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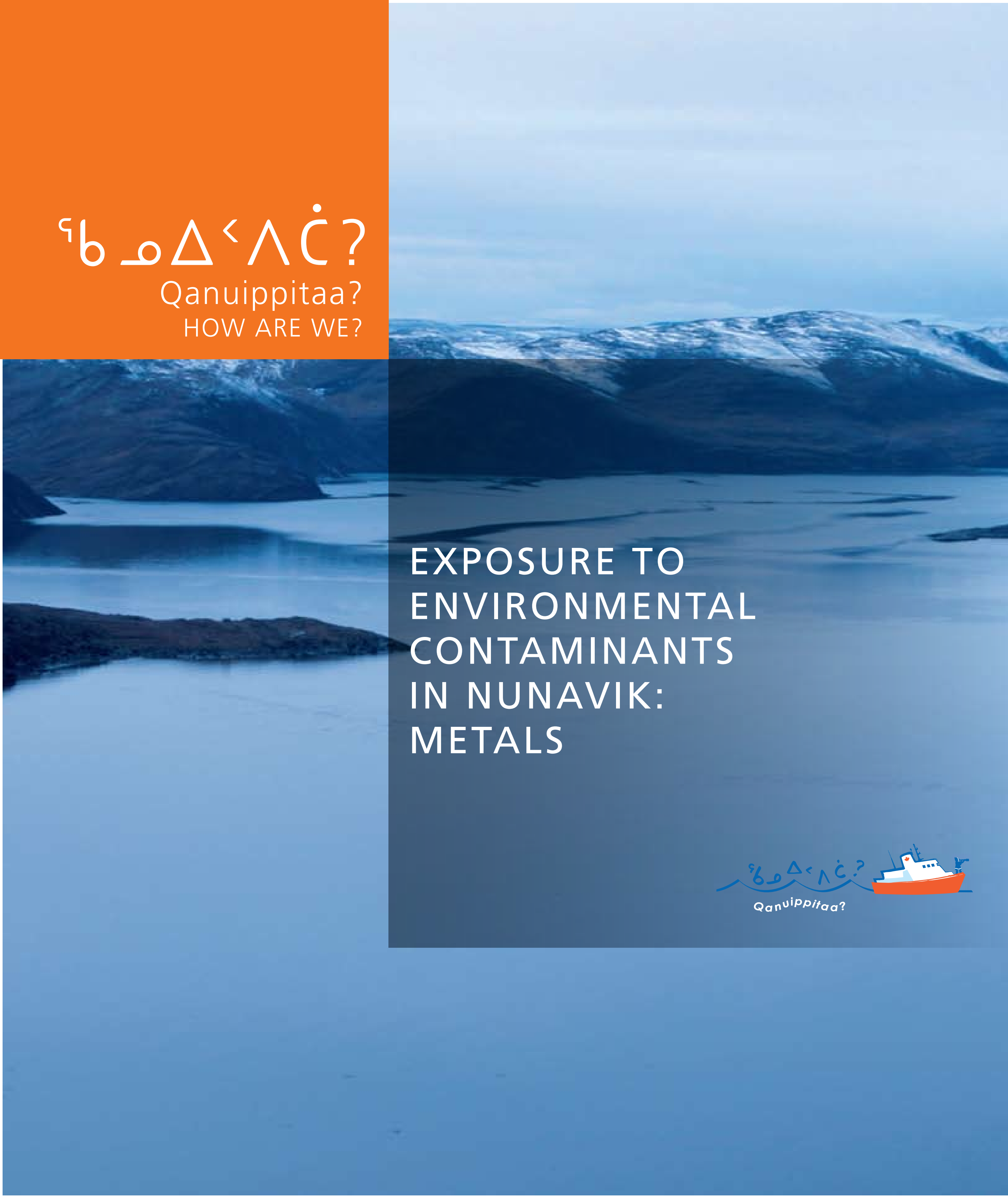

EXPOSURE TO ENVIRONMENTAL CONTAMINANTS IN NUNAVIK: METALS

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EXPOSURE TO ENVIRONMENTAL CONTAMINANTS IN NUNAVIK: METALS

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BACKGROUND OF THE NUNAVIK INUIT HEALTH SURVEY

The monitoring of population health and its determinants is essential for the development of effective health prevention and promotion programs. More specifically, monitoring must provide an overall picture of a population's health, verify health trends and how health indicators vary over distance and time, detect emerging problems, identify priority problems, and develop possible health programs and services that meet the needs of the population studied.

The extensive survey conducted by Santé Québec in Nunavik in 1992 provided information on the health status of the Nunavik population (Santé Québec, 1994). The survey showed that health patterns of the population were in transition and reflected important lifestyle changes. Effectively, the Inuit population has undergone profound sociocultural, economic, and environmental changes over the last few decades. The Inuit have changed their living habits as contact with more southerly regions of Quebec increased. A sedentary lifestyle, the switch to a cash-based domestic economy, the modernization of living conditions and the increasing availability and accessibility of goods and foodstuffs imported from southern regions have contributed to these changes. These observations suggest the need for periodic monitoring of health endpoints of Nunavik Inuit to prevent the negative impact of risk factor emergence and lifestyle changes on subsequent morbidity and mortality from major chronic diseases.

In 2003, the Nunavik Regional Board of Health and Social Services (NRBHSS) decided to organize an extensive health survey in Nunavik in order to verify the evolution of health status and risk factors in the population. The NRBHSS and the Ministère de la Santé et des Services sociaux (MSSS) du Québec entrusted the Institut national de santé publique du Québec (INSPQ) with planning, administering and coordinating the survey. The INSPQ prepared the survey in close collaboration with the Unité de recherche en santé publique (URSP) of the Centre hospitalier universitaire de Québec (CHUQ) for the scientific and logistical component of the survey. The Institut de la statistique du Québec (ISQ) participated in methodology development, in particular the survey design.

The general aim of the survey was to gather social and health information on a set of themes including various health indicators, physical measurements, and social, environmental and living conditions, thus permitting a thorough update of the health and well-being profile of the Inuit population of Nunavik. The survey was designed to permit a comparison of the 2004 trends with those observed in 1992. Data collected in 2004 also allowed researchers to compare the Inuit to other Quebecers.

Target population

The health survey was conducted among the Inuit population of Nunavik from August 27 to October 1, 2004. According to the 2001 Canadian census, the fourteen communities of Nunavik have a total of 9632 inhabitants, 91% of whom identified themselves as Inuit. The target population of the survey was permanent residents of Nunavik, excluding residents of collective dwellings and households in which there were no Inuit aged 18 years old or older.

Data collection

Data collection was performed on the Canadian Coast Guard Ship Amundsen, thanks to a grant obtained from the Canadian Foundation for Innovation (CFI) and the Network of Centres of Excellence of Canada (ArcticNet). The ship visited the fourteen villages of Nunavik, which are coastal villages. The study was based on self-administered and interviewer-completed questionnaires. The study also involved physical and biological measurements including clinical tests. The survey was approved by the Comité d'éthique de la recherche de l'Université Laval (CERUL) and the Comité d'éthique de santé publique du Québec (CESP). Participation was voluntary and participants were asked to give their written consent before completing interviews and clinical tests. A total of 677 private Inuit households were visited by interviewers who met the household respondents to complete the identification chart and the household questionnaire. A respondent was defined as an Inuit adult able to provide information regarding every member of the household. The identification chart allowed demographic information to be collected on every member of the household. The household questionnaire served to collect information on housing, environment, nutrition and certain health indicators especially regarding young children.

All individuals aged 15 or older belonging to the same household were invited to meet survey staff a few days later, on a Canadian Coast Guard ship, to respond to an interviewer-completed questionnaire (individual questionnaire) as well as a self-administered confidential questionnaire. Participants from 18 to 74 years of age were also asked to complete a food frequency questionnaire and a 24-hour dietary recall, and to participate in a clinical session. The individual questionnaire aimed to collect general health information on subjects such as health perceptions, women's health, living habits and social support. The confidential questionnaire dealt with more sensitive issues such as suicide, drugs, violence and sexuality. During the clinical session, participants were invited to answer a nurse-completed questionnaire regarding their health status. Then, participants had a blood sample taken and physical measurements were performed including a hearing test, anthropometric measurements, an oral glucose tolerance test (excluding diabetics) and toenail sampling. Women from 35 to 74 years of age were invited to have a bone densitometry test. Finally, participants aged 40 to 74 could have, after consenting, an arteriosclerosis screening test as well as a continuous measure of cardiac rhythm for a two-hour period.

Survey sampling and participation

The survey used a stratified random sampling of private Inuit households. The community was the only stratification variable used. This stratification allowed a standard representation of the target population. Among the 677 households visited by the interviewers, 521 agreed to participate in the survey. The household response rate is thus 77.8%. The individual response rates are obtained by multiplying the household participating rate by the individual collaboration rate since the household and individual instruments were administered in sequence. The collaboration rate corresponds to the proportion of eligible individuals who agreed to participate among the 521 participating households. In this survey, about two thirds of individuals accepted to participate for a response rate in the area of 50% for most of the collection instruments used in the survey. A total of 1056 individuals signed a consent form and had at least one test or completed one questionnaire. Among them, 1006 individuals answered the individual questionnaire, 969 answered the confidential questionnaire, 925 participated in the clinical session, 821 had a hearing test, 778 answered the food frequency questionnaire, 664 answered the 24-hour dietary recall, 282 had an arteriosclerosis test, 211 had a continuous measure of their cardiac rhythm for a two-hour period and 207 had a bone densitometry test. More details on the data processing are given in the Methodological Report.

INTRODUCTION[1]

Human exposure to environmental contaminants is a well-known phenomenon in the Canadian Arctic. The Inuit of Nunavik are exposed to a plethora of toxic substances that are carried from southern to northern latitudes by oceanic and atmospheric transport and biomagnified in Arctic food webs. As the Inuit traditional diet comprises large amounts of tissues from marine mammals, fish and terrestrial wild game, the Inuit are more exposed to metals and persistent organic pollutants (POPs) than populations living in southern regions. Metals of concern include mercury (Hg), lead (Pb) and cadmium (Cd) and other contaminants of concern are persistent organic pollutants (POPs).

Mercury is an environmental contaminant originating from both anthropogenic and natural sources. Despite significant reduction in mercury emissions in Europe and North America, mercury levels are still high in the Arctic (AMAP, 2002b). Although most of the mercury released in the environment is inorganic or elemental, it can accumulate in the water where it is transformed into methyl mercury (MeHg) by microbial action. This highly toxic form of mercury is accumulated in animal tissues, especially in the liver and the kidney, and is biomagnified in the food chain (Hansen & Gilman, 2005). The most significant sources of human exposure to methyl mercury are fish and marine mammal consumption (Bjerregaard & Hansen, 2000; Dewailly et al., 2001; Grandjean et al., 1992; Hansen & Gilman, 2005; Van Oostdam et al., 2005). Methyl mercury is known to cross the blood-brain barrier and the placenta where it accumulates in fetal blood and the brain (WHO, 1990). Methyl mercury mainly affects the nervous system and can cause paresthesia, ataxia and tunnel vision in adults (ATSDR, 1999b). The effects on fetal brain development are more extensive since neuronal migration and cell division are affected by methyl mercury (Castoldi et al., 2001). Acute prenatal exposure may lead to neuronal lost and result in hyperactive reflexes, deafness, blindness, cerebral palsy, mental retardation or paralysis. Low chronic prenatal exposure like that observed in populations exposed mainly via fish consumption may still have subtle neurodevelopment consequences (Counter & Buchanan, 2004). Indeed, prenatal exposure to methyl mercury is associated with detrimental effects on memory, attention, language and visual spatial perception that appear

[1] For ease of readability, the expression "Inuit" is used throughout the theme paper to define the population under study even though a small percentage of individuals surveyed identified themselves as non-Inuit. Refer to "Background of the Health Survey" for further details regarding the definition of the target population.

later in childhood (Grandjean et al., 1997) and persist during adolescence (Debes et al., 2006). Visual information processing (Saint-Amour et al., 2006) and higher tremor amplitude (Despres et al., 2005) were shown to be affected by methyl mercury in preschool-aged Inuit children from Nunavik. Methyl mercury is also toxic to the kidney, liver, reproductive organs, and the cardiovascular system (ATSDR, 1999b).

Most of the lead in the environment comes from anthropogenic sources and is carried to the Arctic by atmospheric transport (AMAP, 2002b). It has been clearly shown that environmental levels of lead have been decreasing in Arctic regions since the ban of leaded gasoline (AMAP, 2002b; Van Oostdam et al., 2005). However, high levels of lead can still be found in Inuit populations in certain Arctic regions due to the past and/or present use of lead shots for harvesting wild game (AMAP, 2002b; Dewailly et al., 2001; Levesque et al., 2003). In 1999, the use of lead cartridges for the hunting of migratory birds was banned in Canada, and the public health authorities of Nunavik actively informed the population about lead (Levesque et al., 2003) in order to reduce lead shot use and lead exposure. Environmental exposure to lead can have detrimental neurological effects in children and adults. Peripheral neuropathies tend to be more prevalent in adults, although an accelerating decline in cognitive function was also observed (Weisskopf et al., 2004). In children, exposure to lead can have irreversible adverse effects on cognitive, behavioural and fine motor function. Blood lead concentration in Inuit children from Nunavik was associated with deficits in several fine motor tasks (Despres et al., 2005) and correlated positively with impulsivity and activity (Fraser et al., 2006). Lead can also cause kidney damage and dysfunction, anemia, intestinal dysfunction, and reproductive problems (ATSDR, 2005).

Cadmium from both anthropogenic and natural sources is released in the environment and can accumulate in lichen and vegetation (Crete et al., 1989; Nash III & Gries, 1995), which is then eaten by caribou and moose (Robillard et al., 2002). Cadmium accumulates in the soft tissues rather than in the muscle or fat and its concentration is typically higher in the kidney than in the liver (Robillard et al., 2002). However, studies have shown that human exposure to cadmium is most often attributable to tobacco smoking. The maternal cadmium level assessed in populations from the Canadian Arctic was mainly associated with tobacco use (Butler Walker et al., 2006). The major health risk associated with cadmium is nephrotoxicity (WHO, 2004). Chronic exposure can also cause anemia, disturbed calcium and vitamin D metabolism, bone loss and cardiovascular disease (ATSDR, 1999a).

Given the efforts during the past decade to reduce the global use of metals and POPs and the North Aboriginals' exposure to them, periodic re-assessments of exposure are necessary to evaluate the efficiency of implemented programs and information campaigns (i.e. ban of lead shots, earlier publicity campaigns, etc.). As several new compounds sharing properties similar to POPs are entering the Arctic environment and its food webs, it is of prime importance to assess their levels among the Inuit in order to provide up-to-date information to the population and to offer effective and viable public health advice that is respectful of the Inuits' traditional lifestyle.

METHODOLOGICAL ASPECTS

Based on this background perspective, one of the research themes in the Nunavik Inuit Health Survey 2004 addressed the following objectives: 1) to assess changes in contaminant exposure among the Inuit of Nunavik during the past decade by updating information available on contaminant levels by measuring levels in adult blood in the 2004 Nunavik Inuit Health Survey, and by comparing this information with data collected in 1992 in the Santé Québec survey; 2) to begin monitoring the emerging contaminants of concern in northern regions. In this theme paper, only results pertaining to metal exposure assessment are presented. Assessment of persistent organic pollutants (POPs) and new halogenated hydrocarbon concentrations such as PBDEs, PFOS, hydroxy-PCBs, methyl-sulfone PCBs and chlorophenols was planned in the framework of the 2004 Nunavik Inuit Health Survey and is still in progress at the human toxicology laboratory of the Institut national de santé publique du Québec. Laboratory methods and results for these contaminants will be presented in a separated thematic leaflet on POPs exposure.

Laboratory methodology for metals

Laboratory analysis for contaminants was performed at the human toxicology laboratory of the Institut national de santé publique du Québec (INSPQ). In 1992, blood mercury concentrations were determined by cold vapour atomic absorption spectrometry. This analytic method has a detection limit of 1 nmol/L. Blood lead and cadmium concentrations were measured by atomic absorption spectrometry. Detection limits were 0.05 µmol/L for lead and 0.2 µg/L for cadmium. For the 2004 Nunavik Inuit Health Survey, blood mercury, lead and cadmium concentrations were measured by ICP-MS (Inductively coupled plasma mass spectrometry) and detection limits were 0.5 nmol/L, 0.001 μmol/L and 0.4 nmol/L, respectively.

Consumption of traditional/country food

Data on food and nutrient intakes was obtained using a food frequency questionnaire and a 24-hour dietary recall. The food frequency questionnaire was administered to women and men. It measured their consumption of traditional/country food for all four seasons during the year before the survey. Traditional/country food refers to food items derived from fishing and hunting.

Statistical analysis

Descriptive statistics were performed in order to present plasma concentrations of metal concentrations in whole blood. Analyses of variance were used to assess metal concentrations according to gender, age category, ethnicity, coastal region, tobacco consumption, consumption of marine mammals, fish, caribou and game birds. Statistical analyses for comparisons have been conducted at a threshold of $\alpha = 0.05$. It should also be noted that the Nunavik territory has been divided in two regions because place of residence could influence life habits. The Hudson coast includes the villages of Kuujjuarapik, Umiujaq, Inukjuak, Puvirnituq, Akulivik, Ivujivik and Salluit while the Ungava coast includes Kangiqsujuaq, Quaqtaq, Kangirsuk, Aupaluk, Tasiujaq, Kuujjuaq and Kangiqsualujjuaq.

Some comparisons have been made with results obtained during the 1992 Santé Québec survey where the questions asked are comparable. The variation in metal levels between 1992 and 2004, stratified according to gender, age category, coastal region and tobacco consumption was compared using analysis of variance models adjusted for age and survey design. The Wald chi-square statistic with Satterthwaite correction for degrees of freedom (Aguirre-Torres, 1994) was used for this model.

RESULTS

Descriptive statistics for the blood concentrations of cadmium, mercury and lead detected among the Inuit adult population aged 18 to 74 during the 1992 Santé Québec survey and the 2004 Nunavik Inuit Health Survey are presented in Table A1 (Appendix). Statistically significant declines ($p < 0.001$) in blood levels for the three metals are observed between 1992 and 2004. Blood lead concentration shows a two-fold decrease over the 12 year period. Nevertheless, 36%, 9% and 28% of individuals have blood concentrations exceeding the acceptable level set by Health Canada for cadmium, lead and mercury, respectively (data not shown). Similarly, 35%, 2% and 72% of women of childbearing age have cadmium, lead and mercury concentrations that are also above Health Canada's recommended blood level (data not shown).

Tables A2, A3 and A4 (Appendix) show the 1992 and 2004 mean blood concentrations of metals stratified for gender, age and coastal region, respectively. Significant decreases in mean metal concentrations have occurred in both genders between the two surveys (Table A2, Appendix). In 2004, mean blood mercury levels were significantly higher in women than in men, whereas mean lead levels were higher in men. Cadmium concentrations did not vary significantly according to gender. Metal concentrations decreased for all age categories between 1992 and 2004, except for cadmium concentrations in adults aged 18 to 24, who show the highest level (Table A3, Appendix). Adults aged 45 to 74 have significantly higher levels ($p < 0.001$) of mercury and lead than younger adults. Non-natives show significantly lower blood concentrations of metals compared to Inuit ($p < 0.001$, data not shown). A significant decrease in metal levels occurred in communities along Hudson coast and Ungava coast during the 12-year period (Table A4, Appendix). In 2004, mean cadmium and mercury concentrations were significantly higher in communities along Hudson coast ($p < 0.001$), but no difference was observed between the two regions for blood lead concentration ($p = 0.187$).

Potential associations between metal blood concentrations, tobacco smoking, traditional food consumption and hunting frequency are presented in Tables A5, A6, A7 and A8 (Appendix). In 2004, mean blood cadmium concentrations in smokers were six times higher compared with ex-smokers and non-smokers ($p < 0.001$), whereas no difference in individual lead concentrations appeared according to smoking status ($p < 0.778$). Since 1992, there has been a significant decrease in cadmium and lead blood levels ($p < 0.01$) among smokers, ex-smokers and non-smokers (Table A5, Appendix), with a stronger decrease in cadmium concentrations observed in non-smokers and ex-smokers compared to smokers. Consumption of marine mammals is not associated with cadmium blood levels in simple regression analysis (data not shown). Mercury concentration increased significantly with quartiles of annual consumption of marine mammals meat ($p < 0.001$) and fish ($p < 0.001$) (Table A6, Appendix). Similarly, blood lead levels increased slightly with quartiles of game birds annual consumption, ($p < 0.001$) (Table A7, Appendix) and with frequency of hunting practice ($p < 0.001$) (Table A8, Appendix).

DISCUSSION

Mercury

In 2004, mean blood mercury levels remained higher than the reference levels for the population of Quebec (reference levels of < 0.1-16 nmol/L) (Leblanc et al., 2004), but they were lower than the acceptable blood level of 99.7 nmol/L established by Health Canada for the general adult population (Health Canada Mercury Issues Task Force, 2004). Nevertheless, the range of observed levels reached a maximum of 1200 nmol/L. Furthermore, 28% of individuals from the general population and 72% of women of reproductive age were above the recommended blood level. More specifically, average blood mercury level was higher in women than in men. Associations between mercury and gender observed in other studies are inconsistent and vary in different populations (Dewailly et al., 2001; Dumont et al., 1998; Kosatsky et al., 2000). Also, mercury blood concentrations were statistically higher in adults aged 45 to 74 compared with younger adults. This increasing trend in relation to age probably reflects higher intake of traditional food among this group. As in other studies, mercury blood concentrations increased significantly with quartiles of annual consumption of mammals (Bjerregaard & Hansen, 2000; Dewailly et al., 2001; Grandjean et al., 1992) and fish (Cole et al., 2004; Grandjean et al., 1992; Mahaffey & Mergler, 1998). Evidence for increasing levels of mercury in the Canadian Arctic is observed in a number of marine birds and mammals (AMAP, 2002a). However, human blood levels do not follow this increasing trend and show a decrease of 30%, which could be attributable to changes in dietary habits. Interestingly, a similar decrease has also been observed in newborns with significantly lower levels in the years 1998 and 2000 (Dallaire et al., 2003). These decreasing blood mercury concentrations could result from the promotion of less contaminated food (like Arctic char) in the Arctic (Berti et al., 1998) or from the decrease in traditional food consumption (and the consequent shift to a non-traditional, westernized diet). Over the last decade, the Nunavik Health Board had emitted, at various occasions, recommendations to restrict mercury exposure during pregnancy. An analysis of participants' n-3 fatty acid concentrations derived from marine mammal and fish consumption and the food frequency questionnaire from the 2004 Nunavik Inuit Health Survey will help to clarify this question. Therefore, despite the observed decrease, mercury body burden in this population is still of concern and international efforts to reduce global mercury emission should be maintained and strengthened.

Lead

Levels of lead in 2004 were within the reference values (0.04-0.32 µmol/L) for the general population of southern Quebec (Leblanc et al., 2004). Mean blood lead levels in 2004 (0.19 µmol/L) were lower than the blood level recommended by Health Canada, which is 0.48 µmol/L (Health Canada, 1994; Van Oostdam et al., 2005). However, almost 10% of individuals and 2% of women of childbearing age were still over this level, with a maximum observed blood concentration of 2.4 µmol/L. The average lead level was higher in men and in adults aged 45 to 74, as reported in other studies (Bjerregaard & Hansen, 2000; Bjerregaard et al., 2004; Chu et al., 1999; Dewailly et al., 2001; Ducoffre et al., 1990). Similarly, blood lead levels increased slightly with quartiles of annual game bird consumption and hunting frequency, which is consistent with other studies (Bjerregaard et al., 2004; Dewailly et al., 2001; Hanning et al., 2003; Kosatsky et al., 2001). However, many studies have also shown an association between blood lead levels and smoking (Dewailly et al., 2001; Grandjean et al., 1992; Levesque et al., 2003; Rhainds et al., 1999), but this association could not be observed in the current study, thus suggesting that smoking does not represent a major source of lead exposure in the Nunavik population and that dietary intake of game birds and hunting activities represent a significant but small source of exposure to lead. Blood lead concentration shows a twofold decrease over the 12-year period. This decreasing trend has also been observed in Nunavik newborns' cord blood, with markedly lower concentrations in 1999 (Dallaire et al., 2003). Therefore, the strong decrease in lead levels in adults and newborns may be due to the ban on lead shots for hunting implemented by the Public Health Directorate in 1998 (Levesque et al., 2003). In an effort to reduce exposure the public health authorities of Nunavik also actively informed the population about the toxic effects of lead from ammunition on children's health (Levesque et al., 2003).

Cadmium

Levels of blood cadmium observed in Nunavik in 2004 were within the reference values for the general population of Quebec (1.8-55 nmol/L) (Leblanc et al., 2004). Health Canada recommended a blood concentration below 44.5 nmol/L (INAC, 2003). In 2004, the mean cadmium levels observed (26.6 nmol/L) were below this value, but as with mercury and lead, one-third of individuals and women of childbearing age remained above the recommended blood concentration (maximum of 130 nmol/L). Concentrations did not vary according to gender, as was observed in other studies (Benedetti et al., 1999; Rey et al., 1997). Decreases in blood cadmium were observed in age groups over 25, but cadmium concentrations in adults aged 18 to 24 did not change from 1992 to 2004 and this group showed the highest levels. Blood cadmium levels showed a 23% decrease between 1992 and 2004. It is unlikely that decreases in blood cadmium can be attributed to dietary shifts, since smoking was found to be the main source of cadmium exposure in Nunavik (Benedetti et al., 1994; Rey et al., 1997) and the association of cadmium with smoking status has been observed in numerous other studies (Benedetti et al., 1992; Butler Walker et al., 2006; Levesque et al., 2003). In support to this, we observed that consumption of marine mammals was not associated with cadmium blood levels in simple regression analysis (data not shown). The decrease in cadmium blood levels could be partially explained by a decrease in the cadmium content of cigarettes sold in Canada. Indeed, blood cadmium among Quebec City smokers was 46 nmol/L in 1994 (Benedetti et al., 1994) and 10 nmol/L in 2001 (Leblanc et al., 2004), which represents a decrease of 80%. A sound evaluation of smoking habits considering gender and age differences, the age when people started smoking, numbers of cigarette smoked per day, cigarette brands and exposure to second-hand smoke, is needed to better explain changes (or the absence of changes) in blood levels of cadmium. As far as we know, the smoking rate did not decrease significantly in Nunavik and this public health issue deserves more attention, especially in younger age groups and women of reproductive age considering the adverse effects of tobacco smoking on the developing fetus.

CONCLUSION

These encouraging results clearly demonstrate that implementation of public health campaigns such as the ban of lead cartridges may reduce Inuit exposure to metals and consequently, possible health effects. The continued high levels of cadmium require more active and coordinated public health interventions against tobacco use in order to decrease cadmium exposure and to prevent health risks including lung cancer, cardiovascular disease and childhood asthma. In terms of mercury, the cause of the observed lower levels is not clearly defined and will be clarified with further analysis of the traditional food consumption measurements conducted in the framework of the 2004 Nunavik Inuit Health Survey. Nevertheless, a significant proportion of individuals still have blood concentrations above the level recommended by Health Canada. Promoting the consumption of less contaminated fish species should continue, particularly for pregnant women and women of childbearing age.

KEY ISSUES

Trend since 1992

- Between 1992 and 2004 significant decreases in the mean blood level concentrations for the three metals were observed.

Mercury

- In 2004, mean blood mercury levels remained higher than the reference levels for the population of Quebec, but they were lower than the acceptable blood level established by Health Canada for the general adult population. Nevertheless, 28% of individuals from the general population and 72% of women of childbearing age were above the recommended blood level.
- Average blood mercury level was higher in women than in men.
- Mercury blood concentrations were statistically higher in adults aged 45 to 74 compared with younger adults. This increasing trend in relation to age probably reflects a higher intake of traditional food.

Lead

- Levels of lead in 2004 were within the reference values for the general population of southern Quebec. Mean blood lead levels in 2004 were lower than the blood level recommended by Health Canada. However, close to 10% of individuals and 2% of women of childbearing age were above this level.
- The average lead level was higher in men and adults aged 45 to 74, as reported in other studies.

- Smoking does not represent a major source of lead exposure in the Nunavik population and dietary intake of game birds and hunting activities represent significant but small sources of exposure to lead.

Cadmium

- Levels of blood cadmium observed in Nunavik in 2004 were within the reference values for the general population of Quebec.
- In 2004, the mean cadmium levels observed were below the cadmium blood concentration recommended by Health Canada, but one third of individuals and women of childbearing age remained above the recommended blood concentration.
- Decreases in blood cadmium were observed in age groups above the age of 25, but cadmium concentrations in adults aged 18 to 24 did not change from 1992 to 2004 and this group showed the highest levels.
- As in numerous other studies, an association between cadmium and smoking status has been observed.
- Consumption of marine mammals is not associated with cadmium blood levels in simple regression analysis.

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APPENDIX

Table A1
Average blood levels for metals, population aged 18 to 74 years, Nunavik, 1992 and 2004

Contaminant	1992					2004							
	n	Arithmetic mean	95% confidence interval (lower-upper limit)	Geometric mean	95% confidence interval (lower-upper limit)	n	Arithmetic mean	95% confidence interval (lower-upper limit)	Geometric mean	95% confidence interval (lower-upper limit)	Minimum	Maximum	% det.[1]
Cadmium (nmol/L)	493	45.1	(42.5-47.6)	33.2	(30.7-35.9)	917	36.6	(35.1-38.1)	26.6	(25.0-28.2)*	1.4	130.0	100,0
Mercury (nmol/L)	492	103.8	(96.6-110.9)	74.8	(69.2-80.9)	917	86.0	(80.0-91.9)	51.2	(47.9-54.7)*	0.4	1200.0	99.8
Lead (µmol/L)	493	0.49	(0.46-0.51)	0.42	(0.40-0.44)	917	0.25	(0.23-0.26)	0.19	(0.18-0.20)*	0.028	2.40	100,0

[1] Percentage of detection; detection limit (DL): Mercury = 0.5 nmol/L, lead = 0.001 µmol/L, and cadmium = 0.4 nmol/L.
* Significant variation between health surveys, $p < 0.001$.

Sources: Nunavik Inuit Health Survey 2004 and Santé Québec survey 1992.

Table A2
Average blood levels for metals according to gender, population aged 18 to 74 years, Nunavik, 1992 and 2004

Contaminant	Gender	1992			2004					
		n	Mean[1]	95% confidence interval (lower-upper limit)	n	Mean[1]	95% confidence interval (lower-upper limit)	Minimum	Maximum	P-value[2]
Cadmium (nmol/L)	Men	209	45.6	(41.5-49.8)	414	37.0	(35.0-39.0)*	2.1	110.0	0.436
	Women	284	44.5	(41.5-47.5)	503	36.1	(34.3-37.9)*	1.4	130.0	
Mercury (nmol/L)	Men	209	70.3	(62.1-79.6)	414	45.8	(41.5-50.5)*	0.4	1200.0	< 0.001
	Women	283	79.9	(74.4-85.8)	503	57.6	(53.7-61.8)*	1.0	820.0	
Lead (µmol/L)	Men	209	0.46	(0.43-0.49)	414	0.22	(0.21-0.24)*	0.044	2.40	< 0.001
	Women	284	0.38	(0.35-0.40)	503	0.17	(0.16-0.17)*	0.028	1.50	

[1] Arithmetic mean for cadmium and geometric mean for lead and mercury.
[2] Significant difference between gender in 2004; based on the Satterthwaite χ^2 test.
* Significant variation between health surveys, $p < 0.001$.

Sources: Nunavik Inuit Health Survey 2004 and Santé Québec survey 1992.

Table A3
Average blood levels for metals according to age group, population aged 18 to 74 years, Nunavik, 1992 and 2004

Contaminant / Age group	1992			2004					
	n	Mean[1]	95% confidence interval (lower-upper limit)	n	Mean[1]	95% confidence interval (lower-upper limit)	Minimum	Maximum	P-value[2]
Metals									
Cadmium (nmol/L)									
18 to 24 years	107	43.9	(38.8-48.9)	206	45.4	(42.3-48.5)	2.1	110.0	< 0.001
25 to 44 years	233	48.1	(44.2-52.0)	471	37.7	(35.5-39.9)*	1.4	110.0	
45 to 74 years	153	40.6	(35.3-45.8)	240	26.2	(23.4-28.9)*	2.0	130.0	
Women of childbearing age (18 to 39 years)	175	46.7	(42.9-50.5)	308	38.1	(36.0-40.3)*	1.4	110.0	
Mercury (nmol/L)									
18 to 24 years	107	50.6	(43.0-59.7)	206	31.5	(27.7-35.8)*	2.2	820.0	< 0.001
25 to 44 years	233	69.2	(62.3-76.7)	471	44.3	(40.1-48.9)*	0.4	420.0	
45 to 74 years	152	135.9	(120.2-153.6)	240	106.6	(96.1-118.2)**	4.6	1200.0	
Women of childbearing age (18 to 39 years)	175	64.5	(59.2-70.3)	308	41.7	(38.2-45.6)*	1.0	820.0	
Lead (µmol/L)									
18 to 24 years	107	0.31	(0.28-0.34)	206	0.14	(0.13-0.15)*	0.033	0.8	< 0.001
25 to 44 years	233	0.43	(0.40-0.46)	471	0.19	(0.17-0.20)*	0.028	2.4	
45 to 74 years	153	0.56	(0.52-0.60)	240	0.29	(0.27-0.31)*	0.039	1.5	
Women of childbearing age (18 to 39 years)	175	0.33	(0.31-0.36)	308	0.13	(0.12-0.14)*	0.028	1.0	

[1] Arithmetic mean for cadmium and geometric mean for lead and mercury.
[2] Variation with age in 2004; based on the Satterthwaite χ^2 test.
* Significant variation between health surveys, $p < 0.001$.
** Significant variation between health surveys, $p < 0.01$.

Sources: Nunavik Inuit Health Survey 2004 and Santé Québec survey 1992.

Table A4
Average blood levels for metals according to coastal region, population aged 18 to 74 years, Nunavik, 1992 and 2004

Contaminant / Coastal region	1992			2004					
	n	Mean[1]	95% confidence interval (lower-upper limit)	n	Mean[1]	95% confidence interval (lower-upper limit)	Minimum	Maximum	P-value[2]
Cadmium (nmol/L)									
Hudson	274	48.4	(44.9-52.0)	497	39.5	(37.4-41.5)*	2.0	110.0	< 0.001
Ungava	219	40.2	(36.7-43.8)	420	32.8	(30.5-35.1)*	1.4	130.0	
Mercury (nmol/L)									
Hudson	274	93.1	(84.2-102.8)	497	58.7	(53.1-64.8)*	0.4	1200.0	< 0.001
Ungava	218	54.6	(48.4-61.6)	420	42.8	(38.9-47.1)*	1.0	520.0	
Lead (µmol/L)									
Hudson	274	0.48	(0.44-0.51)	497	0.20	(0.19-0.21)*	0.036	2.4	0.187
Ungava	219	0.35	(0.33-0.37)	420	0.19	(0.18-0.20)**	0.028	1.4	

[1] Arithmetic mean for cadmium and geometric mean for lead and mercury.
[2] Variation between coastal regions in 2004; based on the Satterthwaite χ^2 test.
* Significant variation between health surveys, $p < 0.001$.
** Significant variation between health surveys, $p < 0.01$.

Sources: Nunavik Inuit Health Survey and Santé Québec survey 1992.

Table A5
Average blood cadmium and lead levels according to tobacco use, population aged 18 to 74 years, Nunavik, 1992 and 2004

Contaminant / Smoker status	1992			2004					
	n	Mean[1]	95% confidence interval (lower-upper limit)	n	Mean[1]	95% confidence interval (lower-upper limit)	Minimum	Maximum	P-value[2]
Metals									
Cadmium (nmol/L)									
Smoker	312	56.6	(53.9-59.3)	663	45.1	(43.4-46.7)*	3.2	130.0	< 0.001
Ex-smoker	79	15.2	(12.2-18.3)	119	7.6	(6.8-8.4)*	2.0	23.0	
Non-smoker	42	8.9	(6.7-11.0)	76	5.9	(5.2-6.7)**	1.4	22.0	
Lead (µmol/L)									
Smoker	312	0.43	(0.40-0.45)	663	0.19	(0.18-0.20)*	0.028	1.40	0.778
Ex-smoker	79	0.40	(0.36-0.45)	119	0.19	(0.17-0.21)*	0.044	2.40	
Non-smoker	42	0.32	(0.27-0.38)	76	0.18	(0.16-0.21)*	0.033	1.00	

[1] Arithmetic mean for cadmium and geometric mean for lead and mercury.
[2] Variation with smoker status in 2004; based on the Satterthwaite χ^2 test.
* Significant variation between health surveys, p < 0.001.
** Significant variation between health surveys, p = 0.01.

Sources: Nunavik Inuit Health Survey 2004 and Santé Québec survey 1992.

Table A6
Average blood mercury levels according to quartile of consumption of marine mammal meat and country fish (gr/day, annual), population aged 18 to 74 years, Nunavik, 2004

	Mercury (nmol/L)					
	n	Geometric mean	95% confidence interval (lower-upper limit)	Minimum	Maximum	P-value[1]
Consumption of marine mammals meat (quartiles)						
Low (0-25%)	179	28.0	(23.8-33.1)	1.0	520.0	< 0.001
Low-Moderate (25-50%)	204	44.6	(39.1-50.9)	1.8	460.0	
High-Moderate (50-75%)	193	66.5	(58.0-76.4)	3.2	1200.0	
High (75-100%)	192	80.1	(70.9-90.5)	3.0	760.0	
Consumption of country fish (quartiles)						
Low (0-25%)	191	35.7	(30.4-41.8)	1.0	820.0	< 0.001
Low-Moderate (25-50%)	192	49.0	(42.3-56.7)	1.0	760.0	
High-Moderate (50-75%)	192	56.8	(48.0-67.1)	1.1	1200.0	
High (75-100%)	194	69.3	(60.7-79.0)	5.10	720.0	

[1] Based on the Satterthwaite χ^2 test.

Source: Nunavik Inuit Health Survey 2004.

Table A7
Average blood lead levels according to quartile of consumption of game birds (gr/day, annual), population aged 18 to 74 years, Nunavik, 2004

	Lead (µmol/L)					
	n	Geometric mean	95% confidence interval (lower-upper limit)	Minimum	Maximum	P-value[1]
Consumption of game birds (quartiles)						
Low (0-25%)	188	0.16	(0.14-0.18)	0.033	2.40	< 0.001
Low-Moderate (25-50%)	192	0.19	(0.18-0.21)	0.032	1.40	
High-Moderate (50-75%)	195	0.21	(0.20-0.23)	0.040	1.40	
High (75-100%)	194	0.21	(0.19-0.24)	0.046	1.20	

[1] Based on the Satterthwaite χ^2 test.

Source: Nunavik Inuit Health Survey 2004.

Table A8
Average blood lead levels according to hunting frequency, population aged 18 to 74 years, Nunavik, 2004

	Lead (µmol/L)					
	n	Geometric mean	95% confidence interval (lower-upper limit)	Minimum	Maximum	P-value[1]
Hunting frequency (Spring) [2]						
Never	230	0.17	(0.16-0.19)	0.028	1.00	< 0.001
Less than once a month	80	0.15	(0.13-0.17)	0.045	0.59	
1 to 3 days a month	153	0.19	(0.17-0.21)	0.047	1.40	
1 to 3 days a week	212	0.20	(0.18-0.22)	0.033	2.40	
4 or more days week	180	0.22	(0.20-0.25)	0.044	1.50	

[1] Based on the Satterthwaite χ^2 test.
[2] Same associations for the other seasons.

Source: Nunavik Inuit Health Survey 2004.

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