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PCB-Contaminated Food in the Canadian Arctic: Interactions between Environmental Policy, Cultural Values, and the Healthcare System

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Interactions between Environmental Policy, Cultural Values, and the Healthcare System

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Introduction

Quotation

“We have gone too far towards the white society. We think everything about white society works. We have gone away from breastfeeding. We have adopted the white diet. Our traditional diet is far leaner than the Western diet, but it has taken us a generation to realize this. We are in a cross-cultural environment and we need to incorporate the best of both worlds. We have to regain respect for our own world. We have to promote and educate and train our own people.”

> --Mary Wilman, a 50-year-old grandmother who heads the Nunavut Social Development Council (Johnson 1999).

Study Purpose

Current Canadian policies do not adequately prevent water contamination or mitigate the effects of existing polychlorinated biphenyl pollution. There is conflict between the Canadian government and the Inuit people over how to approach the pollution problem, arising from a clash of cultural values and traditions. Legislation related to healthcare is an inherently sensitive issue and some measures that seem acceptable to westernized societies are not appropriate for the Inuit. The purpose of this thesis is to answer (a) why polychlorinated biphenyls (PCBs) are in the Arctic, (b) what the effects of PCBs are on the Arctic people, and (c) how healthcare policy can address the issue.

PCBs and the Inuit People

Environmental degradation disproportionately influences minorities (Bjerregaard & Curtis 2002). The alarming pattern is seen globally and is particularly remarkable among the Canadian Inuit living in the far northern reaches of the country (Figures 1 and 2). Cultural and socio-economic differences have prevented southern, westernized Canadians and northern, indigenous Canadians from adequately addressing the serious environmental contamination in the Arctic, particularly PCB contamination.

PCBs are a group of 209 different chemicals that have a two-ring chemical structure with a varying number of attached chlorine atoms (Figure 3). They are classified as a "probable carcinogen" by the International Agency for Research on Cancer and the United States Environmental Protection Agency (National Cancer Institute of Canada 2007, Appendix I). When PCBs are burned or improperly disposed, they evaporate and travel on northerly winds to the Arctic, where they meet frigid air and quickly condense out of the atmosphere (Environment Canada 2010).

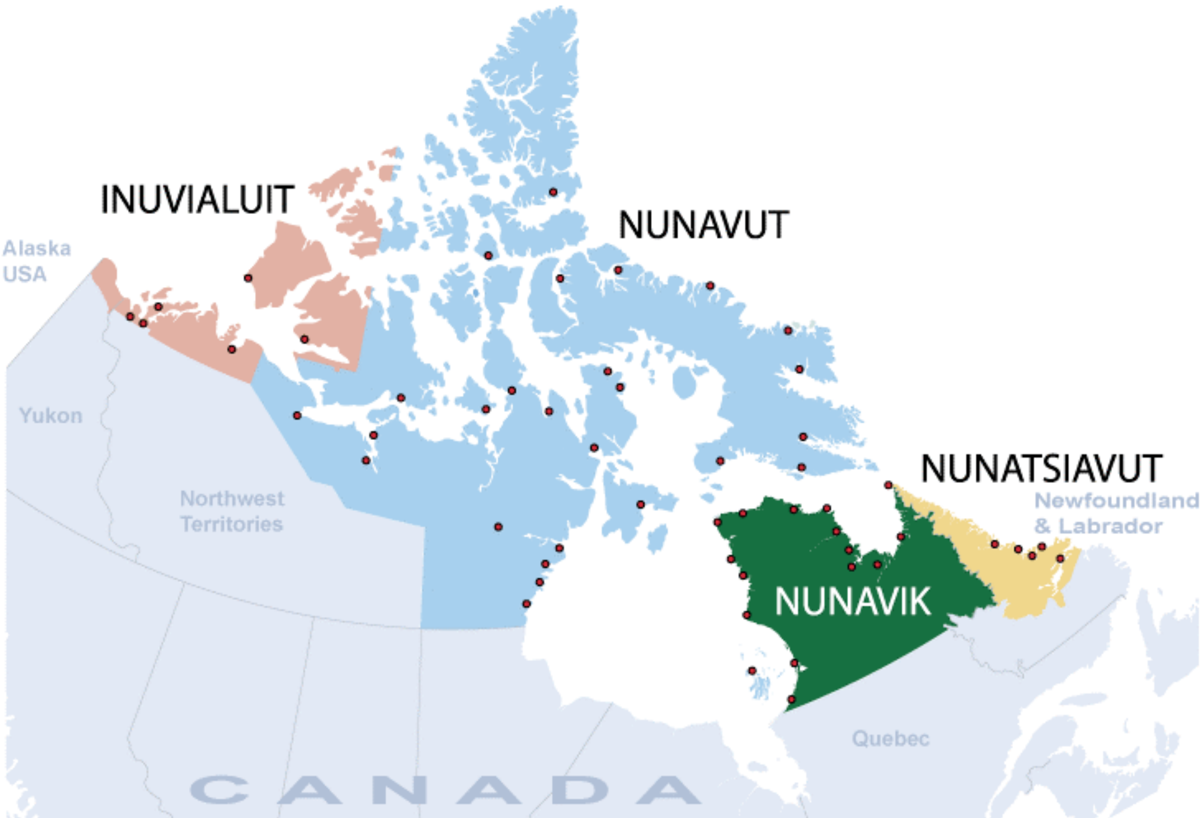


Figure 1. The five regions of Canadian Inuit (Crouthamel 2001). In Canada, Inuit populations are found in the Northwest Territories, Nunatsiavut, Nunavik, and Nunavut. Inuit also live in parts of Greenland, Russia, and Alaska.

Figure 2. Map of Canada (Canada 2001).

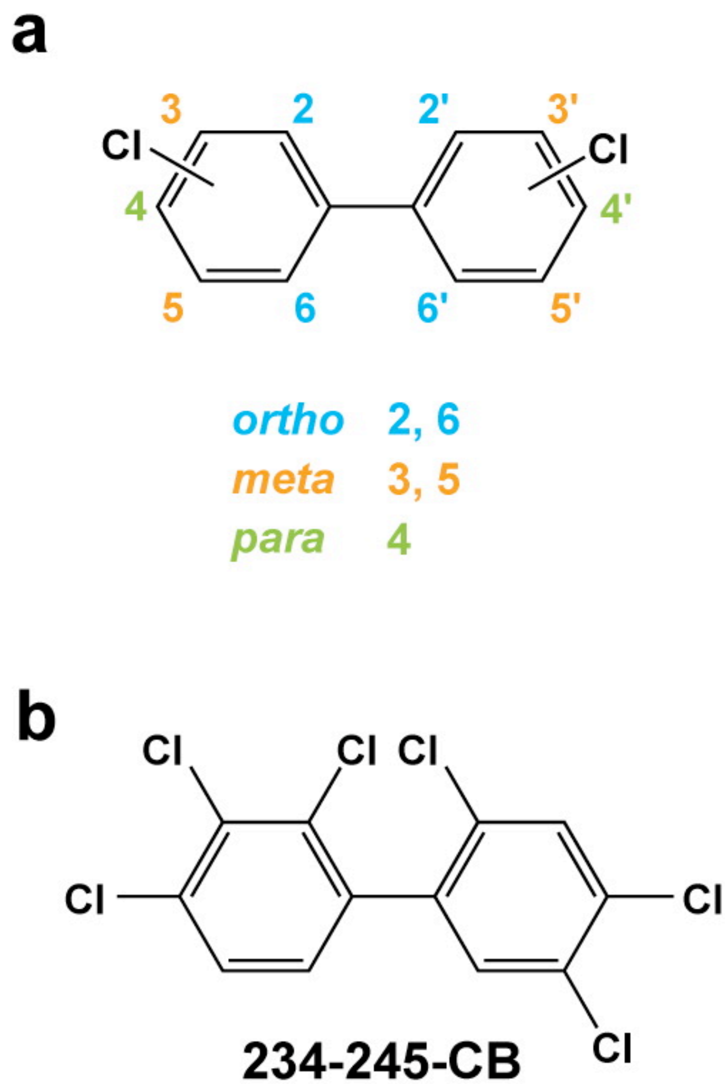


Figure 3. PCB Structure and Nomenclature. (a) PCB structure showing the ortho, meta, and para chlorines. (b) Structure of 2,2′,3,4,4′,5′-tetrachlorobiphenyl. The PCB congener shown is called 234-245-CB (Bedard 2008).

PCB production began as a commercial operation. In the United States, production increased in the 1930s in response to the demand from the electrical industry (Kaley et al. 2006). At the time, PCB was seen as a safer cooling and insulating fluid than standard mineral oil because it was less flammable. PCBs were added to various electronic components to enhance the fire and heat resistance of the PVC coating traditionally used (Kaley et al. 2006). They have infected the Arctic food chain, concentrating in the fatty tissue of longer-living animals such as whales and polar bears. As persistent lipophilic compounds, PCBs accumulate in Inuit people as a result of their large consumption of sea mammal fat (Gadsby 2004).

It is particularly tragic that the environmental degradation is disproportionately affecting a minority group that in no way caused the contamination. To make matters worse, the data are sometimes misrepresented to show aggregate improvement in Inuit health, though certain groups such as middle-age women are actually declining in health status (Dewailly et al. 2010). A long-term solution requires a comprehensive policy that combines cooperation between Inuit and the Canadian national government, concrete advice for clinicians and hospitals, and education for the Inuit.

Section I: Arctic Contamination

Environmental Background

Polar ecosystems are particularly vulnerable to environmental degradation caused by toxins (Alaska Department of Environmental Conservation 2009). In the Arctic, pollution from around the world has accumulated and drastically impacted the Inuit population. In recent decades, the Arctic has seen a steady increase in the contamination of snow, waters, and organisms by "imported" pollutants (Muir et al. 1992). Global pollutants are carried north by rivers, ocean currents, and atmospheric circulation, contributing to transboundary pollution that includes PCBs, fire retardants, furans, cadmium, dioxins, chlordane, selenium, mercury, and radioactive fallout-all (Verhaag 2003).

Compared to ecosystems in temperate latitudes, Arctic ecosystems are more susceptible to biological damage, even at low levels of pollution. Contaminants break down much more slowly in the Arctic due to reduced sunlight, extensive ice cover, and cold temperatures (Weaver 2003). Organochlorines such as dioxins, furans, and PCBs accumulate in fatty tissue and bone marrow (Norstrom et al. 1990). To conserve heat, arctic animals develop and consume large amounts of fatty tissue and use their reserves of marrow during periods of extended inactivity or hibernation (Calder 2003). In this way, extraordinarily high concentrations of toxins result from relatively short food chains (Norstrom et al. 1990). Of serious concern is the health of the northern human populations who eat a high proportion of fatty meats as a part of their traditional diet. Studies of the diets and physiology of Arctic community residents have shown that populations who eat local meat have higher levels of chemicals in their body tissues and in mothers’ breast milk than those who import food from lower latitudes (Wang et al. 2005).

Pollution Origins

PCBs are man-made chemicals that contain two or more chlorine atoms (Appendix I). Before the United States prohibited their manufacture in 1977, they were used by United States factories in oils for electrical equipment and hydraulic fluids (Alaska Department of Environmental Conservation 2009, Figure 4). Today, manufacturing with PCBs continues outside of the United States. The toxic effects of PCBs were quickly recognized after several industrial incidents and there were numerous publications describing the toxicity in the 1930s (Drinker et al. 1937), but manufacturing continued to grow until its peak in the 1960s. Finally, in 1966, Swedish chemist Dr. Soren Jensen classified PCBs as an environmental contaminant (Jensen 1966). There were surprisingly few restraints on their manufacture until the 1970s, when production plants could still be found in Austria, France, Italy, Spain, Japan, Great Britain, the Union of Soviet Socialist Republics, and the United States (Proceedings of the Subregional Awareness 1997).

Figure 4. Sources of PCB Contamination (National Geologic 2008).

In the United States, PCB use in “open” sources, such as plasticizers, fire retardants, and adhesives, was banned in 1973, but their use continued in transformers and capacitors (Proceedings of the Subregional Awareness 1997). In 1971 Japan was the first country to ban production, use, and import of PCBs; the United States Congress followed suit later in the 1970s (US Congress 1979) and the United Kingdom in 1981. The Stockholm Convention on Persistent Organic Pollutants banned PCBs in 2001, but they are still being produced in Russia and in Asia. Total global PCB production over all time has been estimated at 1.5 million tons, with the United States being the largest producer (Breivik et al. 2002, Figure 5).

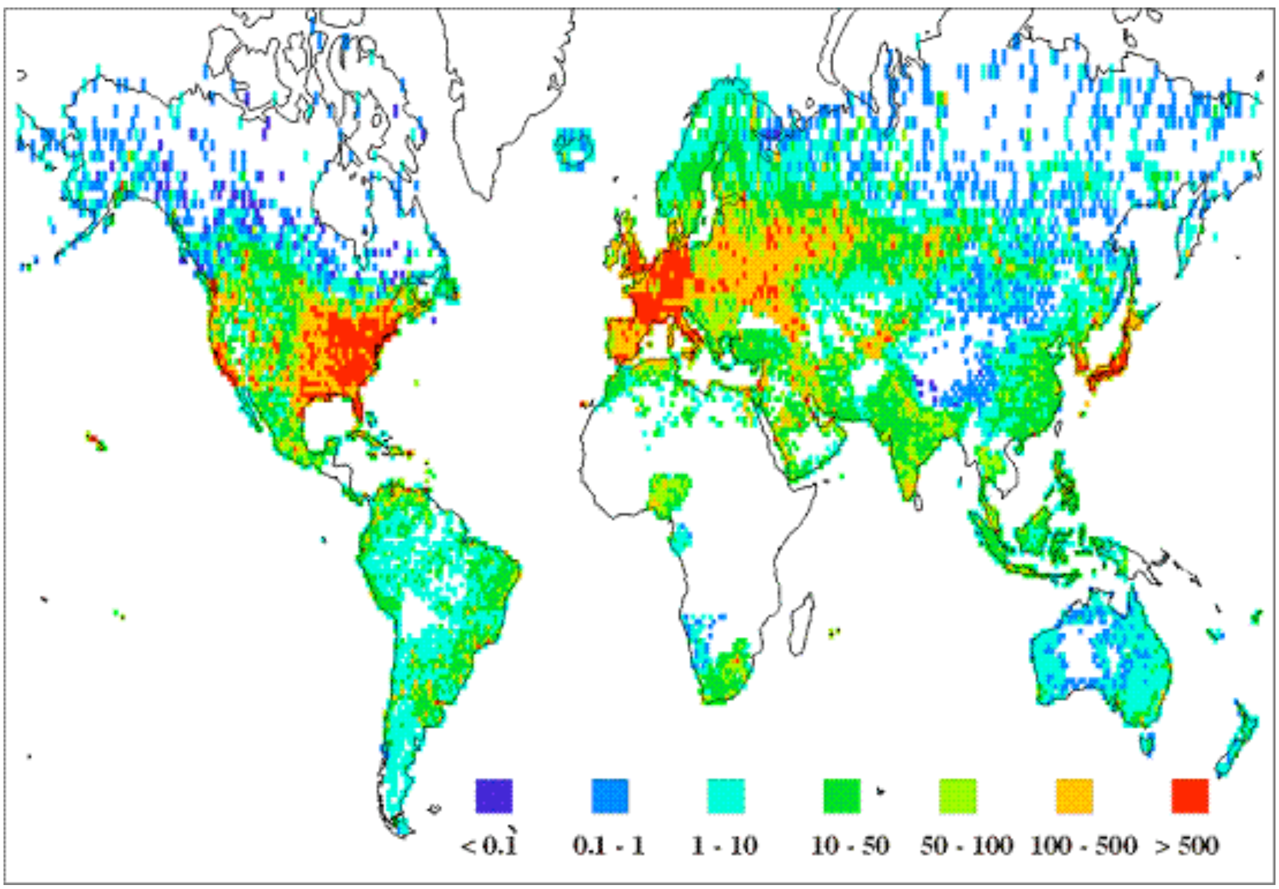


Figure 5. Estimated cumulative usage of PCBs in tons until 1993 (Breivik et al. 2002).

Improper disposal of PCB oil and leaky transformers contributes to contamination of plants, soils, and sediments, making them particularly difficult to contain or clean up. In fact, PCBs found in soil can easily migrate to groundwater or surface water, evaporate into the air, and later settle in dust, rain or snow. The chemicals resist degradation, rendering them "persistent organic pollutants" (POPs). Standard processes of degradation using sunlight, oxygen, and bacteria do not greatly affect PCBs (Bedard 2008). Despite the fact that the chemicals are primarily produced at the mid-latitudes, they concentrate in ecosystems near the poles (Figures 6 and 7).

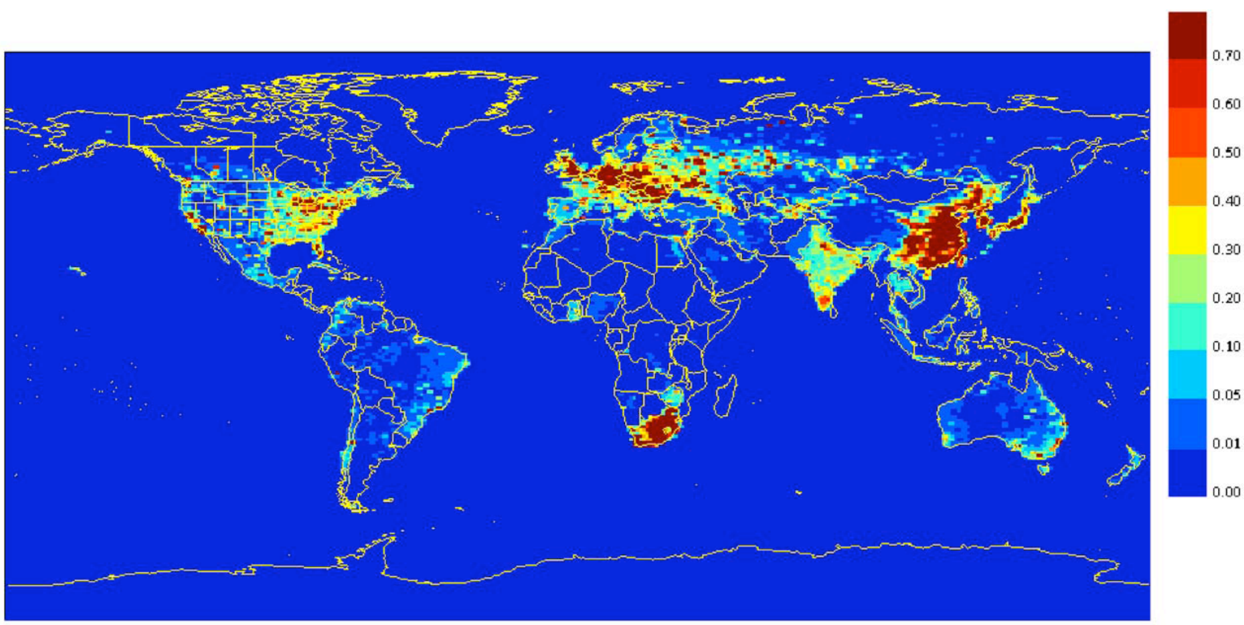


Figure 6. Global anthropogenic emissions in tons/year (Dastoor & Larocque 2004). Note that emissions are minimal in northern Canada.

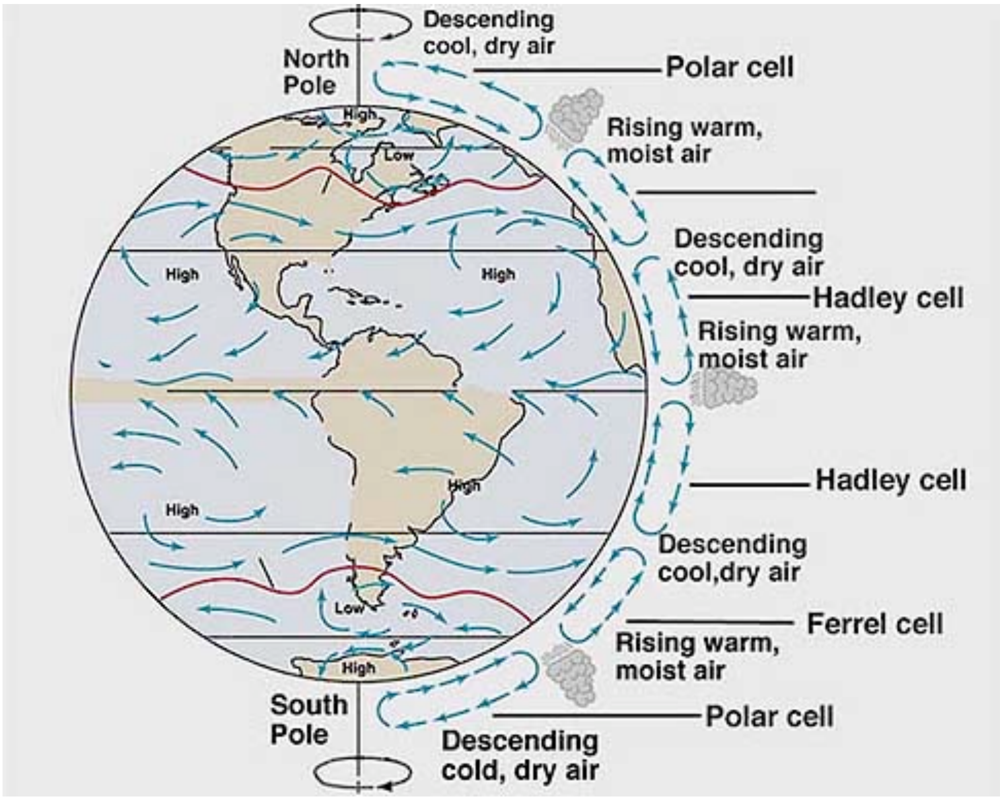
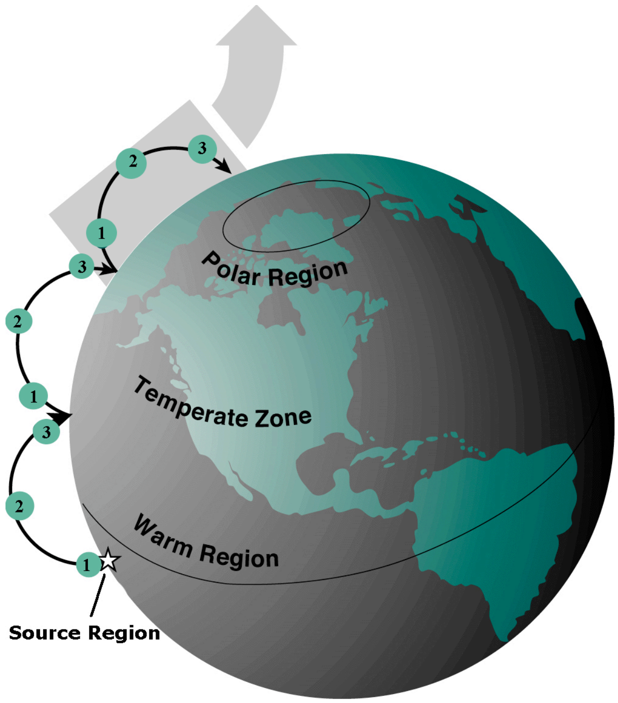


Figure 7. Atmospheric Circulation Patterns (Short 2009).

Even now, with fairly comprehensive regulations in place, PCBs persist in the environment and are transported globally (Proceedings of the Subregional Awareness 1997, Figure 8). The primary accumulation of PCBs is in the hydrosphere, in soil, and in organisms, but the oceans also dissolve a significant quantity (Wania et al. 2000). Rural areas tend to have lower atmospheric concentration of PCBs than urban areas and so water sources near cities are more polluted (Wethington & Hornbuckle 2005). In some American urban residences, inspectors found concentrations ten times higher than the EPA guideline limit (Rudel et al. 2008).



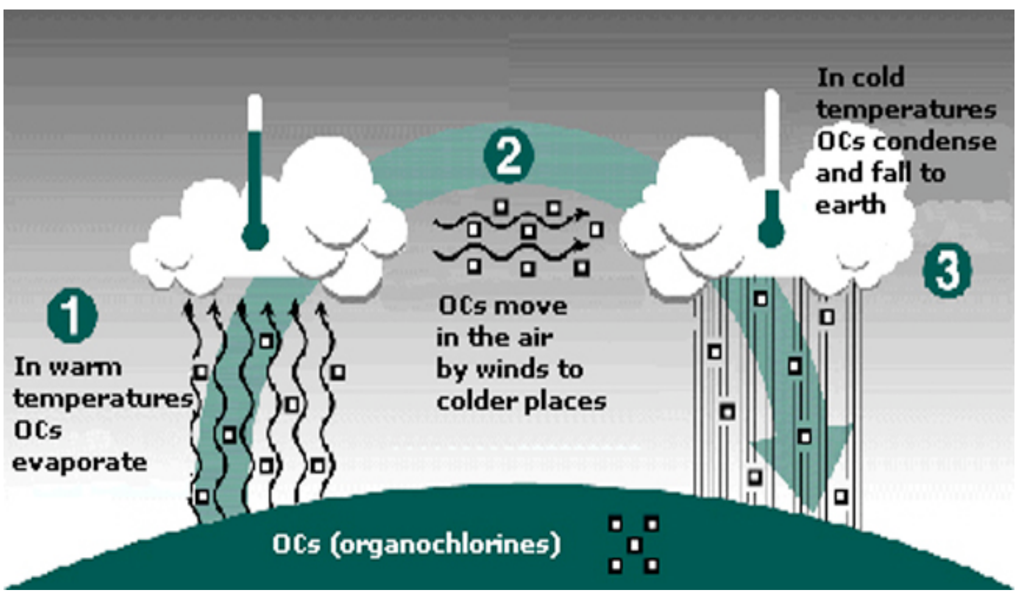


Figure 8. Movement of chemicals (organochlorines) from the tropics to the polar region through the atmosphere (Environment Canada 2010). Global distillation is the process that transports chemicals from tropical to polar regions. When compounds are found in both the gas phase and adsorb to particles or water, they evaporate in warm climates and move with winds to colder climates, where they condense and deposit.

Section II: Human Health Impacts

The Inuit Diet

The Inuit have traditionally eaten a diet comprised of walrus, ringed seal, bearded seal, beluga whale, polar bear, berries, and fireweed (Kuhnlein et al. 2002). The people firmly believe that this diet keeps them warm and strong. The natural surroundings of the Inuit also limit the options, as most food is impossible to grow in the Arctic. Although they gather native plants, a full 75% of the diet's calories are from fat and the average Inuit annually consumes about 232 kilograms of meat and fat from Arctic animals (Gadsby 2004). The Inuit boast an extraordinarily low rate of cancer and virtually no heart disease, in large part due to their active lifestyle and tremendous consumption of fish and sea mammals. A high fat diet does not seem to cause obesity. In fact, Inuit who have given up their traditional diet in favor of a lower fat Western diet have experienced increased obesity, diabetes, high blood pressure, and cardiovascular disease (Kuhnlein et al. 2004).

Traditional foods are slowly losing the prominence they once had as the Inuit are increasingly exposed to industrialized, western cultures. The Inuit were geographically isolated until the middle of the 20th century. In Alaska, Canada, and Greenland they lived a subsistence life revolving around hunting and fishing (Duhaime 1989), activities that promoted physical exertion and high intake of marine meats rich in essential fatty acids. The Inuit's historic protection from cardiovascular disease, diabetes, and cancer could be due to genetics, traditional living or a combination of the two (Bjerregaard & Curtis 2002). Recently, however, the Inuit have had access to increased communication with and transportation to southern regions, resulting in a shift away from their traditions. The young people currently eat much less traditional food than the elderly, as evidenced by the lower blood concentration of omega-3 fatty acids in the Inuit youth (Dewailly et al. 2010). Clinical observations and health records from the past decades indicates that heart disease and diabetes are increasing (Schraer et al. 1997), as are the associated risk factors of obesity, high blood pressure, and high blood lipids. However, mortality and morbidity rates for ischemic heart disease are still lower in Inuit populations than in southern populations, suggesting that active lifestyles and genetic factors may still be operating to a certain extent (Coté et al. 2004).

PCB Health Effects

The most common route of human exposure to PCBs is through consumption of marine animals. Once PCBs enter the body, they are absorbed into fatty tissue. Because they are not water soluble, PCBs are not excreted and so the toxin can accumulate to increasingly high levels over a lifetime. Likewise, PCBs accumulate up through the food chain. For example, a small fish absorbs the chemical from the water and from the plankton that it eats. Then, a larger fish eats the smaller one and absorbs all of the PCB that has accumulated in the small fish (Van Den Berg 2006). In this way, larger fish and marine mammals amass highly concentrated stores. An analogous situation occurs with breast-feeding mothers: PCBs accumulate in women and are concentrated in their milk, meaning that infants ingest PCB levels even higher than those in the foods consumed by their mothers (Korrick & Altshul 1998, Figure 9).

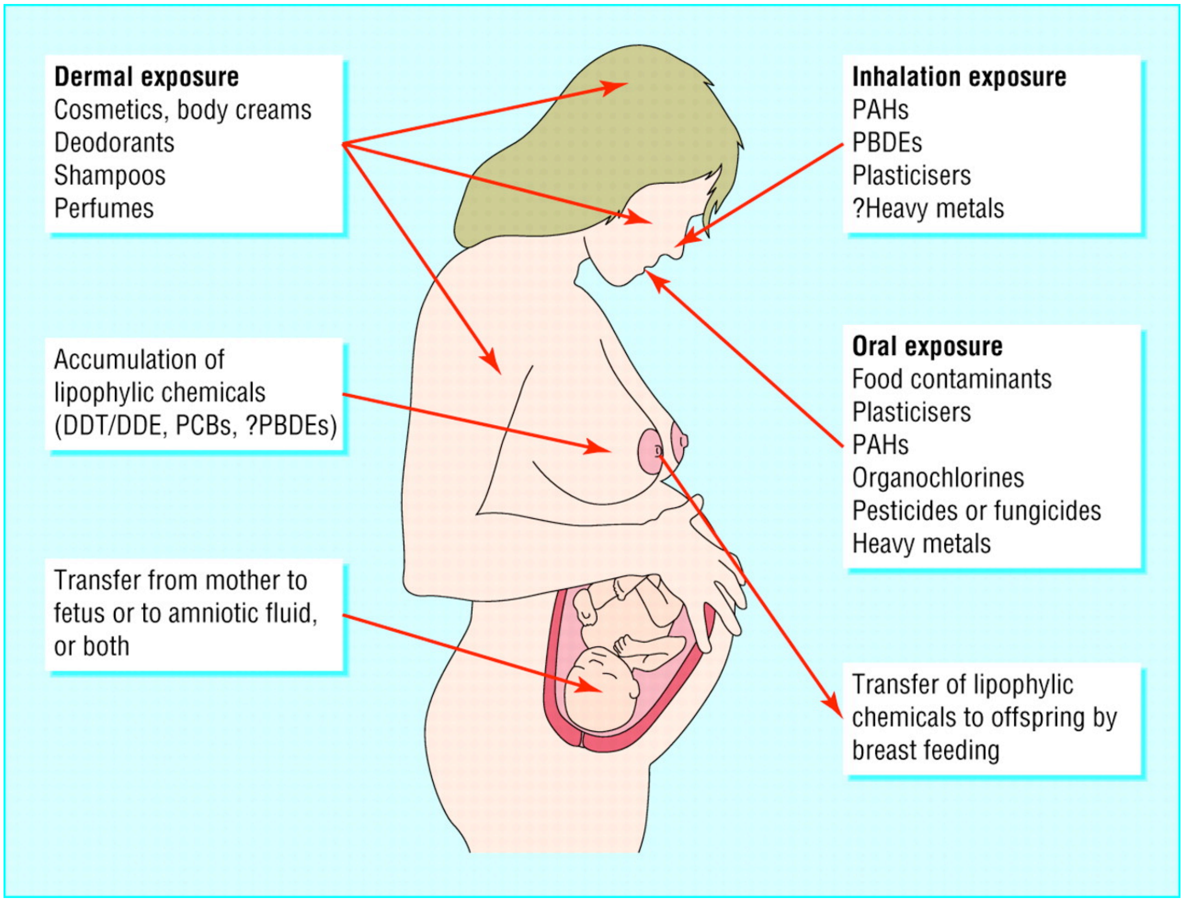


Figure 9. PCB effects on reproductive health (Sharpe & Irvine 2004).

PCB accumulation affects the Inuit through their staple foods and through parts of their diet seen as delicacies. All of the large marine mammals they consume have high contaminant loads, yet the whales and seals are essential sources of food and so there is little choice in whether to continue hunting and fishing. The Inuit often use whales as a source of "maktaaq," soft, rubbery whale skin and blubber. Nearly everyone in the Inuit communities relies on it to supplement expensive southern food they buy from the co-op. Maktaaq has benefits that go beyond its traditional and cultural significance; it is also rich in vitamin A, protein, and the fatty acids that prevent heart disease (Duffy 1998).

Today, however, the maktaaq from marine mammals impairs the development of Inuit children because it is laced with PCBs, DDT, mercury, and other toxic chemical pollutants that can be passed to babies through placenta and breast milk (Dewailly et al. 1989). In humans, chemical accumulation impairs the immune system and alters neurological development, leaving children more susceptible to infection and likely to have difficulties with learning, attention span, and memory (Darwill et al. 2000). Just one piece of maktaaq smaller than a sugar cube contains the maximum recommended intake of PCBs for an entire week and the locals frequently consume ten times that amount in a day (US ATSDR 2000).

Interestingly, the PCB contamination problem was uncovered accidentally. In the mid-1980s, Mr. Dewailly went to the Arctic in search of a pristine control group to use for his research about PCB levels in the breast milk of mothers in southern Québec (Dewailly et al. 1989). Ironically, he found PCB levels among Inuit mothers five times higher than women in the south. Dewailly et al. (1992) compared 24 samples of milk from Inuit women in northern Québec to samples of milk from 48 women from southern Québec. In the Inuit women, the milk fat had an average PCB concentration of 3.59 parts per million, compared with 0.76 parts per million in the milk fat of southern women.

Human data on PCB levels are collected from samples of blood lipids, milk fat, and adipose tissue (WHO 1998. Dewailly et al. (1999) determined organochlorine load in liver, brain, and subcutaneous abdominal fat samples collected from deceased Inuit Greenlanders. In the adipose tissue samples of Greenlanders, mean concentrations of PCBs were 3- to 34-fold higher than those measured in samples from Canadians in Québec City, Québec (Dewailly et al. 1999). When compared with international data on adipose tissue levels, it was found that the organochlorine body burden resulting from environmental exposure in the Inuit is among the highest in the world (Dewailly et al. 1992).

The 1991 Northern Contaminants Program was the first program developed in response to the pollution in the Canadian Arctic, but the magnitude of the pollution problem had been revealed over the prior decades; numerous studies had assessed the impact of POPs, including PCBs, on the people of Canada's Arctic (Fein et al. 1984). Given that the federal agency Health and Welfare Canada set a tolerance level for PCBs at 1.5 parts per million, the fact that some Inuit women had a concentration of greater than 14 parts per million was a cause for great concern, particularly when coupled with the fact that Inuit women in northern Québec breast feed their babies for up to 23 months. An Inuit child nursed by a mother whose milk has the average amount of PCB contamination is likely to develop observable health problems within a year (Heilmann et al. 2003). If the milk is even more highly contaminated, children might begin to exhibit problems with their skin, liver or immune system in as little as four months (Dewailly et al. 2004, Weisgals-Kuperus et al. 2000). Women of child-bearing age are advised to consume the less-contaminated traditional foods such as caribou or fish (Kinlock et al. 1992) because the developing fetus is even more sensitive to toxins than babies and is the age group at greatest risk in the Arctic (Fein et al. 1984). Previous studies of infant development in Nunavik link prenatal exposure to organochlorines to deficits in immune function, an increase in childhood respiratory infections, and low birth weight (Fein et al. 1984).

In a study of Québec Inuit women, the total concentration of PCBs in Inuit milk fat was similar to that in meat from the beluga whale (Norstrom 1990). Most strikingly, the mean concentrations of organochlorines in the Inuit women's milk-fat samples were 2 to 10 times greater than those found in samples from southern Québec women (Dewailly et al. 1989). Since then, dietary surveys of five Inuit regions indicate that mean intakes by 20- to 40-year-old adults exceeded the provisional tolerable daily intakes for organochlorines, chlordane, and toxaphene (Jonson et al. 2005). Women exposed to contamination before or during their pregnancies often give birth to infants with decreased birth weight and head size (Taylor et al. 1989). Further, the children frequently present with motor control problems, low IQs, and poor memory (Jacobson and Jacobson 1996). Even later in life, the children of women who consumed contaminated foods perform poorly on standardized behavioral assessments (Stewart et al. 2000).

Numerous studies of PCBs in humans have found increased rates of melanomas, liver cancer, gall bladder cancer, biliary tract cancer, gastrointestinal tract cancer, and brain cancer (ATSDR 2000 and Johnson et al. 1999), and a potential link to breast cancer. In the New York University Women's Health Study, a prospective investigation analyzed blood samples from women whose blood had been obtained at least six months prior to breast cancer diagnosis (Wolff et al. 2000). Though there was not significant evidence to claim a correlation between PCB blood serum levels and breast cancer risk, the researchers did conclude that changes in PCBs over time are influenced by metabolism, BMI, and current organochlorine exposure and should be incorporated into risk assessment models. When high levels of PCBs contact humans directly, via skin or consumption, the victims experience severe skin irritations, such as chloracne, and eye problems (Johnson et al. 1999).

PCBs' effects have been corroborated by animal studies. One form of PCB retarded growth in rats, along with causing delayed puberty, decreased sperm counts, and genital malformations (Gray et al. 1995). Another study found that exposure of PCBs to rats in utero caused behavioral and psychomotor effects that lasted into adulthood (Weinand-Harer et al. 1997).

Chemical Mechanisms

Quantification of chemical accumulation helps scientists to determine the extent of contamination in a given area (Weaver 2003). A substance has a “bioaccumulation factor” that is the ratio of the concentration of the substance in an organism to the concentration in water; the factor is affected by uptake from the surrounding habitat and food sources (Department of Justice Canada 1999). The “bioconcentration factor” of a substance is the ratio of the concentration of the substance in an organism to the concentration in water, based only on uptake from the surrounding habitat (Department of Justice Canada 1999). A bioaccumulative substance has a bioaccumulation factor of at least 5,000. PCBs are also classified by their “persistence” in the environment because they can be transported in the atmosphere to remote areas, they have a half-life in water greater than 182 days, and a half-life in sediment of greater than one year (Department of Justice Canada 1999).

The toxic effects of the persisting PCBs are in part due to their similarity to natural human biomolecules. Some PCBs have only a few chlorine atoms and can mimic the body’s natural hormones alarmingly well (Mendola et al. 1997). Estrogen is one hormone most affected and it is thus unsurprising that women who consumed PCB-contaminated fish from Lake Ontario were found to have shortened menstrual cycles. Even if PCBs are more highly chlorinated in the environment, they can change form to become lower-chlorinated in the body and increase their estrogenic effects (Mendola et al. 1997). There is also growing evidence that PCBs can reduce sperm counts, alter sex organs, and induce premature puberty (Persky et al. 2001). The more highly-chlorinated

PCBs affect the metabolism of sex steroids in the body (Arcaro et al. 1999, Figure 10). PCBs also upset the balance of thyroid hormones that contribute to normal intellectual and behavioral development (Schell et al. 2000). In addition to altering the function of the hormone systems, PCBs bind receptors that control immune system function and alter the levels of lymphocytes and T cells (Carpenter 1998). A Dutch study found that higher PCB levels correlated to an increased prevalence of ear infections and chickenpox (Weisglas-Kuperus et al. 2000).

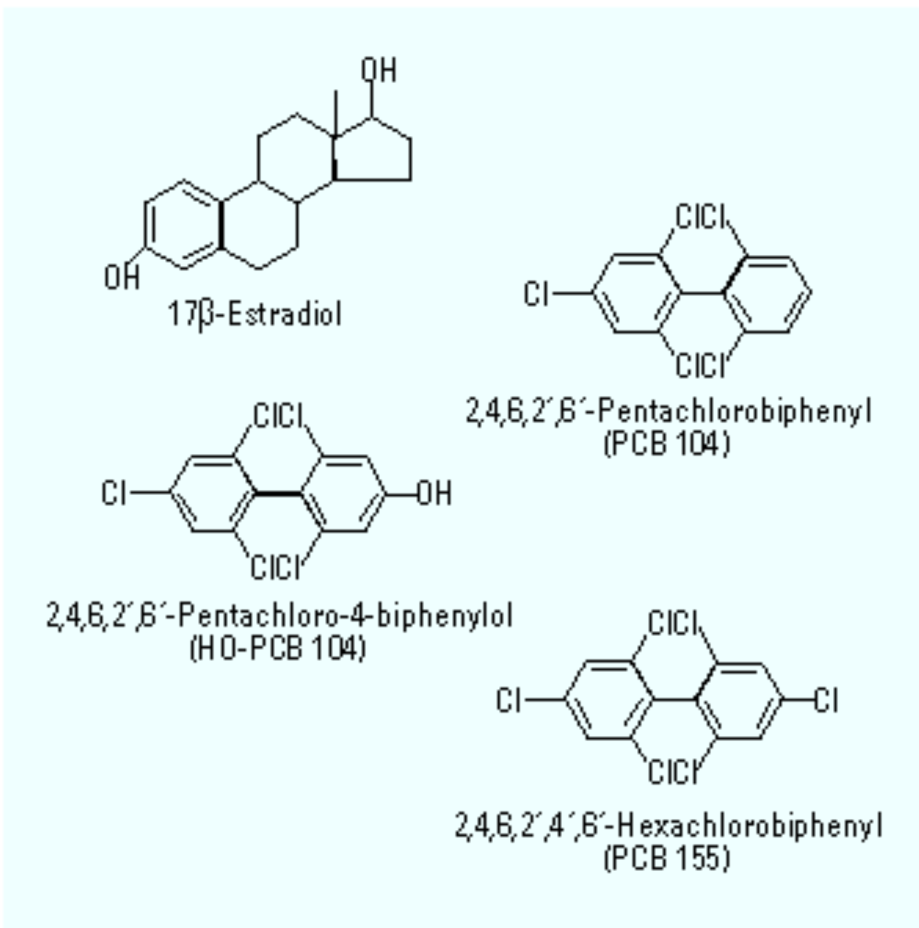


Figure 10. PCBs have similar structures to estrogenic compounds (Fielden et al. 1997) and can induce the same response cascades that estradiol (upper left) is meant to initiate in humans.

The effects of PCBs have been observed across regions and throughout ecosystems, where they affect humans on every inhabited continent to some extent (WHO 1998). Highly toxic coplanar PCBs, such as those released in flue gas from urban incinerators, have been studied with isomer-specific techniques to determine their distribution. Tanabe et al. (1987) analyzed concentrations found in fish, marine mammals, and terrestrial mammals and found that the amount of PCBs per gram of fat tissues ranged from a few picograms to several tens of nanograms. The toxic residues were found to correlate with the total concentration of PCBs, indicating that the toxicity is as widespread as the contamination is and that it results primarily from commercial wastes. Further, marine mammals had a lower ability to metabolize the coplanar PCBs as compared to the terrestrial mammals. For the Inuit, the bioconcentration within marine species is especially pertinent. Analyses based on enzyme induction potencies indicated that PCBs may be even more toxic to humans and wildlife than dioxins and furans (NATO 1988).

Southern Diet Health Effects

The ArcticNet research group has successfully completed the first phase of their research to study the impacts of climate change in the coastal Canadian Arctic (Vincent et al. 2010). ArcticNet is an organization that brings together experts from the natural sciences, human health sciences, and social sciences to comprehensively study environmental issues. Along with partners from Inuit organizations, northern communities, federal and provincial agencies, and the private sector, experts are conducting research and making recommendations. Researchers collaborated to study the impacts of environmental change on Inuit health (Dewailly et al. 2010). Environmental factors examined included climate, contaminants, globalization, and diet. In 2004, the study began in Nunavik with a survey to assess chronic diseases and their associated risk factors, particularly diet and its marine lipid components.

The Nunavik health survey was conducted during the summer of 2004 when the researchers visited 14 villages during a five-week trip. The 924 subjects answered a questionnaire about their personal and family history as related to cardiovascular disease, cancer, and risk factors. There was also extensive medical testing, including osteo-densitometry, blood sampling, ultrasound measurements of carotid thickness, and assessment of height, hip circumference, and blood pressure. The survey results and clinical observations indicated that 17% of participants suffered from hypertension, 7.9% from high cholesterol, and 14.5% from high blood pressure (Dewailly et al. 2010). Compared to the 1992 study, the 2004 results showed improved lipid profiles except for triglycerides (Jetté 1998). Interestingly, the observed reductions in some risk factors did not translate into lower rates of cardiovascular disease. In part, the results are likely due to modifiable factors that have changed since 1992, such as increased tobacco smoking (Jetté 1998).

Although the study's results show a general reduction in cardiovascular risk factors since the 1992 survey, the prevalence of diabetes and associated risk factors for women is astounding (Dewailly et al. 2010). Women are disproportionately influenced by the current health conflict because they are encouraged to shift to a southern diet to a greater extent than men. When there are shortages of traditionally hunted foods, men have preference over women and so women are required to more often supplement their traditional diets (Gittlesohn & Vastine 2003). Further, women of childbearing age are aware of the contamination risk associated with the meat of traditionally hunted animals and thus they choose to avoid many of these foods (Wang et al. 2005).

As with risk factors for cardiovascular disease, the precursors to diabetes appear to have improved: glycemia and insulinemia rates are lower in the people of Nunavik than they were in 1992 (Jetté 1998). Yet, despite the significant improvements seen in risk factors for diabetes, certain subgroups revealed an opposing trend (Dewailly et al. 2010). The overall decrease in prevalence the of hyperinsulinemia was attributable to males; females not only failed to improve, but actually showed an increased prevalence of hyperinsulinemia as compared to 1992 (Dewailly et al. 2010). The majority (65%) of diabetics were obese, an unsurprising result given that abdominal obesity has increased by a full 10% in the population since 1992; 28% of Inuit participants were obese, compared to 14% in the general Canadian population (Dewailly et al. 2010).

Section III: Current Responses

Inuit Healthcare Status

Canadian healthcare is delivered through a publicly-funded system that satisfies the majority of Canadians (Blizzard 2003), but often shortchanges rural areas. At the point of use, services are mostly provided by subsidized private entities without costs to individuals (Health Canada 2003). Most Canadian doctors practice in urban areas and leave rural areas with healthcare shortages. The problem arises not because insurance companies refuse to cover the conditions associated with contamination, but because doctors are scarce in remote areas (Hackett 2009).

Cultural differences between Inuit and southern doctors pose another obstacle to good healthcare. The unique characteristics of the Inuit include their language, stoicism, and family dynamics (Johnson 1999). To help bridge the gap between southern doctors and Inuit patients, two crucial links exist. First, Ottawa, the capital of Canada, has a resident Inuit community of approximately 500 people (Kent 2000). Second, an Ottawa Health Services Network arranges travel, discharge planning, and interpretation services. Because Inuit families often speak only one of the region's two main dialects, interpreters are needed 24 hours per day. Additionally, many standard Inuit practices are unusual in southern culture; for instance, it is common to have informal adoption of babies by the Inuit (Kent 2000). Differences in family dynamics and other such central issues create an immeasurable gap in understanding. More subtle differences also affect the doctorpatient relationship, such as Inuit stoicism in the face of serious social or medical problems (Kent 2000).

The Inuit's first sustained contact with the outside world was not until during World War II, when the United States Air Force built an airfield at Frobisher Bay, which is now Iqaluit (Johnson 1999). During the Cold War, Arctic communities served as radar bases for the Distant Early Warning Line, the U.S.-Canadian project to protect against an "over-the-Pole" Soviet attack. Recently the Canadian government has adopted a progressive attitude toward the Inuit. In the 1950s and 1960s, though, the government completely disregarded the Inuit's nomadic lifestyle. It established permanent housing settlements, schools, and health and social services (Johnson 1999). Westernized policies were implemented and the government did not solicit input from the Inuit (Van Den Berg et al. 2006); clearly, the stated goals of providing economic opportunities and public services were misguided.

The Canadian government actively prevented traditional activities and lifestyles, moving Inuit people to areas where they had no access to their familiar hunting and fishing grounds (Duhaime 1989). In a situation analogous to how the United States government treated the Native Americans, the Canadian government marginalized the Inuit people while requiring them to conform to southern Canadian ideals. The Inuit were forced to relocate, were prohibited from speaking their Inuktituk language, had their children taken away to boarding schools, and were banned from using traditional hunting techniques (Dussault & Erasmus 1994).

Globalization of the Arctic communities, particularly their markets, is infusing increasing amounts of trans-fatty acids and other processed foods into the Inuit diet. The cultural exchange occurring with globalization is an important contributor to health decline along with environmental degradation. Not only does the contamination encourage a westernized diet with less marine meat, but the media increasingly encourages westernized, processed foods as well (Lougheed 2010).

Social dynamics have been dramatically impacted by globalization. In Nunavut, a full third of the population depends upon social assistance, a rate three times higher than the national average. The Nunavut population is growing rapidly and more than half of all residents are under 19 years of age (Janz et al. 2009). Social services have not kept pace with the rapidly expanding population and the youthful workforce that faces high unemployment, high rates of teen pregnancy, low educational levels, and low average incomes (Janz et al. 2009). Nunavut also has the highest suicide rate in Canada, perhaps because of the new pressure to adapt a Western way of life, high unemployment, and hopelessness (Janz et al. 2009). The infant mortality rate in Nunavut is twice as high as the Canadian average, the territory's tuberculosis rate is eight times as high, and the prevalence of sexually transmitted diseases is 13 to 20 times as high. Additionally, alcohol and substance abuse are rampant; though a pack of cigarettes costs $6, approximately 68 percent of adults are smokers (Janz et al. 2009).

Southern nurses were first sent to the northern communities by Canada's federal government during World War II (Johnson 1999). Then, in the 1980s, responsibility for health care was transferred to the Northwest Territories (NWT) government. The federal and NWT governments currently advise Nunavut's health department, assisting with recruitment of health professionals and advocating within government agencies and departments (Health Canada 2003. It is an immense struggle, though, to find qualified administrators and physicians who are willing to practice in Nunavut. Moreover, the small size of the health care system prevents cost-efficiency. The single largest expense within the health budget is transportation. In the Baffin region, patients from 12 Nunavut communities are flown to Iqaluit's 34-bed hospital. In the Kitikmeot and Kivalliq regions, patients from the other 16 communities can travel 2,000 miles or more to Yellowknife, Edmonton, Churchill or Winnipeg. For more complicated cases, patients are flown to Ottawa, costing them each $30,000 (Kent 2000).

Delivering healthcare to the Inuit is a challenging and expensive operation. Nunavut is two million square kilometers and spans across four times zone in far northern Canada. The ground is primarily frozen rock and ice; the permafrost is widespread, deep, and melts only minimally even in summer, making travel extremely difficult (NSIDC 2010). The 28 isolated communities are home to 25,000 inhabitants, 85% of whom identify as Inuit (Johnson 1999). Though modern housing and computers are now fairly common, many continue to hunt and fish for food, race their dog teams, and engage in other traditional activities.

On Baffin Island just south of the Arctic Circle is Iqaluit, Nunavut's largest community with a population of 4,500 (Receveur et al. 1997). Besides a summer sea-lift of goods, the only entrance is by air and there are just 25 miles of gravel roads (Johnson 1999). The Iqaluit Hospital serves 27,000 people; however, most Inuit live closer to one of the nursing stations scattered throughout the territory. The nationwide nursing shortage is particularly noticeable in Nunavut, where clinics have a 35 to 40 percent vacancy rate (Johnson 1999).

Jurisdiction over the Arctic

Environmental degradation has serious effects on human health. Although specific health impacts can be localized to a particular region, the underlying environmental problems are often global in nature. The study of Canadian Inuit is a case in point, as they were never contributors to the production of PCBs. Despite their lack of fault in causing the problem, the Inuit are affected by the contamination because of the overuse of resources by competing nations (Hardin 1968). The contamination of Inuit food is currently caused by industrialized nations far from the Canadian Arctic, namely Russia and China, but the Inuit have no power to prevent the PCB emissions. Environmental protection must occur at a local level, to prevent disasters such as oil spills, and at a global level, to prevent greenhouse gas emissions and their contribution to climate change.

Melting ice and increasing interest in Arctic shipping has spurred recent challenges to Canada's jurisdiction over the Northwest Passage (Byers et al. 2010, Figure 11). The Arctic is increasingly important for commercial, military, and environmental reasons. A new concern with the region is evidenced by the Russian submarines below the North Pole, the American surveillance planes in the far North, and the Canadian defense efforts in territories once ignored (Byers et al. 2010). Both the U.S. and Canada have a long-term interest in protecting the Passage from environmental and security hazards that will come with the increased use by rogue shipping companies, smugglers, and terrorist groups (Byers et al. 2010). The Canadians think lovingly of their northernmost territories, despite their isolation; the frozen Arctic Archipelago is referred to in the national anthem as "the true north, strong and free" (Department of Canadian Heritage 2008). Besides the wish to protect their land, Canada also has commercial interests in the far north, particularly natural gas and oil (CAPP 2010).

Figure 11. Polar view of the Arctic Ocean (US CIA 2010). Note that the narrow passages will become less important to control and less difficult to navigate as climate change decreases ice coverage and widens the straits.

Since 1986, Canada has claimed as internal waters the straights and channels within the Arctic Archipelago and has controlled activities in the area. Currently the United States and Canada have “agreed to disagree” with respect to the legal status of the Passage, but this precarious arrangement cannot last (Verhaag 2002). Recently, there have been disagreements about exactly what areas fall under Canada’s jurisdiction. The islands north of the mainland in the Arctic belong to Canada, but the water between is less clearly claimed. The Canadian government asserts its right to the waters, but the United States and Russia believe that the Northwest Passage is an international strait open to any ship from any nation (Byers et al. 2010).

Under the United Nations Convention on the Law of the Sea, coastal countries can control a belt of 22 kilometers out from their coasts (United Nations 1982). Because Canada’s islands are separated by stretches of up to 100 kilometers, there would be ample room for foreign ships to travel. However, legally owned territory can be expanded further than 22 kilometers offshore if a country proves that the ridges underneath the water are connected to their continental shelf; a country has exactly one decade from when it ratifies the treaty to submit data for the extension (United Nations 1982). Canada’s two main reasons for desiring control of more water are to direct shipping and to stop the pollution of Arctic waters (Bantz 2003).

Canada firmly believes that the Arctic waters between all of its islands should be considered “internal” to its land. The government’s view is supported by the fact that the waters between the islands are frozen most of the year (Short 2009). Inuit people hunt and work, making the ice effectively an extension of the land. However, the treaty does not address whether ice extensions can be included. In the Arctic Waters Prevention Act, Canada asserts its right to control waters up to 161 kilometers offshore, wary of the potential environmental disaster from foreign tanker spills (Minister of Justice 2009). In addition to controlling the passages between islands, Canada is interested in maintaining control over the Northwest Passage (Bantz 2003).

During the Third United Nations Conference on the Law of the Sea, in New York from 1973 through 1982, committees were formed to address various issues of sovereignty and environmental protection, including a committee focused on the international management of the sea-bed and ocean floor beyond national jurisdiction; (United Nations Convention on the Law of the Sea 1982). The seabed is sometimes seen as a resource that should be parceled out to the numerous northern nations (Arctic Environmental Protection Strategy 1991).

Environmental Protection

By 2003, environmental policy experts had recognized the need for an international treaty designed to protect the Arctic environment (Verhaag 2003) and the native people have gradually begun to assert their rights to protection in recent decades. Canada's environmental legislation is more developed than that in other circumpolar nations, in part because the health problems have worsened severely and been well-publicized. As a nation, notable progress has been achieved toward passing legislation aimed at mitigating the effects of contaminants (Minister of Justice 2009). In 2007, Mary Simon, President of Inuit Tapiriit Kanatami, and Duane Smith, President of Inuit Circumpolar Council of Canada, spoke to the Standing Committee on the Environment and Sustainable Development of the Canadian House of Commons. Simon, on behalf of the Inuit, recommended changes to the Canadian Environmental Protection Act (CEPA) that would result in measurable improvements for Inuit in Canada and other circumpolar nations. Specifically, they asked that CEPA be amended to "require that environmental impacts on vulnerable populations, including Inuit, be considered in all stages of the risk assessment process" (Itkadmin 2007). The legislation would pioneer a more regulated approach to pollution prevention planning for facilities that release toxic substances of concern to Inuit. Simon emphasized that the government should make a greater effort to "collaborate with Inuit to develop practices that are conducive to acquiring, understanding and integrating Inuit traditional knowledge into decision making on the environment and human health" (Itkadmin 2007). The Canadian government has made progress toward this goal by having Inuit representatives at nearly all environmental legislative proceedings (Minister of Justice 2009).

Previous agreements between the United States and Canada demonstrate the potential for cooperation between the Canadian government and the Inuit, and also between the Canadian government and other Arctic nations. The Great Lakes Binational Strategy is an effort to restore and protect the Great Lakes through collaboration of Environment Canada (EC) and the United States Environmental Protection Agency (USEPA). The objective of the Strategy is in line with the Revised Great Lakes Water Quality Agreement of 1978 and further aims to reach the “virtual elimination of persistent toxic substances resulting from human activity, particularly those which bioaccumulate” (USEPA 2000). The governments acknowledge in the Strategy that institutionalized government actions alone cannot achieve the goal of virtual elimination, but that all parts of society must cooperate, creating programs to prevent pollution and confront existing contamination. The Strategy is a landmark agreement that reaffirms the countries’ commitment to managing chemicals in a coordinated, evidence-based manner.

The Canadian Arctic Waters Pollution Prevention Act was enacted to prevent pollution in Canadian Arctic water. In essence, it is a zero discharge act that states, “No person or ship shall deposit or permit the deposit of waste of any type in the Arctic waters.” The Act details specific offences and their corresponding punishments, broken down into two key components, the Arctic Shipping Pollution Prevention Regulations and the Arctic Water Pollution Prevention Regulations (Minister of Justice, Canada 2009).

Tracking pathways of PCB transport will be instrumental in developing effective predictive models for effective regulations. Shindell et al. (2008) examined how changes in emissions from Europe, East and South Asia, and North America affected Arctic gas and aerosol concentrations. Using an integrated model, they found that North America contributes the most to Arctic ozone pollution. They found differences in which sources were most relevant depending on the mode of transport and even on the altitude above the earth's surface. For example, for aerosols and CO, European emissions contribute most at the Arctic surface but East Asian emissions are progressively more important as altitude increases in the Arctic, becoming the primary source in the upper troposphere. Volatilization of PCBs in soil was thought to be the primary source of PCBs in the atmosphere, but recent research suggests that ventilation of PCB-contaminated indoor air from buildings is the primary source of PCB contamination in the atmosphere (Jamshidi et al. 2007).

The task of environmental protection remains difficult since eight different sovereign nations have political sovereignty in the Arctic region (Arctic Environmental Protection Strategy 1991). Any lasting agreement must involve all eight countries that take part in the Arctic Council: Canada, Russia, Norway, Denmark, Iceland, the United States, Sweden, and Finland (Figure 12). Though apart from Russia these are not the countries that are currently emitting PCBs, future contamination from other sources could be prevented by them. To this day, no single international treaty exists for the protection of the Arctic environment, though there is the binding 1973 Agreement on the Conservation of Polar Bears (Agreement on the Conservation of Polar Bears 1973).

Figure 12. The Arctic Region (US CIA 2007). Politically, the Arctic can be defined to include any country that has sovereignty in the North Pole region, but geographically the Arctic is only that region within the Arctic Circle where the average temperature for the warmest months is below 10º C.

Climate Change

Climate change is another complicating factor in the health of the Inuit and has already played a large role in decreasing the availability of traditional foods (Stirling 1997). The gradual decrease in ice coverage and therefore abundance of ice algae is slowly decreasing omega-3 fatty acid concentration at all trophic levels (Soreide et al. 2010). Curbing emissions is increasingly important as climate change accelerates, particularly given the serious ecosystem effects already present in the Arctic. Like PCB contamination, climate change is another sad irony for Arctic peoples; many of the immediate environmental effects are magnified in the Arctic, while the fossil fuel consumption that contributes to global warming has primarily occurred in the industrialized nations to the south.

The decreasing availability of marine mammals could to an increase in the consumption of southern foods. The southern foods are imported, expensive, and unhealthy, which could lead to potentially devastating economic and health effects. Compared to a standard Western diet, the nutritional benefits of traditional food are substantial, contributing significantly more protein, iron, and zinc than southern market foods (Ross 2004). Further, the shift away from traditional food and an active hunting lifestyle is linked to an increase in obesity, diabetes, and cardiovascular disease (Kinlock, Kuhnlein & Muir 1992).

Section IV: Potential Solutions

Considerations in Policy Adoption

There is no obvious ideal response to the PCB contamination that impacts the Inuit. The solution is far from simple because communities are forced to balance the costs and benefits of a traditional diet. In addition to the health benefits of traditional food, the social, cultural, and spiritual benefits of traditional foods should not be overlooked (Kinlock, Kuhnlein & Muir 1992). The contamination issues cannot be resolved by a simple equation involving risk-based health advisories and food substitutions; the solution should involve the community and consider the socio-cultural aspects in addition to the nutrition and safety. Dietary changes are complex because of the cultural and economic constraints (Gittlesohn & Vastine 2003).

In the Canadian Arctic today, Inuit diet is changing; traditional animal food sources are being displaced by purchases from southern markets, particularly for children. Arctic animals and fish contributed 6-40% of daily energy of adults and 0.4-15% of energy of children (Kuhnlein & Receveur 2007). In every age category, a single portion of local animal or fish food resulted in increased levels of energy, protein, vitamin D, vitamin E, riboflavin, vitamin B-6, iron, zinc, copper, magnesium, manganese, phosphorus, and potassium (Kuhnlein & Receveur 2007).

Canada, and other governments, needs to evaluate the benefits of environmental regulations in a more robust fashion. Many current methods of assessing the benefits of environmental regulations underestimate the value that people place on children's health (Dickie & Ulery 2002). A model relating parental preferences to relieve their children's acute illness instead of their own indicated a marginal rate of substitution between child and parent illness of two, meaning that parents value relieving children's illness twice as highly as their own (Dickie & Ulery 2002). Parents' willingness to pay to avoid illness increases with income, declines with fertility, and strongly depends on perceived discomfort (Dickie & Ulery 2002). A more accurate evaluation of regulatory benefits might lead to stricter regulations or greater efforts to prevent contaminant exposure at the local or national level (Appendix II). Better information might also stir renewed international efforts to limit further use of harmful chemicals, by making it a higher priority to bind nations that have not yet participated in treaties that limit toxic emissions.

Policy makers should consider the direct costs of PCB contamination; such consideration might motivate better regulation and treatment. Researchers estimated United States and Canadian health care costs for four conditions related to PCB exposure: diabetes, Parkinson's, hypothyroidism, and lost intelligence (IQ). The cumulative cost of these four diseases alone was estimated at $514-$711 billion per year, in Canadian dollars in the year 2000, for Canada and the United States combined. A monetary value of IQ was determined, estimating that a loss of 5 IQ points cost $30 billion per year for Canada and $283-$333 billion per year in the United States (Muir & Zegarac 2001). Health conditions related to change in diet are extraordinarily costly. Coronary artery disease is one of the most costly burdens on the health care system and its prevalence among Inuit is increasing due to their change in diet. A Markov model of the economic costs of coronary artery disease can be generated using incidence-based estimates of direct medical costs; ten-year cumulative costs for patients in the United States with coronary artery disease are in the hundreds of billions of dollars (Russell et al. 1998).

Quality of life is greatly determined by health, which in turn is affected by a complex interaction of biological, behavioral, cultural, and social factors. "Death" is easily defined as the end of life and "morbid" as diseased or unhealthy (Tolley et al. 1986). However, a definition of "health" is more difficult to agree upon because true health is more than simply the absence of illness. Health includes "physical and mental well-being, soundness, vitality, prosperity . . . a flourishing condition" (Weber 2002). A healthy person can "function effectively, happily, and as long as possible in a particular environment (Carroll, Miller & Nash 1976). The World Health Organization describes more than freedom from disease, describing health as "a state of complete mental and social well-being" (WHO 1948). Recent reports issued by Statistics Canada have revealed that the Inuit receive far less healthcare than they need. Not only has chronic disease incidence risen, but also self-rated health status has decreased markedly since 2001 (Janz et al. 2009).

Future Healthcare Policy

There have been efforts to increase awareness of the contamination, but education is no longer the largest obstacle to overcoming the PCB toxicity in the Inuit people. For decades, the basic message has already been clear to the Inuit: the contamination and their changing diet are causing their people to have serious health problems. Whether they can analyze the statistical changes for themselves is irrelevant because they are living out the problem, but have no power to change it. The major barrier is not a lack of understanding but a lack of means.

Despite those challenges, public health authorities in Nunavut can use the ArcticNet Phase 1 results to analyze dietary changes that could influence public health decisions and natural resource management. Clinicians must be made aware of dietary changes because they are important risk factors for chronic disease. Knowledge of general trends will help clinicians know what causal mechanisms for heart disease and diabetes might be present and also what questions to ask of their patients. Policies regarding intercommunity trade and development of fisheries will also be informed by dietary habits because the availability of traditional marine food sources is changing with climate and the availability of imported southern market foods is changing with globalization. Territorial governments can use the evidence provided by ArcticNet to motivate food policies including taxes and bans (Chan et al. 2006).

Nunavut's creation as a territory finally eliminates much of the southerners' control and provides the Inuit with sovereignty over their land. Now that Nunavut is an official territory, the governmental models are changing to better reflect a compromise of traditional and modern Inuit culture. For instance, Inuktitut is the official government language and there are public healing circles. The decentralization of various departments and agencies of the government has helped to distribute services and employment more evenly across the communities (Johnson 1999). To attract nurses and other healthcare workers, there must be financial incentives that entice southerners to move north.

Another goal should be to remedy the lack of Inuit who work in healthcare; there are very few Inuit nurses and doctors, partly because they have to go south for post-secondary training and deal with dramatic culture shock and loneliness. Training local nurses has many advantages because they will speak the language and better relate to the patients. The medical establishments in populated cities of southern Canada could begin programs to train village health aids. Empowering the Inuit to care for themselves is crucial to the long-term health and happiness of the population.

Telemedicine could drastically reduce healthcare expenses. The expenses are more than simply monetary: travel disrupts families and employment, making it likely that Inuit will not take advantage of preventive care. The other major cost, besides emergency transport, is the cost of the visits that general practitioners make once a month. Specialists from Ottawa fly in as well, simply for routine check-ups or for patients who do not merit emergency medivac transport. Telemedicine could be the solution to inexpensively taming these large distances. Doctors in Ottawa, thousands of miles away, could observe patients in isolated communities using satellites and video images and then decide whether to airlift them south for treatment.

Conclusions

The future health of the Inuit depends on levels of PCB contamination, composition of diet, and quality of healthcare. To prevent further contamination, the Canadian government must actively engage with other Arctic nations to develop environmental policy. Existing Canadian legislation must also be critically reexamined each year to determine if stated goals are being met and adjustments in regulations or punishments could even further reduce ongoing pollution.

Arctic nations can cooperate to develop policy that will prevent pollution and mitigate the effects of climate change. In contrast to the Arctic, the Antarctic's international environmental management serves as a successful model of international law. Despite the differences between the Arctic and the Antarctic, the concept of a global commons could be useful in the design of Arctic policy (Hunter et al. 1998). The treaties that are in effect in Antarctica have mooted unresolved territorial claims by implementing a set of regulations under which no nation can exert sovereign control over any aspect of the continent (Antarctic Treaty 1959). The Antarctic Treaty system is made up of five international treaties and is an example of how the eight Arctic States could attempt to prevent and mitigate pollution in their region.

Because Canada is no longer a source of PCB pollution, regulations in Canada must focus on the aspects of the problem that can legally be addressed. As the Canadian government has no jurisdiction over Asia's and Russia's continued emission, the focus should be on mediating the health effects of the contaminants on their citizens.

The changing Inuit diet and lifestyle will continue to play a key role in their health. Although PCB contamination has led some to believe that Inuit should consume less traditional foods, there are serious repercussions of a standard southern diet. Continued hunting and supplementation of the market foods with traditional animal-source foods will be essential in ensuring a high quality diet (Murphy & Allen 2003). Studies of Yukon First Nations, Dene, Métis, and Inuit cultural groups demonstrate extensive knowledge of diverse food sources, foods with exceptional nutrient quality, and unique patterns of food use incorporating varying levels of local cultural food with purchased market food (Receveur et al. 1997).

Finally, and perhaps most importantly, the healthcare system must reach out to more fully incorporate the Inuit people. Recent innovations in "telemedicine" offer a promising solution. Satellite links already connect the Children's Hospital of Eastern Ontario (CHEO) with the Iqaluit Hospital so that care can be provided by rotating medical residents from CHEO. Eventually, the satellite link will be expanded to remote nursing stations, allowing doctors to evaluate babies and communicate with parents at nursing stations across the remote expanses of Inuit territory (Kent 2000). Telelinks will provide faster, more convenient, less expensive service.

Despite efforts to combat the problem, individual methods are hindered by a lack of proper communication between and by deep-set differences in values between the Inuit and the southern Canadians. Few Inuit northern natives are directly involved in the healthcare system or the national government. The southerners do not understand the cultural implications of their recommendations. For these reasons, and given the tradeoffs between contaminated traditional diets and substiute southern diets, there are not any ideal recommendations to be made at present. Traditional Inuit foods are contaminated, but the alternative southern diet causes new health problems, such as heart disease and diabetes, that were not previously experienced by the Inuit. Decontamination research is called for and could potentially uncover ways in which to detoxify animal fat and mothers' breast milk.

Inuit people deserve the same attention and specialists that other Canadian citizens receive; the government should make every effort to take advantage of technological opportunities that can extend specialized medical services to the Inuit. The social aspects of reaching the Inuit are equally important and so funds should be dedicated to training local health aids and working through cultural misunderstandings.

The future health of the Inuit remains to be determined, but the current situation is untenable. If environmental policy makers, nutritional education leaders, and healthcare system workers are motivated by the explicit goals of the Inuit people themselves, progress can be made. The solution, though, cannot be imposed upon them but must come from within. In order to "regain respect for [their] own world, [they] have to promote and educate and train [their] own people" (Johnson 1999). Only the Inuit people themselves can accurately analyze the costs and benefits associated with a given proposal.

Appendix I: Chemical Details

PCBs and their associated metabolites have a diverse array of biochemical and toxic responses. Studies suggest that the coplanar PCBs, such as 3,3',4,4'-tetrachlorobiphenyl, 3,3',4,4',5-pentaCB, 3,3',4,4',5,5'-hexaCB, and their mono-ortho analogs are aryl hydrocarbon receptor (Ah-R) agonists. A protein inside the cell can bind aryl hydrocarbons to form a complex that migrates to the nucleus. Inside the nucleus, the complex initiates a series of biotransformations for the excretion of hydrocarbon compounds. However, Ah-R binding can also result in the synthesis of proteins that interfere with cellular growth and differentiation. Because Ah-Rs easily bind halogenated aromatic hydrocarbons such as PCBs, exposure to PCBs can results in changes cellular growth, form, and function. In this way, PCBs can be carcinogenic and teratogenic (GreenFacts 2009).

The coplanar PCBs make the greatest contribution to the toxicity of PCB mixtures (Safe 1994). The persistence of PCBs is mitigated by certain biological processes. Hydroxyl radicals in the atmosphere or direct photolysis can degrade PCBs as they travel in air currents. Once they reenter the biosphere, bacteria utilize dioxygenase enzyme to perform reductive or oxidative dechlorination. Likewise, eukaryotes use mixed function oxidase to oxidize PCBs (Pfafflin & Ziegler 2006). The speed of the organic reactions depends on the number and the disposition of chlorine atoms in the molecule, with the less substituted, meta- or para-substituted PCBs undergoing biodegradation faster than more substituted phenyls (Pfafflin & Ziegler 2006).

Appendix II: Economic Valuation

A recent statistical analysis of 40 studies published between 1974 and 2002 offered insight into the value of a statistical life (VSL). The study employed concluded that the adjusted VSL has a mean of \$5.4 million and a standard deviation of \$2.4 million (Kochi, Hubbell & Kramer 2006). The extraordinarily high value demonstrates the need to prioritize environmental protection as related to public health. Labor market contracts can also be used to estimate the VSL, but the reported estimates vary from less than \$100,000 to more than \$25 million in 1998 dollars (Mrozek & Taylor 2002). To be conservative when using current estimates, it should be assumed that the value is closer to the high end in designing new protective policies.

There is an unavoidable trade-off between government expenditures and health benefits and so the risk of death must be considered in a wide variety of decisions. Ideally, the consideration should be explicit and consistent across policy areas; to consistently implement a valuation policy of the benefits of reduced risk, estimates should be based on the required compensation for exposure to risk. Inuit interpretation of risk reduction may play a role in their hesitance to follow advice to switch away from contaminated traditional foods (Ritov et al. 1993). By using data from the Canadian labor market to estimate the VSL, public policy applications in Canada can follow more specific guidelines (Meng & Smith 1990).

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