 in northern Québec). Although, it was reported that omega-3 fatty acids are strong protective factors for cardiovascular diseases among Inuit (Dewailly *et al.*, 2001b), the protection could also result from a high intake of selenium, through the consumption of traditional/country food such as muktuk (beluga and narwhal skin) and sea mammal liver which are rich in selenium.

Methylmercury is a highly toxic environmental neurotoxin that can cause irreparable damage to the central nervous system (Choi, 1989; Clarkson, 1993; 1997). Although the underlying biochemical and molecular mechanisms that lead to impaired cell function and nerve cell degeneration are not well understood, there is abundant evidence supporting the hypothesis that a major mechanism of methylmercury neurotoxicity involves oxidative stress (Sarafian and Verity, 1991; Yee and Choi, 1996). Mercury increases production of reactive oxygen species (ROS) via deregulation of mitochondrial electron transport, as well as through glutathione (GSH) depletion (Lund *et al.*, 1993). The oxidative stress hypothesis is clearly supported by the finding that methylmercury neurotoxicity can be inhibited by various antioxidants, including selenium (Park, 1996) and N-acetyl-L-cysteine, a precursor of GSH (Ornaghi, 1993).

Glutathione peroxidase (GSHPx) and glutathione reductase (GSHRd) activities were measured in blood samples from 142 residents of Salluit, Nunavik (Dewailly, 2001c). Activities of enzymes involved in detoxication of free radicals were measured to investigate the relationships between mercury, selenium and oxidative stress. Mercury was found to be negatively correlated with GSHRd activity, an NADPH-dependent enzyme that regenerates glutathione from glutathione disulfide. In contrast, plasma selenium concentration was positively correlated to GSHPx activity, a selenoenzyme that catalyzes the conversion of hydrogen peroxide to water. Mercury exposure may, therefore, diminish defence mechanisms against oxidative stress by limiting the availability of glutathione, while selenium may afford protection by favouring the destruction of hydrogen peroxide.

A biochemical assessment of the oxidative stress in adult residents of Salluit, Nunavik is underway using the following three other indices:

1. The first is the ratio of coenzyme Q10-reduced form (ubiquinol-10) to oxidized coenzyme Q10 (ubiquinone-10) in plasma, which is now considered one of the most reliable and sensitive indices of an oxidative stress *in vivo* (Yamashita, 1997). In contrast to the total level of coenzyme Q10, which is reported to be associated with multiple factors including gender, age, cholesterol and triglyceride levels (Kaikkonen, 1999), the ubiquinol-10/ubiquinone-10 ratio index is apparently independent of these variables and thus represents an oxidative stress index of choice.
2. Increased levels of specific F2-isoprostanes (direct oxidation metabolites of arachidonic acid) in plasma and/or urine are another index recently used to demonstrate oxidative stress in several pathological conditions involving oxygen free-radical formation (Pratico, 1999; Patrono, 1997). The most easily measurable and frequently used F2-isoprostane species as a marker of oxidative stress *in vivo* is 8-isoprostaglandin F2-alpha (Pratico, 1999; Patrono, 1997).
3. The level of plasmatic LDL oxidation could also be assessed as a potential marker of oxidative stress.

These results will become available soon. This study also includes a neurological assessment and should produce some interesting results on another measure of oxidative stress and its possible relationship to neurological outcomes.

Conclusions:

- *Conducting epidemiological studies in the Arctic is difficult due to a variety of limiting factors: exposure to complex contaminant mixtures; small population size; contaminant-nutrient interactions; genetic factors; confounders; and health priorities. For this reason, epidemiological studies conducted in other parts of the world on PCB- and methylmercury-induced neurotoxicity should be used as much as possible for risk assessment. However, different factors may limit the external validity of these studies.*
- *For methylmercury, the Faroe Islands study appears to be more valid than the Seychelles study for extrapolating results to the Canadian Arctic [exposure to PCBs and mercury, similar sources (e.g., marine mammals)], intake of omega-3 polyunsaturated fatty acids). Differences remain, however, such as the genetic profile, a higher intake of selenium among Inuit, and a different pattern of exposure (peaks).*
- *In Nunavik,* otitis media *(middle ear infection) during the first year of life was associated with prenatal exposure to* p,p′*-DDE, HCB and dieldrin. The relative risk of recurrent* otitis media *increased with prenatal exposure to these compounds. An ongoing Nunavik study also supports the hypothesis that the high incidence of infections observed in Inuit children (mostly respiratory infections) may be due in part to high prenatal exposure to POPs. Definitive conclusions on this study await the final collection of all data and adjustment for important possible confounders (e.g., parental smoking, vitamin A status).*
- *Recent research suggests that the daily vitamin A intake in Nunavik falls below the recommended intake. POPs such as organochlorines have been shown to alter vitamin A homeostasis in many species, including primates. It is thus important to gain a better understanding of the relationships between vitamin A, OC levels, and infectious disease incidence in Arctic populations. Vitamin A status is being measured in studies of preschool children and newborns currently underway in Nunavik.*
- *Although efforts have been made to also use effect biomarkers (vitamin A, cytokines) in studies of immune function, the low predictivity of these markers limits their use. The usefulness of new markers (antibodies post-immunization, complement system) is currently being assessed within the cohort study in place in Nunavik.*
- *The strength of the negative association of PCBs on birth weight for newborns in northern Québec was comparable to the associations with prenatal exposure to alcohol and smoking during pregnancy. The negative effects of prenatal PCB exposure on birth weight and duration of pregnancy could still be demonstrated despite the beneficial effects of omega-3 fatty acids from the traditional/country diet.*
- *In the prospective, longitudinal study in the Faroe Islands the effects of prenatal exposure to PCBs as well as low doses of methylmercury via consumption of marine mammals were examined. The overall pattern of exposure to PCBs and methylmercury from marine mammals is similar for Canadian Inuit. Detailed analyses of the Faroe Island cohort provide some evidence that the neurobehavioural deficits identified are the effects of methylmercury and not the consequence of exposure to PCBs.*
- *The Faroe Islands study reported associations between maternal hair mercury concentrations during the pregnancy period and children's performance on neurobehavioural tests, particularly in the domains of fine motor function, attention, language, visual-spatial abilities, and verbal memory. Those effects were subsequently also found to be associated with cord blood mercury concentration.*
- *Epidemiological research has found an inverse association between levels of free thyroxine and total phenolic compounds [sum of pentachlorophenol and hydroxylated PCBs (OH-PCBs)] in umbilical cord plasma of Canadian Inuit newborn infants. Total chlorinated phenolic compounds were also negatively associated with T3 levels.*
- *Typical OC mixtures found in highly exposed human populations contain a large variety of OC compounds, including substances with estrogenic, anti-estrogenic or anti-androgenic capacities. These OC compounds can interact with different receptors involved in cell differentiation and growth, and could affect reproduction and development, and be involved in the pathogenesis of hormonally responsive cancers.*
- *Mercury exposure may diminish defence mechanisms against oxidative stress by limiting the availability of glutathione, while selenium may potentially afford protection by favouring the destruction of hydrogen peroxide. The oxidative stress hypothesis is supported by the finding that methylmercury neurotoxicity can be inhibited by various antioxidants, including selenium and N-acetyl-L-cysteine, a precursor of glutathione (GSH).*
- *The ongoing Nunavik cohort study should help to shed more light on contaminant exposure and potential related health effects in the areas of neurodevelopment and immune function.*

GNWT/NWT Archives/Tessa Macintosh

Risk and Benefit Characterization, Assessment and Advice

The information presented in previous chapters on exposure assessment (Chapter 2), toxicology (Chapter 3), and epidemiology (Chapter 4) provides the background for characterizing and assessing the contaminant exposure risks (Section 5.1) related to consuming contaminants in traditional/country foods in Arctic Canada. Complementing the risk-related aspects of traditional/country food consumption as the primary pathway of exposure to environmental contaminants is the consideration of the benefits of Arctic traditional/country food diets. These benefits are an equally important and essential part of the benefit and risk characterization and assessment process, and include nutritional benefits (Section 5.2) as well as social, cultural, spiritual, and economic benefits (Section 5.3) of a traditional/country food diet. The assessment of peoples' perceptions of the risks, benefits, and safety of traditional/country foods is also important in this process (Section 5.4).

Information on the elements of benefit and risk characterization and assessment is then considered in the context of benefit and risk management (Chapter 5.5); recommendations are developed and ultimately communicated to Arctic communities in the risk communication component of the process; and advice is provided about the risks and benefits of traditional/country food consumption.

These elements of risk and benefit characterization, assessment and advice are discussed in detail in this chapter.

5.1 Contaminant exposure risks

In understanding contaminant exposure, the studies cited in Section 2.1 show that the primary contaminants of concern in the context of traditional/country food consumption in Arctic Canada are the persistent organic pollutants PCBs, chlordane and toxaphene (Section 5.1.1), the toxic metals mercury and lead (Section 5.1.2), and radionuclides (Section 5.1.3). Assessing contaminant exposure risks includes estimating contaminant intakes via a traditional/country food diet and making comparisons with Tolerable Daily Intakes (TDIs) for these contaminants, plus assessing contaminant tissue levels among the various groups and comparing these levels to contaminant tissue guidelines. Contaminant intake in the Yukon First Nations, Dene and Métis, and Inuit communities were estimated by combining the dietary consumption information and food contaminant concentrations in the CINE contaminant database derived from CINE food analysis and literature values (Chan, 1998; Chan, 2002).

GNWT/NWT Archives/Fran Hurcomb

5.1.1 Persistent organic pollutants

Contaminant intakes

As was outlined in the CACAR-I (CACAR, 1997), the contaminants having the greatest exceedances of dietary guidelines were chlordane and toxaphene. Figure 5.1.1 shows the overall mean intakes of chlordane and toxaphene for various Aboriginal groups, based on data collected in the mid to late 1990s and described in Section 2.1.1. Mean intakes of Dene and Métis of the NWT and Yukon First Nations were below the provisional Tolerable Daily Intakes (pTDIs) for these contaminants, whereas the mean intakes in Inuit communities exceeded the pTDIs for chlordane and toxaphene (Chan, 2002).

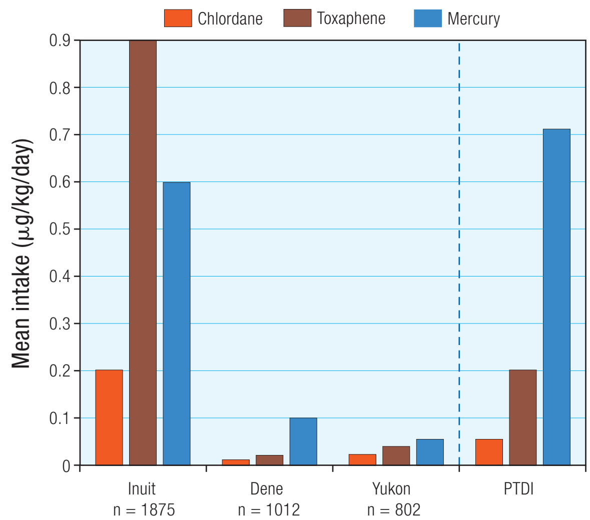

FIGURE 5.1.1

Mean intakes of chlordane, toxaphene and mercury in northern Canada (µg/kg/day).

Source: Kuhnlein and Receveur (2001)

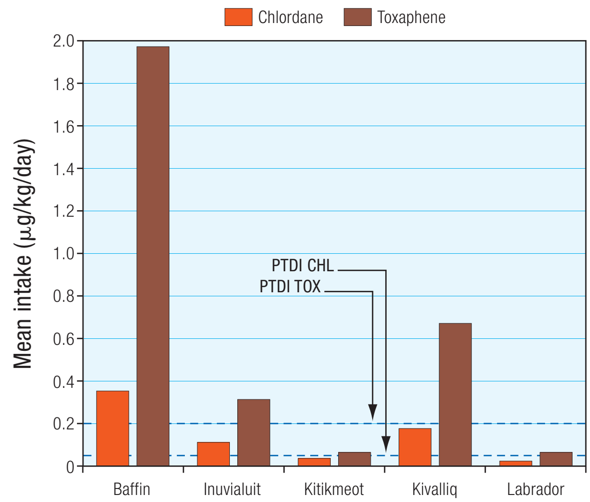

FIGURE 5.1.2

Mean intakes of toxaphene (TOX) and chlordane (CHL) in different regions (ages 20–40 years) (µg/kg/day).

Source: Kuhnlein and Receveur (2001)

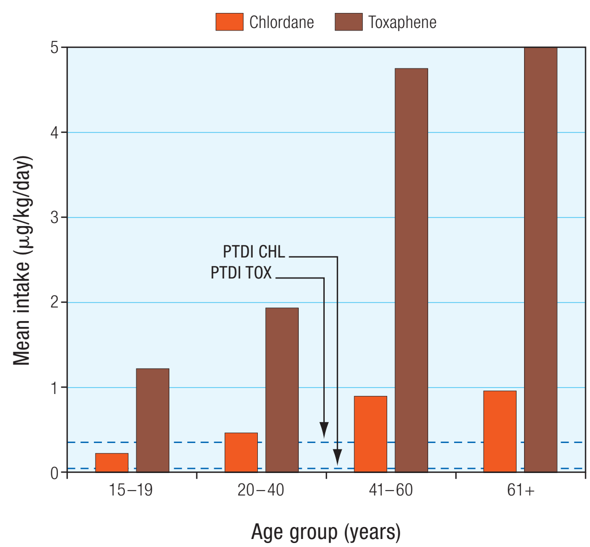

FIGURE 5.1.3

Mean intakes of toxaphene (TOX) and chlordane (CHL) among different age groups in Baffin (µg/kg/day).

Source: Kuhnlein and Receveur (2001)

Among the five major Inuit regions, in Baffin, Kivalliq and Inuvialuit communities mean intakes of 20–40-year-old adults exceeded the pTDIs for chlordane and toxaphene while the intakes for Kitikmeot and Labrador did not exceed the pTDIs (Figure 5.1.2). When intake data in the Baffin region were separated by age group, it was seen (Figure 5.1.3) that mean intakes of all age groups exceeded the pTDI for toxaphene, and that the three adult age-groups exceeded the pTDI for chlordane. The intake of both contaminants increases with each age group. This increasing level of exposure with age is associated with the corresponding age-related increased intake of traditional/country food as was documented in CACAR-I (CACAR, 1997).

TABLE 5.1.1 Sources of organochlorines in the Baffin region (% contribution)

Species	Part	Weight – % contribution[1]	Chlordane – % contribution[2]	PCBs – % contribution[2]	Toxaphene – % contribution[2]
Caribou	Flesh	38.2	0.9	1.3	0.1
Ringed seal	Flesh	18.7	0.8	2.4	8.9
Arctic char	Flesh	15.6	2.2	1.5	3
Narwhal	Muktuk	5	1.8	7	0.1
Walrus	Flesh	3.2	1.7	0.6	0.1
Ringed seal	Broth	2.9	0.2	1.1	0.1
Polar bear	Flesh	2.8	1.5	3.1	0.1
Narwhal	Blubber	1.9	37.9	44.5	35.6
Ptarmigan	Flesh	1.3	0	0	0
Beluga	Muktuk	1.2	1.7	1.7	0.9
Walrus	Blubber	1.2	34.9	22.2	43.1
Beluga	Blubber	0.4	11.1	8.5	6.3
Ringed seal	Blubber	0.3	1.9	1.3	0.3
Polar bear	Fat	0.1	2.3	1.6	0.5
TOTAL %		**92.8**	**98.9**	**96.8**	**99.1**

Source: Kuhnlein and Receveur (2001)

[1]Percent by weight of each species contributing to the traditional diet; [2]Percent of each contaminant contributed by each food.

The individual dietary intake depends on the amount of each traditional/country food consumed by the individual and the concentration of contaminants in that food. Table 5.1.1 shows the sources of chlordane, toxaphene, and PCBs in the dietary intake profiles of the Baffin region (n = 522 interviews). It can be seen that the three most important food species, by their proportional contribution to total weight of food consumed, are caribou, ringed seal and Arctic char. The three species representing the largest proportions of chlordane and PCB exposure, however, were narwhal blubber, walrus blubber, and beluga blubber. For toxaphene, the greatest proportional contributions were made by walrus blubber, narwhal blubber, ringed seal flesh, and beluga blubber. Species which only make up a small proportion of the diet but high proportions of the contaminant exposure have markedly higher concentrations of these contaminants (Kuhnlein *et al.*, 2000). Proportionate contributions to chlordane and toxaphene exposures are also shown in Table 5.1.2 for all five Inuit regions. In regions such as Baffin and Kivalliq which had intakes higher than the pTDI for chlordane and toxaphene (Figure 5.1.2) it can be seen that the major sources of exposure are marine mammal blubber (beluga, walrus or narwhal). In regions such as Labrador where the mean intakes did not exceed the pTDI, caribou meat and various fish species were the major source of exposure, indicating lower concentrations in these species.

TABLE 5.1.2 Proportionate contributions of three main food sources of chlordane and toxaphene, in five Inuit regions, by food item

Inuit region	Food item and proportionate contribution of chlordane (%)	Food item and proportionate contribution of toxaphene (%)
Inuvialuit	Beluga blubber (84%) Caribou meat (5%) Beluga muktuk (5%)	Beluga blubber (81%) Beluga muktuk (4%) Arctic char flesh (3%)
Kitikmeot	Beluga blubber (59%) Arctic char flesh (13%) Caribou meat (7%)	Beluga blubber (52%) Arctic char flesh (26%) Ringed seal flesh (9%)
Kivalliq	Beluga blubber (62%) Beluga muktuk (15%) Walrus blubber (8%)	Beluga blubber (53%) Walrus blubber (15%) Arctic char flesh (10%)
Baffin	Narwhal blubber (38%) Walrus blubber (35%) Beluga blubber (11%)	Walrus blubber (43%) Narwhal blubber (36%) Ringed seal flesh (9%)
Labrador	Caribou meat (30%) Lake trout flesh (20%) Salmon flesh (12%)	Salmon flesh (41%) Lake trout flesh (29%) Arctic char flesh (9%)

Source: Kuhnlein and Receveur (2001)

The population distributions of seven organochlorines are shown in Table 5.1.3 for Qikiqtarjuaq, a community selected because of high traditional/country food use. Mean intakes exceeded the organochlorine pTDIs for chlordane, PCBs and toxaphene, while median intakes exceeded the pTDI only for toxaphene. The 95th percentile indicates the level of intake by the highest 5% of consumers. When the 95th percentile/pTDI was computed, it was noted that high consumers are exceeding the pTDIs by more than 100-fold for toxaphene and chlordane, and 15-fold for PCBs (Kuhnlein *et al.*, 2000; 2001a; 2001b; Batal, 2001). It is understood from dietary survey results that any one individual will not likely eat the same amount of high contaminant food items on several consecutive days. If more days of intake data from individuals were available, a tighter distribution and therefore a lower prevalence of high levels of exposure would result. The risk associated with usual levels of exposure (that is, levels lower than the ones characterized by the 95th percentile/pTDI but higher than the pTDI) need to be characterized, since they appear prevalent in the Baffin region. These results (Kuhnlein *et al.*, 2000; 2001a; 2001b; Batal, 2001) confirm the earlier studies indicating higher exposures to various POPs in Inuit communities and reviewed in CACAR-I (CACAR, 1997).

Possible changes in dietary intake of contaminants are a significant concern in the Canadian Arctic. Insight into the change in contaminant intake over the past twelve years in Qikiqtarjuaq (Broughton Island), Nunavut, a community known to have high traditional/country food consumption levels, can be achieved by comparing data collected in 1987–1988 (Kuhnlein *et al.*, 1995a; Chan *et al.*, 1997) to data collected in 1998–1999 (Kuhnlein *et al.*, 2000). Intakes of organochlorines including PCBs, chlordane, and toxaphene (Table 5.1.4), were higher in the more recent study, particularly among the high-end consumers (95th percentile). While the organochlorine concentrations used for the estimation of the two surveys were similar (data not shown), the amount of narwhal muktuk and blubber consumed was significantly higher in 1998–1999. The major sources of organochlorines were narwhal blubber and muktuk, walrus blubber, and ringed seal blubber reported in 1987–1988 compared to narwhal blubber and muktuk in 1998–1999, (Kuhnlein *et al.*, 1995c; 2000).

TABLE 5.1.3 Population distribution of organochlorine intake in Qikiqtarjuaq (µg/kg bw/day)

Organochlorine	n	PTDI (µg/kg/d)	n > PTDI	Mean	Median	95th percentile	95th / PTDI
Chlordane	110	0.05	34	0.62	0.02	5.18	104
HCB	110	0.27	14	0.23	0.02	1.7	6
DDT	110	20	9	1.58	0.04	13.1	0.7
HCH	110	0.3	11	0.06	0	0.36	1
Mirex	110	0.07	5	0.01	0	0.04	0.6
PCBs	110	1	16	1.9	0.05	15.3	15
Toxaphene	110	0.2	52	3.34	0.26	26.2	131

Source: Kuhnlein and Receveur (2001)

TABLE 5.1.4 Comparison of daily intake of selected contaminants in Qikiqtarjuaq in 1987–1988 and 1998–1999

Contaminant	Daily intake (µg/kg bw/day) in 1987–88 [1]		Daily intake (µg/kg bw/day) in 1998–99 [2]	
	Median	95th percentile	Median	95th percentile
Mercury	1	7	0.6	6.4
PCBs	0.3	3.6	0.05	15
Chlordane	0.06	2.1	0.02	5.2
Toxaphene	0.05	8.1	0.26	26

Sources: [1]Kuhnlein *et al.* (1995a), Chan *et al.* (1997); [2]Kuhnlein *et al.* (2000).

- *Mean intakes of toxaphene and chlordane for Dene and Métis of the NWT and Yukon First Nations were below the Provisional Tolerable Daily Intakes (pTDIs), whereas the mean intakes for these same contaminants in some Inuit communities exceeded the pTDIs.*
- *In recent dietary surveys among the five major Inuit regions, mean intakes by 20–40-year-old adults in Baffin, Kivalliq and Inuvialuit communities exceeded the pTDIs for chlordane and toxaphene. Baffin had mean intakes in all age groups which exceeded the pTDI for toxaphene, and the three adult age groups exceeded the pTDI for chlordane. This increasing exposure with age is associated with the corresponding age-related increased intake of traditional/country food.*
- *High consumers (95th percentile) of traditional/country foods are exceeding the pTDIs by many-fold for toxaphene, chlordane, and to a lesser extent for other POPs such as PCBs.*
- *In one Inuit community, Qikiqtarjuaq (Broughton Island), Nunavut, intakes of organochlorines including PCBs, chlordane, and toxaphene were higher in 1998–1999 than in 1987–1988, particularly among the high-end consumers (95th percentile). While the organochlorine concentrations used for the estimations were similar, variations in the amounts of certain traditional/country foods consumed likely account for this difference.*

PCB tissue levels and guidelines

While chlordane and toxaphene are of significant concern due to exceedances of dietary guidelines, there are only limited human or animal toxicological data available for these contaminants and no human tissue guidelines have been developed. More information is available on human tissue levels and on the animal and human toxicity of PCBs, which has allowed the development of human tissue PCB guidelines. This section compares PCB tissue levels in various northern ethnic groups to the PCB guidelines developed by Health Canada.

Blood contaminant levels in the NWT, Nunavut, and Nunavik, are presented and compared in Section 2.2.1. For PCBs (as Aroclor 1260), Health Canada's maternal blood guidelines have a Level of Concern where concentrations are > 5 µg/L, and an Action Level where concentrations are ≥ 100 µg/L. The most recent findings (Figure 5.1.4) indicate that, on average, 43% of the blood samples from Inuit mothers in NWT/Nunavut exceeded the Level of Concern; of these, 87% were < 20 µg/L, and none exceeded the Action Level of 100 µg/L (Walker *et al.*, 2001). The corresponding values for Dene and Métis, and Caucasians exceeding the Level of Concern were 3.2% and 0.7%, respectively (Walker *et al.*, 2001). Figure 5.1.4 also shows that exceedances of the 5 µg/L PCB blood guideline vary markedly among five Inuit regions, with greater exceedances in Baffin (73%), Kivalliq (59%), and Nunavik (59%), where greater levels of PCBs were observed (Walker *et al.*, 2001; Ayotte 2001). Inuvik had the lowest percentage exceedance (16%) among the Inuit regions. This information on blood guideline exceedances supports the previous assessment of dietary intakes, as it is the Inuit groups that exceed the TDIs for food intakes as well as the tissue guidelines.

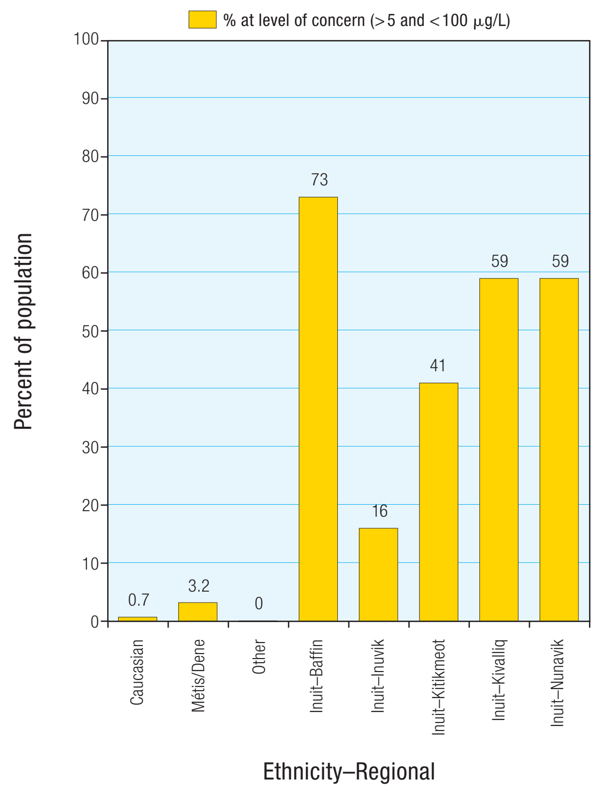

FIGURE 5.1.4

Maternal blood guideline exceedances for PCBs as Aroclor 1260 in Arctic Canada, by region and ethnicity.*

Source: Van Oostdam (2001)

* Values were only within the Level of Concern; no values exceeded the Action Level of 100 µg/L.

- *The most recent findings in NWT and Nunavut indicate that almost half of the blood samples from Inuit mothers exceeded the Level of Concern value of 5 µg/L for PCBs as Aroclor 1260 but none exceeded the Action Level of 100 µg/L. These exceedances were higher in Baffin, Kivalliq, and Nunavik, where higher levels of PCBs were observed. Very low percentages of Dene and Métis, and Caucasians exceeded the Level of Concern. This information on blood guideline exceedances supports the previous assessment of dietary intakes, as it is the Inuit groups that exceed the TDIs for food intakes as well as the tissue guidelines.*

5.1.2 Toxic metals — mercury, cadmium, and lead

Contaminant intakes

Toxic metals such as mercury, cadmium, and lead can bioaccumulate and this was well documented in the CACAR-I (CACAR, 1997). Concentrations of these metals vary markedly between tissues and species of animals. Metals accumulate most markedly in organs such as liver and kidney (Chan *et al.*, 1995). The dietary surveys outlined in Section 3.1 measured both dietary intakes for all traditional/country foods as well as contaminant levels and allow estimates of exposures to be calculated for specific population groups. Figure 5.1.1 shows that the Inuit have the highest intakes of mercury and their mean intakes approach the provisional tolerable daily intake (pTDI) for total mercury of 0.71 µg/kg/day (WHO/FAO, 1996) while the mean intakes of mercury among First Nations peoples in the Yukon and NWT are well below the pTDI. The pTDI of 0.71 µg/kg/day is based on total mercury; the pTDI for methylmercury is 0.47 µg/kg/day. Much of the present data on dietary levels of mercury in food are only available for total mercury so the comparisons made in Figure 5.1.1 are reasonable. Certain species, such as marine mammals, contain mostly inorganic mercury while other species such as fish contain mostly organic mercury (Wagemann *et al.*, 1997), so more accurate risk assessments could be undertaken if methylmercury was specifically measured in traditional/country foods. Recently Health Canada has developed a new Provisional TDI for methylmercury for children and women of child-bearing age of 0.2 µg/kg/day (Health Canada, 1998). It would not be reasonable to use this pTDI in Figure 5.1.1 as the results are for all men and women sampled in these communities but it does indicate that children and women of child-bearing age could be exceeding the pTDI.

Table 5.1.5 shows that for the Inuit regions some food items with low concentrations of mercury, such as caribou meat, contribute a significant proportion of mercury exposure due to the high intake of this traditional/country food. Other traditional/country foods only rarely eaten, such as ringed seal kidney, contribute a significant proportion of the contaminant exposure due to the high concentration of mercury therein. There is also marked regional variability in the traditional/country foods contributing to exposure. In the Baffin region, where the highest levels of mercury in human tissues (Section 2.2.2) were found, the most significant sources of exposure were marine mammals, ringed seals and walrus. This necessitates dietary recommendations that are specific to local populations and that reflect the particular species contributing the most significant exposure.

TABLE 5.1.5 Proportionate contributions of three main food sources of mercury, and mercury concentrations by food item in five Inuit regions

Inuit region	Food item	Proportionate contribution of Hg (%)	Hg concentration (mg/kg)
Inuvialuit	Caribou meat	52	0.06
	Beluga muktuk	11	0.73
	Lake trout	11	0.85
Kitikmeot	Caribou meat	27	0.06
	Arctic char flesh	15	0.10
	Caribou ribs	7	0.14
Kivalliq	Caribou meat	38	0.06
	Beluga muktuk	24	0.73
	Lake trout flesh	12	0.85
Baffin	Ringed seal meat	36	0.40
	Narwhal muktuk	14	0.56
	Caribou meat	12	0.06
Labrador	Caribou meat	37	0.06
	Lake trout flesh	36	0.85
	Ringed seal kidney	6	2.84

Source: Kuhnlein and Receveur (2001)

Exposure to mercury also varies markedly among the various Inuit groups as was the case for the various organochlorines. Figure 5.1.5 indicates that the Inuit from Baffin have the highest exposure to mercury and that the older age groups have higher exposures to mercury. As was noted for the intake of POPs, Section 5.1.1, this increased exposure with increasing age is associated with the corresponding age-related increased intake of traditional/country food.

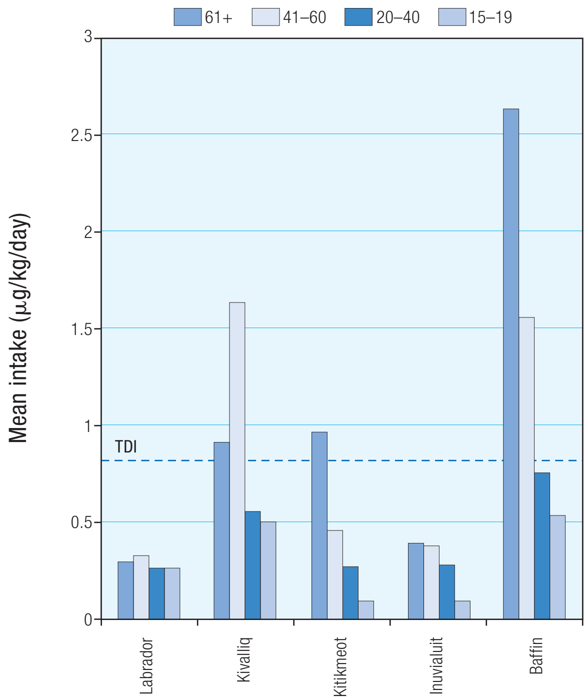

FIGURE 5.1.5

Mean intake of total mercury in different regions (µg/kg/day).

Source: Kuhnlein and Receveur (2001)

To further examine metal exposures, data are presented for Qikiqtarjuaq (Broughton Island), Nunavut, as these data exemplify the range of exposures to toxic metals (arsenic, cadmium, mercury and lead). Table 5.1.6 shows that mean intakes exceed the pTDIs for mercury and lead, but that median intakes exceed the pTDIs only for mercury. The 95th percentile indicates the level of intake by the highest 5% of consumers. In computing the 95th percentile/pTDI ratio, it was noted that high consumers are exceeding the pTDIs by nine-fold for mercury and ratios for all other metals are less than three. This indicates that mercury is of the greatest concern. As noted earlier in the case of organochlorines, it is understood from dietary survey results that any one individual will not likely eat the same level of high contaminant food items on several consecutive days. If more days of intake data from individuals were available, a tighter distribution and therefore a lower prevalence of high levels of exposure would result. Nevertheless, it is advisable to discourage high intakes by individuals whenever possible and, since usual levels of exposure (i.e., levels lower than the ones characterized by the 95th percentile/pTDI but higher than the pTDI) appear widespread in the Baffin region, the risk associated with this exposure needs to be characterized. These results (Kuhnlein *et al.*, 2000; 2001a; 2001b; Batal, 2001) confirm the earlier studies reviewed in the CACAR-I (CACAR, 1997).

To see whether there was a temporal change in mercury intake in Qikiqtarjuaq (Broughton Island), data on the daily intakes of mercury collected in 1998–1999 (Kuhnlein *et al.*, 2000) were compared to those data collected in 1987–1988 (Kuhnlein *et al.*, 1995c; Chan *et al.*, 1997). Intakes of mercury were similar in the two surveys (Table 5.1.4), indicating there has been little change in dietary pattern and/or mercury concentrations in the foods. The major sources of mercury in 1998–1999 were ringed seal meat, narwhal muktuk and polar bear flesh. In 1987–1988, the major sources were also ringed seal meat, narwhal muktuk and polar bear (Chan *et al.*, 1995).

- *Inuit have the highest intakes of mercury and their mean intakes approach the provisional tolerable daily intake (pTDI) for total mercury.*
- *Dietary recommendations should be specific to local populations and reflect the particular species contributing the most significant exposure to toxic metals.*
- *Intakes of mercury in one Inuit community, Qikiqtarjuaq, Nunavut were similar in the two surveys conducted in 1987–1988 and 1998–1999 which suggests there has been little change in dietary pattern and/or mercury concentrations in traditional/country foods.*

TABLE 5.1.6 Population distribution of heavy metal intake in Qikiqtarjuaq (µg/kg bw/day)

Metal	n	PTDI (µg/kg/day)	n > PTDI	n > 0	Mean	Median	95th percentile	95th/PTDI
Arsenic	110	2	30	110	1.3	0.3	5.6	2.8
Cadmium	110	1	27	110	0.6	0.2	2.3	2.3
Mercury	110	0.71	47	110	1.6	0.6	6.4	9
Lead	110	3.57	49	110	3.6	2.7	10.4	2.9

Source: Kuhnlein and Receveur (2001)

Contaminant tissue levels and guidelines

Mercury

In the 1970s Health Canada developed blood guidelines for mercury. Blood levels below 20 µg/L are classified as being in the acceptable range, between 20–100 µg/L as "increasing risk" and levels greater than 100 µg/L in blood as "at-risk" (Wheatley *et al.*, 1979). The United States undertook a re-evaluation of mercury and developed a Bench Mark Dose Level of 58 µg/L for this metal (NRC, 2000). Applying the United States' suggested 10-fold safety factor to the bench mark dose level allows the development of a maternal blood guideline of 5.8 µg/L.

Walker *et al.* (2001) and Ayotte (2002) show that among the mothers from NWT/Nunavut and Nunavik, only Inuit exceeded the Canadian Level of Concern of 20 µg/L and almost no Caucasian or Dene Métis mothers exceeded the lower guideline of 5.8 µg/L based on the United States evaluation. These differences among the three ethnic groups are almost certainly due to different lifestyles and eating patterns. Among five Inuit regions, percentage exceedances of the Canadian guideline Level of Concern of 20 µg/L for mercury were highest in Nunavik (16%) and Baffin (10%) (see Table 5.1.7 and Figure 5.1.6). The percentage exceedance of the 5.8 µg/L United States blood guideline for mercury among Canadian Inuit women ranged from a low of 16% in Inuvik to highs of 79% in Nunavik and 68% in Baffin. No mothers were in the "at-risk" range of >100 µg/L. The groups that have the greatest exceedance of these blood guidelines are also the same groups that most often exceed the tolerable daily dietary intakes discussed previously.

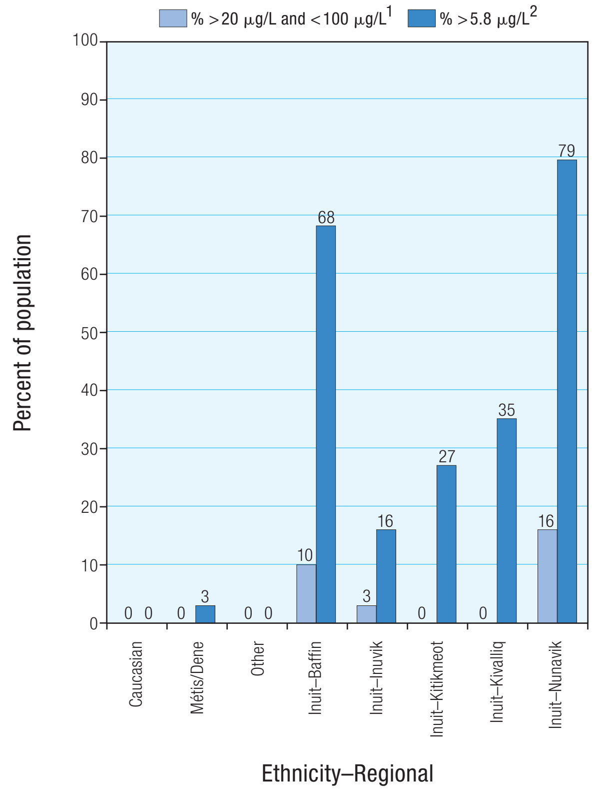

FIGURE 5.1.6

Maternal blood guideline exceedances for total mercury in Arctic Canada, by region and ethnicity.

Source: Van Oostdam (2001)

[1] "Increasing risk" range based on Health Canada guideline; no values were > 100 µg/L, the "at risk" range.

[2] Based on the US 1999 re-evaluation which derived a mercury Benchmark Dose Level (58 µg/L) and advised a ten-fold safety factor, allowing the development of a maternal blood guideline of 5.8 µg/L.

TABLE 5.1.7 Blood guideline exceedances for mercury (total), lead, and cadmium in Arctic Canada, by region and ethnicity (%)

Region/Ethnic group	n	Mercury (total)		Lead	Cadmium
		% of samples exceeding 5.8 µg/L[3]	% of samples exceeding or equal to 20 µg/L[4]	% of samples exceeding 100 µg/L	% of samples exceeding 5 µg/L[5]
NWT/Nunavut					
Caucasian[1] (1994–99)	134	0	0	0	6
Dene and Métis[1] (1994–99)	92	1	0	2	3
Other[1] (1995)	13	0	0	0	0
Inuit (1994–2000)					
Baffin[1] (1996)	31	68	10	10	13
Inuvik[1] (1998–99)	31	16	3	3	7
Kitikmeot[1] (1994–95)	63	27	0	2	10
Kivalliq[1] (1996–97)	17	35	0	0	18
Nunavik[2,6] (1995–2000)	162	79	16	12	n/a[7]

Sources: [1]Walker *et al.* (2001); [2]Ayotte (2001)

[3]Based on US EPA (1999) re-evaluation of mercury; [4]Increasing risk range is 20–100 µg/L; [5]Guideline value of 5 µg/L is for occupational exposure; [6]≥ 5.8 µg/L blood guideline; [7]not available.

The proportion of Inuit mothers who are in the "increasing risk" range for mercury has decreased quite markedly over the years. Wheatley and Paradis (1996) reported that 56% of mothers included in their 1972–1989 monitoring study were in the "increasing risk" range compared to 3–16% of Inuit mothers in the 1990s (Table 5.1.7). However care must be taken in concluding trends based on some of the historical mercury data as this data set may be biased due to resampling communities and individuals with high mercury values (CACAR, 1997). Based on the new United States evaluation, a much greater proportion of Inuit women exceed the guideline indicating that even though levels of exposure may have decreased, health concerns associated with exposure still exist.

Lead

Canada and the United States use 100 μg/L as the Action Level for lead. In NWT/Nunavut, all average lead levels in women's blood samples were markedly lower than the 100 μg/L Action Level, but 3.4% and 2.2% of the blood samples from the Inuit, and Dene and Métis women, respectively, exceeded the Action Level (Walker *et al.*, 2001) (see Table 5.1.7). Among Inuit women, percentage exceedances ranged from a low of 0% in Kivalliq to a high of 10% in Baffin. Historical data have shown that levels among many populations have decreased in parallel to the phaseout of lead in gasoline around the world (AMAP, 1998), indicating that the lead issue in the Arctic may be due to local use of lead. Recent research by Dewailly *et al.* (2000b) using lead isotope tracers has indicated that most of the current lead exposure among Nunavik Inuit results from the use of lead shot.

Cadmium

The guideline of 5 μg/L for cadmium is an occupational level and in the absence of any other guideline is offered as general guidance. In NWT/Nunavut cadmium levels in women's blood exceeded this guideline in 10% of Inuit, 6% of Caucasians, 3% of Dene and Métis, and 0% of women in the Other group. Among Inuit the percentage exceedances ranged from a low of 7% in the Inuvik region to a high of 18% in the Kivalliq region (Walker *et al.*, 2001) (see Table 5.1.7). A number of studies have shown that there are markedly higher smoking rates among northern Aboriginal peoples (Benedetti *et al.*, 1994), and other studies have found that smoking and not traditional/country food consumption contributes most cadmium exposure (Walker *et al.*, 2001).

- *Only Inuit mothers exceeded the Canadian Level of Concern for mercury (20 μg/L) and almost no Caucasian, or Dene or Métis mothers exceeded the lower guideline (5.8 μg/L) based on the US EPA evaluation.*
- *Based on the new US EPA mercury evaluation, a much greater proportion of Inuit women would exceed the guideline indicating that even though levels of exposure may have decreased, health concerns associated with exposure still exist.*
- *In NWT/Nunavut, lead levels in all women's blood samples on average were markedly lower than the Action Level, but 3.4% and 2.2% of the blood samples from the Inuit, and Dene and Métis women, respectively, exceeded the Action Level. Recent research by Dewailly et al. (2000b) using lead isotope tracers has indicated that most of the current lead exposure among Nunavik Inuit is from the use of lead shot.*

5.1.3 Radionuclides

The debate continues in international scientific circles as to whether there is a dose threshold for radiation-induced cancer. Radiation protection authorities have always assumed a linear, no-threshold hypothesis in setting exposure limits. This means that all radiation exposures, no matter how small, carry a risk of producing cancer which is proportional to the dose received. However, there is mounting evidence that a threshold may exist for radiation. The US-based Health Physics Society has recommended against quantitative estimation of health risk below an individual dose of 50 mSv (millisieverts) in one year or a lifetime dose of 100 mSv over and above normal background radiation (Health Physics Society, 1996). The issue is of significance to northerners, who were exposed in the past to nuclear weapons fallout, or who have slightly higher exposures from caribou meat consumption.

Even if one assumes that the linear no-threshold hypothesis is correct, the risk of continued consumption of caribou meat is very small. Table 3.2.9 (Section 3.2.6) indicates a maximum dose rate (at present) of about 3 to 4 mSv/year. The International Commission on Radiological Protection (ICRP) gives a lifetime risk coefficient of 7.5×10^{-5} per millisievert of exposure for cancer and other serious illnesses (ICRP, 1991). If a person were to receive a lifetime radiation dose of:

$$3.5 \text{ mSv/year} \times 70 \text{ years} = 245 \text{ mSv}$$
$$245 \text{ mSv} \times 7.5 \times 10^{-5}/\text{mSv} = \text{lifetime risk of}$$
1.8% from caribou meat consumption.

A normal background radiation of 2.4 mSv/year would give a lifetime risk of 1.3%. The normal incidence of cancer in the general population is approximately 25%. The only way to reduce these doses further would be to restrict caribou meat consumption, which would deny northerners the nutritional, social and cultural benefits of this important source of nutrients. Other lifestyle choices such as smoking and alcohol consumption have a much greater influence on rates of cancer.

Recent evidence from A-bomb survivors (Shimizu *et al.*, 1999) and Chernobyl emergency workers (Ivanov *et al.*, 2001) indicates that high dose radiation may be a factor in increased mortality from cardiovascular disease. This link needs to be studied further in groups exposed to high levels of radiation. The relevancy of this to northerners who have lower exposures is uncertain at this time.

- *There is mounting evidence that a threshold may exist for radiation-induced cancer and this threshold may be equal to or greater than 100 mSv. The issue is of significance to northerners, who were exposed in the past to nuclear weapons fallout, or who have slightly higher exposures from caribou meat consumption. More research is needed on the threshold for radiation-induced cancer.*
- *Even if it is assumed that the linear no-threshold hypothesis is correct, the risk of continued consumption of caribou meat is very small. A maximum dose rate (at present) is estimated to be about 3 to 4 mSv/year (millisieverts per year). The only way to reduce these doses further would be to restrict caribou meat consumption, which would deny northerners the nutritional, social and cultural benefits of this important traditional/country food.*

5.2 Nutritional benefits of traditional/country food

The nutritional benefits of traditional/country food and its contribution to the total diet are substantial, even though only 6–40% of total dietary energy may be from this food source. These foods are important sources of lipids, vitamins, minerals and protein and in many cases are the primary source of many important nutrients (CACAR, 1997). New information reported since CACAR-I demonstrates that, in all three of the CINE dietary studies, days "with" traditional/country food have significantly less fat, saturated fat, sucrose and total carbohydrate than do days "without" traditional/country food (Table 5.2.1).

TABLE 5.2.1 Carbohydrate and fat on days with or without traditional/country food (least square means +/- SEM)

Energy from	Region/Ethnic group	Percentage of energy with traditional/country food	Percentage of energy without traditional/country food
Carbohydrate	Yukon	37 ± 0.6 (n = 413)	42 ± 0.7* (n = 389)
	Dene and Métis	38 ± (n = 662)	44 ± 1* (n = 350)
	Inuit	37 ± 0.5	49 ± 0.6* (n = 783)
Sucrose	Yukon	9 ± 0.3	12 ± 0.4*
	Dene and Métis	9 ± 1	13 ± 1*
	Inuit	13 ± 4	18 ± 0.5*
Fat	Yukon	30 ± 0.6	40 ± 0.5*
	Dene and Métis	31 ± 1	37 ± 1*
	Inuit	30 ± 0.4	35 ± 0.5*
Saturated Fat	Yukon	11 ± 0.3	14 ± 0.2*
	Dene and Métis	11 ± 0.3	13 ± 0.3*
	Inuit	9 ± 0.1	12 ± 0.2*

*Significant $p < 0.05$
Source: Kuhnlein and Receveur (2001)

These findings are consistent across the Canadian Arctic and confirm that decreasing traditional/country food in the diet is likely to have negative health consequences in part through the corresponding increase in total fat, saturated fat and sucrose above recommended levels. For example, at those levels of fat intakes, an increasing number of cardiovascular deaths can be expected (NRC, 1989); similarly, high saturated fat intake and high sucrose intake have been associated with increased risk of colorectal cancers (World Cancer Research Fund, 1997). The rising levels of excess weight and obesity documented in Yukon (Receveur *et al.*, 1998a) and Inuit communities (Kuhnlein *et al.*, 2000) need to be further considered when the balance between traditional/country foods and imported foods is evaluated: 18% of women 20–40 years of age, and 33% of women 40–60 years of age in the five Inuit regions surveyed by CINE in 1998–1999 had a body mass index (BMI) over 30. An increase in mean BMI over a five year period (1992–1997) has also been reported for women in the Inuit communities of Repulse Bay and Pond Inlet (Lawn and Harvey, 2001). This increase in the proportion of energy derived from fat observed on days when no traditional/country food is consumed could be associated with the growing prevalence of excess weight observed in Yukon and Inuit communities.

Although usually providing smaller proportions of daily energy and total dry weight in diets than imported food, traditional/country food was shown to contribute significantly more protein, iron and zinc to the diets of Baffin Inuit children (Berti *et al.*, 1999).

In Table 5.2.2, the top three sources of several nutrients in the total daily diet as reported consumed in the five Inuit regions show that at least one traditional/country food is mentioned for each nutrient with the exception of calcium. It is also clear that iron and zinc are almost entirely contributed by traditional/country food, whereas the top three calcium sources are entirely from imported food, especially from bannock, the typical home-prepared bread product (Kuhnlein *et al.*, 2001b; 2001c; Blanchet *et al.*, 2000).

Since CACAR-I, new analytical results for nutrients in traditional/country foods have shown some remarkable nutrient properties. For example, exceptional sources of vitamin C (> 20 mg/100 g fresh weight) in Inuit traditional/country foods have been shown for beluga muktuk, narwhal muktuk, seal liver, caribou liver, cisco eggs and blueberries. Excellent sources of omega fatty acids, vitamin A, vitamin D and vitamin E have been shown to be beluga blubber and oil, narwhal blubber, Arctic char,

TABLE 5.2.2 Top three sources of selected nutrients from 24-hour recalls (fall and late winter combined) in five Inuit regions

	Inuit Region				
Nutrient	**Inuvialuit (n = 387)**	**Kitikmeot (n = 300)**	**Kivalliq (n = 341)**	**Baffin (n = 522)**	**Labrador (n = 417)**
Vitamin A	Caribou liver	Caribou liver	Carrots	Walrus liver	Carrots
	Carrots	Carrots	Beluga blubber	Ringed seal liver	Margarine
	Beef liver	Mixed frozen vegetables	Caribou meat	Narwhal blubber	Ringed seal kidney
Omega-3 Fatty Acids	Margarine	Arctic char flesh	Arctic char flesh	Arctic char flesh	Margarine
	Arctic char flesh	Caribou meat	Caribou meat	Walrus blubber	Salmon flesh
	Beluga blubber	Margarine	Beluga blubber	Ringed seal broth	Salad dressing
Vitamin E	Margarine	Caribou meat	Caribou meat	Caribou meat	Margarine
	Potato chips	Bannock	Potato chips	Bannock	Potato chips
	Caribou meat	Margarine	Bannock	Narwhal blubber	Caribou meat
Calcium	White bread	Bannock	Bannock	Bannock	Evaporated milk
	2% milk	Pizza	Pizza	2% milk	2% milk
	Pizza	White bread	White bread	Pizza	White bread
Zinc	Caribou meat	Caribou meat	Caribou meat	Caribou meat	Caribou meat
	Ground beef	Ground beef	Ground beef	Ringed seal meat	Ground beef
	Caribou dried meat	Caribou dried meat	Beluga muktuk	Narwhal muktuk	Chicken
Iron	Caribou meat	Caribou meat	Caribou meat	Ringed seal meat	Caribou meat
	White bread	Ringed seal meat	Bearded seal meat	Caribou meat	Partridge meat
	Ground beef	Caribou dried meat	Ringed seal meat	Walrus meat	White bread

Source: Kuhnlein and Receveur (2001)

burbot eggs, beluga muktuk and narwhal muktuk. As well, several nutritionally essential minerals have recently been reported in high levels in Arctic foods, including iron, zinc, selenium, copper, magnesium and manganese (Blanchet *et al.*, 2000; Kuhnlein *et al.*, 2001a).

Fish are an important part of the traditional/country food diet across the Canadian North. The health benefits of consuming 1–2 servings of fish per week (17–34 g/day) have been well documented (Simopoulos, 1991; Kromhout *et al.*, 1995; Weisburger, 2000) and some studies support recommendations for greater amounts, up to 69 g/day (Kris-Etherton *et al.*, 2000). Health benefits would accrue most likely for preventing heart disease (Shmidt *et al.*, 2000), but also possibly for certain cancers (World Cancer Research Fund, 1997) and type-2 diabetes (Feskens *et al.*, 1991; 1995; Ekblond *et al.*, 2000). Fish intake by Aboriginal peoples is summarized in Table 5.2.3 and suggests that they are likely to fully benefit at the current levels of consumption. Any decrease in fish consumption among the younger generation in particular could be expected to have negative health consequences. Limiting fish consumption in any way based on levels of mercury exposure would be further unwarranted in Inuit communities, given that the main source of exposure in these communities was caribou, representing 52%, 27%, 38% and 27% of total exposure in Inuvialuit, Kitikmeot, Kivallik, and Labrador, respectively (Kuhnlein *et al.*, 2000). In Baffin, seal meat was the single main contributor of mercury (36% of the total exposure level). Seal meat and caribou are not highly contaminated with mercury, but their frequent consumption makes them the main sources of mercury in Baffin. In contrast to fish, the health benefits of consuming seal and caribou, above and beyond what can be inferred from their specific nutritional values, have not been studied, and remain unknown.

Other researchers have also noted that the shift away from traditional/country food diets may also be linked to the rise in obesity, diabetes, and cardiovascular disease among Aboriginal peoples in the United States and Canada (Young, 1993; Young *et al.*, 1993). Increased saturated fat, sucrose, and alcohol in diets has led to higher incidences of gall bladder disease, tooth decay, alcoholism and its complications, and fetal alcohol syndrome. Poor diet quality has also been associated with higher incidences of anemia, *otitis media*, a variety of infections, and to some kinds of cancer (Kuhnlein and Receveur, 1996).

- *The nutritional benefits of traditional/country food and its contribution to the total diet are substantial, even though only 6–40% of total dietary energy may be from this food source.*
- *Research findings are consistent across the Canadian Arctic and confirm that decreasing traditional/country food in the diet is likely to have negative health consequences, in part through the corresponding increase in total fat, saturated fat and sucrose above recommended levels.*

TABLE 5.2.3 Reported daily fish consumption by gender and age group in three recent dietary surveys among Canadian Arctic Aboriginal peoples[1]

Indigenous peoples region (main fish species)	Women – age 20–40 g/person/day (No. of 24-hr recalls)	Women – age 41+ g/person/day (No. of 24-hr recalls)	Men – age 20–40 g/person/day (No. of 24-hr recalls)	Men – age 41+ g/person/day (No. of 24-hr recalls)
Yukon First Nations (salmon, trout, grayling,whitefish)	48 (n = 253)	76 (n = 169)	69 (n = 221)	91 (n = 159)
Dene and Métis				
Gwichin (whitefish, loche, inconnu, Arctic char, lake trout)	65 (n = 47)	66 (n = 54)	35 (n = 51)	158 (n = 43)
Sahtu (whitefish, lake trout, cisco, loche)	13 (n = 49)	154 (n = 42)	37 (n = 46)	105 (n = 43)
Dogrib (whitefish, pike, trout, loche)	8 (n = 28)	82 (n = 29)	32 (n = 21)	120 (n = 31)
Deh-Cho (whitefish, lake trout, loche)	10 (n = 72)	39 (n = 38)	37 (n = 51)	13 (n = 56)
Akaitcho (whitefish, lake trout, loche)	21 (n = 85)	34 (n = 67)	44 (n = 79)	30 (n = 80)
Inuit				
Inuvialuit (Arctic char, whitefish, cisco, herring, lake trout)	54 (n = 121)	111 (n = 74)	12 (n = 100)	124 (n = 45)
Kitikmeot (Arctic char, lake trout, whitefish)	34 (n = 113)	137 (n = 49)	36 (n = 76)	136 (n = 41)
Kivallik (Arctic char, lake trout)	21 (n = 112)	109 (n = 68)	65 (n = 87)	169 (n = 48)
Baffin (Arctic char, arctic cod, cisco)	39 (n = 160)	72 (n = 105)	47 (n = 112)	73 (n = 102)
Labrador (lake trout, salmon, rock cod, Arctic char)	24 (n = 112)	50 (n = 97)	29 (n = 80)	60 (n = 89)

[1]Estimates obtained by averaging food intake over all 24-hr recalls collected in two seasons (September–November and February–April). Data adapted from Receveur *et al.* (1996; 1998a), Kuhnlein *et al.* (2000).

- *The increase in the proportion of energy derived from fat observed on days when no traditional/country food is consumed could be associated with the growing prevalence of excess weight observed in Yukon and Inuit communities. Although usually providing smaller proportions of daily energy and total dry weight in diets than imported food, traditional/country food contributes significantly more protein, iron and zinc to the diets of Baffin Inuit children.*
- *New analytical results for nutrients in traditional/country foods have shown some remarkable nutrient properties. Many traditional/country foods contain excellent sources of vitamin C, omega fatty acids, vitamins A, D and E, as well as iron, zinc, selenium, copper, magnesium and manganese.*
- *Fish intake by Canadian Arctic Aboriginal peoples suggests that they are likely to fully benefit from protection against cardiovascular disease at the current levels of consumption of traditional/country food. Any decrease in fish consumption among the younger generation, in particular, could be expected to have negative health consequences.*
- *Other researchers have also noted that the shift away from traditional/country food diets may also be linked to the rise in obesity, diabetes, and cardiovascular disease among Aboriginal peoples in the United States and Canada.*

5.3 Social, cultural, spiritual and economic benefits of traditional/country food

Historically, circumpolar northern Indigenous populations have relied on a variety of Arctic flora and fauna for survival. The way of life for Aboriginal people in Arctic Canada has been and still is very much defined by their relationship with the environment. Today, traditional/country foods are still central to cultural, social, spiritual and personal well-being in many regions. They are essential to the nutritional and social health of individuals and communities (e.g., Van Oostdam, 1999; Receveur *et al.*, 1996; Santé Québec, 1995; Condon *et al.*, 1995). According to Aboriginal people, traditional/country foods, and related activities (hunting, fishing, collecting, distribution, preparation, consumption), still play critical roles in everyday life in many northern communities for reasons that include their social and cultural importance, formal and informal economic value, and contributions to physical and mental well-being (Dewailly *et al.*, 2000d). Each food, and its related activities, provide specific benefits which must be considered when balancing the benefits and risks of exposure to environmental contaminants through traditional/country food consumption.

Arctic Canada is undergoing significant economic, political, social, cultural and environmental change as a result of influences and pressures both from within and outside of the region. The maintenance of the link between people and the land is therefore that much more important, further stressing the importance of the collection, sharing, and consumption of wild foods in the North. Aboriginal people report that traditional/country foods define, maintain, and increase aspects of the cultural, social and spiritual identity and well-being (Dewailly *et al.*, 2000d; Kuhnlein *et al.*, 2000; Bjerregaard and Young, 1998; Egeland *et al.*, 1998). Culture is strongly tied to language and participation in traditional activities and hunting and gathering various traditional resources provide the opportunity for these aspects of culture to be expressed. As the Inuit Circumpolar Conference states, hunting is an integral social activity to Inuit communities.

> "hunting ... is crucial to sustaining, reproducing, and expressing Inuit social relations. Where disruptions in primary cooperative subsistence activities occur, social relations at the community level suffer. Sealing ... is ... '... the patterned acquisition and use of (an animal) in such a way as to enhance the social relationships existing in a community...' ... Inuit have always depended [sic] animals and other Inuit to maintain their culture and perpetuate their society. ... sealing continues to establish and reaffirm productive and cooperative social relationships that are so crucial to Inuit survival through the hunting and sharing of seals. For many Inuit sealing is ... a 'set of culturally established responsibilities, rights, and obligations.'" (Inuit Circumpolar Conference, 1996)

Hunting, fishing and gathering of wild resources and the subsequent sharing of those items with individuals throughout the community are social activities bringing together individuals, families and generations, and are often the focus of celebrations and festivities. In this way, they form and maintain an important social fabric among individuals which supports community health and well-being. For example, not only is muktuk nutritionally and psychologically beneficial, but its widespread sharing among relatives and between communities creates and sustains the bonds that remain the basis of Inuit social and economic relationships in the North today (Freeman *et al.*, 1998). Further, these activities are opportunities for the transfer of knowledge between generations and the maintenance of language, as they necessitate and use traditional knowledge and components of Aboriginal language, thus passing on information about hunting techniques, places and local history while on the land. Similarly, the preparation of traditional/country foods provides opportunities for coming together, learning and sharing among individuals in communities. The link between Aboriginal people and the land, seas and waterways they travel and use is also regarded in a spiritual sense as an offering or gift. This spiritual relationship with the environment is expressed, maintained and strengthened by the ongoing practices of hunting, fishing and gathering of resources in a respectful way. Specifically, in regards to social and mental health, traditional/country foods and related activities are reported to define and maintain aspects of identity and Aboriginal culture.

> "Inuit foods may have contaminants, they also have much more. They have sustained us, nourished us, brought us together, and given us the sense of who we are" (Egede, 1995).

To the people who have traditionally hunted on particular traplines, these areas are their primary world. Their roots and their ideas of who they are, are tied to their lands. The ties of particular people to the land are strongest to their own traplines since much of their own personal history and their family history is knit into the geography of these lands (Weinstein, 1976). Berkes and Farkas (1978) state that the retention and rejuvenation of Aboriginal practices (traditional food habits, such as eating of fish and game) probably depend to some extent on maintaining a sense of identity and pride. The nutritional problem, therefore, is part of the larger problem of acculturation in the maintenance of social health in communities (Berkes and Farkas, 1978).

Northerners state:

> "Inuit foods give us health, well-being and identity. Inuit foods are our way of life... Total health includes spiritual well-being. For us to be fully healthy, we must have our foods, recognising the benefits they bring. Contaminants do not affect our souls. Avoiding our food from fear does." (Egede, 1995).

> "For the old people, the food for them is real food — strong food like igunaq, seal and all kinds of country food, and when they do not have it for a long time, they start to crave it...it's their way of life." (Quaqtaq resident, Nunavik, 1997)

> "They are so important to me because they are who we are. They are part of being Inuit. I have always eaten them and always will." (Labrador Inuk, 1999)

There are also economic realities which influence how much Aboriginal peoples rely on traditional/country food. Employment and incomes are often low or uncertain compared to southern Canada, fluctuating with development projects and seasonal opportunities. In many cases, and for many people the cost of nutritious imported food is prohibitively high in northern communities. For example, in 1989 the cost to purchase equivalent amounts of imported meat in local stores was estimated to be over $10,000 per Aboriginal household per year (Usher and Wenzel, 1989). Traditional/country food, therefore, is an economic necessity for many Aboriginal northerners.

In a recent study, Kuhnlein *et al.* (2000) documented the cultural, economic and social benefits of traditional/country food among adult Inuit in five regions of the Canadian Arctic. Preliminary results indicate that ≥ 90% of 1721 respondents believe that harvesting and using traditional/country food by the family:

- contributes to physical fitness and good health
- provides people with healthy food
- favours sharing in the community
- is an essential part of the culture
- is an occasion for adults to display responsibility for their children
- provides education on the natural environment
- contributes to children's education
- provides skills in survival
- provides skills in food preparation at home

In addition, the survey reported that interviewees recognize traditional/country food as being significantly more healthy for children, healthy for pregnant/breastfeeding women, tasty and more important to community life compared to market food. It is clear from the research initiative by Kuhnlein *et al.* (2000) that traditional/country food provides multiple social and cultural benefits to Inuit. The effects of losing these benefits as a result of decreasing use of traditional/country food are of concern in several ways, including increased incidences of diabetes and heart disease, and effects on mental health (CACAR, 1997).

When traditional/country food is compromised by contaminants, more than Aboriginal peoples' health is affected; their economy, culture, spiritual well-being and way of life are also threatened. The importance of traditional/country food is further stressed by the lack of healthy, accessible and economically viable alternatives in many communities and for many individuals. Many market foods are expensive, of lower nutritional value and deprive Aboriginal people of the cultural and social significance and other benefits of hunting and consuming traditional/country food. Consequently, the contamination of traditional/country food raises problems which go far beyond the usual confines of public health and cannot be resolved simply by health advisories or food substitutions alone.

- *Harvesting, sharing, processing and consuming traditional/country foods from the land and waters provides not only the primary source of food and income, but it is also the foundation of the social, cultural and spiritual way of life for Aboriginal peoples.*
- *Perceived and real risks of contaminants in traditional/country foods pose significant threats to the way of life for Arctic residents.*
- *Traditional/country food is an economic necessity for many Aboriginal northerners.*
- *Alternatives to consuming traditional/country food for northern Aboriginal peoples are often not an option. Many southern foods are expensive, have lower content of many important nutrients and deprive Aboriginal peoples of the cultural and social significance/benefits of hunting and consuming traditional/country food.*

5.4 Assessment of perceptions of risks, benefits and safety of traditional/country foods

5.4.1 Introduction

Decisions must be made regarding the risks posed by contaminants in traditional/country foods in the North, even if it is only to decide if nothing must be done. Data are collected, risks and benefits of exposure to various contaminants and nutrients, and social and cultural benefits of consuming wildlife species are assessed, and this information is weighed. In the case of formal health hazard assessments, it is then decided by territorial or provincial health authorities in consultation with their partners listed in Section 5.5 whether or not to take action to reduce or minimize the risks, and how to maximize the benefits associated with the consumption of traditional/country foods in the North. At the most fundamental level, all individual northern residents make these decisions every day when deciding what to eat. The task of deciding what to do in relation to contaminants in traditional/country foods is for some a straightforward and simple decision and, for others, a much more complex and challenging exercise. One of the reasons for this is the fact that each individual involved in this process "sees" or "perceives" the issue differently. This difference in perception of the risks and benefits is influenced by such things as an individual's experience and knowledge (technical, traditional and layperson), comprehension or understanding of the issue, direct involvement in the issue, social and cultural background, and/or their ability to choose to be exposed to the hazard or not, among other things.

5.4.2 Differences in perceptions among individuals

It is widely understood that the public does not see risk in the same way as technical "experts" (Kasperson, 1986; Erikson, 1990; Douglas, 1992) and that even among experts there are differences in their judgments of certain risks (e.g., Kraus *et al.*, 1992). Individual factors such as age, gender, education, occupation, language, world view, and culture may all influence individuals' perceptions and concerns about certain hazards (e.g., Flynn *et al.*, 1994; Slovic and Peters, 1995). Also, certain attributes of hazards have been identified as being strongly influential on the perception and acceptance of risks among the public. These factors include: involuntary exposures, uncertainty about probabilities or consequences of exposure, lack of personal experience with the risk (fear of the unknown), effects of exposure delayed in time, genetic effects (effects on the next generation), accidents related to human activity (anthropogenic, not "natural" causes), unequally distributed risks and benefits, and the ease of perception of the associated benefits (Slovic, 1987; Douglas, 1986; Pidgeon *et al.*, 1992).

For the individual, perception is a combination of personal and collective (i.e., social) factors that influence the way in which one understands issues, and to which one reacts and takes action at the individual level (i.e., personal behaviours). It is recognized that individuals' basic conceptualizations of risk are much richer than that of experts and reflect legitimate concerns that are often omitted from formal risk assessments (Slovic, 1987). It is for these reasons that the perceptions of those involved and affected by a hazard must be considered as they directly influence the effectiveness of any risk management decisions and actions (including communications) taken to minimize risks and to maximize the benefits of, in this case, consuming traditional/country foods in the North. It is critical to assess and understand the northern public's perception of food-chain contamination and the way in which this issue is being addressed in order for decision-makers and risk communicators to design successful activities to support the reduction of risks. Better, more effective risk management processes, decisions and communications help minimize anxiety, build trust, and avoid negative repercussions (e.g., confusion, misperception, rejection of advice, mistrust, introduction of exposure to indirect risks). Consideration of public perception in these activities supports the development of more effective risk reduction strategies.

ITK/Eric Loring

5.4.3 Perceptions of risks in the North

With the issue of food-chain contamination by various organochlorines, heavy metals and radionuclides, through primarily long-range transport, northern people are faced with involuntary exposure to a different type of hazard, as it is not easily observed or detected by traditional/conventional means. Furthermore, because of the central importance of traditional/country foods in Aboriginal communities in the North, even today, understanding and considering this context is critical to effectively communicating and managing these issues. Due to the significant qualitative and symbolic benefits attributed to traditional/country foods in Aboriginal cultures (see Sections 5.2 and 5.3), the perceptions and concerns related to food contamination are not simply proportional to the level of harvesting and consumption activities in communities. Reports of contamination undermine confidence in the environment and harvesting activities as sources of individual and collective well-being. These and other characteristics complicate the management of this issue further emphasizing the need to understand the public perceptions of this issue and how it is addressed.

5.4.4 Research on the perceptions of food-chain contamination in the north

CACAR-I (CACAR, 1997) details efforts made in assessing and collecting both qualitative and quantitative data on the perceptions of environmental contaminants among northern residents, and related to activities during Phase I of the NCP. The discussion of results presented here summarizes this information and presents any further knowledge gained in this area to date.

The Santé Québec (1994) survey assessed perceptions of Nunavik residents towards contaminants in traditional/country foods and revealed the high level of awareness (62%) and the desire to know more (87%) about this issue. Overall, 55% of Nunavik residents considered traditional/country foods to be more healthful and nutritious than commercial foods, and 21% believed that commercial foods were of higher quality either because they were better, more modern, or because traditional/country foods were contaminated. These perceptions varied with age, with the most favourable attitudes towards traditional/country foods being among individuals in the 25–44-year age group, and the least favourable attitudes among the younger participants. The survey also indicated that 14% of people reported having changed their habits upon becoming aware of food-chain contamination. About 11% reduced of traditional/country food, while 3% discontinued consumption altogether (Dewailly *et al.*, 1994). The survey, however, did not assess the duration of these changes. Work done by O'Neil *et al.* (1997) and Poirier and Brooke (1997) in Nunavik communities further documented these positive perceptions of traditional/country foods. More recent work by Dewailly *et al.* (1999) in Salluit found that most individuals in this community (71%) believed traditional/country food to be "very good for their health", as was found by Furgal (1999) among most (91%) of the Labrador Inuit surveyed in the community of Nain, who reported their belief in the safety of traditional/country foods. As Nunavik residents state:

> "Country food is preventing you from diseases. Therefore it is a medicine. When you are sick and you are trying to gain back your strength, you eat country food, it's your medicine." (Quaqtaq resident; O'Neil *et al.*, 1997)

> "In the winter we feel that wild meat is better to keep warm and for the body to feel good. We even bring frozen meat with us to eat while we are out because it is better for maintaining warmth and vitality out on the land. It is different in this way from Qallunat food, like chicken and other fry-pan type foods, because when we eat this we get cold more easily and become hungry again rather quickly." (Inuit health official; Poirier and Brooke, 1997)

Despite the strong belief in the health and safety of traditional/country foods, concern is raised in some regions about the presence of and potential effects of contaminants on animal and human health, as well as the activities used to investigate these issues in wildlife (e.g., Furgal, 1999; O'Neil *et al.*, 1997). Commonly expressed concerns among northerners in relation to contaminants include those for the health of wildlife, safety of the consumption of traditional/country foods, human health, and the safety of other aspects of the environment (e.g., Usher *et al.*, 1995; O'Neil *et al.*, 1997; LIA, 1997; Poirier and Brooke, 1999; Furgal, 1999). As one Nunavimmiut hunter states:

"I even discarded a beluga, a fine healthy, young adult male at his best because I thought it had mercury in him. He had this noticeable but tiny hole in his skin. I'd heard somewhere that there were people who injected mercury into beluga and I was afraid that this one had been contaminated." (Nunavimmiut hunter; Poirier and Brooke, 1997)

In a review of 13 contaminant cases in Aboriginal communities from Alaska to Nunavik, Usher *et al.* (1995) found that a lack of attention and understanding of the perception of contaminants among Aboriginal peoples in communication efforts had significant impacts on the receptiveness and effect of messages that were delivered to address public concerns. In most cases communities were alerted to the possibility of food-chain contamination only from reports of laboratory results from animal tissues, which were sometimes obtained for purposes not even directly related to local food safety concerns. With the exception of cases where there were visible pollution events (e.g., Exxon Valdez oil spill in Alaska) it was only after the reports of the presence of the contaminant(s) and the possible toxic effects that residents started to suspect that previously unexplained events, particularly abnormalities in animals, fish, or humans, might be related to contaminants (CACAR, 1997).

Almost all cases reviewed gave rise to local uncertainty and anxiety, potentially related to the absence of clear and credible information on toxicity (especially in cases of chronic but low-level exposure) or "safe" levels. Such concepts, standards, safety factors, and chronic exposures are all aspects of risk messages that are difficult and confusing, yet critical to explain in risk communication exercises. In cases where there has been fairly strong evidence of low risk (e.g., cadmium in caribou liver and kidneys) or of benefits outweighing the risks (e.g., organochlorines in marine mammal fat), and this is clearly communicated, the problem of uncertainty and anxiety appears to have been minimized (Usher *et al.*, 1995).

The connection between anxiety about potential health effects from traditional/country food consumption and actual consumption behaviours is complex. Significant reductions in traditional/country food consumption can occur when people are informed of "invisible contaminants" in the local food supply. Yet, invisibility alone is not the problem as Aboriginal people have for years dealt with problems of trichinosis, botulism, and vitaminosis using their experience and traditional knowledge.

Northerners also regularly report knowing when an animal is unfit for consumption. These statements are often based on knowledge of visible abnormalities in wildlife such as parasitic or other infections. Confusion among these concepts has been reported by residents in some communities. Participants in a study conducted in Salluit, Nunavik stated a belief that mercury was caused by a bug, bacteria, germ or worm (Dewailly *et al.*, 1999). The association could be made here with a significant amount of work done in this and other Nunavik communities on trichinosis in walrus. The combination of factors on this issue means that community residents have only scientists to trust in confirming the presence of contaminants in traditional/country foods. There is often uncertainty as to how to respond to the hazard. They must rely on individuals using different modes of understanding, communication and inquiry, and there are often competing messages about the nature and extent of the risks by different experts (Elias and O'Neil, 1995). Work by Usher *et al.* (1995), O'Neil *et al.* (1997) and Poirier and Brooke (1999) shows the potential distrust resulting from this confusion and the effects this has on the reception of later explanations or clarifications of the situation.

5.4.5 Impacts of these perceptions

Regardless of the knowledge of pollution or contaminants, many northerners report that they would continue to eat traditional/country foods despite the advice given by health officials, because traditional/country foods are part of their culture, lifestyle and health (e.g., O'Neil *et al.*, 1997; Furgal *et al.*, 1999). Nunavik residents participating in recent work investigating the factors influencing individuals' intent to eat traditional/country foods (Furgal *et al.*, 2001) report various advantages to eating traditional/country foods, including: the health and nutritional benefits; the economic/cost advantages; as well as aspects of taste and freshness. These participants, and women in the western Canadian Arctic (Kuhnlein and Dickson, 2001), did not identify the concern of contaminants or food safety issues as a factor strongly influencing their choice of whether or not to eat traditional/country foods.

Further work on the potential effects of differing perceptions and on the public understanding of contaminants on individuals' behaviours conducted in one Baffin Island community (Clyde River), shows that some adjustment in hunting activities has occurred as a result of concern for contamination in the local area (Wenzel and Qillaq, 2000). Ongoing work in Nunavik will shed light on the social processes involved in risk perception and the effects of perception on individual health-related behaviours (Bruneau *et al.*, 2001).

- *The result of the sum of this work on risk perception in the North informs decision makers and risk communicators about the understandings and misunderstandings of the issues and the potential effects they have on individual behaviour and activities. Within the NCP, there has been increasing recognition for the need to document and understand public perceptions of contaminants and how issues are being addressed in the North, but much still remains to be done.*
- *Few projects have been conducted under the NCP to specifically investigate these topics. Various forms of informal assessments of perceptions are conducted within the program through the modes of interaction and communication that have been developed (e.g., Contaminant Tours, establishment of Regional Contaminant Coordinators, etc.). More empirical evidence is required, however, to support risk management decision making and communication activities so that initiatives are best suited to specific regional and local populations and sub-groups, and therefore more likely to succeed.*
- *In consideration of the wealth of information disseminated through the NCP and other sources on contaminants in the Arctic, there is an excellent opportunity for valuable social science research to add to the understanding of many aspects of the public perception of this issue. Recognizing the work that has been conducted to date, however, and how it informs the understanding of public perceptions in the North will likely lead to more effective risk management and communication efforts on this issue.*

5.5 Benefit and risk management framework for the Northern Contaminants Program

The contamination of wildlife in the Arctic ecosystem poses a complex problem for risk assessors and managers alike. Weighing the various benefits of traditional/country food use against contaminant risks is not easily done, and cuts across the disciplines of nutrition, toxicology, environmental policy, and public health practice; and each discipline has its unique perspective. A comprehensive risk assessment/management framework is needed to coordinate the various perspectives and to respond to the challenging task of weighing the risks and benefits of traditional/country food consumption in northern Canada.

The NCP has adopted such a framework for risk assessment/management, one which involves a cooperative, multi-agency approach, where the problem is considered in its ecological and public health context, and those who are affected by the risk management decisions are involved in the decision-making process. This collaborative approach is required under the NCP as the territories and provinces are responsible for delivering health advice to their residents but the broad range of issues requires input from all NCP partners (federal and territorial departments, Aboriginal groups, local communities and other interested parties). The need for a collaborative, multi-agency approach in risk assessment and management was identified in the late 1980s, and has now evolved into a broad comprehensive framework that is detailed in this section.

5.5.1 Risk management frameworks

The main objective of the NCP is: *to reduce and, whenever possible, eliminate contaminants in traditional/country foods while providing information that assists informed decision-making by individuals and communities in their food use* (CACAR, 1997). This could be considered the overriding risk management goal for all activities under the NCP.

The Presidential/Congressional Commission on Risk Assessment and Risk Management presented a very useful *Framework for Environmental Risk Management* (Figure 5.5.1) in its final report in 1997. In this report, principles for risk management decision making are outlined, and are consistent with those of the NCP. Among them are:

1. identifying and clearly characterizing the problem in its public health and ecological context;
2. establishing a process that elicits the views of those affected by the decision, so that different values and perceptions are considered;
3. careful analyzing the weight of scientific evidence concerning potential effects to human health and to the environment; and
4. considering a range of risk management options.

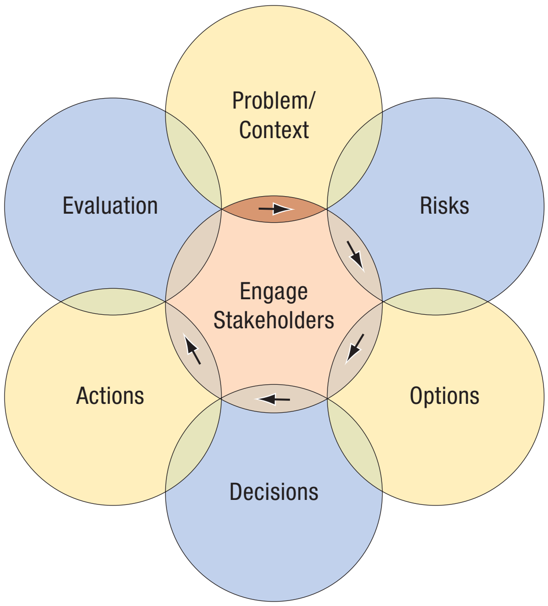

FIGURE 5.5.1

Framework for environmental health risk management.
Source: Presidential/Congressional Commission on Risk Assessment and Risk Management (1997)

Health Canada's updated (1997) risk management framework, described in the document *Health Canada Decision-making Framework for Identifying, Assessing, and Managing Health Risks* (Health Canada, 2000), is similar to the *Framework for Environmental Health Risk Management* developed by the Presidential/Congressional Commission on Risk Assessment and Risk Management. Guiding principles for risk management presented in Health Canada's framework include:

- maintaining and improving health as a primary objective
- involving interested and affected parties
- communicating in an effective way
- taking a broad perspective
- using a collaborative and integrated approach
- tailoring the process to the issue and its context
- using a precautionary approach
- clearly defining roles, responsibilities and accountabilities
- striving to make the process transparent.

Common to both risk management frameworks are the importance of engaging stakeholders and affected parties during each phase of the process; the importance of appropriate and timely risk communication; and ensuring that the health risks are considered within the appropriate ecological and public health context.

5.5.2 Problem identification and context

The problem identification and context stage of the environmental health risk management framework is extremely important in identifying, assessing and managing health risks. In this stage the problem is identified, put into its ecological and public health context, risk management goals are determined, and stakeholders are identified and engaged. The NCP is a research and evaluation program and as such involves stakeholders much earlier in the problem identification stage than many environmental monitoring programs.

The NCP has extensive processes in place to ensure that project proposals are reviewed by all stakeholders and that goals and objectives of projects are relevant for the NCP and follow principles set out by the NCP and its partners.

Project proposals are reviewed by Territorial Contaminant Committees (TCCs) in the Yukon, NWT, Nunavut and Nunavik/Labrador. These committees have representation from local, territorial and federal governments, community representatives and Aboriginal groups. Committee members rank the proposal in terms of relevance, communication and capacity building, among other criteria. Proposals then go to review committees for human health, social cultural relevance, education and communication, and biological monitoring, where more detailed technical reviews occur. The projects undergo a final review at the level of the NCP Management Committee. Stakeholders have the opportunity at several levels to be engaged in the problem/context stage of the NCP risk management framework.

A small funding envelope is also available for locally identified contaminant concerns, such as a potential contaminated site or wildlife species that may pose a risk to the health and well-being of local community members. This is one example under the NCP where those who are affected by the risk management decisions are directly involved in identifying and characterizing the problem, and in each subsequent step of the risk management process.

5.5.3 Benefit and risk assessment

Benefit and risk assessment provides the scientific foundation for risk management decision making. It involves the careful objective analysis of the weight of evidence and scientific information on risks and benefits, and thorough consideration of the qualitative values associated with risk perception, and social, cultural and spiritual identity.

Benefit and risk assessment includes the identification and development of options to manage the health risk. Under the NCP framework, the assessment of risks and benefits is undertaken in a multi-disciplinary fashion with participation from researchers, several levels of government, and community representatives. This process evolves as new scientific information on health outcomes, nutritional, social and cultural benefits, and risk perception becomes available. Much of this information comes from research funded by the NCP.

Under the NCP, benefit and risk assessment is undertaken on a case-by-case basis, and involves both scientific evidence and good judgement. Risks are assessed by Health Canada using the Department's risk assessment process (Health Canada 1993; 1994; 2000), and in recent years also by the Centre for Indigenous Peoples' Nutrition and Environment (CINE). The risk assessment process used for assessing the human health implications of traditional/country food consumption in Arctic communities was described in detail in the CACAR-I (CACAR, 1997), and is summarized in the following text.

Risk assessment

There is no universal definition of health risk. It has been defined as: the probability that a substance or event will produce harm under specified conditions (US EPA, 1997). Risk arises from exposure to a harmful substance or event and depends on whether that substance or situation can cause harm. Risk is determined by the careful consideration of the nature, likelihood, and severity of adverse effects on human health and the environment. What must be understood is that risk is complex and multifaceted. It does not mean the same thing to all people, and the consideration of individual concepts, perspectives, and perceptions of risk are important in both risk assessment and management, and in related decision making.

Risk assessment is the process wherein information is gathered and analyzed to determine the likelihood that a specific adverse health effect will occur in an individual or population following exposure to a hazardous agent. This process often establishes a best estimate of the risk, as there are often gaps in information.

The Health Canada risk assessment process consists of four steps: 1) hazard identification; 2) hazard characterization; 3) exposure assessment; and 4) risk characterization.

Hazard identification and characterization are based on toxicological studies conducted in laboratories and/or epidemiological studies to establish dose-response relationships for contaminants. This involves gathering information on what type of adverse health effects might be expected as a result of exposure to the agent, and how quickly these effects might be experienced. The no-observed-adverse-effect-level, or NOAEL, is the dose at which no biologically adverse effects are observed in the study population compared to the control population.

After the identification of the appropriate NOAELs and uncertainty factors, exposure guidelines (acceptable or tolerable daily intakes, provisional tolerable daily or weekly intakes: ADI/TDI/pTDI/pTWI) can be calculated by dividing the NOAEL by the uncertainty factor. The uncertainty factor adjusts for the inter- and intra-species variation between and within animal and human populations. These intakes when averaged over the course of the entire human lifespan are thought to represent the exposure for humans that is without appreciable risk of adverse effects, based on the best available information (Van Oostdam *et al.*, 1999). These guidelines are reviewed when new toxicological and epidemiological information becomes available, as was the case for the mercury and for the pTDI for women of child-bearing age and for children established in 1998 (Health Canada, 1998).

To estimate risk, contaminant levels in traditional/country foods are used to estimate the probable daily intake (PDI). The PDI is calculated by multiplying the average contaminant concentration in a food by the estimated daily intake of the food and this number is then divided by the average body weight of the consumer. The PDI is then compared to the exposure guideline value for the particular contaminant in question to estimate risk. If the PDI exceeds the TDI, then advice to limit consumption may be issued, and risk management decisions need to be considered. Health Canada does not complete a benefit assessment of traditional/country foods, and does not use dietary information specific to the North to complement their assessments of the risks associated with traditional/country food consumption. Risk characterization, benefit assessment, and the identification and evaluation of risk management options are completed by the Territorial Health agencies and their partners.

Different risk assessment procedures are used for substances determined to be genotoxic carcinogens. A more conservative approach is taken where no exposure level is considered to be free of risk. Animal and/or human study data are used to mathematically predict the exposure doses for various cancer risks, with risks usually assessed as one additional cancer per 100,000 population (10^{-5} risk) or one additional cancer per million (10^{-6} risk) (Van Oostdam *et al.*, 1999).

In recent years the Centre for Indigenous Peoples' Nutrition and Environment (CINE) at McGill University has been active in assessing risks and benefits associated with traditional/country food consumption. For example, a risk characterization of arsenic in berries in the Akaitcho Territory was completed, and toxaphene in fish from Fort McPherson, NWT (Stephens and Chan, 2001). CINE assesses risks using a process similar to that previously described, but with a significant difference, in that they use information from dietary studies they have conducted under the NCP across northern Canada. These dietary studies provide consumption information by community, by sex and age group, and by season. The three reports published by CINE [*Assessment of Dietary Benefit/Risk In Inuit Communities* (Kuhnlein *et al.*, 2000), *Variance in Food Use in Dene and Métis Communities* (Receveur *et al.*, 1996), and *Yukon First Nations Assessment of Dietary Benefit/Risk* (Receveur *et al.*, 1998)], also present information on the nutritional benefits of traditional/country foods being consumed, on the cultural and social significance of traditional/country foods, and on risk perceptions.

Benefit assessment

Sections 5.2 and 5.3 provide detailed descriptions of the nutritional, social, cultural, spiritual and economic benefits associated with traditional/country food consumption. The challenge is the comparison of quantitative risks with primarily qualitative benefits associated with traditional/country food consumption. Although attempts have been made to assess the nutritional benefits of traditional/country food consumption, and to qualify the social/cultural benefits, no formal quantitative method has been established to compare and weigh these elements against the health risks of traditional/country food consumption. It has been well demonstrated in Section 5.2 that fish consumption has significant health benefits in reducing cardiovascular disease among northern populations. Benefits (known and potential) are assessed and relative risks related to the benefits are considered, as are perceptions of risk.

Benefits are often assessed at the territorial or local level; Territorial Health Departments and TCCs (or sub-committees of these groups) come together to discuss benefits, and the other determinants involved in the risk characterization. Information on the benefits of traditional/country food consumption gained from research activities is considered, and local Aboriginal representatives are included in the meeting to ensure their knowledge and perspectives are included in the consideration of benefits. Local representatives are best positioned to consider the social, cultural and economic importance of traditional/country foods.

5.5.4 Risk characterization

Risk characterization provides a key source of information for risk management decision making. It is a process where the uncertainty and assumptions that were used in the risk analysis are evaluated and the strength of scientific evidence for health effects associated with the contaminant is considered. "To be truly useful risk characterization must be accurate, balanced and informative" (Health Canada, 2000). Risk characterization involves the use of reliable scientific information from a range of disciplines (biology, physiology, economics, social sciences) and should provide opportunities for discussion and deliberation. Scientific uncertainties, related assumptions, potential impacts on decision making, and health-related needs of interested and affected parties are carefully considered. The success of the risk characterization process depends on the participation of interested and affected parties in discussions, so that they may understand and participate effectively in the risk management process.

Within the NCP risk management framework, risk characterization is discussed by risk assessors, risk managers, health authorities, Aboriginal groups, community or regional representatives, territorial and federal governments, and researchers. Risks are characterized and discussed within the same forum in which health benefits and risk management options are discussed. Risk assessors and scientists would provide information on the uncertainties and assumptions that are associated with the TDIs and ADIs for various contaminants and on the strength of evidence for health effects associated with a particular contaminant. Researchers provide information on co-variables for studies to assess all factors that may have had an influence on outcomes of a study. Territorial government and community representatives, local health authorities, Aboriginal groups and other interested parties help to ensure that all health-related questions of concern are answered and that the risk characterization has put the risk in the proper perspective.

Assumptions/uncertainties of concern

The effects of chronic low-dose exposure in human populations remain controversial because of the inconsistency of findings among different studies and populations. Moreover, multiple factors such as smoking, substance abuse, nutrition and pre-existing health status can potentially affect the development of health effects associated with a particular contaminant. Additional considerations must include the fact that most traditional/country foods contain many toxic metal or organochlorine contaminants (Chan *et al.*, 1995; 1997; Kuhnlein *et al.*, 1995c; Berti *et al.*, 1998a). Risk characterization of multiple chemical exposure poses a major challenge for risk managers, as most risk assessments address only single chemicals. Information on toxicologic interactions of environmental contaminants is limited. However, there is ample evidence suggestive of supra-additive and infra-additive interactions among environmental contaminants (Krishnan and Brodeur, 1994). Although research is being conducted under the NCP to gain a better understanding of toxicologic interactions between contaminants and between nutrients and contaminants, science has not progressed far enough to allow this to be included in the present risk characterizations (see Section 5.6).

5.5.5 Weighing benefits and risks — challenges in practice

After risks have been characterized, and the nature and extent of uncertainty and assumptions are understood, the characterized risk must be weighed and compared with the known and potential benefits. Risks and benefits are discussed and weighed in a multi-agency forum, with participation from risk assessors, risk managers, health authorities, Aboriginal governments, and community or regional representatives, territorial and federal governments and researchers. It is important to have as much technical and non-technical information as possible on which to base the comparison of risks and benefits, and to consider the perspectives of all interested and affected parties. These working groups or committees must take on the challenging task of considering the uncertainty associated with the health risks, the difficulty in comparing quantitative risks with qualitative benefits, and the consideration of other associated health risks and issues in the region.

Health risks associated with some contaminants in traditional/country foods are mostly qualitative in nature, and are difficult to quantify precisely because of a lack of scientific evidence for health outcomes at specific levels of exposures and because the effects of co-determinants such as nutrition and co-contaminants are not known. The harvesting, sharing and consumption of traditional/country foods are an integral component to good health among Aboriginal peoples, influencing personal health and social, cultural and personal well-being as outlined in Sections 5.2 and 5.3. Measuring the cultural and social benefits and giving them a value that is comparable to the more quantitative risks is a challenging task.

There are also the risks associated with dietary changes which may lead to a reduced consumption of traditional/country foods. In addition to social, cultural, nutrition and economic factors previously discussed in Section 5.3, the shift away from traditional/country foods may result in a rise in obesity, diabetes, and cardiovascular disease.

All of these factors contribute to the challenge of weighing the benefits and risks, and making risk management decisions that will minimize health risks for northerners while providing them with the necessary information to make informed decisions. These factors all support the need for a comprehensive framework for benefit and risk assessment and management.

5.5.6 Option analysis/evaluation

Once risks have been characterized, risk management options can then be identified, and evaluated. At this stage, the specific nature of regional issues must be considered, and public perceptions, uncertainties, and the social, economic and cultural consequences of the options are to be taken into careful consideration. Under the NCP, the identification and evaluation of risk management options occurs at the level of the Territorial Contaminants Committees, or a sub-set of these in the form of a Health Advisory Working Group. Those involved in identifying and analyzing risk management options include: territorial or provincial health authorities, Aboriginal groups, scientists, risk assessors (Health Canada or CINE) community or regional representatives, environmental health officers, nutritionists, and local and/or federal government representatives. It is within these groups that benefits are identified, assessed and compared to risks; assumptions and uncertainties associated with the risks are discussed; and local perceptions of risks are considered.

It is important that options are identified with the wide range of interested and affected parties, because the responsibility for managing the risk is often shared, and various organizations may be involved in implementing the selected strategy. Interested and affected parties can help to identify criteria for analyzing options by providing required information, participating in the analyses, and providing advice as to whether the results of the analysis are acceptable and help to redefine risk management goals as required.

When analyzing potential risk management strategies the following are considered: risks versus benefits; expected costs of implementing the plan; available resources; unintended consequences (creation of new risk, or unwanted social, cultural, ethical, environmental and other indirect health impacts); and the perceptions, concerns and values of interested and affected parties. Risk management options relevant to the issue of contaminants in traditional/country food can include: regulatory measures (at the local or international level); the release of consumption advice or identification of alternative food sources; education and communication strategies to help people make informed decisions; or not taking action when action is not required.

5.5.7 Selecting a risk management option

The results of the option analysis are used to select the most appropriate risk management option or options. Selecting an appropriate risk management strategy is always a challenge because complete information is often not available. Uncertainty factors relating to the intake values (TDI/ADI) may be large making it difficult to accurately characterize the risk for particular contaminants. Data on dietary exposures may be limited and actual exposures may be lower than estimated. Good information on risk perceptions may also not be available.

There have been several cases for the Canadian Arctic where recommendations to continue consuming traditional/country foods have been made despite the potential risk of adverse effects from exposure to contaminants. The benefits of continued consumption are great (nutritional, social, cultural and economic), and there is uncertainty associated with the assessment of risk. All individuals are exposed to mixtures of contaminants, not sole contaminants as health risk assessments assume; there is evidence of interaction between nutrients and contaminants that may reduce the potential harm posed by the contaminants. The assessments, in adition, are based on daily consumption levels over a lifetime that are not consistent with the largely seasonal diet of northern Aboriginal peoples.

Managing the risk associated with contaminants in traditional/country food in Arctic Canada continues to be a confusing public, moral and political dilemma. Risk management decisions or strategies can do more harm than good, as they may raise fear and result in unintentional actions leading to other associated health risks. Risks associated with contaminants, however, can be real and cannot be ignored. Most risk management decisions under the NCP are taken using the broad approach described in this chapter.

5.5.8 Implementation

Once the preferred risk management option is selected, a strategy for its implementation is developed. All affected parties need to participate in developing the management strategy. A protocol is established for the release of information related to contaminants in a prompt and understandable way. The communication of information must take into consideration cultural differences, language differences, and other potential barriers to comprehension, such as individual perception of risk. Personal perception of risk can have a significant impact on personal and community reaction to the information presented (CACAR, 1997).

5.5.9 Monitoring and evaluating the decision

Once a risk management decision has been made, its implementation is carefully monitored and evaluated to see if it is appropriate and effective. If implementation problems occur, or if knowledge of the hazard or the risks changes, the decision should be reviewed. This step is extremely important and illustrates how the process of risk management is an evolving process and is subject to change as new information about the situation is learned and assessed. The approach must be continually modified to suit each situation and each community (CACAR, 1997).

- *Benefit and risk assessment and management relating to contaminants in traditional/country food involves a consideration of the type and amount of food consumed and the sociocultural, nutritional, economic, and spiritual benefits associated with traditional/country foods. Benefit and risk management decisions must involve the community and must take all aspects into account to arrive at a decision that will be the most protective and least detrimental to the communities. Regardless of the decision taken, some health risks associated with exposure to contaminants may remain. In the Arctic, these risks are outweighed by the benefits of continued consumption of traditional/country foods. The uncertainty over risks and benefits will continue to pose a large and complex public, moral and political dilemma.*
- *Benefit and risk management is an evolving process subject to change as new information about the situation is learned and assessed. The approach must be continually modified to suit each situation and each community and the advice monitored to ensure it is providing the best possible health outcome.*

5.6 Benefit and risk communication

Effective communication is fundamental to the aims of the NCP. Northerners must have appropriate information on the contaminant risks, nutritional benefits, and importance of a traditional lifestyle to overall health and well-being to make informed decisions about the harvesting and consumption of traditional/country foods. A substantial amount of information is now available on the various benefits associated with consuming traditional/country foods (Sections 5.2 and 5.3); information is also available on the health risks associated with levels of contaminants found in many of these foods (Chapters 3 and 5); and general protocols for weighing the associated benefits and risks are in place and implemented by the responsible health authorities such as the territorial/regional health departments. Communicating this information in a balanced, clear, accessible and meaningful way to northern communities requires sound and accurate technical information as well as a respect for and understanding of the knowledge, perceptions, concerns and priorities of northerners. Thus, benefit and risk communication of the potentially sensitive environmental health information generated under the NCP presents its own unique set of considerations and challenges, and has been a focus of resources, efforts and research during NCP-II.

Communicating about contaminants in general is a challenging process in the North, due in part to the complex nature of the subject matter. Stiles and Usher (1998) acknowledge that messages describing risk are the most difficult ones to generate. There is a fundamental difference between the *quantitative* way in which risk assessment results are characterized and the *qualitative* terms with which the general public thinks about risk. While health professionals are accustomed to risk calculations given as probabilities with built-in uncertainty factors, people receiving the message generally want definitive, clear-cut answers to the question of "What does it mean to me?" or "Is my food safe to eat?". This requires that technical terminology be put into plain language, whether it be English, French, or the Aboriginal language understood by the audience; that visual representations of risk avoid the use of complex data graphs and figures; and that the messages be developed and delivered with consideration for the cultures and knowledge systems of Aboriginal peoples, which differ from those of southern audiences and vary across the regions of the North.

The contextual, technical, social and procedural challenges for communicators associated with these differences were reported in detail in CACAR-I (Gilman *et al.*, 1997) and by Usher *et al.* (1995), and reiterated in more recent work by Lampe *et al.* (2000) and Furgal *et al.* (2002; in preparation). These reports emphasize the fact that within the cultures of northern Aboriginal peoples, the environment, including the foods that it offers, is a defining element of identity and overall well-being. Traditional/country food is much more than a source of nutrition; as discussed in Section 5.3, its importance is also economic, cultural, social and spiritual. Practical alternatives to traditional/country food are also not readily accessible to many northerners due to the associated costs and availability. Communicators must thus be sensitive and aware that any information that leads to a disruption of the traditional/country food production, sharing and consumption patterns of northern communities has the potential to affect the northern way of life and the social fabric that keeps communities healthy, active and sustainable.

Effective benefit and risk communication is a process, not simply a product (Usher *et al.*, 1995). Ideally, it is a dialogue: an ongoing two-way or multi-directional exchange of information, perspectives, ideas and feelings among individuals that creates and fosters opportunities for feedback and mutual learning. Effective benefit and risk communication makes use of various media (e.g., reports, pamphlets, posters and audio-video materials), not as substitutes for face-to-face discussion, but to complement, enhance and facilitate dialogue and exchange. Ideally, too, it will portray a situation accurately such that recipients of the information will have a sound and shared appreciation of the issue at hand and its solutions, and will feel empowered to take action or make informed choices (Gilman *et al.*, 1997). Practical guidelines for developing communications materials specific to various media and delivering presentations to northern audiences have been developed by Stiles and Usher (1998) and Lampe *et al.* (2000), and an in-depth assessment of NCP communications materials and methods can be found in the *Knowledge in Action* companion report of CACAR-II.

An appreciation of the profound importance of effective communication was gained through the experiences of early communications efforts that fell short of the ideal. These instances made it evident that misguided communication efforts, however well-intended, can and have led to significant impacts, both direct and indirect, intentional and unintentional, among the affected populations. The implications of poor risk communication of contaminants in traditional/country foods — and recommendations for improving communication efforts — are becoming well-documented (Wheatley and Wheatley, 1981; Usher *et al.*, 1995; CACAR, 1997; Powell and Leiss, 1997; Furgal *et al.*, 2002; Lampe *et al.*, 2000). In their review of 13 instances since the 1970s of dealing with contaminant issues in Aboriginal communities, Usher *et al.* (1995) reported that deficient communications efforts on environmental contamination had left communities feeling anxious, angry and confused, and disrupted social and cultural aspects of life related to harvesting and consumption of traditional/country food.

In Broughton Island, for example, studies during the mid-1980s showed high intakes of PCBs through a diet rich in marine mammals, and elevated concentrations in Inuit residents' blood and breast milk (Usher *et al.*, 1995). The communication of risk assessment information by the researchers was sensationalized by the media, and the perceived secrecy on the part of the federal government led to anxiety and confusion. The exclusion of Aboriginal leaders from a key meeting also caused considerable controversy and provoked further anxiety among community members (Furgal *et al.*, 2002). By the time the researchers presented their principal message that the nutritional benefits of traditional/country food outweighed the health risks associated with its consumption, and recommended that the Inuit of Broughton Island should continue to consume traditional/country food and breastfeed their babies, the message was met with scepticism and confusion by distressed local residents who were receiving mixed messages.

Usher *et al.* (1995) reported that three years following the completion of follow-up studies, residents were still anxious about the health risk posed by PCBs, and attributed many of their health problems, including cancer, suicides and premature births, to these contaminants. Hunters also shifted their seal hunting to areas more distant from the perceived area of contamination (Wenzel and Qillaq, 2000). In this case, the communication process had begun in earnest by the researchers, through seeking appropriate permission to conduct the study and informing residents by community radio. Several factors, however, compounded to create the communication crisis. This may have been averted through a more careful consideration of the particular benefit and risk trade-offs of traditional/country food consumption, and by a thorough communication plan developed in cooperation with the community using funds allocated for communication activities (Usher, 1995; Powell and Leiss, 1997).

The practice of risk communication related to contaminants in northern traditional/country foods has changed over the past two decades, building upon lessons learned along the way. This parallels loosely what Powell and Leiss (1997) describe as three distinct stages in the evolution of risk communication:

1. the early days focussed on the quantitative and comparative expressions of risk estimates;
2. the next phase adopted additional aspects of enhancing the credibility of the source and message by building trust through public discussion and developing messages based on understanding the information needs, perceptions and concerns of the audience; and
3. the current efforts further emphasize the social context of risk management by building effective stakeholder relationships through long-term organizational commitments to practising responsible risk communication.

In terms of the NCP, this has meant a transition from risk communication to benefit/risk communication; that is, from delivery of risk assessment results to ongoing two-way dialogue on the benefits and risks associated with the issue. As indicated in Section 5.5, risks are placed within the context of the nutritional, social, cultural, economic and spiritual benefits of consuming traditional/country foods, and within a greater public health context relating to general health and well-being. In place of one-way models of message dissemination, NCP-II strove toward shared decision-making through partnerships involving territorial and regional contaminants/health committees and representatives of Aboriginal organizations at all stages of the risk management and risk communication process. As a result of these changes, there has also been a shift away from health authorities issuing advisories to providing general advice which is discussed and delivered by individuals who are trusted in the community, using various formats and materials.

To support the shared decision-making process for benefit and risk communication, the NCP established various protocols and support networks in all northern regions. In the Yukon, NWT and Nunavut, the Territorial Contaminants Committees, whose members include representatives of Aboriginal organizations and territorial health departments, determine the applicability of Health Canada recommendations to northerners and devise an appropriate communication plan for the release of the information. Depending on the significance of the risk assessment results, the information may be released through a number of methods, including a press release, radio phone-in shows, community meetings, individual face-to-face meetings, and various forms of print media. The territorial Health Departments, in association with the regional Aboriginal organizations, take the lead in ensuring that people receive the appropriate information. Similar processes are in place in Nunavik and Labrador, involving, respectively, the Nunavik Regional Board of Health and Social Services in consultation with the Nunavik Nutrition and Health Committee, and the Labrador Inuit Association in consultation with the relevant health authority.

Five case studies of risk determination/communication during NCP-I were detailed in CACAR-I (Gilman *et al.*, 1997). These case studies characterize the evolution of benefit and risk communication processes pertaining to contaminants in traditional/country foods under NCP and underscore the complexity involved. These case studies can be consulted if the reader wants to see how this communication process has changed.

The NCP recognizes the importance of communication and as research results become available, a significant proportion of program resources are committed to the mutual exchange of information and ideas between program participants. In addition, these results demonstrate the value placed on a high quality database, cooperative strategies to understand the risks, and communication/consultation initiatives to ensure there is a clear understanding of risk reduction and health promotion.

One case study, described in the following text, demonstrates the direction taken during NCP-II with respect to benefit and risk communication.

Communication of the dietary benefit and risk study in five Inuit regions

In this extensive study led by the Centre for Indigenous Peoples' Nutrition and Environment (CINE) in cooperation with the Inuit Tapirisat of Canada (ITC), communication was an integral aspect of the project throughout its duration. The research, to derive quantitative estimates of traditional/country food and imported food intake among Inuit in order to characterize exposure to contaminants and the multiple benefits of traditional/country food use, was conducted in five Inuit regions [Qikiqtaaluk (Baffin), Labrador, Kivalliq, Kitikmeot and Inuvialuit] from 1997 to 2000. The 18 communities were selected through regional workshops, attended by community leaders of 39 communities and health professionals, in which representatives participated in developing methodology, identifying the extent of traditional/country food used seasonally by all communities, and determining the types of interviews to be used and the food samples to be collected for contaminant and nutrient analysis. Research agreements were negotiated with all participating communities. The results of this study make it very clear that the traditional/country food of the Inuit provides a rich nutritional and cultural resource with multiple social and economic benefits, and that losing these benefits as a result of decreasing the use of these foods would have negative effects on physiological and mental health. Most traditional/country food items identified as being frequently consumed and containing contaminants are also good or excellent sources of essential nutrients. Unless nutrient supplements are routinely used, a decrease in the use of marine mammal foods would place some individuals at a health risk from nutrient deficiency (Kuhnlein *et al.*, 2000).

What has been unique about this study is that prior to the delivery of study results and benefit and risk messages, a process of community dialogue was established to evaluate and interpret the study data from an Inuit perspective. Once the field work and analyses were completed, Inuit leaders had an opportunity to evaluate a draft report and develop a plan for the future communication of results to communities. They shaped the messages by helping to assess the significance of the study's findings on: Inuit subsistence practices and diet; imported food consumption; the risks and benefits to health; the potential impacts of lifestyle decisions on culture, economy and community; the use of this research; and approaches to communicating with and educating communities about contaminants issues. A final report will not be completed until all regions have had an opportunity to discuss the draft information and express their perspectives, concerns and recommendations.

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ITC assumed responsibility for the communication of the study results, with continued support from the NCP and the involvement of CINE. The ongoing communication strategy, *Avatiptinnit Niqittiavait — Good Food in the Environment*, places particular emphasis on the benefits side of the benefit and risk study. It makes use of a number of communication methods that were defined through direct discussions and recommendations from past meetings and workshops with Inuit from these regions, and from the experience gained by ITC through its work over several years. At the Eastern Arctic Workshop in December 1998, Inuit Elders called for a balanced approach to communications that would weigh the potential health risks against the known benefits of subsistence harvesting and diet, and still maintain the cultural identity and total health and well-being of Inuit. They indicated that a potential fear about contaminants may outweigh the knowledge about actual risks posed by contaminants, thereby causing greater harm. Communication efforts for this study, therefore, incorporate Inuit knowledge on the dietary benefits and risks associated with contaminant levels found in traditional/country food, and the benefits and risks associated with the consumption of imported food. Because direct, face-to-face discussion and interaction is key, a major focus of the communications strategy is a workshop in each of the five participating Inuit regions. ITC, however, understood that it was essential for the communication of results to continue to reach Inuit via many different media and to include many different audiences, such as Elders, youth, health care workers and wildlife experts. The workshops, therefore, are further supported and followed up with newsletters, radio shows, posters, a web site and an informational CD-ROM.

It is anticipated that these communication efforts will ensure that Inuit have the appropriate information on the risks, benefits and importance of a traditional lifestyle in order to make informed decisions about harvesting and the consumption of traditional/country and imported foods, and also to avoid some of the mistakes of earlier communication efforts related to environmental contaminants. To assess whether or not these communication efforts have in fact resulted in comprehension and synthesis of the information, and have led to informed decision making, would require conducting formal reviews and evaluations. This is beyond the scope of the communication plan; however, informal evaluations at workshops in the Labrador and Inuvialuit regions indicate that participants learned a lot and were happy with the way that the information was presented and how they promoted interaction (Loring *et al.*, 2001).

In summary, despite all the efforts made by NCP researchers, organizations and agencies to develop and deliver accurate and easily understandable benefit and risk information, more work must be done to evaluate the effectiveness of these strategies. Little empirical evidence exists to date on the effectiveness of various aspects of risk communications, or their impacts.

Recently, Lampe *et al.* (2000) conducted focus groups of Labrador Inuit to review environmental health communication materials for the level of attractiveness of the materials, their ease of comprehension, and general suggestions for their adaptation and improvement. They also conducted a telephone survey to evaluate a communication strategy carried out in three Labrador communities in terms of the message reception, comprehension, perception of the issue, and ways to improve the communication of information to Labrador communities.

The findings of Lampe *et al.* (2000) support the knowledge gained to date and the existing guidelines for benefit and risk communication. However, Lampe *et al.* (2000) also found that the general level of condensing information for communicating these issues in the North was still not enough to clarify messages for the Labrador Inuit. Different community-of-origin dialects of Inuktitut can significantly affect the reading comprehension of printed material, and some of the methods thought to be effective in conveying environmental health information (e.g., pie charts and bar graphs for illustrative ways; and community meetings as a means for information dissemination) were not effective (Lampe *et al.*, 2000).

This recent research points to a further need for evaluation, and indicates that there is a level of assumption that awareness equals understanding. Two "proxy measures" studies of communications reception and impacts have been carried out by Wenzel and Qillaq (2000) and Bruneau *et al.* (2001). These measured individuals' reactions to years of communication on the issues rather than their reaction to just one communication event. Similar innovative methods of communicating risk and assessing the reception and impacts of communications should help to ensure a better understanding of the benefits and risks of traditional/country food use.

- *Effective communication is fundamental to the aims of the NCP. Communication efforts incorporate Aboriginal knowledge on the nutritional benefits and risks associated with the consumption of traditional/country foods and of imported foods, and on the importance of a traditional lifestyle to overall health and well-being. These efforts provide northerners with the appropriate information to make more informed decisions about harvesting and consumption of both traditional/country and imported foods, and also to avoid some of the mistakes of earlier communication efforts related to environmental contaminants.*
- *Through the evolution of the NCP and its activities and experiences with communication, the NCP and communicators in the North have learned that effective benefit and risk communication is not just about messages and their delivery, but about connecting with northerners and their perceptions, priorities and ways of understanding and trusting information.*
- *The practice of risk communication related to contaminants in northern traditional/country foods has changed over the past two decades, building upon lessons learned along the way. In place of one-way models of message dissemination, NCP-II strove toward shared decision making through partnerships involving territorial and Health Departments, regional contaminants/health committees and representatives of Aboriginal organizations at all stages of the risk management and risk communication process.*
- *No one method of communication is best, but what is needed is a variety of methods and materials appropriate to communities in different regions and specific to groups within each community, all aimed at providing opportunities for two-way exchanges of information and allowing an understanding of the issue to develop. This builds a collective comprehension of the benefits and risks, as well as the limitations of the scientific assessment.*
- *Informal risk communication plays a role, as well. The NCP has therefore dedicated a large amount of resources and effort to ensure this type of communication has continuity within the program, and to secure opportunities and support for the continuing evolution of effective communication to continue to evolve.*
- *As there is little empirical evidence available to date on the effectiveness of various aspects of risk communications, or their impacts, continued efforts are needed to evaluate the effectiveness and impact of strategies to develop and communicate accurate and easily understandable benefit and risk information relating to traditional/country food use.*

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Quality Assurance and Quality Control Aspects of NCP Human Health Studies

6.1 Introduction

Like all research and monitoring programs, the NCP requires an ongoing quality assurance (QA) program that provides assurance to its managers of the quality, reliability and comparability of measured results being generated within its research projects. During Phase I of the NCP, considerable attention was devoted to identifying contaminants and their sources, and monitoring the pathways, trends and fate of substances of concern in the Arctic environment. Phase II, however, has had more focus on immediate human health and safety issues associated with these contaminants in traditionally harvested foods for northern people. Two surveys were conducted during 1998 to assess and establish priorities for the changing QA needs of the NCP. By evaluating the analytical programs and capabilities of the laboratories and organizations that were contributing measurement data to the NCP, the first survey identified what measurements were being made, which laboratories were conducting these measurements, and what quality control procedures were already in place (Stokker *et al.*, 1999a). The second survey reviewed the suitability of a number of external interlaboratory programs that would be pertinent to the QA needs of the NCP. In this report, several interlaboratory programs were identified as being suitable replacements for NCP-run intercomparison studies on human tissue samples, and recommendations were made for the continued participation by the health laboratories in these QA programs (Stokker *et al.*, 1999b).

Table 6.1.1 provides a listing of the Canadian laboratories that have contributed data to human health studies of the NCP over the past several years. At the onset of Phase II of the NCP, a review of the QA/QC procedures being conducted in the NCP health laboratories indicated that the data quality of NCP measurements was being adequately addressed by in-house quality control procedures, by comparison of standards and methodologies between collaborative partners, and by participation in several intercomparison programs that addressed the measurement of contaminants in human tissue samples such as blood and urine. The internal and external quality control procedures being implemented in these facilities are described in the following text, as well as brief descriptions of the three Canadian intercomparison programs that support the facilities' human health measurements. Lastly, the quality of data for the quantification of contaminant and nutrient intake by northerners is described.

TABLE 6.1.1 Laboratories that have contributed measurement data to NCP human health studies

Laboratory	Measurement data contributed
AXYS Analytical Services Ltd. Sidney, British Columbia	Organic contaminants in biological fluids and human tissues
Centre de Toxicologie du Québec (CTQ) CHUQ/CHUL Ste-Foy, Québec	Metals and organics in biological fluids and human tissues; toxicological and epidemiological measurements
Centre for Indigenous Peoples Nutrition and Environment (CINE) McGill University Campus Ste-Anne-de-Bellevue, Québec	Nutrients, metals and organic contaminants in traditional foods (occasionally blood and human tissues); toxicological and epidemiological measurements
First Nations and Inuit Health Branch (FNIHB) Health Canada, Ottawa, Ontario	Metals, PCBs, OCs in blood, serum, urine and hair
Envirotest Laboratories Edmonton, Alberta	Metals and organics in biological fluids and tissues
Bureau of Chemical Safety Health Protection Branch Health Canada, Ottawa, Ontario	Risk assessment studies
Food Research Division Residue Laboratory Health Canada, Ottawa, Ontario	Organic contaminants in blood and adipose tissue
Toxicology Research Division Health Protection Branch Health Canada, Ottawa, Ontario	Toxicological studies of contaminants and their metabolites
National Wildlife Research Centre (NWRC) Canadian Wildlife Service Environment Canada, Ottawa, Ontario	Metals and organics in biotic fluids and tissues
Saskatchewan Research Council Saskatoon, Saskatchewan	Radionuclide measurements (radiochemical and radioactivity measurements)

Source: Stokker (2002)

6.2 Internal quality control activities

Human health studies supported by the NCP that incorporate an analytical measurement component have included analyses ranging from contaminant measurements in biological fluids (blood, urine, milk) to the measurement of dietary nutrients, hormones and biomarkers in human, primate and other tissues. Because the NCP QA Program does not conduct intercomparisons on human tissue samples, it is imperative that good QA/QC programs be implemented in each facility conducting biological monitoring or health risk-related studies. A review of the quality management systems in the key health laboratories of the NCP shows that the organizational structure, responsibilities, procedures, processes and resources used are well-documented and suited to the analytical programs conducted at each facility. Internal quality control procedures employed include the use of control standards to monitor calibration accuracy and stability, appropriate certified reference materials (CRMs) and reference materials (RMs) to monitor method accuracy, duplicates to monitor method precision, analyte or surrogate spikes to monitor method recovery, and solvent and method blanks to assess for contamination. In addition, participation in the NCP intercomparisons on standards and biotic tissues,

TABLE 6.2.1 Interlaboratory programs for human health issues in which NCP laboratories participate

Program	Matrices	Analytes
Organic and inorganic contaminants		
BLLRS	blood	lead
CDCP	blood	lead
CFIA	fish tissue	mercury
CTQ: AMAP Ring Text	blood plasma	congener PCBs and OC pesticides
CTQ Interlab Comparison Program	blood, serum, urine	Al, As, Cd, Cr, Cu, F, Hg, Pb, Se, Zn
CTQ Interlab Comparison Program for ICP-MS	blood, urine, serum, hair	Al, Be, Bi, Cd, Co, Cu, Cr, Hg, Mn, Mo, Ni, Pb, Sb, Se, Sn, Sr, Te, Ti, Tl, V, W, Zn
FNIHB: Interlab Mercury QA Program	hair	mercury
GLRP	blood serum	mercury, pesticides, and PCB congeners
GSOEM	Blood plasma	congener PCBs, OC pesticides
GSOEM	urine, blood	arsenic, manganese, mercury, creatinine
NCP	tissues	toxaphene, OCPs and PCBs, heavy metals, methylmercury
QUASIMEME	tissues	PCBs and organochlorines
State of New York Dept. of Health	blood, ZPP	lead
World Health Organization	breast milk	contaminants
Wisconsin State Laboratory of Hygiene		lead
WIAQC	water, serum	aluminum
Clinical and bio-monitoring		
AAB: TDM		valproic acid, carbamazepine, diphenylhydantoin, ethosuximide, phenobarbital, primidone
CAP: Serum alcohol	blood serum	acetone, ethanol, isopropanol, methanol
CAP: Toxicology	serum, urine	general toxicology
CAP: Forensic urine drug testing	urine	amphetamines, cannabinoids, cocaine, phencycladine, opiates
FIOH: Organic solvent metabolites	urine	muconic acid, phenol, trichloroacetic acid, 2,5-hexanedione
GSOEM	urine	cotinine
GSOEM	urine	hippuric acid, mandelic acid, methylhippuric acid, phenylglyoxylic acid, trichloroacetic acid, phenol, petachlorophenol, 2.5-hexanedione, hydroxypyrene
SQBC		acetaminophen, diphenylhydantoin, phenobarbital

Source: Stokker (2002)

Acronyms:
AAB – American Association of Bioanalysts (USA); AMAP – Arctic Monitoring and Assessment Programme; BLLRS – Blood Lead Laboratory Reference System (Centre for Disease Control, Atlanta, USA); CAP – College of American Pathologists (USA); CDCP – Centre for Disease Control and Prevention (USA); CFIA – Canadian Food Inspection Agency; CTQ – Quebec Toxicology Centre; FIOH – Finland Institute of Occupational Health; FNIHB – First Nations and Inuit Health Branch Laboratory Services, Health Canada; GLRP – Great Lakes Research Program (MDCH/Labs, USA); GSOEM – German Society for Occupational and Environmental Medicine (Germany); NCP – Northern Contaminants Program (Environment Canada); QUASIMEME – Quality Assurance for Marine Environmental Monitoring in Europe (UK); SQBC – Quebec Society of Clinical Biology; WIAQC – Worldwide Interlaboratory Aluminum Quality Control (France).

as well as a number of external intercomparison programs that address the analysis of human tissues and other health related matrices, ensure comparability with other laboratories and among different research projects of the NCP. Table 6.2.1 provides a list of these external interlaboratory programs.

A wide variety of RMs and CRMs are used regularly by the NCP laboratories. For the data quality assurance of human tissue analyses, some of these health-related RMs and CRMs are listed in Table 6.2.2. In-house reference materials have also been developed by the Centre de Toxicologie du Québec (CTQ) and Health Canada's First Nations and Inuit Health Branch (FNIHB) within their own interlaboratory programs including blood serum for PCBs and metals, and hair samples for mercury analysis.

6.3 External data quality assurance

6.3.1 Northern Contaminants Interlaboratory Quality Assurance (QA) Program

The primary objective of the Northern Contaminants Interlaboratory Quality Assurance (QA) Program is to provide assurance to NCP managers and researchers of the quality, reliability and comparability of measured results being generated within the NCP studies. Several intercomparison studies are conducted annually to address the quality of data being generated for heavy metals, methylmercury, and POPs, including PCB congeners, organochlorine (OC) pesticides and toxaphene. Due to the focus of NCP Phase II on traditional/country foods, a significant portion of NCP contaminant measurements have been on environmental and biotic (wildlife) tissues. The check samples used in the NCP QA intercomparisons, therefore, have included standard solutions, environmental materials and tissues from

TABLE 6.2.2 Reference materials used for data quality assurance in NCP human health studies

Reference material/ Certified reference material code	Supplier	Matrix	Analytes
CRM-188	BCR	milk powder	OC pesticides (spiked)
CRM-397	BCR	hair powder	total mercury
CRM-450	BCR	milk powder	PCB congeners
CRM-463	BCR	fish powder	total mercury
IAEA-085 and IAEA-086	IAEA	hair powder	heavy metals, total mercury, methylmercury
NIES No. 13	NIEH	hair powder	total mercury, methylmercury
SRM-966	NIST	blood	toxic elements
SRM-968c	NIST	human serum	retinoids, tocopherols, carotenoids, cholesterol
SRM-1544	NIST	frozen diet composite	fatty acids, cholesterol, proximate
SRM-1588a	NIST	cod liver oil	PCB congeners, OC pesticides, _- tocopherol
SRM-1589a	NIST	blood serum	PCB congeners, OC pesticides, dioxins/furans
SRM-1945	NIST	whale blubber	PCB congeners, OC pesticides
SRM-2383	NIST	Bay food composite	vitamins, proximate, minerals
AMIB-1701, -1702, -1703	Promochem AB (Sweden)	lyophilized human blood	lead, cadmium, chromium, manganese

Source: Stokker (2002)

Acronyms:

BCR – Community Bureau of Reference (Belgium); IAEA – International Atomic Energy Agency (Austria); NIEH – National Institute for Environmental Health (Japan); NIST – National Institute of Standards and Technology (USA).

Arctic biota (see Chapter 7 in the CACAR-II Report: Contaminant Levels, Trends and Effects in the Biological Environment, for further details on laboratory performance in the studies conducted within the NCP QA Program). While the current NCP QA program does not include human tissues as check samples, many of the health laboratories have participated in the studies by analyzing the injection-ready standard solutions and/or the wildlife tissue samples, where feasible. In addition, their participation in the NCP QA program is complemented by participation in several excellent external QA programs that directly address human tissue measurements with matrices such as biological fluids and tissues, e.g., the two Canadian QA programs described in the following sections.

6.3.2 Centre de Toxicologie du Québec — Interlaboratory Comparison Program

Although there have been several laboratories that have provided human tissue measurements to the NCP (see Table 6.1.1), much of the work has been conducted at the Centre de Toxicologie du Québec (CTQ). This laboratory is the reference laboratory in human toxicology for the Province of Québec. It is accredited by the Standards Council of Canada (SCC) under ISO/IEC 17025. The expertise of this laboratory is in the determination of heavy metals and persistent organic pollutants in biological fluids and tissues. Human health samples for the NCP research program have included blood, urine, milk, placental and adipose tissue, and hair.

In 1979, in order to support its internal quality control needs as well as to provide a measure of comparability with other international toxicology laboratories, CTQ developed an Interlaboratory Comparison Program for laboratories conducting measurements of toxic trace metals in blood and urine. The check samples are prepared, whenever possible, by pooling specimens obtained from exposed workers or patients. This meets the need for matrix-matching that cannot be optimally achieved with most commercial reference materials which are often either freeze-dried and/or spiked with the analytes of interest. A parallel program, called the ICP-MS Comparison Program, addresses the comparability of analytical clinical laboratories using inductively coupled plasma mass spectrometry (ICP-MS) to analyze for trace metals in biological samples (blood, urine, serum and hair). At present, more than 200 laboratories worldwide participate in these programs for one or more toxic substances. The distribution frequency, cost, and the selection of parameters being assessed in these studies are detailed in Table 6.3.1.

More recently, as a reference health laboratory for the Arctic Monitoring and Assessment Programme (AMAP), the CTQ became a provider of annual intercomparison studies on the analysis of selected POPs in blood. This program, known as AMAP Ring Test (Weber, 2002) is mandatory for laboratories providing analytical results for PCBs in blood to AMAP. Details of the frequency, cost, and specific analytes for the AMAP Ring Test intercomparison studies are provided in Table 6.3.1.

TABLE 6.3.1 Intercomparison studies available from the Centre de Toxicologie du Québec

Name of scheme	Type of proficiency testing study	Target group	Matrices	Analytes	Concentration	Sample distribution	Period of time	Fee
Interlaboratory Comparison Program (for trace metals in biological fluids)	laboratory comparison	analytical clinical laboratories	human urine, human whole blood, human serum	**urine** total As, non-dietary As, Cd, Cr, Cu, F, Hg, Pb, Se, Zn **whole blood** Cd, Hg, Pb **serum** Al, Cu, Mn, Se, Zn	physiological and pathological	three samples per round	six rounds/year	Annual: US $150 registration and US $160 per control material
ICP-MS Comparison Program (for trace metals in biological samples)	laboratory comparison	analytical clinical laboratories using ICP-MS instrumentation	human urine, human whole blood/serum, human hair	Ag, Al, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Pt, Sb, Se, Sn, Te, Tl, U, V, Zn	physiological and pathological	three samples per round (usually 1 urine, 1 blood or serum and 1 hair)	six rounds/year	Annual: US $210
AMAP Ring Test (for PCBs and OCs in plasma)	laboratory comparison	analytical laboratories	serum/plasma	**PCB congeners** # 28, # 118, # 138, # 153, # 170 # 180 **OC pesticides** p,p'-DDE, p,p'-DDT oxychlordane β-HCH	physiological	three samples per round	six rounds/year	Annual: US $210

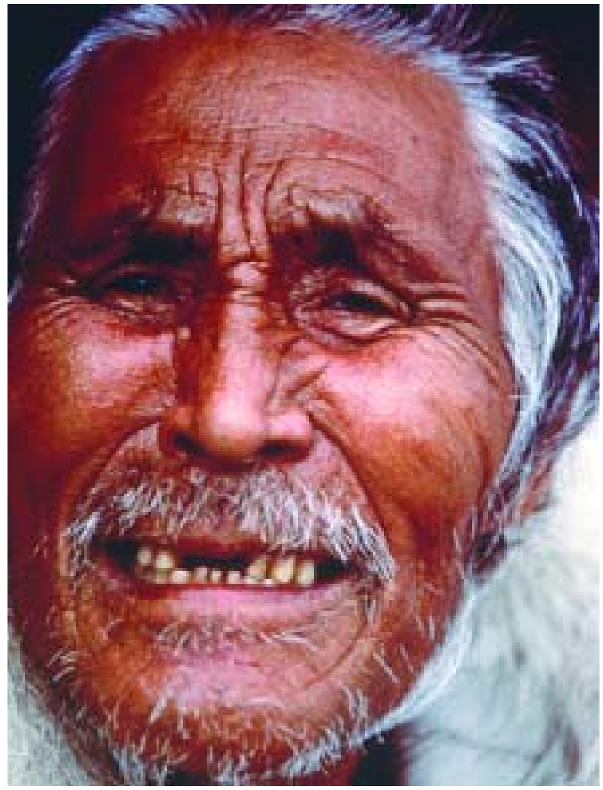
Source: Stokker (2002)

Participants in the AMAP Ring Test are provided with frozen human blood plasma samples spiked with various levels of the PCB and OC analytes. At the close of each study, they receive a summary report with their laboratory performance clearly detailed. In the first run of this intercomparison program, 26 laboratories provided results, but the data were generally not normally distributed. While there was good correlation between related analytes, poor performance was noted at concentrations < 0.5 µg/L. In the second run, most analytes and most results from the 25 reporting laboratories were within ± 20% of their assigned values in the study. Examples of the performance of three different laboratories over two runs of this program are shown in Figures 6.3.1 to 6.3.3. Each figure is a modified Youden plot (Youden, 1959) where the results for each parameter are plotted against their assigned value in the test sample. In Figure 6.3.1, the laboratory clearly provided consistent, accurate results for each parameter in each run. In Figure 6.3.2, the laboratory demonstrated a systematic error or bias in the first run with a dramatic improvement in their results in the second run. Figure 6.3.3 illustrates the results for a laboratory with random variations in their analyses on both runs 1 and 2.

Thus, as a provider of data quality assurance to the NCP, the interlaboratory and intralaboratory quality control procedures for this facility were reviewed (CTQ, 1999). Consistent with their SCC accreditation to ISO 17025, these procedures were found to be well documented and adequately address the data quality of measurements produced in this laboratory.

6.3.3 Hair Mercury Quality Control Program

Health Canada's First Nations and Inuit Health Branch (FNIHB) Laboratory Services offers analytical testing services for total PCBs (as Aroclor 1254 and 1260), 35 PCB congeners, 34 organochlorine pesticides (OCs), and mercury, including total mercury, inorganic mercury and organic mercury (Health Canada, 2001). Human health samples include biological fluids such as blood, serum and urine, and tissues (hair samples). This laboratory is proceeding toward accreditation by the Standards Council of Canada (SCC) for these tests. Along with developing a quality management system that follows ISO Guide 17025 (SCC, 2000), this laboratory has participated regularly in the NCP QA program for mercury analyses in biotic tissues.



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Health Canada's FNIHB has also conducted a mercury in hair interlaboratory QA/QC program since 1990 (Gill, 2002) in which more than 30 laboratories from 10 countries have participated. The check samples were prepared from hair specimens from the Canadian population and assessed for suitability in the intercomparison study by replicate measurements of total mercury and inorganic mercury. To assess homogeneity, the FNIHB laboratory analyzed six replicates of each sub-sample and consistently produced measurements with a repeatability of better than 10%. In fact, more than 90% of these homogeneity measurements produced a repeatability of better than 5%. These results not only verify the homogeneity of the sub-samples produced, but are also an indication of good in-house precision at the FNIHB. Figure 6.3.4 illustrates a comparison of the homogeneity test mean from the FNIHB laboratory with the consensus mean from the participants in the studies. In 24 studies conducted from 1990–2000, 95% of the participating laboratories using their own in-house techniques produced results that agreed well with the FNIHB results from the respective studies (Gill *et al.*, 2002). From the plot of results presented in Figure 6.3.4, it can be clearly seen that the FNIHB has consistently produced reliable data for total mercury in hair.

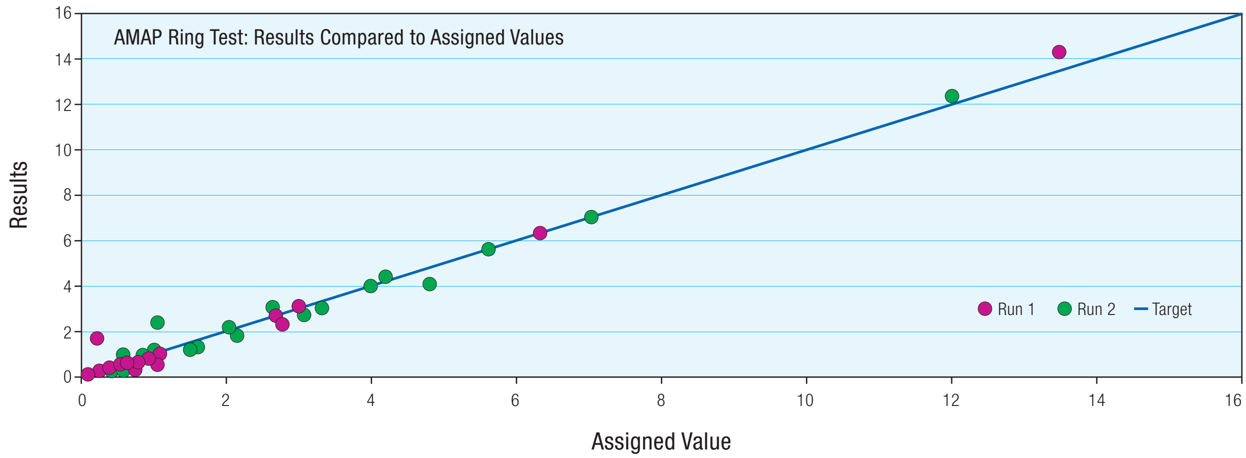

FIGURE 6.3.1

Example of a proficient laboratory.

Source: Weber (2002)

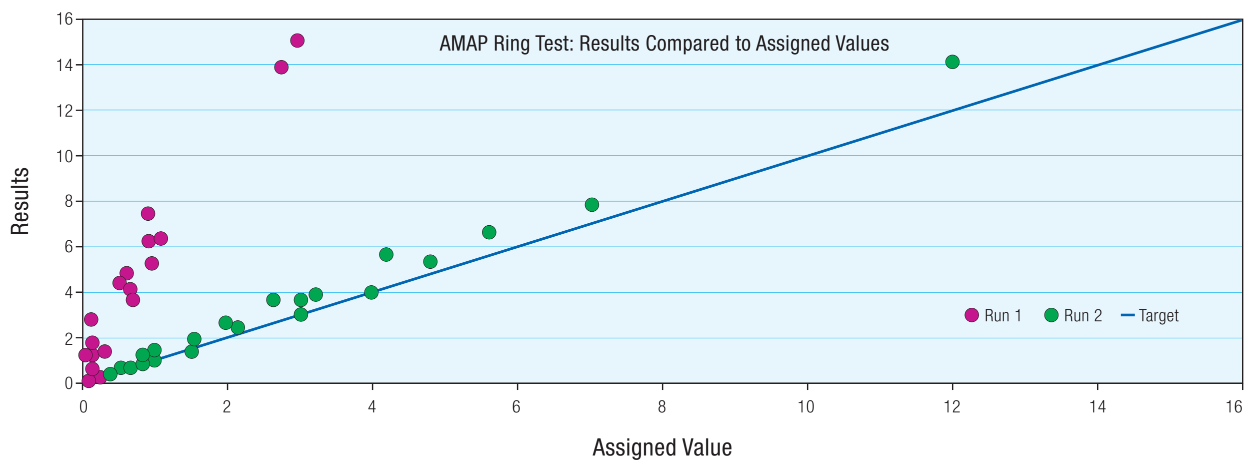

FIGURE 6.3.2

Example of improvement from Run 1 to Run 2.

Source: Weber (2002)

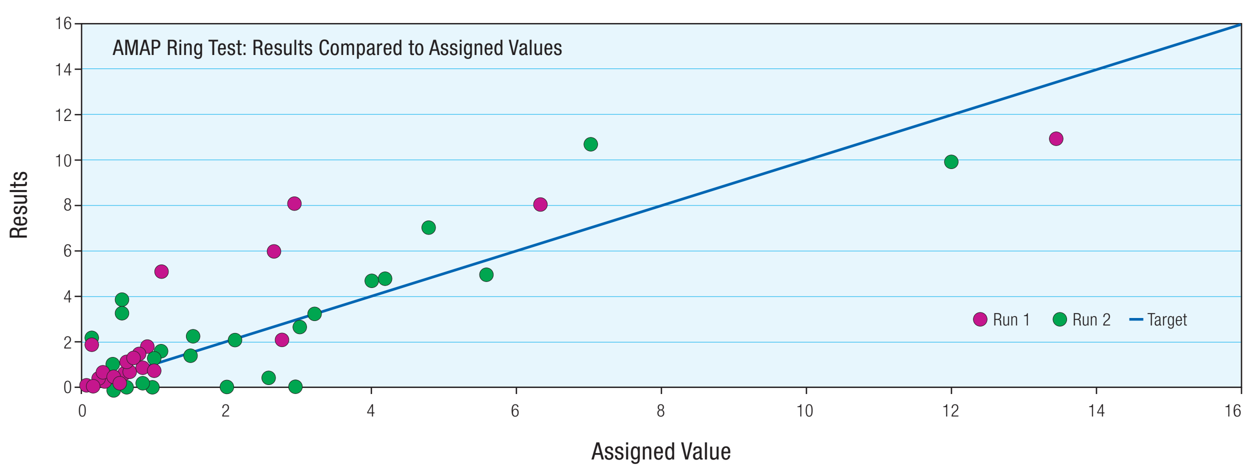

FIGURE 6.3.3

Example of random variations.

Source: Weber (2002)

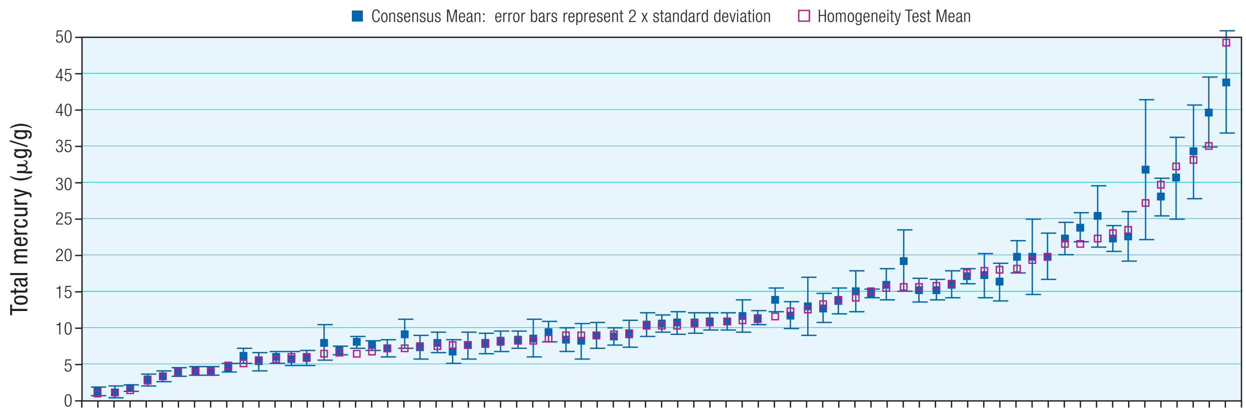

FIGURE 6.3.4

FNIHB homogeneity test means and consensus means for total mercury in each intercomparison sample, 1990–2000. Samples are plotted from lowest to highest concentration (i.e., not in chronological order).
Source: Stokker (2002)

6.4 Dietary surveys and measurements

Along with the chemical measurement of contaminants in the environment, food and tissues of northerners, an equally important aspect to monitoring their health is the determination of their dietary intake of both nutrients and contaminants. This area of NCP research has been addressed by several multi-year projects conducted by scientists at the Centre for Indigenous Peoples' Nutrition and Environment (CINE), a multi-disciplinary research and education resource for Indigenous peoples. The research and education activities conducted at CINE focus on the concerns of Aboriginal peoples regarding the health and integrity of their traditional/country food systems incorporating various issues related to the ecosystem, contaminants, health and culture. CINE's scope of work within the NCP includes evaluating the nutrient content and contaminant levels in traditional/country foods, conducting dietary surveys, benefit/risk studies and toxicological studies, and developing and distributing educational materials to northern communities. For the generation of NCP measurement data, CINE's laboratory focusses primarily on food samples, with less emphasis on the routine analysis of hair, blood and urine. Since their methodologies for contaminants in traditional/country foods are similar to those being conducted by wildlife laboratories, CINE's data quality is regularly monitored by their participation in the Northern Contaminants Interlaboratory Quality Assurance Program for both POPs and heavy metals.

- *At the onset of Phase II of the NCP, an assessment of the analytical programs and internal quality control procedures of the NCP health laboratories indicated that the data quality of the measurements generated in these laboratories was being adequately addressed.*
- *More recently, a review of the QA/QC procedures being followed in the NCP's key health laboratories showed that they have sound quality management systems in place that continue to address their data quality needs. These procedures include traceability and comparability checks on standards, samples and methodologies, good documentation of policies, procedures and protocols, and regular participation in external interlaboratory QA programs.*
- *As well as generating comparable results in the NCP Interlaboratory QA Program on standards and biotic tissues, many of these laboratories also routinely participate in external intercomparison programs on human tissue samples, such as Centre de Toxicologie du Québec Interlaboratory Comparison Program and Health Canada FNIHB's Hair Mercury Quality Control Program.*
- *As these laboratories continue their research and monitoring of human health measurement issues into Phase III of the NCP, their continued participation in the above three intercomparison programs is strongly recommended.*

GNWT/NWT Archives/Tessa Macintosh

Conclusions

The key objectives of this report are to assess the impact of exposure to current levels of environmental contaminants in the Canadian Arctic on human health, and to identify the data and knowledge gaps that need to be filled by future human health research and monitoring.

7.1 Introduction

7.1.1 Aboriginal peoples of Canada

1. About 7.5% (or 56,000) of Canada's Aboriginal population live in the five major regions of Arctic Canada, where they comprise just over half (53%) of the total combined population of the Canadian Arctic.
2. Arctic populations, especially Inuit, are generally younger than the Canadian population, which has a more even age distribution.

7.1.2 Aboriginal perspectives on food and health

3. Traditional/country foods are an integral component of good health among Aboriginal peoples, and their social, cultural, spiritual, nutritional and economic benefits must be considered in concert with the risks of exposure to environmental contaminants via the consumption of traditional/country foods.

7.1.3 Factors contributing to exposure to traditional/country food contamination

4. Persistent environmental contaminants such as PCBs, toxaphene, DDT and mercury biomagnify and bioaccumulate in the food chain. Because a substantial proportion of the Aboriginal diet consists of traditional/country food, Aboriginal peoples have a greater contaminant exposure than non-Aboriginal peoples or people in southern Canada.
5. Traditional/country food is an economic necessity for many Aboriginal peoples, and provides additional benefits beyond the activity of hunting itself, as it is the tie that binds Aboriginal peoples together and allows the sharing and teaching of their traditional social and cultural values.

7.1.4 Evaluation of research in CACAR and its application to benefit and risk assessment/management

6. In assessing causal associations between findings in any epidemiological or toxicological study the following factors must be considered: strength and magnitude of the association, consistency of the association, dose-response relationship, temporally correct association, and biological plausibility of the association.
7. Determining the adverse human health effects due to the presence of contaminants in traditional/country foods is very difficult as many factors contribute to the health of an individual. In fact, contaminants may only play a modest role in determining an individual's health status. Factors such as lifestyle (e.g., alcohol consumption, smoking, and substance abuse), diet, socioeconomic status and genetic predisposition need to be considered when evaluating the results in this report.

7.1.5 Research ethics

8. Methodologies and guidelines have been developed through the NCP to ensure an ethical and responsible approach to NCP-funded contaminants research in the Arctic. These guidelines help to ensure researchers respect and appreciate their responsibilities to the Aboriginal communities in all aspects of their research.


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7.2 Exposure assessment

7.2.1 Dietary information

9. Traditional/country food use for women and men 20–40 years of age is highest in Inuit communities, followed by Dene and Métis of the NWT and then First Nations people of the Yukon. Age and sex are factors influencing traditional/country food use, with men having higher average intakes than women, and traditional/country food consumption increasing with age.

7.2.2 Tissue contaminant levels

Persistent organic pollutants

10. Inuit mothers have oxychlordane and *trans*-nonachlor levels that are 6–12 times higher than those in Caucasians, Dene and Métis, or Other mothers, with Baffin Inuit mothers having the highest levels. Similar patterns were observed for PCBs, HCB, mirex and toxaphene.

11. Levels of β-HCH are 5–12 times higher among the Other mothers than in Inuit, Caucasians, or Dene and Métis mothers, while DDE levels in the Other mothers are also roughly 3–6 times higher. This higher exposure may be due to the fact that the Other mothers group consists of people whose exposure may be related to their possible African or East Asian country of origin or foods imported from these regions.

12. PCBs are a major contaminant of concern in the Arctic. Inuit mothers have the highest levels of PCBs compared to Caucasians, Dene and Métis, and the Other mothers, with Baffin Inuit having the highest levels. There are no marked differences in congener patterns among the various ethnic groups.

13. Caucasians mothers from the NWT have slightly higher levels of total TCDD-TEQs (dioxins and furans and dioxin-like PCBs) than Inuit or Dene mothers. The relative contributions of dioxins and furans and dioxin-like PCBs to the total TCDD-TEQs are very different in the three groups. Among Inuit mothers dioxin-like PCBs account for 80% of the total TCDD-TEQs while for Caucasian mothers, it is only 27%; Dene mothers have a relatively equal contribution from both sources.

Mercury

14. Recent research has revealed significantly higher levels of mercury in the maternal blood of Inuit women compared to Caucasian, Dene and Métis, or the Other group. Nunavik and Baffin Inuit have higher levels in maternal/cord blood than those seen in the Kitikmeot, Kivalliq and Inuvik regions.

15. Mercury levels in Salluit residents vary markedly from year to year due to variation in the availability of traditional/country foods, but recent tissue levels are similar to the levels found in the late 1970s. Mercury levels in some NWT communities are markedly lower than those in the 1970s and 1980s, but different sampling strategies may affect any conclusion drawn on trend.

Lead and cadmium

16. Research on lead isotope signatures has shown that the slightly elevated blood lead levels among some of the Inuit groups and the Dene and Métis are likely due to the use of lead shot for hunting traditional/country foods, and thus its presence in consumed wild game.

17. Blood cadmium levels are roughly 1.5–5 times higher among Inuit than in Dene and Métis, Caucasians, and Other. This difference is likely due to the high rate of smoking among Inuit mothers and the high cadmium content in Canadian tobacco.

Radionuclides

18. Radiocesium entered the atmosphere as a result of atmospheric testing of nuclear weapons. Since CACAR-I (CACAR, 1997), measurements of radiocesium levels in Canadian caribou herds have shown that levels are now considered insignificant and are continuing to decrease, with an ecological half-life of about 10 years.

19. The radionuclides lead-210 and polonium-210 are naturally occurring and supply most of the radiation dose to consumers of traditional/country foods. These radionuclides have been present in the Arctic environment for thousands of years at more or less the same concentrations as today and accumulate in the lichen → caribou → human food chain. Current estimates of polonium exposure would give a radiation dose of 3–4 mSv/year to a high consumer of caribou meat over and above normal background radiation exposure of 2–3 mSv/year.

7.2.3 Trends in traditional/country food dietary intakes and contaminant exposures

20. For Canadian Inuit, intakes of traditional/country food do not seem to have significantly changed in the last 20 years.

21. Surveys of dietary intake in one Inuit community, Qikiqtarjuaq (Broughton Island), Nunavut have shown that mercury exposures were similar in 1987–1988 and 1999, thus implying little change in dietary pattern or mercury concentration in food. However, reported intakes of the organochlorines were somewhat higher in 1999, particularly among the highest users (95th percentile). This was due to a higher reported consumption of narwhal muktuk and blubber in the community.

7.3 Toxicology

Toxaphene

22. In experimental studies to clarify the potential toxicity of toxaphene, a no-observed-effect-level (NOEL) of 0.1 mg toxaphene/kg bw/day was found for non-human primates regarding immunological effects. These findings support those seen in rodents where doses were 10 times higher (no NOEL was found in these studies).

23. In certain Arctic populations, toxaphene residues are within the same range as the experimental studies where effects on immune function and infant size have been observed.

24. While more information is needed on the carcinogenic and endocrine-disruptive capacity of toxaphene, new and forthcoming information will be useful in a re-assessment of the toxicity and provisional tolerable daily intake (pTDI) of this chemical.

Chlordane compounds

25. The pattern of chlordane-related residue accumulation in humans parallels that seen in the highest levels of the Arctic marine food chain. Estimated chlordane intake values for Arctic residents vary from levels below the Health Canada pTDI to levels approaching or exceeding the higher US EPA TDI, depending on marine mammal fat consumption.

26. Based on the latest rodent studies at Health Canada, a thorough risk assessment with the goal of re-assessing the TDI should take into account that the major chlordane metabolite oxychlordane is almost 10-fold more toxic than the parent chlordanes and nonachlors, and that *trans*-nonachlor and oxychlordane are among the more bioaccumulative chlordane contaminants.

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7.3.1 Toxicological effects from exposure to contaminant mixtures

27. The results of experimental studies using the pig as the animal model suggest that a high dose of an organochlorine mixture can induce subtle effects on development, especially on *in utero* growth and on the development of the male reproductive system. High-dose exposure also resulted in adverse immunological effects.

7.3.2 Contaminant and dietary nutrient interactions

28. There is some evidence that dietary nutrients such as polyunsaturated fatty acids, fish protein, and selenium may interact with methylmercury toxicity at least on the mechanistic level. The two former nutrients may be protective against methylmercury neurotoxicity; however, there is no conclusive evidence of such an effect.

29. Selenium has been the main nutritional factor considered by epidemiological and clinical studies to date. No epidemiological studies, however, have ever shown a correlation between selenium intake and the occurrence or absence of symptoms for methylmercury intoxication. There are also inconsistencies in the protective effects seen in animal studies, and the role of selenium remains to be confirmed.

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30. In animal studies, selenium alone did not provide protection against fetal mortality caused by *in utero* methylmercury treatment, while vitamin E alone and the combination of vitamin E and selenium treatments did.

7.4 Epidemiology and biomarkers

31. Neurobehavioural effects of perinatal exposure to environmental contaminants are best studied in prospective longitudinal cohort studies starting during pregnancy because there are numerous other determinants of infant and child development that need to be documented and are best assessed during pregnancy or at birth. Examples of these determinants are prenatal exposure to alcohol, drugs and tobacco; exposure to other environmental contaminants such as lead; and intake of nutrients such as selenium and omega-3 polyunsaturated fatty acids (PUFA) during pregnancy.

32. Conducting epidemiological studies on contaminants in the Arctic is difficult due to a variety of limiting factors: exposure to complex contaminant mixtures; small population size; contaminant-nutrient interactions; genetic factors; confounders; and health priorities. For this reason, epidemiological studies conducted in other parts of the world (e.g., the Faroe Islands) on PCB- and methylmercury-induced neurotoxicity should be used as much as possible for risk assessment. Differences in the limiting factors, however, may limit the external validity of these studies.

33. For methylmercury, the Faroe Islands study appears to be the most useful to extrapolate results to the Canadian Arctic [exposure to PCBs and mercury, similar sources (e.g., marine mammals), intake of omega-3 polyunsaturated fatty acids]. Differences remain, such as the genetic profile, a higher intake of selenium among Inuit, and a different pattern of exposure (peaks). Detailed analyses provide some evidence that the neurobehavioural deficits identified are the effects of methylmercury and not the consequence of exposure to PCBs.

34. In Nunavik, *otitis media* (middle ear infection) during the first year of life was associated with prenatal exposure to *p,p'*-DDE, HCB and dieldrin. Furthermore, the relative risk of recurrent *otitis media* increased with prenatal exposure to these compounds. To date, the ongoing Nunavik study supports the hypothesis that the high incidence of infections observed in Inuit children (mostly respiratory infections) may be due in part to high prenatal exposure to POPs, though definitive conclusions need to await final adjustment for important possible confounders (e.g., parental smoking, vitamin A).

35. The strength of the negative association of PCBs and birth weight for newborns in northern Québec was comparable to the associations of prenatal exposure to alcohol and smoking during pregnancy. The negative effects of prenatal PCB exposure on birth weight and duration of pregnancy could still be demonstrated despite the beneficial effects of omega-3 fatty acids from the traditional/country diet.

36. The ongoing Nunavik cohort study should help to shed more light on contaminant exposure and potential related health effects in the areas of neurodevelopment and immune function.

7.5 Risk and benefit characterization, assessment and advice

7.5.1 Contaminant exposure risks

37. The primary contaminants of concern in the context of traditional/country food consumption in Arctic Canada are the persistent organic pollutants PCBs, chlordane and toxaphene, the toxic metal mercury and naturally occurring radionuclides.

Persistent organic pollutants

38. In recent dietary surveys among five Inuit regions (Baffin, Inuvialuit, Kitikmeot, Kivalliq and Labrador), mean intakes by 20–40-year-old adults in Baffin, Kivalliq and Inuvialuit communities exceeded the pTDIs for chlordane and toxaphene. High consumers (95^{th} percentile) of traditional/country foods are exceeding the pTDIs by many-fold for toxaphene, chlordane, and PCBs. The Inuit populations that had the greatest exceedance of the pTDIs also had the greatest exceedance of the PCB maternal blood guideline.

39. In one Inuit community, Qikiqtarjuaq (Broughton Island), Nunavut intakes of organochlorines including PCBs, chlordane, and toxaphene were higher in 1998–1999 than in 1987–1988, particularly among the high-end consumers (95^{th} percentile). While the organochlorine concentrations used for the estimates were similar, variations in the amounts of certain traditional/country foods consumed likely account for this difference.

40. The most recent findings in NWT and Nunavut indicate that almost half of the blood samples from Inuit mothers exceeded the Level of Concern value of 5 μg/L for PCBs but none exceed the Action Level of 100 μg/L. Very low percentages of Dene and Métis, and Caucasian mothers had concentrations that exceeded the Level of Concern.

Metals

41. Mercury is the toxic metal of greatest concern in the Canadian Arctic. Dietary intakes of mercury were similar in the two surveys conducted in 1987–1988 and 1998–1999, indicating there has been little change in dietary pattern and/or mercury concentrations in traditional/country foods.

42. Based on the exceedances of the provisional tolerable daily intake (pTDI) and of various blood guidelines, mercury, and to a lesser extent lead (from the use of lead shot in hunting game), may be a significant concern among Arctic peoples. It may be easier to change people's use of lead shot, as the users of the shot are also the consumers of the wild game. For mercury, the connection between those affected in the North and sources of pollution in the south is not as direct and it may be more difficult to institute appropriate pollution abatement measures.

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Radionuclides

43. There is mounting evidence that a threshold may exist for radiation-induced cancer and this threshold may be equal to or greater than 100 mSv. The issue is of significance to northerners, who were exposed in the past to nuclear weapons fallout, or who have slightly higher exposures due to caribou meat consumption.

44. Even if one assumes that the linear no-threshold hypothesis is correct, the risk of continued consumption of caribou meat is very small. A maximum radiation dose rate at present is estimated to be about 3–4 mSv/year. The only way to reduce these radiation doses further would be to restrict caribou meat consumption, which would deny northerners the nutritional, social and cultural benefits of this important traditional/country food.

7.5.2 Nutritional benefits of a traditional/country food diet

45. The nutritional benefits of traditional/country food and its contribution to the total diet are substantial, even though only 6–40% of total dietary energy may be from this food source. Research findings are consistent across the Canadian Arctic and confirm that decreasing the amount of traditional/country food in the diet is likely to have negative health consequences, in part through the corresponding increase in total fat, saturated fat and sucrose above recommended levels. Traditional/country food also contributes significantly more protein, iron and zinc to the diets of Inuit children than imported foods.

7.5.3 Social, cultural, and spiritual benefits of a traditional/country food diet

46. Harvesting, sharing, processing and consumption local renewable resources from the land and waters provides not only the primary source of food and income, but it is also the foundation of the social, cultural and spiritual way of life for Aboriginal peoples.

7.5.4 Assessment of people's perceptions of risks, benefits, and safety of traditional/country foods

47. The result of the sum of this work on risk perception in the North informs decision makers and risk communicators about the understandings and misunderstandings of the issue and the potential effects they have on individual behaviour and activities. Within the NCP, there has been an increasing recognition for the need to document and understand public perceptions of contaminants and how the issue is being addressed in the North, but much still remains to be done.

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7.5.5 Benefit and risk management and assessment framework

48. Benefit and risk assessment and management relating to contaminants in traditional/country food involves a consideration of the type and amount of food consumed and the sociocultural, nutritional, economic, and spiritual benefits associated with traditional/country foods. Benefit and risk management decisions must involve the community and must take all aspects into account to arrive at a decision that will be the most protective and least detrimental to the communities. Regardless of the decision taken, some health risks associated with exposure to contaminants may remain. In the Arctic, these risks are outweighed by the benefits of continuing consumption of traditional/country foods. The uncertainty over risks and benefits will continue to pose a large and complex public, moral and political dilemma.

49. Benefit and risk management is an evolving process subject to change as new information about the situation is learned and assessed. The approach must be continually modified to suit each situation and each community and the advice monitored to ensure it is providing the best possible outcome.

7.5.6 Benefit and risk communication

50. Effective communication is fundamental to the aims of the NCP. Communication efforts incorporate Aboriginal knowledge on the nutritional benefits and risks associated with the consumption of traditional/country foods and of imported foods, and on the importance of a traditional lifestyle to overall health and well-being. These efforts provide northerners with the appropriate information to make more informed decisions about harvesting and consumption of both traditional/country and imported foods, and also to avoid some of the mistakes of earlier communication efforts related to environmental contaminants.

51. No one method of communication is best, but what is needed is a variety of methods and materials appropriate to communities in different regions and specific to groups within each community, all aimed at providing opportunities for two-way exchanges of information and allowing an understanding of the issue to develop. This builds a collective comprehension of benefits and risks, as well as the limitations of the scientific assessment.

52. The practice of risk communication has changed over the past two decades, building upon lessons learned along the way. In place of one-way models of message dissemination, NCP-II strove toward shared decision making through partnerships involving territorial Health Departments and regional contaminants/health committees, community representatives and representatives of Aboriginal organizations at all stages of the risk management and risk communication process.

7. 6 Quality assurance and quality control

53. At the onset of Phase II of the NCP, an assessment of the analytical programs and internal quality control procedures of the NCP health laboratories indicated that the data quality of the measurements generated in these laboratories was being adequately addressed.

54. More recently, a review of the QA/QC procedures being followed in the NCP's key health laboratories showed that the labs have sound quality management systems in place that continue to address their data quality needs. These procedures include traceability and comparability checks on standards, samples and methodologies, good documentation of policies, procedures and protocols, and regular participation in external interlaboratory QA programs.

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Knowledge Gaps

8.1 Exposure assessment

Dietary information

1. Continued monitoring and assessment of the frequency of consumption of traditional/country foods in a limited number Dene and Métis, Yukon First Nations, and Inuit communities is needed to identify any significant changes in consumption patterns. Focus needs to be placed on communities with the highest exposure but must include an assessment of regional variations.

Tissue contaminant levels

8.1.1 Persistent organic pollutants

2. The monitoring of organochlorines in human tissues does not have a long history in the Canadian Arctic, and continued monitoring of tissue levels is needed to determine contaminant trends. Special attention should be given to oxychlordane, *trans*-nonachlor, HCB, mirex, toxaphene, PCBs, and mercury, especially among the Inuit of Nunavut and Nunavik. There may be systematic differences among subgroups in these regions, and more data are needed.

8.1.2 Mercury

3. Although there is a longer history of Arctic environmental monitoring of mercury than of organochlorines, differences in sampling strategies have made any conclusions on trends very tenuous. Regular monitoring of tissue levels among communities with a range of exposures for mercury and selenium is advisable.

8.1.3 Radionuclides

4. Ongoing concern about the effects of naturally occurring polonium-210 in northern food chains has led to a research project looking at the evidence of damage from this radionuclide in cultured human and animal cells using advanced techniques in molecular biology. This work needs to be completed, as the detection of these effects could either serve as an early warning, long before any overt health effects occur, or alleviate unfounded concerns.

Linkages between trends in dietary intakes and contaminant tissue levels

5. Focussed monitoring of traditional/country food consumption in specific Arctic communities through surveys of dietary intakes of environmental contaminants, particularly of organochlorines (e.g., PCBs, chlordane, toxaphene) will help to provide more spatial and temporal data on changes in dietary patterns or contaminant concentrations in food. Communities with high traditional/country food consumption and a range of contaminant exposures need to be included.

6. Surveys of dietary intake in one Inuit community have shown that mercury exposures were similar in 1987–1988 and 1999, thus implying little change in dietary pattern or mercury concentration in food. However, monitoring in a range of communities would provide additional data points on which to base firmer conclusions.

8.2 Toxicology

8.2.1 Toxaphene

7. All experimental research funded by the NCP and Health Canada on toxaphene needs to be reported in peer reviewed literature. This will allow an assessment of the present pTDI.

8. More research is needed on the bioaccumulation and/or metabolism of toxaphene congeners by aquatic and terrestrial organisms, including human, in order to ascertain the number of congeners present in "toxaphene" and in the environment; to clarify their specific toxicity (e.g., immunological effects, infant size, mutagenicity and genotoxicity, and endocrine effects); and the appropriate TDI for these congeners.

8.2.2 Chlordane

9. The most relevant toxicological issues to be addressed in future research on chlordane contaminants are the relationship between tissue levels in humans and in experimental animals, and the occurrence of specific functional changes, including but not limited to immune suppression.

10. Since *trans*-nonachlor and oxychlordane appear to be present at higher levels in marine mammal tissues than other chlordane-related contaminants, it would be useful if future human exposure assessments focussed on *trans*-nonachlor and oxychlordane tissue levels.

8.2.3 Organochlorine mixtures

11. Additional experimental animal and *in vitro* studies on the toxicological effects of complex organochlorine mixtures in the Arctic environment and elsewhere in the world are needed to provide more information on which to base hypotheses about the potential human health effects of exposure to organochlorine mixtures.

12. Future studies should also include an assessment of the interactions between substances that may result in antagonism, additivity, or synergism, and identify the compounds responsible for toxic effects. Particular attention needs to be paid to *in utero* and lactational exposure and developmental, reproductive effects, as well as immunological effects.

8.2.4 Contaminants and dietary nutrient interactions

13. It is clear that there is a need for more studies designed specifically to address the role of nutrition in the metabolism and detoxification of methylmercury. It is also important to collect more detailed dietary information in future epidemiological studies of methylmercury exposure. A controlled human study on the effects of various nutrients such as the omega-6 fatty acids, selenium and vitamin E on methylmercury toxicokinetics will be useful to confirm the results obtained from the animal experiments.

8.3 Epidemiology

Neurodevelopment

14. The Nunavik cohort study should allow differentiation between the specific deficits attributable to PCBs and those associated with mercury, since the cord blood PCB-mercury intercorrelation is low. With the establishment of a prospective Arctic birth-cohort, there will be opportunities to look at other contaminants which may have neurodevelopmental effects, as well as to study long-term effects that can only be documented at school age or later in the course of development.

Immune system

15. The only recent epidemiological study of contaminant effects conducted in the Canadian Arctic is the one in Nunavik. This study suggested an association between *in utero* exposure to POPs and susceptibility to infections during the first year of life. Although efforts have been made to also use effect biomarkers (vitamin A, cytokines), as noted earlier the low predictive ability of these markers limits their use. The usefulness of new markers (antibodies post-immunization, complement system) needs to be assessed within the cohort study in Nunavik and elsewhere in the Arctic.

Endocrine disruption

16. Epidemiological studies on stochastic diseases (e.g., breast cancer and other hormonal cancers) are extremely difficult to conduct in the Arctic because the number of cases is low. This is due to 1) the size of the population, and 2) the fact that many chronic diseases (cancer) have a low incidence. To assess these health endpoints, long-term circumpolar studies need to be used to increase the sample size and increase the likelihood of detecting any real effects.

17. Epidemiological studies in the Canadian Arctic should be restricted to diseases or conditions that: 1) have high-incidence rates; 2) have gradients of severity (from normality to overt abnormalities); and 3) are easy to diagnose.

8.4 Risk and benefit characterization, assessment and advice

Contaminant exposure risks

18. Focussed monitoring and assessment of organochlorine intake, especially by high-end consumers of traditional/country foods in specific Inuit communities, is strongly warranted.

19. The risks associated with the usual levels of exposure to mercury via the consumption of contaminated traditional/country foods also need to be characterized, since they too appear prevalent in the Baffin and Nunavik regions.

Benefits of a traditional/country food diet

20. The substantial nutritional benefits of traditional/country food and its contribution to the total diet have been documented; however, further research is needed on the negative health consequences of not consuming traditional/country food.

Assessment of people's perceptions of the risks, benefits, and safety of traditional/country foods

21. Few projects have been conducted under the NCP to specifically investigate public perceptions of contaminants in traditional/country foods, the related risks, understandings and misunderstandings of the issue, or the potential impacts they may have on individual behaviour and activities. There is a continuing need to document and understand public perceptions of contaminants and how the issue is being addressed in the North.

Benefit-risk communication

22. There is a need to further clarify messages for Aboriginal peoples, taking into account different community-of-origin dialects that can significantly affect the reading comprehension of printed material, and improving the effectiveness of some of the methods used to convey environmental health information.

23. Research is also needed on ways that women of childbearing age use information to make informed decisions regarding the consumption of PCB- and mercury-contaminated traditional/country food items.

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References

Addison, R.F. and T.G. Smith. 1998. Trends in organochlorine residue concentrations in ringed seal (*Phoca hispida*) from Holman, Northwest Territories, 1972–91. *Arctic*, *51(3)*:253–261.

Agriculture Canada. 1980. Trade Memorandum: *Changes in the Regulatory Status of Toxaphene*. T-1-231. October.

Åhman, B. and G. Åhman. 1994. Radiocesium in Swedish reindeer after the Chernobyl fallout: seasonal variations and long-term decline. *Health Physics*, *66(5)*:503–512.

Allen, A., L.D. Koller and G. Pollock. 1983. Effect of toxaphene exposure on immune responses in mice. *J. Toxicol. Environ. Health*, *11*:61–69.

AMAP. 1998. *AMAP Assessment Report: Arctic Pollution Issues*. Arctic Monitoring and Assessment Programme, Oslo, Norway. 859 pp.

Anderson, F., J. Lampe and F. Murphy, 1999. Labradorimiut perspectives on environmental health. In: *Synopsis of Research Conducted under the 1998–1999 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 295–302.

Andrews, P., W.H. Newsome, M. Boyle and P. Collins. 1993. High resolution selective ion monitoring GC-MS determination of toxaphene in Great Lakes fish. *Chemosphere 27*:1865–1872.

Arnold, D.L., F. Bryce, C. Baccanale, S. Hayward, J.R. Tanner, E. MacLellan, T. Dearden, and S. Fernie. 2001. Toxicological consequences of toxaphene ingestion by cynomolgus (*Macaca fascicularis*) monkeys. Part 1. Pre-mating phase. *Food Chem. Toxicol.*, *39*:467–476.

ATSDR. 1996. *Toxicological Profile for Toxaphene*. U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry. Augusta, Georgia, USA. No. 205-93-0606.

Auger, J., J.M. Kunstmann, F. Czyglik, and J.P. Jouannet. 1995. Decline in semen quality among fertile men in Paris during the past 20 years. *New Engl. J. Med. 332*:281–285.

Ayotte, P. 2001. *Personal communication*. Laval University, Ste-Foy, Québec.

Ayotte, P. 2002. *Personal communication*. Laval University, Beauport, Québec.

Barsotti, D.A., R.J. Marlar, and J.R. Allen. 1976. Reproductive dysfunction in rhesus monkeys exposed to low levels of polychlorinated biphenyls (Aroclor 1248). *Food Cosmet. Toxicol.*, *14*:99–103.

Barsotti, D.A. and J.P. van Miller. 1984. Accumulation of commercial polychlorinated biphenyl mixture (Aroclor 1016) in adult rhesus monkeys and their nursing infants. *Toxicology*, *30*:31–44.

Batal, M. 2001. *Sociocultural Determinants of Traditional Food Intake Across Indigenous Communities in the Yukon and Denendeh*. Ph.D. thesis. Dietetics and Human Nutrition, and CINE (Centre for Indigenous Peoples' Nutrition and Environment), McGill University, Montreal, Québec, Canada.

Beard, J., S. Marshall, K. Jong, R. Newton, T. Triplett-McBride, B. Humphries, and R. Bronks. 2000. 1,1,1-trichloro-2,2-*bis* (*p*-chlorophenyl)-ethane (DDT) and reduced bone mineral density. *Arch. Environ. Health*, *55(3)*:177–180.

Benedetti, J.L., É. Dewailly, F. Turcotte, and M. Lefebvre. 1994. Unusually high blood cadmium associated with cigarette smoking among three subgroups of the general population, Québec, Canada. *Sci. Tot. Environ. 152*:161–167.

Berkes, F., and C.S. Farkas. 1978. Eastern James Bay Cree Indians: Changing patterns of wild food use and nutrition. *Ecology of Food and Nutrition*, *7*:155–172.

Berti, P.R., O. Receveur, H.M. Chan, and H.V. Kuhnlein. 1998a. Dietary exposure to chemical contaminants from traditional food among adult Dene/Métis in the western Northwest Territories, Canada. *Environ. Res.*, *76(2)*:131–142.

Berti, P.R., H.M. Chan, O. Receveur, C.R. MacDonald, and H.V. Kuhnlein. 1998b. Population exposure to radioactivity from consumption of caribou among the Dene/Métis of Denendeh (western Northwest Territories, Canada). *J. Expo. Anal. Environ. Epidemiol.*, *8(2)*:145–158.

Berti, P.R., S.E. Hamilton, O. Receveur, and H.V. Kuhnlein. 1999. Food use and nutrient adequacy in Baffin Inuit children and adolescents. *J. Diet. Pact. Research., 60(2)*:63-70.

Bérubé, B., C. Guillemette, P. Ayotte, J.L. Bailey. 2002. The impact of maternal exposure to an environmentally relevant organochlorine mixture on female reproductive parameters and offspring growth in the porcine model. In preparation.

Beyrouty, P. 2002. *Effects of methylmercury on reproduction and offspring development and potential benefits of supplemental selenium and vitamin E intake in rats*. M.Sc. thesis. Department of Natural Resources Sciences, McGill University, Montreal, Québec, Canada.

Bilrha, H., E. Wagner, R. Roy, B. Bérubé, J. Bailey, É. Dewailly, and P. Ayotte. 2000. Adverse developmental effects in pigs following *in utero* and lactational exposure to organochlorines: Effects on immune function. *Organohalogen Compounds, 49:*112–115.

Bitman, J. and H.C. Cecil. 1970. Estrogenic activity of DDT analogs and polychlorinated biphenyls. *J. Agr. Food Chem*. *18(6):*1108–1112.

Bjerregaard, P. and T.K. Young. 1998. The Circumpolar Inuit: Health of a Population in Transition. Munksgaard, Copenhagen.

Bjerregaard, P. and J.C. Hansen. 2000. Organochlorines and heavy metals in pregnant women from the Disko Bay area in Greenland. *Sci. Total Environ*., *245(1-3):*195–202.

Blanchet, C., S. Dodin, M. Dumont, Y. Giguere, L. Turcot-Lemay, J. Beauchamp, and D. Prud'homme. 1998. Bone mineral density in French Canadian women. *Osteoporos. Int., 8(3):*268–273.

Blanchet, C., É. Dewailly, P. Ayotte, S. Bruneau, O. Receveur, and B.J. Holub. 2000. Contribution of selected traditional and market foods to the diet of Nunavik Inuit women. *Can. J. Diet. Prac. Res.*, *61(2):*50–59.

Bloem, M., M.Wedel, R.J. Egger, A.J. Speek, J. Schrijver, S. Saowakontha, and W.H.P. Schreurs. 1990. Mild vitamin A deficiency and risk of respiratory tract diseases and diarrhea in preschool children in Northeastern Thailand. *Am. J. Epidemiol.*, *131(2):*3320–3339.

Bondy, G.S., W.H. Newsome, C.L. Armstrong, C.A.M. Suzuki, J. Doucet, S. Fernie, S.L. Hierlihy, M.M. Feeley, and M.G. Barker. 2000. *Trans*-nonachlor and *cis*-nonachlor toxicity in Sprague-Dawley rats: Comparison with technical chlordane. *Toxicol. Sci.*, *58:*386–398.

Bondy, G., C. Armstrong, L. Coady, J. Doucet, P. Robertson, M. Feeley and M. Barker. Toxicity of the chlordane metabolite oxychlordane in female rats: clinical and histopathological changes. *Food and Chemical Toxicology*. In press.

Borré, K.S. 1994. The healing power of the seal: The meaning of Inuit health practice and belief. *Arctic Anthropology, 31(1):*1–15.

Braekevelt, E., G.T. Tomy, and G.A. Stern. 2001. Comparison of an individual congener standard and a technical mixture for the qualification of toxaphene in environmental matrices by HRGC/ECNI-HRMS. *Environ. Sci.*, *35(17):*3513–3518.

Brouwer, A. 1991. Role of biotransformation in PCB-induced alterations in vitamin A and thyroid hormone metabolism in laboratory and wildlife species. *Biochem. Soc. Trans., 19:*731–737.

Bruneau, S., C. Furgal, É. Dewailly, and M. Grey. 2001. Incorporation of scientific knowledge into Inuit knowledge in Nunavik. In: *Synopsis of Research Conducted under the 2000-2001 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 291–293.

Bryce, F., F. Iverson, P. Andrews, M. Barker, W. Cherry, R. Mueller, O. Pulido, S. Hayward, S. Fernie, and D.L. Arnold. 2001. Effects elicited by toxaphene in the Cynomolgus monkey: A pilot study. *Food Chem. Toxicol.*, *39(12):*1243–1251.

Budtz-Jorgensen, E., N. Keiding, P. Grandjean, R.F.White, and P. Weihe. 1999. Methylmercury neurotoxicity independent of PCB exposure. *Environ. Health Perspect*. *107(5):*A236–237.

CACAR. 1997. *Canadian Arctic Contaminants Assessment Report*. Jensen, J., K. Adare, and R. Shearer (eds.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada.

Carlsen, E., A. Giwercman, N. Keiding, and N.E. Skakkebaek. 1992. Evidence for decreasing quality of semen during past 50 years. *Brit. Med. J., 305:*609–613.

Chan, H.M., C. Kim, K. Khoday, O. Receveur, and H.V. Kuhnlein. 1995. Assessment of dietary exposure to trace metals in Baffin Inuit food samples. *Environ. Health Perspect., 103(7–8):*740–746.

Chan, H.M., P.R. Berti, O. Receveur, and H.V. Kuhnlein. 1997. Evaluation of the population distribution of dietary contaminant intakes in an Arctic population using Monte Carlo statistics. *Environ. Health. Perspect., 105(3):*316–321.

Chan, H.M. 1998. A database for environmental contaminants in traditional foods in northern and Arctic Canada: development and applications. *Food Addit. Contam., 15:*127–134.

Chan, H.M. 2000a. Dietary Effects on Methylmercury Toxicity in Rats. In: *Synopsis of Research Conducted under the 1999-2000 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 11–15.

Chan, H.M. 2000b. *Toxicology of Mercury and Selenium in Ringed Seal Tissues. In: Synopsis of Research Conducted under the 1999–2000 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 16–19.

Chan, H.M., K. Krishnan, F. Iverson, and C. Suzuki. 2000. Use of Physiologically Based Toxicokinetic (PBTK) Model for Risk Assessment of Exposure to Mixtures of Organochlorines in Traditional Food. In: S*ynopsis of Research Conducted under the 1999–2000 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 20–27.

Chan, H.M., 2002. *Personal communication*. Centre for Indigenous Peoples' Nutrition and Environment (CINE), Ste-Anne-de-Bellevue, Québec.

Chan, H.M., S.Y. Kubow, K.S. Yoo, E. Lok, and R. Mehta. 2002. Effects of dietary protein and lipids on methylmercury toxicity in rats. In preparation.

Chandra, J. and G. Durairaj. 1993. Effect of toxaphene toxicity on enzyme activity and residue levels in vital organs of guineapig. *Indian J. Med. Res., 98:*193–198.

Chang, K., K. Hsieh, T. Lee, S. Tang, and T. Tung. 1981. Immunologic evaluation of patients with polychlorinated biphenyl poisoning: determination of lymphocyte subpopulations. *Toxicol. Applied Pharmacol., 61:*58–63.

Chanoine, J.P. and L.E. Braverman. 1992. The role of transthyretin in the transport of thyroid hormone to cerebrospinal fluid and brain. *Acta. Med. Austriaca, 19 (suppl. 1):*25–28.

Chao, W., C. Hsu, and Y.L. Guo. 1997. Middle-ear disease in children exposed prenatally to polychlorinated biphenyls and polychlorinated dibenzofurans. *Arch. Environ. Health, 52(4):*257–262.

Chauhan, K.R., P.R.S. Kodavanti, and J.D. McKinney. 2000. Assessing the role of ortho-substitution on polychlorinated biphenyl binding to transthyretin, a thyroxine transport protein. *Toxicol. Appl. Pharmacol., 162:*10–21.

Cheek, A.O., K. Kow, J. Chen, and J.A. McLachlan. 1999. Potential mechanisms of thyroid disruption in humans: interaction of organochlorine compounds with thyroid receptor, transthyretin, and thyroid-binding globulin. *Environ. Health Perspect., 107(4):*273–278.

Chernoff, N. and R.J. Kavlock. 1982. An *in vivo* teratology screen utilizing pregnant mice. *J. Toxicol. Environ. Health, 10:*541–550.

Choi, B.H. 1989. The effects of methylmercury on the developing brain. *Prog. Neurobiol., 32:*447–470.

Clarkson, T.W. 1993. Mercury: major issues in environmental health. *Environ. Health Perspect., 100:*31–38.

Clarkson, T.W. 1997. The toxicology of mercury. *Crit. Rev. Clin. Lab. Sci., 34(3):*369–403.

Condon, R.G., P. Collings, and G. Wenzel. 1995. The best part of life: subsistence hunting, and economic adaptation among young adult Inuit males. *Arctic, 48(1):*31–46.

Crump, K.S., T. Kjellström, A.M. Shipp, A. Silvers, and A. Stewart. 1998. Influence of prenatal mercury exposure upon scholastic and psychological test performance: Benchmark analysis of a New Zealand cohort. *Risk Anal., 18(6):*701–713.

CTQ. 1999. *Intralaboratory and Interlaboratory Quality Control Procedure*. Centre de Toxicologie du Québec Procedure PL-016-D (StarLIMS0).

Curran, I. and R. Mehta. 2002. *Personal communication*. Health Canada, Ottawa, Ontario.

Dallaire, F., É. Dewailly, C. Vézina, G. Muckle, P. Ayotte, G. de Serres, J.P. Weber, C. Infante-Rivard, and J. Jacobson. 2002a. *Increased Risks of Recurrent Infectious Diseases in Infants Prenatally Exposed to POPs*. (Presented at the 2002 AMAP meeting.)

Dallaire, F., É. Dewailly., R. Shademani, C. Laliberté, S. Bruneau, C. Blanchet, M. Lefebvre, M. Rhainds, and P. Ayotte. 2002b. Vitamin A status in umbilical cord blood of infants from three separate regions of the province of Québec, Canada. *Submitted*.

Dallaire, F. 2002. *Personal communication*. Laval University, Ste-Foy, Québec.

Dar, E., M.S. Kanarek, H.A. Anderson, and W.C. Sonzogni. 1992. Fish consumption and reproductive outcomes in Green Bay, Wisconsin. *Environ. Res., 59*:189–201.

Darvill, T., E. Lonky, J. Reihman, P. Stewart, and J. Pagano. 2000. Prenatal exposure to PCBs and infant performance on the Fagan Test of Infant Intelligence. *Neurotoxicology., 21(6):*1029–1038.

Daum, J.R. 1993. Immunotoxicology of cadmium and mercury on B-lymphocytes -1. Effects on lymphocyte function. *Int. J. Immunopharmacol., 15(3):*383–394.

Davidson, P.W., G.J. Myers, C. Cox, C. Shamlaye, D.O. Marsh, M.A. Tanner, M. Berlin, J. Sloane-Reeves, E. Cernichiari, O. Choisy, A. Choi, and T.W. Clarkson. 1995. Longitudinal neurodevelopmental study of Seychellois children following *in utero* exposure to methylmercury from maternal fish ingestion: Outcomes at 19 and 29 months. *Neurotoxicology., 16(4):*677–688.

Davidson, P.W., G.J. Myers, C. Cox, C. Axtell, C. Shamlaye, J. Sloane-Reeves, E. Cernichiari, L. Needham, A. Choi, Y. Wang, M. Berlin, and T.W. Clarkson. 1998. Effects of prenatal and postnatal methylmercury exposure from fish consumption on neurodevelopment. *JAMA, 280(8):*701–707.

Dequeker, J., L.Tobing, V. Rutten, P. Geusens. 1991. Relative risk factors for osteoporotic fracture: a pilot study of the MEDOS Questionnaire. *Clin. Rheum., 10(1):*49-53.

Deutch, B. and J.C. Hansen. 2000. High human plasma levels of organochlorine compounds in Greenland. Regional differences and lifestyle effects. *Dan. Med. Bull., 47:*132–137.

Dewailly, É., P. Ayotte, S. Bruneau, C. Laliberté, D.C.G. Muir, and R.J. Norstrom. 1993. Inuit exposure to organochlorines through the aquatic food chain in Arctic Québec. *Environ. Health Perspect., 101:*618–620.

Dewailly, É. 1994. Human contaminant trends in Arctic Canada: A cord blood study in Nunavik. In: *Synopsis of Research Conducted under the 1993–1994 Northern Contaminants Program*. J.L. Murray and R.G. Shearer (eds.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 373–380.

Dewailly, É., S. Bruneau, C. Laliberte, G. Lebel, S. Gingras, J. Grondin, and P. Levallois. 1994. Contaminants. In: *A Health Profile of the Inuit: Report of the Sante Québec Health Survey Among the Inuit of Nunavik, 1992. Volume I*. J. Jetté (ed.). Montreal, Ministère de la Santé et des Services Sociaux, Governement du Québec, Montréal. pp. 73–107.

Dewailly, É., S. Bruneau, P. Ayotte, and G. Lebel. 1998. Evaluation of Prenatal Exposure to Organochlorines and Heavy Metals in Nunavik Newborns 1993–1996. *Environ. Studies., 74:*293–312.

Dewailly, É., S. Bruneau, and P. Ayotte, 1999. Mercury in Salluit: Temporal trend and interaction with selenium. In: *Synopsis of Research Conducted under the 1998-1999 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 265–271.

Dewailly, É., P. Ayotte, S. Bruneau, H. Schwartz, M. Grey, J. Weber, A. Leblanc, J. Proulx, J. Grondin, and M.E. Mirault. 2000a. Mercury in Salluit: Temporal trend and interaction with selenium. In: *Synopsis of Research Conducted under the 1999–2000 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 32–36.

Dewailly, É., B. Levesque, J. Duchesne, P. Dumas, A. Scheuhammer, C. Gariepy, M. Rhainds, and J.F. Proulx. 2000b. Lead shot as a source of lead poisoning in the Canadian Arctic. *Epidemiology, 11(4):*S146.

Dewailly, É., P. Ayotte, S. Bruneau, S. Gingras, M. Belles-Isles, and R. Roy. 2000c. Susceptibility to infections and immune status in Inuit infants exposed to organochlorines. *Environ. Health Perspect., 108(3):*205–211.

Dewailly, É., C. Blanchet, P. Chaumette, O. Receveur, J. Lawn, E. Nobmann, T. Pars, P. Bjerregaard, and J.F. Proulx. 2000d. *Diet Profile of Circumpolar Inuit*. GÉTIC, Université Laval, Québec, Canada.

Dewailly, É.C., F. Dallaire, C. Vézina, and G. Muckle. 2001a. Effects of prenatal exposure to organochlorines and mercury on the immune system of Inuit infants. In: *Synopsis of Research Conducted under the 2000–2001 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 17–21.

Dewailly, É.C., C. Blanchet, S. Lemiuex, L. Sauvé, S. Gingras, P. Ayotte, and B.J. Holub. 2001b. n-3 fatty acids and cardiovascular disease risk factors among the Inuit of Nunavik. *Am. J. Clin. Nutr., 74(4):*464–473.

Dewailly, É., C. Blanchet, S. Gingras, C. Furgal, and S. Bruneau. 2001c. Sociodemographic factors influencing nutrition and contaminant exposure in Nunavik. In: *Synopsis of Research Conducted under the 2000–2001 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 26-35.

Dewailly, É., A. Beuter, P. Ayotte, S. Bruneau, M.-É. Mirault, M. Grey, and J.-P. Weber. 2001d. Mercury in Salluit: Effects of mercury on oxidative status and sensorimotor functions. In: *Synopsis of Research Conducted under the 2000-2001 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 22–25.

Dewailly, É. 2002. *Personal communication*. Laval University, Ste-Foy, Québec.

Dodin, S., É. Dewailly, S. Côté, C. Blanchet, P. Ayotte, G. Mulvad, and H.S.Petersen. 2002. PCB exposure and risk of osteoporosis in Greenlandic menopausal women. In preparation.

Dougherty, C.P., S.H. Holtz, J.C. Reinert, L. Panyacosit, D.A. Axelrad, and T.J. Woodruff. 2000. Dietary exposures to food contaminants across the United States. *Environ. Res., A84:*170–185.

Douglas, M. 1986. *Risk Acceptability According to the Social Sciences*. Basic Books, New York, U.S.A.

Douglas, M. 1992. *Risk and blame — Essays in cultural theory*. Routledge, London, England and New York, U.S.A.

Dumont, C., M. Girard, F. Bellavance, and F. Noel. 1998. Mercury levels in the Cree Population of James Bay, Québec, from 1988 to 1993/94. *Can. Med. Assoc. J., 158(11):*1439–1445.

Egede, I. 1995. *Inuit Food and Inuit Health: Contaminants in Perspective*. Presentation to Inuit Circumpolar Conference, Seventh General Assembly, Nome, Alaska. July.

Egeland, G.M., L.A. Feyk, and J.P. Middaugh. 1998. The use of traditional foods in a healthy diet in Alaska: Risks in perspective. Anchorage, Alaska: Department of Health and Social Services, Alaska Division of Public Health. 140 pp.

Ekblond, A., A. Mellemkjaer, L. Tjonneland, M. Suntum, C. Stripp, K. Overvad, C. Johansen, and J.H. Olsen. 2000. A cross-sectional study of dietary habits and urinary glucose excretion: a predictor of non-insulin-dependent *diabetes mellitus. Eur. J. Clin. Nutr., 54:* 343–9.

Elias, B. and J. O'Neil. 1995. *A Study into the Social, Cultural and Disciplinary Understanding of Risk Perception and Risk Acceptability of Contaminants in the Canadian Arctic*. Report prepared for the Arctic Environmental Strategy Contaminants Program. Northern Health Research Unit, Department of Community Health Sciences, University of Manitoba, Manitoba, Canada.

Elinder, C.G. 1992. Cadmium as an environmental hazard. *IARC Sci. Publ., 118:*123-132.

Erikson, K. 1990. Toxic reckoning: Business faces a new kind of fear. *Harvard Business Review, 90(1):*118–126.

Fediuk, K., N. Hidiroglou, R. Madere, and H.V. Kuhnlein. 2002. Vitamin C in Inuit traditional food and women's diets. *J. Food Compos. Anal.* In press.

Feeley, M. 2002. *Personal communication*. Health Canada, Ottawa, Ontario.

Fein, G.G., J.L. Jacobson, S.W. Jacobson, P.M. Schwartz, and J.K. Dowler. 1984. Prenatal exposure to polychlorinated biphenyls: Effects on birth size and gestational age. *J. Pediatr., 105:*315–320.

Feskens, E.J.M., C.H. Bowles, and D. Kromhout. 1991. Inverse association between fish intake and risk of glucose intolerance in normoglycemic elderly men and women. *Diabetes Care, 14(11):*935–941.

Feskens, E.J.M., S.M. Virtanen, L. Räsänen, J. Tuomilehto, J. Stengard, J. Pekkanen, A. Nissinen, and D. Kromhout. 1995. Dietary factors determining diabetes and impaired glucose tolerance. *Diabetes Care, 18(8):*1104–1112.

Flynn, J., P. Slovic, and C.K. Mertz. 1994. Gender, race, and perception of environmental health risks. *Risk Analysis, 14(6):*1101–1108.

FAO (Food and Agriculture Organisation)/WHO (World Health Organisation). 1986. *FAO Plant Production and Protection Paper 77*. Report of the Joint Meeting of the FAO Panel of Experts on Pesticide Residues in Food and the Environment and a WHO Expert Group on Pesticide Residues. FAO, Rome, Italy. p.16.

Fournier, M., V. Degas, T. Colborn, F.O. Omara, F. Denizeau, E.F. Potworowski, and P. Brousseau. 2000. Immunosuppression in mice fed on diets containing beluga whale blubber from the St. Lawrence estuary and the Arctic populations. *Toxicol. Lett., 15(112-113):*311–317.

Fredriksson, A., A. Teiling Gardlund, K. Bergman, A. Oskarsson, B. Ohlin, B. Danielsson, and T. Archer. 1993. Effects of maternal dietary supplementation with selenite on the postnatal development of rat offspring exposed to methylmercury *in utero. Pharmacol. Toxicol., 72:*377–382.

Freeman, M.M.R., L. Bogoslovskaya, R.A. Caulfield, I. Egede, I.I. Krupnik, and M.G. Stevenson (eds.). 1998. Inuit, whaling, and sustainability. AltaMira Press, Walnut Creek, CA. 208 pp.

Fry, D.M. and C.K. Toone. 1981. DDT-induced feminization of gull embryos. *Science, 213:*922–924.

Furgal, C. M. 1999. *Addressing Northern Decision Making Capacity: The case of health advisories and the Labrador Inuit*. Ph.D. Thesis. Faculty of Environmental Studies, School of Planning, University of Waterloo, Waterloo, Ontario, Canada.

Furgal, C.M., S. Bernier, G. Godin, S. Gingras, J. Grondin, and É. Dewailly. 2001. Decision making and diet in the North: Balancing the physical, economic and social components. In: *Synopsis of Research Conducted under the 2000–2001 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 42-43.

Furgal, C.M., S. Powell, and H. Myers. 2002. Communicating on Contaminants and Health in the Canadian North: Review and Recommendations for the Future. In preparation.

Gailer, J., G.N. George, I.J. Pickering, S. Madden, R.C. Prince, E.Y. Yu, M.B. Denton, H.S. Younis, and H.V. Aposhian. 2000. Structural basis of the antagonism between inorganic mercury and selenium in mammals. *Chem. Res. Toxicol., 13:*1135–1142.

Geyer, H.J., A. Kaune, K.M. Schramm, G. Rimkus, I. Scheunert, R. Brüggemann, J. Altschuh, C.E. Steinberg, W. Vetter, A. Kettrup, and D.C. Muir. 1999. Predicting bioconcentration factors (BCFs) of polychlorinated bornane (toxaphene) congeners in fish and comparison with bioaccumulation factors (BAFs) biota from the aquatic environment. *Chemosphere, 39(4):*655–663.

Giesy, J.P. and K. Kannan. 1998. Dioxin-like and non-dioxin-like toxic effects of polychlorinated biphenyls (PCBs): implications for risk assessment. *Crit. Rev. Toxicol., 28(6):*511–569.

Gill, U.S. 2002. *The "Mercury in Hair" Interlaboratory Comparison Program*. Health Canada Research and Environmental Health Division Special Operating Procedure.

Gill, U.S., H.M. Schwartz, and L. Bigras. 2002. Results of multi-year interlaboratory comparison program for mercury in human hair. *Arch. Environ. Contam. Toxicol.* In press.

Gilman, A., É. Dewailly, M. Feeley, V. Jerome, H. Kuhnlein, B. Kwavnick, S. Neve, B. Tracy, P. Usher, J. Van Oostdam, J. Walker, and B. Wheatley. 1997. Chapter 4: Human Health. In: *Canadian Arctic Contaminants Assessment Report*. J. Jensen, K. Adare and R. Shearer (eds.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada.

Gladen, B.C., W.J. Rogan, P. Hardy, J. Thullen, J. Tingelstad, and M. Tully. 1988. Development after exposure to polychlorinated biphenyls and dichlorodiphenyl dichloroethene transplacentally and through human milk. *J. Pediatr., 113(9):*991–995.

Goodman, J.I., D.J. Brusick, W.M. Busey, S.M. Cohen, J.C. Lamb, and T.B. Starr. 2000. Reevaluation of the cancer potency factor of toxaphene: Recommendations from a peer review panel. *Toxicol. Sci., 55:*3–16.

Grandjean, P., P. Weihe, P.J. Jorgensen, T. Clarkson, E. Cernichiari, and T. Videro. 1992. Impact of maternal seafood diet on fetal exposure to mercury, selenium, and lead. *Arch. Environ. Health, 47(3):*185–195.

Grandjean, P., P. Weihe, R.F. White, F. Debes, S. Araki, K. Yokoyama, K. Murata, N. Sorensen, R. Dahl, and P.J. Jorgensen. 1997. Cognitive deficit in 7-year old children with prenatal exposure to methylmercury. *Neurotoxicol. Teratol., 19:*417–428.

Grandjean, P., E. Budtz-Jorgensen, R.F. White, P.J. Jorgensen, P. Weihe, F. Debes, and N. Keiding. 1999. Methylmercury exposure biomarkers as indicators of neurotoxicity in children aged 7 years. *Am. J. Epidemiol., 150(3):*301–305.

Guillemette, C., B. Bérubé, P. Ayotte, and J.L. Bailey. 2002. Development of the male reproductive tract following *in utero* and lactational exposure to an environmentally relevant organochlorine mixture. In preparation.

Guo, Y.L., C.J. Lin, W.J Yao, J.J. Ryan, and C.C. Hsu. 1994. Musculoskeletal changes in children prenatally exposed to polychlorinated biphenyls and related compounds (Yu-Cheng children). *J. Toxicol. Environ. Health, 41:*83–93.

Guo, Y.L., G.H. Lambert, and C. Hsu. 1995. Growth abnormalities in the population exposed *in utero* and early postnatally to polychlorinated biphenyls and dibenzofurans. *Environ. Health Perspect., 103:* 117–122.

Hainzl, D., J. Burhenne, and H. Parlar. 1994. Theoretical consideration of the structural variety in the toxaphene mixture taking into account recent experimental results. *Chemosphere, 28(2):*245–252.

Hamburgh, M. 1969. The role of thyroid and growth hormones in neurogenesis. In: *Current Topics in Developmental Biology*. A. Moscona and A. Monroy (eds.). Academic Press, New York, U.S.A. pp. 109–148.

Hany, J., H. Lilienthal, A. Sarasin, A. Roth-Harer, A. Fastabend, L. Dunemann, W. Lichtensteiger, and G. Winneke. 1999. Developmental exposure of rats to a reconstituted PCB mixture or Aroclor 1254: effects on organ weights, aromatase activity, sex hormone levels, and sweet preference behaviour. *Toxicol. Appl. Pharmacol., 158:*231–243.

Health Canada. 1979. *Methylmercury in Canada: Exposure of First Nations and Inuit residents to methylmercury in the Canadian environment*. Medical Services Branch, Department of National Health and Welfare, Ottawa, Ontario, Canada. Vol. 1, 200 pp.

Health Canada. 1993. *Health Risk Determination: The Challenges of Health Protection*. Minister of Supply and Services Canada. Cat. No. H49-40/1993E.

Health Canada. 1994. *Human Health Risk Assessment for Priority Substances*. Canada Communication Group, Ottawa, Canada, 36 pp.

Health Canada. 1998. Food directorate memo on re-evaluation of mercury TDI. Ottawa, Ontario, Canada.

Health Canada. 1999. *Methylmercury in Canada. Exposure of First Nations and Inuit residents to methylmercury in the Canadian environment*. Medical Services Branch, Health Canada, Ottawa, Ontario, Canada, 150 pp.

Health Canada. 2000. *Health Canada Decision-making Framework for Identifying, Assessing, and Managing Health Risks*. Minister of Public Works and Government Services Canada, Ottawa, Ontario, Canada. 75 pp.

Health Canada. 2001. *Quality Assurance Manual*. First Nations and Inuit Health Branch (FNIHB) Laboratory Services, Health Canada. November. Draft.

Health Physics Society Newsletter. 1996. Volume XXIV, Number 3, March. p. 3

Hedli, C.C., R. Snyder, R.K. Kinoshita, and M. Steinberg. 1998. Investigation of hepatic cytochrome P-450 enzyme induction and DNA adduct formation in male CD/1 mice following oral administration of toxaphene. *J. Appl. Toxicol., 18:*173–178.

Henning, B., R. Slim, M. Toborek, and L.W. Robertson. 1999. Linoleic acid amplifies polychlorinated biphenyl-mediated dysfunction of endothelial cells. *J. Biochem. Mol. Toxicol., 13(2):*83–91.

Heo, Y., P.L. Parsons, and D.A. Lawrence. 1996. Lead differentially modifies cytokine production in vitro and in vivo. *Toxicol. Appl. Pharmacol., 138:*149–157.

Hewitt, K. 1983. The idea of calamity in a technocratic age. In: *Interpretations of Calamity from the Viewpoint of Human Ecology*. K. Hewitt (ed.). Allen and Unwin, Boston, Massachusetts, U.S.A. pp. 3–32.

Hojbjerg, S., J.B. Nielsen, and O. Andersen. 1992. Effects of dietary lipids on whole-body retention and organ distribution of organic and inorganic mercury in mice. *Food Chem. Toxic., 30(8):*703–708.

Hooper, N.K., B. Ames, M.A. Saleh, and J.E. Casida. 1979. Toxaphene, a complex mixture of polychloroterpenes and a major insecticide, is mutagenic. *Science, 205*:591–593.

Huisman, M., C. Koopman-Esseboom, V. Fidler, M. Hadders-Algra, C.G. Van der Paauw, L.G.M.T. Tuinstra, N. Weisglas-Kuperus, P.J.J. Sauer, B.C.L. Touwen, and E.R. Boersma. 1995a. Perinatal exposure to polychlorinated biphenyls and dioxins and its effect on neonatal neurological development. *Early Hum. Dev., 41:*111–127.

Huisman, M., C. Koopman-Esseboom, C.I. Lanting, C.G. Van der Paauw, L.G.M.T. Tuinstra, V. Fidler, N. Weisglas-Kuperus, P.J.J Sauer, E.R. Boersma, and B.C.L. Touwen. 1995b. Neurological condition in 18-month-old children perinatally exposed to polychlorinated biphenyls and dioxins. *Early Hum. Dev., 43:*165–176.

ICRP (International Commission on Radiological Protection). 1991. *1990 Recommendations of the International Commission on Radiological Protection*. ICRP Publication 60. Pergamon Press, Oxford, England.

Inuit Circumpolar Conference 1996. The arctic sealing industry: A retrospective analysis of its collapse and options for sustainable development. Part I : Retrospective analysis. Arctic Environmental Protection Strategy. pp. 83.

Inuvik Regional Human Contaminants Monitoring Program: Regional Report, 2000. Inuvik Regional Health and Social Services Board. July 2000.

Ivanov, V.K., A.I. Gorski, M.A. Maksioutov, A.F. Tsyb, and G.N. Souchkevitch. 2001. Mortality among the Chernobyl emergency workers: estimation of radiation risks (preliminary analysis). *Health Physics, 81:*514–521.

Jacobson J.L., G.G. Fein, S.W. Jacobson, P.M. Schwartz, and J.K. Dowler. 1984. The transfer of polychlorinated biphenyls (PCBs) and polybrominated biphenyls (PBBs) across the human placenta and into maternal milk. *Am. J. Public Health, 74(4):* 378–379.

Jacobson, J.L., S.W. Jacobson, and H.E.B. Humphrey. 1990a. Effects of *in utero* exposure to polychlorinated biphenyls and related contaminants on cognitive functioning in young children. *J. Pediatr., 116:*38–45.

Jacobson, J.L., S.W. Jacobson, and H.E.B.Humphrey. 1990b. Effects of exposure to PCBs and related compounds on growth and activity in children. *Neurotoxicol. Teratol., 12(4):*319–326.

Jacobson, J.L., S.W. Jacobson, R.J. Padgett, G.A. Brumitt, and R.L. Billings. 1992. Effects of prenatal PCB exposure on cognitive processing efficiency and sustained attention. *Dev. Psychol., 28:*297–306.

Jacobson, J.L. and S.W. Jacobson. 1996. Intellectual impairment in children exposed to polychlorinated biphenyls *in utero*. *N. Engl. J. Med., 335(11):* 783–789.

Jacobson, S.W., G.G. Fein, J.L. Jacobson, P.M. Schwartz, and J.K. Dowler. 1985. The effects of intrauterine PCB exposure in visual recognition memory. *Child Dev., 56:*853–860.

Jobling, S., T. Reynolds, R. White, M.G. Parker, and J.P. Sumpter. 1995. A variety of environmentally persistent chemicals, including some phthalate plasticizers, are weakly estrogenic. *Environ. Health Perspect., 103:*582–587.

Kaikkonen, J., K. Nyyssonen, T. Tuomainen, U. Ristonmaa, and J.T. Salonen. 1999. Determinants of plasma coenzyme Q_{10} in humans. *FEBS Lett., 443:*163–166.

Kasperson, R.E. 1986. Six propositions on public participation and their relevance for risk communication. *Risk Analysis, 6(3):*275–281.

Kelce, W.R., C.R. Stone, S.C. Laws, L.E. Gray, J.A. Kemppainen, and E.M. Wilson. 1995. Persistent DDT metabolite *p,p'*-DDE is a potent androgen receptor agonist. *Nature, 375:*581–585.

Kim, C., H.M. Chan, and O. Receveur. 1998. Risk assessment of cadmium exposure in Fort Resolution, Northwest Territories, Canada. *Food Addit. Contam., 15(3):*307–317.

Kinloch, D., H. Kunhlein, and D.C.G Muir. 1992. Inuit foods and diet: A preliminary assessment of benefits and risks. *Sci. Total Environ., 122:*247–278.

Kjellström, T., P. Kennedy, S. Wallis, and C. Mantell. 1986. *Physical and Mental Development of Children with Prenatal Exposure to Mercury from Fish. Stage 1: Preliminary Test at Age 4*. National Swedish Environmental Protection Board, Solna, Sweden.

Klopov, V., J.O. Odland, and I.C. Burkow. 1998. Persistent organic pollutants in maternal blood plasma and breast milk from Russian arctic populations. *Int. J. Circump. Health, 57:*4239–4248.

Klopov, V.P. 2000. *Hygienic Assessment of Environmental Pollution in the North of Russia and its Effect on Population Health*. Doctoral thesis. St. Petersburg. 46 p. (in Russian).

Klopov, V.P. and V.N. Shepovalnikov. 2000. *The levels of exposure to key POPs among adult and children populations in Yamal Peninsula, Arctic Russia*. Proceedings of Workshop on Persistent Organic Pollutants (POPs) in the Arctic: Human Health and Environmental Concerns. Rovaniemi, 18–20 January 2000. University of the Arctic: Rovaniemi, 2000. Abstract 19: 4 pp.

Klopov, V.P. and V.P. Tchachchine. 2001. *Environmental Pollution and Risk Assessment for Population in the Russian North*. St. Petersburg, Russia. 225 p. (in Russian).

Koopman-Esseboom, C., M. Huisman, N. Weisglas-Kuperus, E.R. Boersma, M.A.J. de Ridder, C.G. Van der Paauw, L.G.M.T. Tuinstra, and P.J.J. Sauer. 1994a. Dioxin and PCB levels in blood and human milk in relation to living areas in the Netherlands. *Chemosphere, 29(9–11):*2327–2338.

Koopman-Esseboom, C., M. Huisman, N. Weisglas-Kuperus, C.G. Van der Paauw, L.G.M.T. Tuinstra, E.R. Boersma, and P.J.J. Sauer. 1994b. PCB and dioxin levels in plasma and human milk of 418 Dutch women and their infants. Predictive value of PCB congener levels in maternal plasma for fetal and infant's exposure to PCBs and dioxins. *Chemosphere, 28(9):*1721–1732.

Koopman-Esseboom, C., D.C. Morse, N. Weisglas-Kuperus, I.J. Lutkeschipholt, C.G. Van der Paauw, L.G. Tuinstra, A. Brouwer, and P.J. Sauer. 1994c. Effects of dioxins and polychlorinated biphenyls on thyroid hormone status of pregnant women and their infants. *Pediatr. Res., 36(4):*468–473.

Kraus, N., Malmfors, T., and Slovic, P. 1992. Intuitive toxicology expert and lay judgements of chemical risks. *Risk Analysis, 12(2):*215–231.

Kris-Etherton, P.M., D. Shaffer Taylor, S. Yu-Poth, P. Huth, K. Moriarty, V. Fishell, R.L. Hargrove, G. Zhao, and T.D. Etherton. 2000. Polyunsaturated fatty acids in the food chain in the United States. *Am. J. Clin. Nutr. 71 (suppl.):*179S–188S.

Krishnan, K and J. Brodeur. 1994. Toxic interactions among environmental pollutants: corroborating laboratory observations with human experience. *Environ. Health Perspect., 102 (suppl.) 9:*11–17.

Kromhout, D., E.J.M. Feskens, and C.H. Bowles. 1995. The protective effect of a small amount of fish on coronary heart disease mortality in an elderly population. *Internat. J. Epidemiol., 24(2):*340–344.

Kuhnlein, H.V. 1989. *Nutritional and Toxicological Components of Inuit Diets in Broughton Island, NWT*. School of Dietetics and Human Nutrition, McGill University, Montreal, Québec, Canada. 100 pp.

Kuhnlein, H.V. 1995. Benefits and risks of traditional food for Indigenous Peoples focus on dietary intakes of Arctic men. *Can. J. Physiol. Pharmacol., 73(6):* 765–771.

Kuhnlein, H.V., R. Soueida, and O. Receveur. 1995a. Baffin Inuit food use by age, gender and season. *J. Can. Diet. Assoc., 56(4):*175–183.

Kuhnlein, H.V., O. Receveur, N.E. Morrison, D.M. Appavoo, R. Soueida, and P. Pierrot. 1995b. Dietary nutrients of Sahtú Dene/Métis vary by food source, season and age. *Ecol. Food Nutr., 34:*183–195.

Kuhnlein, H.V., O. Receveur, D.C.G Muir, H.M. Chan, and R. Soueida. 1995c. *Arctic indigenous women consume greater than acceptable levels of organochlorines. J. Nutr., 125(10):*2501–2510.

Kuhnlein, H.V. and O. Receveur. 1996. Dietary change and traditional food systems of Indigenous Peoples. *Ann. Rev. Nutr.,16:*417–42.

Kuhnlein, H.V., O. Receveur, H.M. Chan, and E. Loring. 2000. *Assessment of Dietary Benefit/risk in Inuit Communities*. Centre for Indigenous Peoples' Nutrition and Environment (CINE), Ste-Anne-de-Bellevue, Québec.

Kuhnlein, H.V. and C. Dickson, 2001. Food Choice Decisions by Western Arctic Aboriginal Women and Children, Year 1. In: *Synopsis of Research Conducted under the 2000-2001 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 54–55.

Kuhnlein, H.V. and O. Receveur. 2001. *Personal communication*. Centre for Indigenous Peoples' Nutrition and Environment (CINE), Ste-Anne-de-Bellevue, Québec.

Kuhnlein, H.V., O. Receveur, and H.M. Chan. 2001a. Nutrient Benefits of Arctic Traditional/Country Food. In: *Synopsis of Research Conducted under the 2000-2001 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 56–64.

Kuhnlein, H.V., O. Receveur, and H.M. Chan. 2001b. Traditional food systems research with Canadian Indigenous Peoples. *Internat. J. Circump. Health, 60(2):*112–122.

Kuhnlein, H.V. and O. Receveur, and A. Ing. 2001c. Energy, fat and calcium in bannok consumed by Canadian Inuit. *J. Am. Diet. Assoc., 101(5):*580–581.

Kuhnlein, H.V. 2002. *Personal communication*. Centre for Indigenous Peoples' Nutrition and Environment (CINE), Ste-Anne-de-Bellevue, Québec.

Kuhnlein, H.V., H.M. Chan, D. Leggee, and V. Barthet. 2002. Macronutrient mineral fatty acid composition of Canadian Arctic traditional food. *J. Food Comp. and Analysis*. In press.

Kuratsune, M., T. Yoshimura, J. Matsuzaka, and A. Yamaguchi. 1972. Epidemiologic study on Yusho, a poisoning caused by ingestion of rice oil contaminated with commercial brand of polychlorinated biphenyls. *Environ. Health Perspect., 1:*119–128.

Labrador Inuit Health Commission (LIHC). 1996. Workshop on Social Health and Environmental Change. March 26-28, 1996, Nain, Labrador. Labrador Inuit Health Commission, Nain, Labrador.

Lagueux, J., D. Pereg, P. Ayotte, É. Dewailly, and G.G. Poirier. 1999. Cytochrome P450 CYP1A1 enzyme activity and DNA adducts in placenta from women environmentally exposed to organochlorines. *Environ. Res., 80(4):*369–382.

Lampe, J., F. Murphy, C. Furgal, and L. Craig. 2000. Country food nutrition and health: developing effective communication strategies in Labrador (Year 2). In: *Synopsis of Research Conducted under the 1999-2000 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 271–280.

Lans, M.C., C. Spiertz, A. Brouwer, and J.H. Koeman. 1994. Different competition of thyroxine binding to transthyretin and thyroxine-binding globulin by hydroxy-PCBs, PCDDs and PCDFs. *Eur. J. Pharmacol-Environ. Toxic., 270:*129–136.

Lapierre, P., S. De Guise, D.C. Muir, R. Norstrom, P. Beland, and M. Fournier. 1999. Immune functions in the Fisher rat fed beluga whale (*Delphinapterus leucas*) blubber from the contaminated St. Lawrence estuary. *Environ. Res., 80(2 Pt2):*S104–S112.

Lawn, J. and N. Langer. 1994. *Air Stage Subsidy Monitoring Program. Final Report. Food Consumption Survey*, *Vol. 1.* Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. 64 pp.

Lawn, J. and F. Hill. 1998. *Alternative Northern Food Baskets*. Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. 47 pp.

Lawn, J. and D. Harvey. 2001. *Change in Nutrition and Food Security in Two Inuit Communities, 1992 to 1997*. Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. 108 pp.

LIA (Labrador Inuit Association). 1997. Environmental Health Study, Final Report. Eco-Research Project. Labrador Inuit Association, Nain, Labrador, Canada. 63 pp.

Longnecker, M.P., M.A. Klebanoff, J.W. Brock, H. Zhou, K.A. Gray, L.L. Needham, and A.J. Wilcox. 2002a. Maternal serum level of 1,1-dichloro-2,2-*bis(p*-chlorophenyl)ethylene and risk of cryptorchidism, hypospadias, and polythelia among male offspring. *Am. J. Epidemiol., 155(4):*313–322.

Longnecker, M.P., M.S. Wolff, B.C. Gladen, J.W. Brock, P. Grandjean, J.L. Jacobson, S.A. Korrick, W.J. Rogan, N. Weisglas-Kuperus, I. Hertz-Picciotto, P. Ayotte, P. Stewart, G. Winneke, M.J. Charles, S.W. Jacobson, É. Dewailly, E.R. Boersma, L.M. Altshul, B. Heinzow, J.J. Pagano, and A.A. Jensen. 2002b. Comparison of polychlorinated biphenyl (PCB) levels across studies of human neurodevelopment. *Environ. Health Perspect.* In press.

Loring, E., S. Nickels, H. Chan, F. Murphy, M. Denniston, B. Archie, and O. Receveur. 2001. Avatiptinnit Niqittiavait — Good Food in the Environment. In: *Synopsis of Research Conducted under the 2000-2001 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 313–319.

Lucier, G., K. Nelson, R. Everson, T. Wong, R. Philpot, T. Tiernan, M. Taylor, and G. Sunahara. 1987. Placental markers of human exposure to polychlorinated biphenyls and polychlorinated dibenzofurans. *Environ. Health Perspect., 76:*79–87.

Lund, B.O., D.M. Miller, and J.S. Woods. 1993. Studies on Hg(II)-induced H_2O_2 formation and oxidative stress *in vivo* and *in vitro* in rat kidney mitochondria. *Biochem. Pharmacol., 45(10):*2017–2024.

Mably, T.A., D.L. Bjerke, R.W. Moore, A. Gendron-Fitzpatrick, and R.E. Peterson. 1992. *In utero* and lactational exposure of male rats to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin. 3. Effects on spermatogenesis and reproductive capability. *Toxicol. Appl. Pharmacol., 114:*118–126.

MacDonald, C.R., L.L. Ewing, B.T. Elkin, and A.M. Wiewel. 1996. Regional variation in radionuclide concentrations and radiation doses in caribou (*Rangifer tarandus*) in the Canadian Arctic. *Sci. Tot. Environ., 182:*53–73.

MacDonald, C.R. 2002. *Personal communication*. Northern Environmental Consulting. Pinawa, Manitoba.

Magos, L. 1991. Overview on the protection given by selenium against mercurials. In: *Advances in Mercury Toxicology*. T. Suzuki, N. Imura, and T.W. Clarkson (eds.). Plenum Press, New York, U.S.A. pp. 289–297.

Marsh, D.O., M.D. Turner, J.C. Smith, P. Allen, and N. Richdale, 1995. Fetal methylmercury in a Peruvian fish-eating population. *Neurotoxicology, 16(4):*717–726.

Marshall, H. and B.L. Tracy. 1989. *Radiocesium in the Caribou of Northern Canada*. Internal report available from the Radiation Protection Bureau 6302D1, Health Canada, Ottawa, Ontario, Canada.

McKeown-Eyssen, G.E. and J. Ruedy. 1983. Prevalence of neurological abnormalities in Cree Indians exposed to methylmercury in Northern Québec. *Clin. Inves. Med., 6(3):*161–169.

McKeown-Eyssen, G.E., J. Ruedy, and A. Neims. 1983. Methyl mercury exposure in northern Québec. II. Neurologic findings in children. *Am. J. Epidemiol., 118(4):*470–479.

McLean, M.R., L.W. Robertson, and R.C. Gupta. 1996. Detection of PCB adducts by the ^{32}P-postlabeling technique. *Chem. Res. Toxicol., 9:*165–171.

Meerts, I.A.T.M., J.J. van Zanden, E.A.C. Luijks, I. van Leeuwen-Bol, G. Marsh, E. Jakobsson, A. Bergman, and A. Brouwer. 2000. Potent competitive interactions of some brominated flame retardants and related compounds with human transthyretin *in vitro. Toxicol. Sci., 56(1):*95–104.

Muckle, G. 2000. *Personal communication*. Laval University, Beauport, Québec.

Muckle, G., P. Ayotte, É. Dewailly, S.W. Jacobson, and J.L. Jacobson. 2001a. Determinants of polychlorinated biphenyls and methylmercury exposure in Inuit women of childbearing age. *Environ. Health Perspect., 109(9):*957–963.

Muckle, G., P. Ayotte, É. Dewailly, S.W. Jacobson, and J.L. Jacobson. 2001b. Prenatal exposure of the northern Québec Inuit infants to environmental contaminants. *Environ. Health Perspect., 109(12):* 1291–1299.

Muckle, G., P. Ayotte, É. Dewailly, S.W. Jacobson, and J.L Jacobson. 2002. Prenatal exposure to PCBs and birth size in Northern Québec Inuit, Canada. In preparation.

Muir, D.C.G., E.W. Born, K. Koczansky, and G.A. Stern. 2000. Temporal and spatial trends of persistent organochlorines in Greenland walrus (*Odobenus rosmarus romarus*). *Sci. Total Environ., 245:*73–86.

Muir, D.C.G. 2001. *Personal communication*. Environment Canada, Burlington, Ontario.

Myers, G.J., D.O. Marsh, C. Cox, P.W. Davidson, C.F. Shamlaye, M.A. Tanner, A. Choi, E. Cernichiari, E. Choisy, and T.W. Clarkson. 1995a. A pilot neurodevelopmental study of Seychellois children following *in utero* exposure to methylmercury from a maternal fish diet. *Neurotoxicology, 16(4):*629–638.

Myers, G.J., D.O. Marsh, P.W. Davidson, C. Cox, C.F. Shamlaye, M.A. Tanner, A. Choi, E. Cernichiari, O. Choisy, and T.W. Clarkson. 1995b. Main neurodevelopmental study of Seychellois children following *in utero* exposure to methylmercury from a maternal fish diet: Outcome at six months. *Neurotoxicology, 16(4):*653–664.

Newsome, W.H. and J.J. Ryan. 1999. Toxaphene and other chlorinated compounds in human milk from northern and southern Canada. *Chemosphere, 39(3):*519–526.

Nielsen, J.B. and O. Andersen. 1992. The toxicokinetics of mercury in mice offspring after maternal exposure to methylmercury — effect of selenomethionine. *Toxicology, 74:*233–241.

NIH (National Institute of Health). 1998. Clinical Guidelines on the Identification and Treatment of Overweight and Obesity in Adults — the Evidence Report. *Obes. Res., 6(Suppl):*51S–209S.

Nishikido, N., K. Furuyashiki, A. Naganuma, T. Suzuki, and H. Imura. 1987. Maternal selenium deficiency enhances the fetolethal toxicity of methylmercury. *Toxicol. Appl. Pharmacol., 88:*322–328.

Nordic Council of Ministers. 1997. *Nordic Risk Assessment of Toxaphene Exposure*. Nordic Council of Ministers, Copenhagen, Denmark.

NRC (National Research Council). 1992. *Biological markers in immunotoxicology.* National Academic Press, Washington, DC.

NRC. 2000. *Toxicological Effects of Methylmercury.* National Academy Press, Washington, DC.

Oakley, G.G., L.W. Robertson, and R.C. Gupta. 1996. Analysis of polychlorinated biphenyl-DNA adducts by ^{32}P-postlabeling. *Carcinogenesis, 17(1):*109–114.

Odland, J.O. 2001. *Personal communication*. Institute of Community Medicine, University of Tromsø, Tromsø, Norway.

OECD (Organisation for Economic Cooperation and Development). 1995. *Guideline for the Testing of Chemicals. Guideline 407, Repeated Dose 28-Day Oral Toxicity Study in Rodents*. OECD, U.S.A.

Ohi, G., S. Nishigaki, H. Seki, Y. Tamura, T. Maki, H. Konno, S. Ochiai, H. Yamada, Y. Shimamura, I. Mizoguchi, and H. Yagyu. 1976. Efficacy of selenium in tuna and selenite in modifying methylmercury intoxication. *Environ. Res., 12:*49–58.

Okey, A., S. Riddick, and P. Harper. 1994. The Ah receptor: mediator of the toxicity of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and related compounds. *Toxicol. Lett,. 70:*1–22.

Olson, J.A. 1994. Hypovitaminosis A: Contemporary scientific issues. Symposium: *Clinical Nutrition in Developing Countries: Towards the Application of Contemporary Concepts and Technology*. American Institute of Nutrition, Ames, Iowa, U.S.A. pp. 1461S–1466S.

O'Neil, J.D., B. Elias, and A. Yassi. 1997. Poisoned food: cultural resistance to the contaminants discourse in Nunavik. *Arctic Anthropology, 34(1):*29–40.

Ornaghi, F., S. Ferrini, M. Prati, and E. Giavini. 1993. The protective effects of N-acetyl-L-cysteine against methyl mercury embryotoxicity in mice. *Fundam. Appl. Toxicol., 20:*437–445.

Park, S.T., K.T. Lim, Y.T. Chung, and S.U. Kim. 1996. Methylmercury-induced neurotoxicity in cerebral neuron culture is blocked by antioxidants and NMDA receptor antagonists. *Neurotoxicology, 17(1):*37–45.

Parlar, H. 1985. Analysis of toxaphene. *Int. J. Environ. Anal. Chem., 20:*141–158.

Patandin, S., C. Koopman-Esseboom, M.A.J. De Ridder, N. Weisglas-Kuperus, and P.J.J. Sauer. 1998. Effects of environmental exposure to polychlorinated biphenyls and dioxins on birth size and growth in Dutch children. *Pediatr. Res., 44(4):*538–545.

Patandin, S., C.I. Lanting, P.G.H. Mulder, E.R Boersma, P.J. Sauer, and N. Weisglas-Kuperus. 1999. Effects of environmental exposure to polychlorinated biphenyls and dioxins on cognitive abilities in Dutch children at 42 months of age. *J. Pediatr., 134(1):*33–41.

Patrono, C. and G.A. FitzGerald. 1997. Isoprostanes: potential markers of oxidant stress in atherothrombotic disease. *Arterioscler. Thromb. Vasc. Biol., 17*:2309–2315.

Pelkonen, O., N. Kärki, M. Koivisto, R. Tuimala, and A. Kauppila. 1979. Maternal cigarette smoking, placental aryl hydrocarbon hydroxylase and neonatal size. *Toxicol. Lett., 3:*331–335.

Pereg, D., J. Lagueux, É. Dewailly, G.G. Poirier, and P. Ayotte. 2001. Cigarette smoking during pregnancy: comparison of biomarkers for inclusion in epidemiological studies. *Biomarkers, 6:*161–173.

Pereg, D., É. Dewailly, G.G. Poirier, and P. Ayotte. 2002. Placental CYP1A1 activity in Inuit women environmentally exposed to polychlorinated biphenyls. *Env. Health Perspect., 110(6):*1–6.

Pidgeon, N., C. Hood, D. Jones, B. Turner, and R. Gibson. 1992. *Risk: Analysis, Perception, Management. Chapter 5: Risk Perception.* Report of a Royal Society Study Group. The Royal Society, London, England. 201 pp.

Poirier, S., and L. Brooke. 1997. *Inuit perceptions of contaminants, environmental knowledge and land use in Nunavik: The case of Salliut*. Preliminary research report, Eco-Research Program, CHUL Research Centre, Beauport, Québec, Canada.

Poirier, S., and L. Brooke. 1999. Inuit Perceptions of Contaminants, Environmental Knowledge and Land Use in Nunavik. In: *Eco-Research Avativut/Ilusivut Research Program, Final Report*. L. Craig (ed.). Unité de recherche en santé publique, CHUQ-Pavillon CHUL, Beauport, Québec, Canada. pp. 43–53.

Porterfield, S.P. and L.B. Hendry. 1998. Impact of PCBs on thyroid hormone directed brain development. *Toxicol. Ind. Health, 14(1/2):*103–120.

Powell, D. and W. Leiss (eds.). 1997. *Mad Cows and Mother's Milk. The Perils of Poor Risk Communication*. McGill-Queen's University Press, Montreal, Québec, Canada.

Pratico, D. 1999. F^2-isoprostanes: sensitive and specific non-invasive indices of lipid peroxidation *in vivo*. *Atherosclerosis, 147:*1–10.

Preparatory Commission. 1996. *Comprehensive-Nuclear-Test-Ban Treaty (CTBT)*. Preparatory Commission for the CTBT Organization, Provisional Technical Secretariat, Vienna, Italy.

Presidential/Congressional Commission on Risk Assessment and Risk Management. 1997. *Framework for Environmental Health Risk Management*. Washington, D.C.

Presidential/ Congressional Commission on Risk Assessment and Risk Management. 1997. *Symposium on a public health approach to environmental protection*. Presidential/ Congressional Commission on Risk Assessment and Risk Management, Washington, DC, U.S.A. 17 pp.

Receveur, O., M. Boulay, C. Mills, W. Carpenter, and H. Kuhnlein. 1996. *Variance in Food Use in Dene/Métis Communities*. Centre for Indigenous Peoples' Nutrition and Environment (CINE), McGill University, Montreal, Québec, Canada. October.

Receveur, O., M. Boulay, and H.V. Kuhnlein. 1997. Decreasing traditional food use affects diet quality for adult Dene/Métis in 16 communities of the Canadian Northwest Territories. *J. Nutr., 127(11):* 2179–2186.

Receveur, O., N. Kassi, H.M. Chan, P.R. Berti, and H.V. Kuhnlein. 1998a. *Yukon First Nations Assessment of Dietary Benefit/Risk*. Centre for Indigenous Peoples' Nutrition and Environment (CINE), McGill University, Montreal, Québec, Canada. pp. 160. May.

Receveur, O., H.V. Kuhnlein, Dene Nation and Métis Nation (NWT). 1998b. Benefits of traditional food in Dene/Métis communities. *Internat. J. Circump. Health, 57(Suppl.):*219–221.

Reuber, M.D. 1979. Carcinogenicity of toxaphene: a review. *J. Toxicol. Environ. Health 5:*729–748.

Rice, C.P. and M.S. Evans. 1984. Toxaphene in the Great Lakes. In: *Toxic contaminants in the Great Lakes*. J.O. Nriagu and M.S. Simmons (eds.). John Wiley, New York, U.S.A. pp. 163–194.

Ridington, R. 1988. *Trail to heaven: Knowledge and Narrative in a Northern Native Community*. Douglas and McIntyre, Vancouver, British Columbia, Canada.

Rogan, W., B.C. Gladen, J.D. McKinney, N. Carreras, P. Hardy, J. Thullen, J. Tinglestad, and M. Tully. 1986a. Neonatal effects of transplacental exposure to PCBs and DDE. *J. Pediatr., 109(2):*335–341.

Rogan,W., B.C. Gladen, J.D. McKinney, N. Carreras, P. Hardy, J. Thullen, J. Tinglestad, and M. Tully. 1986b. Polychlorinated biphenyls (PCBs) and dichlorodiphenyl dichloroethene (DDE) in human milk: Effects of maternal factors and previous lactation. *Am.J. Public Health, 76(2):*172–177.

Rogan, W., B.C. Gladen, K. Hung, S. Koong, and L. Shih. 1988. Congenital poisoning by polychlorinated biphenyls and their contaminants in Taiwan. *Science, 241:*334–336.

Rogan, W. and B.C. Gladen. 1991. PCBs, DDE, and child development at 18 and 24 months. *Ann. Epidemiol., 1*:409–413.

Rowland, I.R., R.D. Robinson, and R.A. Doherty. 1984. Effects of diet on mercury metabolism and excretion in mice given methylmercury: Role of gut flora. *Arch. Environ. Health., 39(6)*:401–408.

Rylander, L., U. Stromberg, and L. Hagmar. 1995. Decreased birthweight among infants born to women with a high dietary intake of fish contaminated with persistent organochlorine compounds. *Scand. J. Work Environ. Health, 21(5):*368–375.

Saleh, M.A. 1991. *Toxaphene: Chemistry, biochemistry, toxicity, and environmental fate*. Reviews of Environmental Contamination and Toxicology. Springer-Verlag, New York Inc., New York, NY, U.S.A. Vol. 118. 85 pp.

Salonen, J.T., G. Alfthan, J.K. Huttunen, J. Pikkarainen, and P. Puska. 1982. Association between cardiovascular death and myocardial infarction and serum selenium in a matched-pair longitudinal study. *Lancet, 2(8291):* 175–179.

Salonen, J.T., K. Seppanen, K. Nyyssonen, H. Korpela, J. Kauhanen, M. Kantola, J. Tuomilehto, H. Esterbauer, F. Tatzber, and R. Salonen. 1995. Intake of mercury from fish, lipid peroxidation, and the risk of myocardial infarction and coronary, cardiovascular and any death in Eastern Finnish men. *Circulation, 91:*645–655.

Sandau, C.D., P. Ayotte, É. Dewailly, J. Duffe, and R.J. Norstrom. 2000. Analysis of hydroxylated metabolites of PCBs (OH-PCBs) and other chlorinated phenolic compounds in whole blood from Canadian Inuit. *Environ. Health Perspect., 108:*611–616.

Sandau, C.D., P. Ayotte, É. Dewailly, J. Duffe, and R.J. Norstrom. 2002. PCP and hydroxylated-PCB metabolites in umbilical cord plasma of neonates from coastal populations in Québec. *Environ. Health Perspect., 110:*411–417.

Santé Québec. 1994. *Santé Québec: A Health Profile of the Inuit*. J. Jetté (ed.). Ministère de la Santé et des Services Sociaux. Gouvernement du Québec, Montreal, Québec, Canada. 271 pp.

Santé Québec. 1995. *Report on the Sante Québec Health Survey among the Inuit of Nunavik, 1992: Diet a health determining factor*. Ministère de la Santé et des Services Sociaux. Gouvernement du Québec, Montreal, Québec, Canada.

Sarafian, T. and M.A. Verity. 1991. Oxidative mechanisms underlying methyl mercury neurotoxicity. *Int. J. Dev. Neurosci., 9(2):*147–153.

SCC (Standards Council of Canada). 2000. *General Requirements for the Competence of Testing and Calibration Laboratories*. ISO/IEC 17025:1999. SCC, CAN-P-4D. March.

Schaefer, O. and J. Steckle. 1980. *Dietary Habits and Nutritional Base of Native Populations of the Northwest Territories*. Science Advisory Board of the Northwest Territories. Government of the Northwest Territories, Yellowknife, Northwest Territories, Canada. 37 pp.

Schmitt, C.J., J.L. Ludke, and D.F. Walsh. 1981. Organochlorine residues in fish: National pesticide monitoring program, 1970-74. *Pesticides Monitoring J., 14:*136-155.

Schuur, A.G., F.F. Legger, M.E. van Meeteren, M.J. Moonen, I. van Leeuwen-Bol, A. Bergman, T.J. Visser, and A. Brouwer. 1998. *In vitro* inhibition of thyroid hormone sulfation by hydroxylated metabolites of halogenated aromatic hydrocarbons. *Chem. Res. Toxicol., 11:*1075–1081.

Schwartz, P.M., S.W. Jacobson, G. Fein, J.L. Jacobson, and H.A. Price. 1983. Lake Michigan fish consumption as a source of polychlorinated biphenyls in human cord serum, maternal serum, and milk. *Am. J. Public Health, 73(3):*293–296.

Semba, R.D., Muhilal, B.J. Ward, D.E. Griffin, A.L. Scott, G. Natadisastra, K.P. West Jr., and A. Sommer. 1993. Abnormal T-cell subset proportions in vitamin-A-deficient children. *Lancet, 341:*5–8.

Semba, R.D. 1994. Vitamin A, immunity, and infection. *Clin. Infect. Dis., 19:*489–499.

Sharma, M. and P. Bhatnagar. 1996. Organochlorine pesticides and preterm labour in human beings. *Curr. Sci., 71(8):*628–631.

Sherbin, I.G. 1979. *Mercury in the Canadian Environment*. Economic and technical review report E.P.S. 3-EC-79-6. Environmental Protection Service, Environment Canada, Ottawa, Ontario, Canada.

Shimizu, Y., D.A. Pierce, D.L. Preston, and K. Machuchi. 1999. Studies of mortality of atomic bomb survivors. Report 12, Part II. Non-cancer mortality: 1950–1990. *Radiation Research 152*:374–389.

Shmidt, E.B., H.A. Skou, J.H. Christensen, and J. Dyerberg. 2000. N-3 fatty acids from fish and coronary artery disease: implications for public health. *Public Health Nutrition, 3(1):*91–98.

Simoneau, N. and O. Receveur. 2000. Attributes of vitamin A and calcium-rich food items consumed in K'asho Got'ine, Northwest Territories, Canada. *J. Nutr. Educ., 32:*84-93.

Simopoulos, A.P. 1991. Omega-3 fatty acids in health and disease and in growth in development. *Am. J. Clin. Nutr., 54*:438–463.

Sjödin, A., L. Hagmar, E. Klasson-Wehler, J. Björk, and A. Bergman. 2000. Neutral and phenolic organohalogen contaminants in human plasma related to intake of Baltic fish. *Environ. Health Perspect., 108(11):*1035–1041.

Slim, R., M. Toborek, L.W. Robertson, and B. Hennig. 1999. Antioxidant protection against PCB-mediated endothelial cell activation. *Toxicol. Sci., 52(2):* 232–239.

Slim, R., B.D. Hammock, M. Toborek, L.W. Robertson, J.W. Newman, C.H.P. Morisseau, B.A. Watkins, V. Saraswathi, and B. Hennig. 2001. The role of methyl-linoleic acid epoxide and diol metabolites in the amplified toxicity of linoleic acid and polychlorinated biphenyls to vascular endothelial cells. *Toxicol. Appl. Pharmacol., 171(3):*184–193.

Slovic, P. 1987. Perception of risk. *Science, 236:*280–285.

Slovic, P. and E. Peters. 1995. *The role of affect and world views as orienting dispositions in the perception and acceptance of nuclear power*. Decision Research, Eugene, Oregon, U.S.A.

Snider, J. and U. Gill. 2001. *Unpublished results*. Health Canada, Ottawa, Ontario.

Sommer, A. and K.P. West. 1996. *Vitamin A Deficiency: Health, Survival, and Vision*. Oxford University Press, New York, U.S.A.

Statistics Canada. 2002. Profile of Canada's Aboriginal Population. Custom Database (Adapted from 1996 data). Ottawa, Ontario, Canada.

Stephens, G., and L. Chan. 2001. Risk Characterization of Arsenic Exposure from Consumption of Berries in the Akaitcho Territory. In: *Synopisis of Research Conducted under the 2000–2001 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development. Ottawa, Ontario, Canada. pp. 271–273.

Stern, G.A., D.C.G. Muir, C.A. Ford, N.P. Grift, É. Dewailly, T.F. Bidleman, and M.D. Walla. 1992. Isolation and identification of two major recalcitrant toxaphene congeners in aquatic biota. *Environ. Sci. Technol., 26(9):*1838–1840.

Steuerwald, U., P. Weihe, P.J. Jorgensen, K. Bjerve, J. Brock, B. Heinzow, E. Budtz Jorgensen, and P. Grandjean. 2000. Maternal seafood diet, methylmercury exposure, and neonatal neurologic function. *J. Pediatr., 136(5):*599–605.

Stewart, P., T. Darvill, E. Lonky, J. Reihman, J. Pagano, and B. Bush. 1999. Assessment of prenatal exposure to PCBs from maternal consumption of Great Lakes fish: an analysis of PCB pattern and concentration. *Environ. Res., 80(2 Pt2):*S87–S96.

Stewart, P., J. Reihman, E. Lonky, T. Darvill, and J. Pagano. 2000. Prenatal PCB exposure and neonatal behavioural assessment scale (NBAS) performance. *Neurotoxicol. Teratol., 22:*21–29.

Stiles M. and P.J. Usher 1998. *A Guide to Making Presentations in Northern Communities for the Northern Contaminants Program*. Minister of Indian Affairs and Northern Development, Ottawa, Ontario, Canada.

Stokker, Y.D. and G. Gomes. 1999a. *Summary Report of the Analytical Programs and Capabilities of Laboratories and Organizations That Contribute Measurement Data to the Northern Contaminants Program*. NWRI Contribution No. 99–302.

Stokker, Y.D. and G. Gomes. 1999b. *Summary Report on the Availability and Suitability of External National and International Quality Assurance Programs Pertinent to the Northern Contaminants Program*. NWRI Contribution No. 99–301.

Stokker, Y.D. 2002. *Personal communication*. Environment Canada, Burlington, Ontario, Canada.

Sumino, K., R. Yamamoto, and S. Kitamura. 1977. Role of selenium against methyl mercury toxicity. *Nature, 268:*73–74.

Suzuki, C.A.M., S.L. Hierlihy, F. Iverson, M.G. Barker, K. Krishnan, and H.M. Chan. 1998. *Toxicity of organochlorine mixtures commonly found in the Inuit diet in female Sprague-Dawley rats*. Abstract presented at the 31st Annual Symposium of the Society of Toxicology of Canada, Montreal, Québec, Canada. December.

Szathmary, E.J.E., C. Ritenbaugh, and C.S.M. Goodby. 1987. Dietary change and plasma glucose levels in an Amerindian population undergoing cultural transition. *Soc. Sci. Med., 24(10):*791–804.

Tardif, R., G. Charest-Tardif, J. Brodeur, and K. Krishnan. 1997. Physiologically-based pharmacokinetic modeling of a ternary mixture of alkyl benzenes in rats and humans. *Toxicol. Appl. Pharmacol., 143:*120–134.

Thomas, P.A. 1994. Dosimetry of ^{210}Po in caribou, wolves and humans in northern Canada. *Health Physics, 66(6):*678–690.

Thomas P.A., I. Fisenne, D. Chorney, A.S. Baweja, and B.L. Tracy. 2001. Human absorption and retention of polonium-210 from caribou meat. *Radiat. Prot. Dosimetry, 97:*241-250.

Thouez, J.P., A. Rannou, and P. Foggin. 1989. The other face of development: Native population, health status, and indicators of malnutrition — the case of the Cree and Inuit of northern Québec. *Soc. Sci. Med., 29(8):*965–974.

Toborek, M., S.W. Barger, M.P. Mattson, P. Espandiari, L.W. Robertson, and B. Hennig. 1995. Exposure to polychlorinated biphenyls causes endothelial cell dysfunction. *J. Biochem. Toxicol., 10(4):*219–226.

Tofflemire, K. 2000. *Inuvik Regional Human Contaminants Monitoring Program: Regional Report*. IRHSSB, Inuvik. July. pp. 38.

Tracy, B.L., G.H. Kramer, J.M. Zielinski, and H. Jiang. 1997. Radiocesium body burdens in residents of northern Canada from 1963–1990. *Health Phys., 72(3):*431–442.

Tracy, B.L. and G.H. Kramer. 2000. A method for estimating caribou consumption by northern Canadians. *Arctic, 53(1):*42–52.

Tracy, B.L. 2001. *Personal communication*. Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario.

Tryphonas, H., F. Bryce, J. Huang, F. Lacroix, M. Hodgen, D.T. Ladouceur, and S. Hayward. 2000. Effects of toxaphene on the immune system of cynomolgus (*Macaca fascicularis*) monkeys: A pilot study. *Food Chem. Toxicol., 38:*25–33.

Tryphonas, H., D.L. Arnold, F. Bryce, J. Huang, M. Hodgen, D.T. Ladouceur, S. Fernie, M. Lepage-Parenteau, and S. Hayward. 2001. Effects of toxaphene on the immune system of cynomolgus (Macaca fascicularis) monkeys. *Food Chem. Toxicol., 39(9):*947–958

Tryphonas, H., G. Bondy, M. Hodgen, L. Coady, M. Parenteau, C. Armstrong, S. Hayward, and V. Liston. 2002. Effects of *cis*-nonachlor, *trans*-nonachlor and chlordane on the immune system of Sprague-Dawley rats following a 28-day oral (gavage) treatment. Submitted.

Twaroski, T.P., M.L. O'Brien, N. Larmonier, H.P. Glauert, and L.W. Robertson. 2001. Polychlorinated biphenyl-induced effects on metabolic enzymes, AP-1 binding, vitamin E, and oxidative stress in the rat liver. *Toxicol. Appl. Pharmacol., 171(2):*85–93.

UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). 1993. *Sources and Effects of Ionizing Radiation*. UNSCEAR. United Nations, New York, U.S.A.

US EPA (United States Environmental Protection Agency). 1997. *Guidance for cumulative risk assessment. Part 1. Planning and scoping*. Washington, DC. (available at http://www.epa.gov/brownfields/pdf/cumrisk2.pdf)

US EPA (Integrated Risk Information System). 1998. *Chlordane (technical)*. CASRN 12789-03-6. Washington, DC. (available at http://www.epa.gov/iriswebp/iris/subst/0142.htm)

Usher, P.J. and G. Wenzel. 1989. Socio-economic aspects of harvesting. In: *Keeping on the Land: A Study of the Feasibility of a Comprehensive Wildlife Support Programme in the Northwest Territories*. R. Ames, D. Axford, P.J. Usher, E. Weick, and G. Wenzel (eds.). Canadian Arctic Resources Committee, Ottawa, Ontario, Canada.

Usher, P., M. Baikie, M. Demmer, D. Nakashima, M.G. Stevenson, and M. Stiles. 1995. *Communicating about Contaminants in Country Food: The Experience in Aboriginal Communities*. Research Department, Inuit Tapirisat of Canada. Ottawa, Ontario, Canada. January.

US NRC (United States National Research Council). 1989. *Diet and Health: Implications for Reducing Chronic Disease Risk*. National Academy Press, Washington, DC, U.S.A.

US NRC. 1992. *Biological Markers in Immunotoxicology*. National Academy Press, Washington, DC, U.S.A.

US NRC. 2000. *Toxicological Effects of Methylmercury*. National Academy Press, Washington, DC, U.S.A.

Van den Berg, K.J. 1990. Interaction of chlorinated phenols with thyroxine binding sites of human transthyretin, albumin and thyroid binding globulin. *Chem.-Biol. Interactions, 76:*63–75.

Van den Berg, K.J., J.A. van Raaij, P.C. Bragt, and W.R. Notten. 1991. Interactions of halogenated industrial chemicals with transthyretin and effects on thyroid hormone levels *in vivo*. *Arch. Toxicol., 65:*15–19.

Van den Berg, M., L. Birnbaum, A.T.C. Bosveld, B. Brunström, P. Cook, M. Feeley, J.P. Giesy, A. Hanberg, R. Hasegawa, S.W. Kennedy, T. Kubiak, J.C. Larsen, F.X.R. van Leewen, A.K.D. Liem, C. Nolt, R.E. Peterson, L. Poellinger, S. Safe, D. Schrenk, D. Tillitt, M. Tysklind, M. Younes, F. Wærn, and T. Zacharewski. 1998. Toxic equivalency factors (TEFS) for PCBs, PCDDs, PCDFs for humans and wildlife. *Environ. Health Perspect., 106(12):*775–792.

Van Loveren, H., D. Germolec, H.S. Koren, M.I. Luster, C. Nolan, and R. Repetto. 1999. Report of the Bilthoven Symposium: Advancement of epidemiological studies in assessing the human health effects of immunotoxic agents in the environment and the workplace. *Biomarkers, 4(2):*135–57.

Van Oostdam, J., A. Gilman, É. Dewailly, P. Usher, B. Wheatley, H. Kuhnlein, S. Neve, J. Walker, B. Tracy, M. Feeley, V. Jerome, and B. Kwavnick. 1999. Human Health Implications of Environmental Contaminants in Arctic Canada: A Review. *Sci. Total Environ., 230:*1–82.

Van Oostdam, J. 2001. *Personal communication*. Health Canada, Ottawa, Ontario, Canada.

Van Oostdam, J., N. Tremblay, J. Walker, E. McMullen, and S. Smith. 2001. Contaminants in cord blood and relationship to maternal blood levels in the Northwest Territories and Nunavut, Canada: 1994–1999. *Epidemiology, 12(4):*S80 (ISEE 428).

Van Oostdam, J. and M. Feeley. 2002. *Personal communication*. Health Canada, Ottawa, Ontario, Canada.

Vetter, W. 1993. Toxaphene. Theoretical aspects of the distribution of chlorinated bornanes including symmetrical aspects. *Chemosphere, 26(6):*1079–1084.

Vetter, W. and M. Oeheme. 2000. Toxaphene. Analysis and environmental fate of congeners. In: *New types of persistent halogenated compounds*. J. Paasivirta (ed.) Springer-Verlag, New York, NY, U.S.A. pp. 237–287.

Wagemann, R., E. Trebacz, R. Hunt and G. Boila. 1997. Percent methylmercury and organic mercury in tissues of marine mammals and fish using different experimental and calculation methods. *Environ. Toxicol. Chem., 16(9):*1859–1866.

Walker, J., J. Van Oostdam, and E. McMullen. 2001. *Human Contaminant Trends in Arctic Canada: Northwest Territories and Nunavut Environmental Contaminants Exposure Baseline. Final Technical Report*. Department of Health and Social Services, Government of the Northwest Territories.

Ward, J.I. and M.K. Lum, D.B. Hall, D.R. Silimperi, and T.R. Bender. 1986. Haemophilus influenzae type b disease in Alaska: background epidemiology for a vaccine efficacy trial. *J. Infect. Dis., 153(1):*17–26.

Watanabe, C., K. Yin, Y. Kasanuma, and H. Satoh. 1999. *In utero* exposure to methylmercury and Se deficiency converge on the neurobehavioral outcome in mice. *Neurotoxicol. Teratol., 21*:83–89.

Weber, J-P. 2002. The AMAP Ring Test: A Laboratory Intercomparison Program for POPs in Human Serum. Presented at the *AMAP Conference and Workshop: Impacts of POPs and Mercury on Arctic Environments and Humans*, Tromsø, Norway. January.

Wein, E.E. and M.M.R. Freeman. 1992. Inuvialuit food use and food preferences in Aklavik, NWT, Canada. *Arctic Med. Res., 51(4)*:159–172.

Wein, E.E. 1995. *Sanikiluaq Traditional Food Study Report*. Canadian Circumpolar Institute, University of Alberta, Edmonton, Alberta, Canada. 58 pp.

Wein, E. E., M.M. Freeman, and J.C. Makus. 1998. Preliminary assessment of nutrients in daily diets of a sample of Belcher Island Inuit adults. *Int. J. Circump. Health, 57(1)*:205–210.

Weinstein, M.S., 1976. What the land provides: An examination of the Fort George subsistence economy and the possible consequences on it of the James Bay hydroelectric project eds. Grand Council of the Crees (eds.). Montreal, Québec, Canada. pp. 255.

Weisburger, J.H. 2000. Approaches for chronic disease prevention based on current understanding of underlying mechanisms. *Am. J. Clin. Nutr. 71(Suppl.)*:1710S–1714S.

Weisglas-Kuperus, N., T.C. Sas, C. Koopman-Esseboom, C.W. van der Zwan, M.A. De Ridder, A. Beishuizen, H. Hooijkaas, and P.J. Sauer. 1995. Immunologic effects of background prenatal and postnatal exposure to dioxins and polychlorinated biphenyls in Dutch infants. *Pediatr. Res., 38(3):*404–410.

Weisglas-Kuperus, N., S. Patandin, G.A.M. Berbers, T.C.J. Sas, P.G.H. Mulder, P.J.J. Sauer, and H. Hooijkaas. 2000. Immunologic effects of background exposure to polychlorinated biphenyls and dioxins in Dutch preschool children. *Environ. Health Perspect., 108(12):*1203–1207.

Wenzel, G.W. and E. Qillaq. 2000. Inuit response to environmental contaminants information: the Cape Christian-Clyde River case. In: *Synopsis of Research Conducted under the 1999-2000 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 301–307.

Whanger, P.D. 1992. Selenium in the treatment of heavy metal poisoning and chemical carcinogenesis. *J. Trace Elem. Electrol. Health. Dis., 6:*209–221.

Wheatley, B., A. Barbeau, T.W. Clarkson, and L.W. Lapham. 1979. Methylmercury Poisoning in Canadian Indians —The Elusive Diagnosis. *J. Can. Sci. Neurol., 6:*417–422.

Wheatley, B. 1994. A new approach to assessing the effects of environmental contaminants on Aboriginal peoples. *Arc. Med. Res., 53(suppl.)2:*386–390.

Wheatley, B. and S. Paradis. 1996. Balancing human exposure, risk and reality: questions raised by the Canadian Aboriginal Methylmercury Program. *Neurotoxicology, 17(1):*241–249.

Wheatley, B. and S. Paradis. 1998. Northern exposure: Further analysis of the results of the Canadian Aboriginal Methylmercury Program. *International J. Circump. Health, 57(Suppl.)1:*586–590.

Wheatley, B. and M.A. Wheatley. 2000. Methylmercury and the health of indigenous peoples: a risk management challenge for physical and social sciences and for public health policy. *Sci. Total Environ., 259:*1–3, 23–29.

Wheatley, M.A. and B. Wheatley. 1981. The effect of eating habits on mercury levels among Inuit residents of Sugluk, P.Q. *Etudes/Inuit Studies, 5(1):*27:43.

Wheatley, M.A. 1996. The Importance of Social and Cultural Effects of Mercury on Aboriginal Peoples. *Neurotoxicology, 17(1):*251–256.

White, K.L.J., H.H. Lysy, and J.A. McKay. 1986. Modulation of serum complement levels following exposure to polychlorinated dibenzo-*p*-dioxins. *Toxicol. Appl. Pharmacol., 84:*209–219.

WHO (World Health Organization). 1990. Methyl Mercury. *Environ. Health Criteria, 101:*144.

Williamson, T. 1997. From Sina to Sikujaluk: Our Footprint: Mapping Inuit Environmental Knowledge in the Nain District of Northern Labrador. Report prepared by T. Williamson for the Labrador Inuit Association. Labrador Inuit Association, Nain, Labrador, Canada.

Wong, M. 1986. *Chemical Residues in Fish and Wildlife Harvested in Northern Canada, Environmental Studies, No. 46*. Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada.

Wong, T., R.B. Everson, and S. Hsu. 1985. Potent induction of human placental mono-oxygenase activity by previous dietary exposure to polychlorinated biphenyls and their thermal degradation products. *Lancet, 1:*721–724.

World Cancer Research Fund, American Institute for Cancer Research. 1997. *Food, Nutrition and the Prevention of Cancer: A Global Perspective*. American Institute for Cancer Research, Washington, DC, U.S.A. 670 pp.

Yamashita, F. 1977. Clinical features of polychlorobiphenyl (PCB)-induced fetopathy. *Paediatrician, 6:*20–27.

Yamashita, S. and Y. Yamamoto. 1997. Simultaneous detection of ubiquinol and ubiquinone in human plasma as a marker of oxidative stress. *Anal. Biochem., 250:*66–73.

Yee, S. and B.H. Choi. 1996. Oxidative stress in neurotoxic effects of methylmercury poisoning. *Neurotoxicology, 17:*17–26.

Youden, W.J. 1959. Graphical diagnosis of interlaboratory test results. In: *Precision Measurement and Calibration, Statistical Concepts and Procedures. Vol. 1.* National Bureau of Standards Special Publication 300, Washington, DC, U.S.A. pp. 133–137.

Young T.K.,1993. *Diabetes mellitus* among native americans in Canada and United States: An epidemiological review. *Am. J. Hum. Biol., 5:*399–413.

Young T.K, M.E.K. Moffat, and J.D. O'Neil, 1993. Cardiovascular diseases in a Canadian Arctic population. *Am. J. Public Health*, 83:881–887.

Zile, M.H. 1992. Vitamin A homeostasis endangered by environmental pollutants. *Proc. Soc. Exp. Biol. Med., 201*:141–153.

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Appendix 1 —
List of Acronyms and Selected Symbols Used Throughout this Report

The following is not an extensive glossary, but is intended to serve as a quick reference to the numerous acronyms and symbols used in this report.

AHH
aryl hydrocarbon hydroxylase

AhR
aryl hydrocarbon receptor

AM
arithmetic mean

AMAP
Arctic Monitoring and Assessment Programme

ATSDR
Agency for Toxic Substances and Disease Registry

β-HCH
beta-hexachlorocyclohexane

BMI
body mass index

BUA
broadband ultrasound attenuation

CACAR
Canadian Arctic Contaminants Assessment Report

Cd
cadmium

CHD
coronary heart disease

CI
confidence interval

CINE
Centre for Indigenous Peoples' Nutrition and Environment

CRM
certified reference materials

Cs
cesium

CTQ
Centre de Toxicologie du Québec

CVD
cardiovascular disease

CYP 1A1
Cytochrome P450 1A1

DIAND
Department of Indian Affairs and Northern Development

DDE
dichlorodiphenyl dichloroethylene

DDT
dichlorodiphenyltrichloroethane

DHA
docosahexaenoic acid

DHEA
dehydroepiandrosterone

DHT
dihydrotestosterone

DNA
deoxyribonucleic acid

EPA
Environmental Protection Agency (US)

EROD
ethoxyresorufin-O-deethylase

FAO
Food and Agriculture Organisation (United Nations)

FNIHB
First Nations and Inuit Health Branch

GD
gestation day

GNWT
Government of the Northwest Territories

GM
geometric mean

GSHPx
glutathione peroxidase

GSHRd
glutathione reductase

HCB
hexachlorobenzene

Hg
mercury

ICP-MS
inductively-coupled plasma mass spectrometry

ICRP
International Commission on Radiological Protection

ITC
Inuit Tapirisat of Canada (now ITK)

ITK
Inuit Tapiriit Kanatami

LDL
low-density lipoprotein

LOAEL
lowest-(observed)-adverse-effect-level

MeHg
methylmercury

MW
molecular weight

MRL
minimum risk level

mSv/yr
millisieverts per year

NCP
Northern Contaminants Program

NK
natural killer

NOEL
no-observed-effect-level

NOAEL
no-(observed)-adverse-effect-level

NRC
National Research Council

NWT
Northwest Territories

OC
organochlorine

OEDC
Organization for Economic Cooperation and Development

Pb
lead

PBPK
physiologically based pharmacokinetic

PBTK
physiologically based toxicokinetic

PCBs
polychlorinated biphenyls

PCDFs
polychlorinated dibenzofurans

PCP
pentachlorophenol

PDI
probable daily intake

Po
polonium

POP
persistent organic pollutant

ppm
parts per million (10^{-6})

ppb
parts per billion (10^{-9})

pTDI
provisional tolerable daily intake

pTWI
provisional tolerable weekly intake

PUFA
polyunsaturated fatty acids

QA
quality assurance

QC
quality control

RCC
Regional Contaminants Coordinators

RfD
reference dose

RM
reference materials

ROS
reactive oxygen species

RR
relative risk

Se
selenium

SOS
speed of sound

SSC
Standards Council of Canada

T3
triiodothyronine

T4
thyroxine

TBARS
thiobarbiturate reactive substances

TBG
thyroxin-binding globulin

TCDD-TEQ
dioxins and furans and dioxin-like PCBs

TDI
tolerable daily intake

TEF
toxicity equivalency factors

TEQ
toxic equivalents

TSH
thyroid stimulating hormone

TTR
transthyretin

UNSCEAR
United Nations Scientific Committee on the Effects of Atomic Radiation

US EPA
United States Environmental Protection Agency

WHO
World Health Organisation