Chapter 7
Arctic Monitoring and Assessment Programme (AMAP)—IPY Meeting in Iqaluit, Nunavut, Canada (June 2009), and AMAP Human Health Assessment 2009

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Executive Summary

The Arctic Monitoring and Assessment Programme (AMAP) Human Health Assessment Group (HHAG) undertook an assessment and meeting to summarize arctic contaminant and human health research undertaken during the International Polar Years (IPYs). This meeting took place in Iqaluit, Nunavut, Canada, on June

In Memoriam for Jens C. Hansen Jens C. Hansen passed away in 2012 only a few years after his retirement from Aarhus University, in Denmark. He devoted his academic life to research, which focused on understanding the exposure pathways for and the effects of contaminants on Arctic residents. Jens was a founding member and chair of the Human Health Assessment Group of the Arctic Monitoring and Assessment Programme (AMAP). He provided leadership and encouragement on all aspects of the work of the group and AMAP for over 17 years. He also created and became the first head of the Centre for Arctic Environmental Medicine at Aarhus University (now Centre of Arctic Health). His kindness and sensitivity toward all he met, worked with, and trained were inspirational. We very fondly dedicate this work to his memory: Jens C. Hansen, an excellent scientist, mentor, and friend to many.

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10–12, 2009. This report summarizes the much more voluminous document *AMAP Assessment 2009*: *Human Health in the Arctic* (AMAP 2009a) that was released and discussed at the Iqaluit meeting.

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Population Health and Effects of Contaminants

In light of current studies, many indigenous populations in the Arctic region have poorer health than national averages. While socioeconomic conditions and lifestyle choices are major determinants of health, contaminants may also have a contributing effect. Toxicological studies show that contaminants, at the levels found in some parts of the Arctic, have the potential for adverse health effects in people. Epidemiological studies, looking at Arctic residents directly, provide evidence for subtle immunological, cardiovascular, and reproductive effects due to contaminants in some Arctic populations. These results indicate that POPs, mercury, and lead can affect health of people and especially children at lower levels of exposure than previously thought. Genetic characteristics of the various Arctic populations also affect their response to contaminants and susceptibility to certain diseases.

A major dietary shift from traditional to store-bought food is underway in most of the Arctic, with important health implications. In addition to environmental concentrations of the contaminants in traditional foods, lifestyle factors and social and cultural practices play a large role in determining human exposure to contaminants in Arctic areas. Despite changes in lifestyle and diet that are resulting in increasing consumption of store-bought foods, traditional foods remain important to Arctic indigenous peoples for social, cultural, nutritional, economic, and spiritual reasons. Store-bought foods are increasingly the main source of dietary energy, but traditional foods provide many nutrients and are still a major contributor to healthy diets in many communities. Some traditional foods can also carry potential risks from contaminants. The combination of high prices for store-bought foods and the work, risks, and costs associated with obtaining traditional foods has made food security a large concern for many Arctic residents.

Recent studies have found a number of mechanisms by which contaminants can affect metabolism. Obesity is associated with an increased risk of cardiovascular disease and of developing diabetes; as in other parts of the world, obesity is increasing in Arctic communities. POPs, even at low concentrations, also increase the risk of diabetes. These new findings emphasize the need to consider the interactions between contaminants and other health conditions.

Trends in Exposure and Contaminant Levels

Human exposure to most legacy POPs and mercury is decreasing in several Arctic populations. This reflects changes in diet, changing levels of environmental contamination, and health advice to critical groups in some areas concerning consumption of certain foods; however, exposure remains high in some populations. The proportion of women of childbearing age who exceed blood-level guidelines for PCBs, mercury, and lead is decreasing. For PCBs and lead, in particular, there is evidence that this reflects the declines in environmental levels of these contaminants.

Marine mammals remain a major dietary source of POPs and mercury, so that people who eat large quantities of marine mammals have higher POPs and mercury levels than those who do not.

Emerging compounds such as brominated flame retardants and fluorinated compounds are a concern for three reasons: They are present in Arctic people and biota, levels globally have increased over the last 15 years, and their toxic effects have not been studied in detail. There is little information on the routes of exposure or trends of these contaminants in Arctic populations.

Reliable interpretation of information on trends and inter-regional differences is critically dependent on an ability to compare data from different studies and different laboratories. Laboratory performance-testing procedures initiated by AMAP and others, including the AMAP interlaboratory comparison program for analysis of contaminants in human tissue, have markedly improved analytical cooperation, data comparability, data reliability, and data accuracy in studies using the participating laboratories and have led to more reliable data on contaminant levels in human tissues. Further improvements can be achieved through continued efforts in this respect.

Increased industrial activity in parts of the Arctic is likely to lead to an increase in local sources of contaminants. Anticipated changes in global and Arctic climate may also result in changes in contaminant transport to the Arctic. Such changes may affect exposure patterns to some contaminants.

Communication

Communicating the results of studies concerning contaminants and people is important in helping Arctic residents make informed food choices. Health advisories issued in response to findings reported in past AMAP assessments have succeeded in reducing exposure to contaminants in some Arctic population groups.

Risk communication must be carried out with great care and respect for culture at a community level. The involvement of community members and organizations, regional health officials, and indigenous organizations is the key to developing and disseminating messages that are appropriate and relevant.

Introduction

The Arctic Monitoring and Assessment Programme (AMAP) Human Health Assessment Group (HHAG) in 2005 envisioned undertaking an assessment and meeting to summarize arctic contaminant and human health research undertaken during the International Polar Years (IPYs). The proposed meeting was accepted by the IPY steering committee as an "educational event." This meeting took place in Iqaluit, Nunavut, Canada, on June 10–12, 2009. This report summarizes the much more voluminous document *AMAP Assessment 2009*: *Human Health in the Arctic* (AMAP 2009a) that was released and discussed at the Iqaluit meeting. Readers are encouraged to consult AMAP (2009a, b) for a more in-depth evaluation of all the topics summarized here.

Factors Influencing Human Exposure to Environmental Contaminants and Population Vulnerability

While most Arctic contamination by POPs and metals is from long-range transport, there are several potential sources of contaminants from within the Arctic that could add to loadings of metals and POPs. Human population exposure comes primarily from country food consumption, and local sources of contamination have the potential to contribute marginally to food contamination.

Climate change is almost certain to affect the biogeochemical fluxes of contaminants within the environment. These fluxes will cause increases and decreases in current human exposures. Current climate trends and future model predictions illustrate the incomplete understanding of the interactions between contaminants and climate. Not all Arctic regions will be affected to the same extent or in the same way. Climate change is also likely to change exposures to pathogens such as viruses and bacteria, and to insect vectors. Climate change can also make human populations more vulnerable. Climate-related "stress" associated with changes in diet, lack of access to traditional prey species and foods, loss of traditional hunting, changes in community practices, and changes in occupation can affect psychosocial health. The combination of changing exposures and vulnerability has the potential to affect health and well-being significantly.

The only practical approach for evaluating the implications of climate change on contaminant fluxes is continued monitoring of humans and key wildlife species to directly assess tissue levels of contaminants. Knowledge of personal contamination levels and awareness of contaminant levels in traditional food species will enable Arctic residents to select, where necessary, alternative and culturally appropriate foods which preserve cultural traditions and the benefits of the traditional diet. Research into climate and contaminant interactions should continue to assist policy development of regionally appropriate adaptation strategies.

Knowledge of how climate and local weather affect contaminant distribution and redistribution and the rates at which these occur are in the early stages of development.

Detailed knowledge of climate-mediated transport pathways is also a relatively new field of investigation. Continued research in this area, coordination between researchers, and careful development of joint research plans are critical components for future progress in the *climate–contaminant transport–human exposure* research effort. Findings from coordinated research of this type will have a direct bearing on how exposure and health will affect Arctic residents in the future.

Arctic countries need to continue to support the implementation of international and regional agreements to control chemical and metal releases to the environment. The USA and Russia have yet to ratify some key environmental agreements that are important for the protection of the Arctic and its people.

Monitoring programs to assess the success of national, regional, and global control initiatives currently in place are essential. Without information on where and how levels are changing and which populations are most at risk, it is impossible to revise control actions to make them more effective.

Mineral exploration and extraction could lead to contamination of the local environment with mine tailings. Depending on the amount, type, and location of the contamination, these activities could increase human exposures to some metals of significance through the intake of local foods, air, water, and wildlife. The in-migration of workers to oil, gas, and mining operations can lead to the introduction and spread of disease if health monitoring and treatment are not adequate. General health is a significant determinant in evaluating how an individual may respond to contaminant loads. This assessment has not undertaken a thorough review of mining activity in the circumpolar Arctic to assess how mining activity may co-contribute to current human exposures to mercury, cadmium, and lead.

Oil and gas exploration and extraction activities are likely to increase in the Arctic, but have the potential to contribute only very small amounts of POPs and metals to the environment. Most on-site wastes are contained and managed to similar high standards. While a large oil spill on land could contaminate a large area, it would not add appreciably to the entry of POPs or metals into the environment. A large spill could lead to significant social disruption, which can influence mental health and affect individual responses to current exposures to POPs and metals received primarily through diet A detailed review of the health implications of oil and gas exploration and extraction in the Arctic has been undertaken by AMAP (2009b). It is worth noting that spills from tankers, where oil can spread among floating ice or under the surface covered by ice, are often very difficult to manage (AMAP 2009b). Also, a well rupture under water in the Arctic (like the BP underwater rupture in the Gulf of Mexico) would be difficult to arrest during the ice season and would likely continue for many months until it was safe for underwater crews and submersibles to operate in and around summer ice. The environmental implications for marine life could be enormous and could affect the health of those living in the Arctic who depend on marine species for food and for part of their social systems.

The security and integrity of domestic and chemical waste sites in the Arctic are important, especially under the conditions of a changing climate. Many military sites in the Arctic, which had caused contamination in local areas, have now been cleaned up or are in the process of being cleaned up. These and other waste sites need to be monitored to ensure that they do not affect community water and food supplies as the permafrost thaws. Leaking waste sites have the potential to add to local population exposure to chemicals, metals, and pathogens that are likely to impact negatively on health.

Social factors can affect health outcomes and should be considered carefully in risk assessments related to contaminants. Excessive smoking, alcohol, and drug use, and crowding and underemployment can affect health. How individuals interact within their communities and families can be affected by their knowledge of the extent of contamination of traditional food, breast milk, and the local environment.

Food, Diet, Nutrition, and Contaminants

This chapter presents recent research findings concerning food sources and diet in Arctic populations and explores how food choices and availability influence human nutritional status and exposure to contaminants. Other factors influencing human exposures to contaminants were addressed in Section "Factors Influencing Human Exposure to Environmental Contaminants and Population Vulnerability." The term traditional *food* is used to represent foods that originate in the populations' habitat (generally foods such as seal, whale, caribou, and fish from the land); other foods are called *imported food.*

In the Arctic, traditional food is beneficial to indigenous populations for cultural, social, psychological, and economic well-being; however, foods from mammals, birds, and fish have been documented as the main source of human exposure to contaminants. Changes in food sources and food choice can influence the nutritional quality, density, and security of the diets of indigenous populations. In addition, the incidence of food-borne botulism and trichinosis is associated with the preparation and consumption of local meat. As a result, studies in Canada indicate that food insecurity is more prevalent among indigenous populations than non-indigenous populations. One of the observed consequences of the changes in diet and lifestyle is an increased prevalence of overweight and obesity.

In indigenous populations where most of the dietary energy was provided from imported food before the turn of the millennium, this pattern has remained the same or increased further. In Russia, on the other hand, the socioeconomic changes and deterioration of the farming and livestock system in the northernmost parts after the dissolution of the former Soviet Union seem to have led to increased use of local foods in some populations. In indigenous populations, the trend toward a higher proportion of imported foods in the diets of young people has continued and appears particularly strong in Alaska, Yukon, and among the Canadian Inuit. Sweet and fatty store-bought food is becoming the main source of energy for children in this region, which has also contributed to an inverse relationship between nutrient density in the diet and age group. In the future, the low consumption of traditional food in the young age groups may perpetuate itself as they grow older and contribute to additional decreases in the consumption of traditional food. The overall contribution of traditional foods to energy intake in indigenous populations of Arctic Canada ranges from 10 to 36 %, with an average of 22 %; this figure is lower among children. Within that proportion, there have also been reports of changes in food choice; for example, more fish and fewer marine mammals are being consumed. In southern

Greenland (Inuit) and northwestern Alaska, local food constituted a lower proportion of the diet than in Canada. In Greenland, studies indicate that the consumption of local food among the Inuit has been reduced by about 50 % over the last 30 years, and today, the community-level proportions among adults range from 11 to 22 %. Women in most indigenous populations in Alaska, Greenland, and Arctic Canada generally consume proportionally less traditional food than men. Consumption is positively associated with the proximity of settlements to a coast or river, but varies with season. Education above elementary school level tends to lead to the consumption of more imported food. Alcohol consumption tends to be underestimated or not accounted for when estimates of energy consumption are made. Thus, the true proportions of energy intake from traditional foods among adults, especially men, are likely to be lower than those reported.

In general, the decreasing proportion of traditional foods in the diet has had a negative impact on the intakes of most nutrients, but imported foods appear to have contributed positively to the intake of vitamin C, folate, and possibly calcium. According to measurements of blood and dietary intakes, nutritional deficiencies of vitamin A, iron, calcium, and magnesium are prevalent in some communities. However, the amount of calcium provided through consumption of local foods is insufficiently researched. In terms of vitamin A, the types of imported foods consumed do not seem to provide the recommended amounts. The transition to diets mainly based on imported foods in the indigenous populations is likely to have led to insufficient intakes of other nutrients as well, especially in the young age groups. Nutritionally, the problem is not the imported food itself, but rather the widespread replacement of traditional food by a diet that is high in sugar and other foods with low nutrient density. However, updated, accessible, and comparable information about nutritional intake is relatively sparse from circumpolar populations outside Alaska, Greenland, and Arctic Canada. Information concerning populations in Russia, where the majority of indigenous and non-indigenous people live, has become more available and accessible since the previous AMAP assessment of human health in the Arctic (AMAP 2003), but still relatively little is known.

Contaminant levels in the Arctic, including levels in dietary items of fish, birds, seals, and whales, are in most cases lower than in more densely populated and industrialized regions. This geographic difference is especially pronounced for the organochlorines. Nevertheless, based on measured levels in Arctic biota and food samples, and based on studies of total dietary intakes of contaminants, it is apparent that dietary exposure to persistent contaminants and metals in Arctic indigenous communities is higher than in neighboring non-indigenous communities. The main explanation is that indigenous populations consume tissue from marine top predators that are not normally eaten in other parts of the world. Within the Arctic, there is therefore a higher exposure to contaminants through the diet in coastal dwelling ethnic communities that eat traditional foods such as marine mammals and some bird species, than in inland dwelling communities that eat reindeer/caribou and freshwater fish. Recent data from Arctic Russia illustrate the markedly higher intake of marine mammals by coastal people and greater intake of terrestrial mammals by inland peoples (Fig. 7.1).

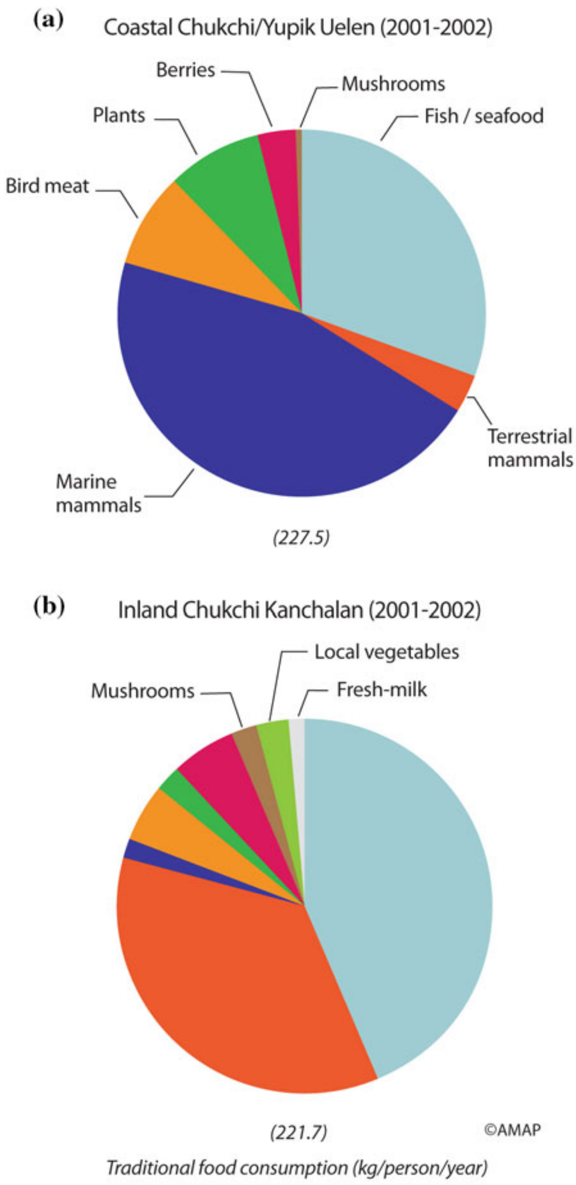

Fig. 7.1 Annual consumption of traditional food in **a** Uelen (coastal Chukchi and Inuit) and **b** Kanchalan (inland Chukchi) on Chukotka Peninsula, northeast Russia. Diagram provided by A. Dudarev (unpublished)

However, for the contaminants investigated, the levels in local food sources appear to be decreasing for some compounds in some areas, for example, polychlorinated biphenyls (PCBs) and DDT in Arctic Canada and Russia and PCBs in Greenland, whereas mercury (Hg) seems to be increasing in Arctic Canada and northwestern Greenland. The overall picture for chlordanes, toxaphenes, hexachlorocyclohexane (HCH), and mirex is uncertain; their levels appear to be decreasing in Arctic Canada, while increasing levels have been measured in Greenlandic food items and high levels of β-HCH were found in both animal biota and human plasma in the eastern part of Arctic Russia.

The research findings presented concerning exposure to contaminants through food consumption indicate that food items from marine mammals have the highest contaminant levels. But other marine foods, such as burbot (Lota *lota*), Greenland shark (Somniosus *microcephalus*), and liver from Greenland halibut (Reinhardtius *hippoglossoides*), and birds such as marine gulls and fulmars (including their eggs) also have relatively high levels of contaminants. Thus, further research and monitoring is needed for these species and for others with a similar role in the food chain. However, the levels of contaminants in the biota vary to a large extent within and between populations and within and between areas of the circumpolar Arctic. Exposure also very signifcantly depends on the amount of local foods consumed.

Analytical Quality Assurance and Quality Control

For more than two decades, researchers from AMAP countries have relied on the data produced by various laboratories to determine the exposure of Arctic populations to persistent organic pollutants (POPs) and heavy metals. In order to establish meaningful temporal trends and spatial distributions in exposure levels, the uncertainties resulting from variations in laboratory performance over time or among laboratories should be as low as possible. Given the analytical difficulties, variations of 20 % or less are considered acceptable. If there are significant variations in the accuracy of results, the biases should be estimated, so as to enable the application of correction factors, or such data should at least be flagged.

Laboratories should therefore participate in intercomparison exercises on a regular basis to determine their performance, relative to that of their peers, in an objective manner. Several international external quality assessment schemes (EQASs) exist for metals in human biological fluids, and laboratories should participate actively in one or more. This was not the case for POPs in human serum, however, where no ongoing intercomparison program existed when the AMAP Ring Test was initiated in 2001 (with the exception of the German EQAS based at the Institute and Out-Patient Clinic of Occupational, Social and Environmental Medicine of the University Erlangen—Nuremberg). Laboratories producing AMAP data were required to participate in the AMAP Ring Test. Results indicated that performance between 2001 and 2007 was generally acceptable. Some biases were identified, however, especially when new compounds were introduced. It was shown that lipid determinations were very method-dependent, with gravimetric methods yielding significantly underestimated results.

The difficulties inherent in comparing data from several laboratories, with different detection limits, were illustrated by reference to the new Russian data on persistent toxic substances. The use of appropriate statistical techniques was crucial in allowing meaningful comparisons.

Emerging persistent compounds create new challenges for laboratories, requiring new analytical technologies and lower detection limits. To ensure comparability of data produced by different laboratories, it is essential that EQAS be developed for these substances.

It is recommended that AMAP take a more proactive role in ensuring that all contributing laboratories produce good quality data. AMAP should determine, promulgate, and enforce formal performance requirements for the measurement of POPs, including emerging compounds, and in future should accept data only from laboratories conforming with these performance requirements. It is also recommended that serum lipids be measured using standard enzymatic methods rather than gravimetric methods.

Human Tissue Levels of Environmental Contaminants

Legacy Persistent Organic Pollutants (POPs) and Metals

This assessment is the third AMAP assessment (AMAP 1998, 2003, 2009a) of human health in Arctic regions but is the first to contain initial trend data for some organochlorines and metals. The assessment also incorporates the first comparison of all Russian Arctic regions as part of a circumpolar human health assessment.

Several important conclusions can be drawn from the information that has been presented in this section on the concentrations of organochlorine chemicals and certain metals in pregnant women and mothers, as well as in adults (both men and women) living in the circumpolar region.

Inuit populations of Greenland, Canada, and the USA continue to have higher concentrations of legacy contaminants, similar to what was seen in the previous assessments (AMAP 1998, 2003) as seen in Fig. 7.2, 7.3, 7.4. These concentrations are linked to the consumption of marine mammals. In addition, this assessment incorporates new regional sampling from Russia, and again, the Inuit or coastal populations that consume marine mammals have the highest concentrations of contaminants. Also, the patterns of DDT and DDE concentrations in some parts of Russia (with greater proportions of DDT) suggest that human exposures to pesticides are associated with local sources of contamination (e.g., soil contamination during food processing) and use of pesticides on the commercial food supply (see AMAP 2009a).

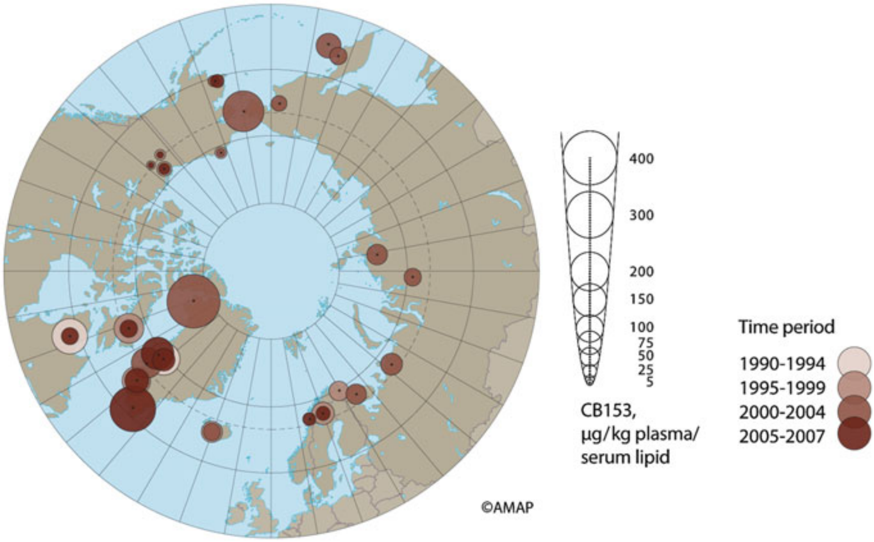

Fig. 7.2 PCB 153 concentrations in blood of mothers, pregnant women, and women of childbearing age in the circumpolar countries

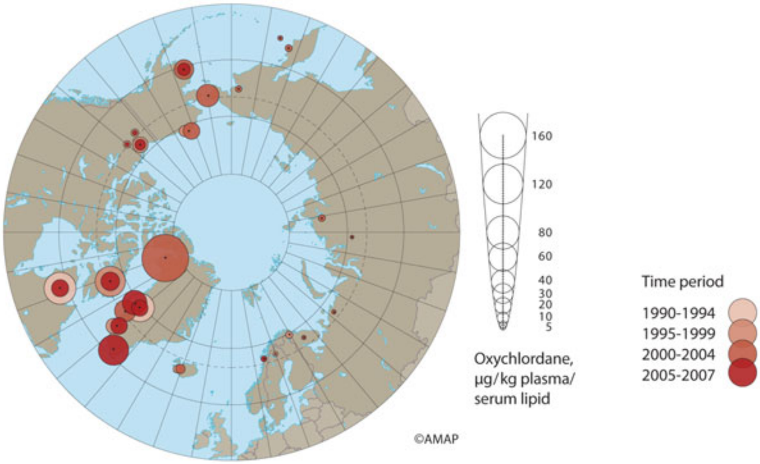

Fig. 7.3 Oxychlordane concentrations in blood of mothers, pregnant women, and women of childbearing age in the circumpolar countries

A series of biomonitoring studies have taken place in the Arctic which allow an initial assessment of changes in contaminant concentrations. The recent data presented in this assessment suggest that concentrations of contaminants such as DDE, PCBs, oxychlordane, Hg, and Pb are decreasing in many Arctic populations as

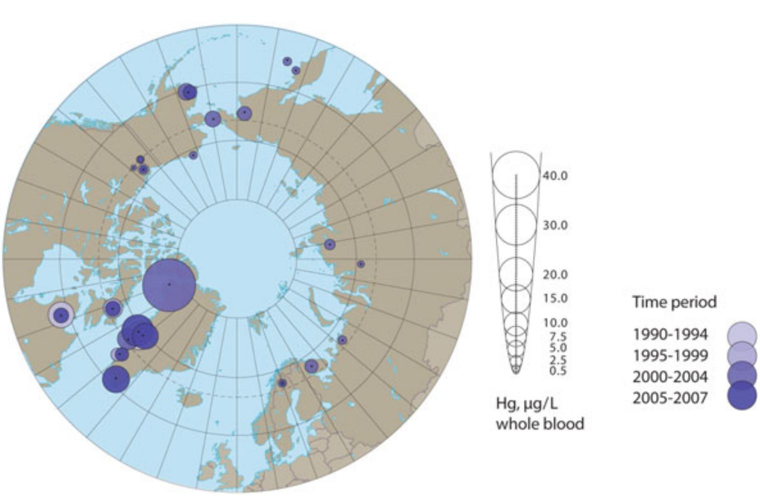

Fig. 7.4 Total mercury concentrations in blood of mothers, pregnant women, and women of childbearing age in the circumpolar countries

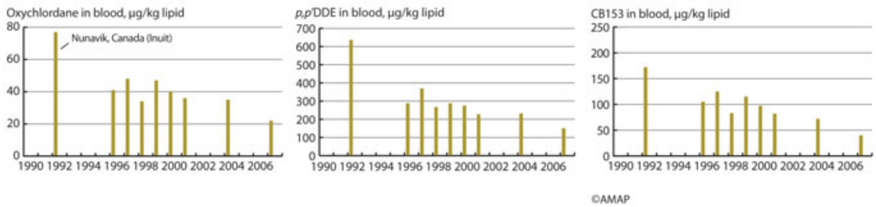

Fig. 7.5 Temporal trends of POPs and metals in maternal blood samples from Nunavik, Canada

shown in Figs. 7.2, 7.3, and 7.4 and in more detail for Nunavik, Canada, and Nuuk/Disko Bay, Greenland as shown in Figs. 7.5 and 7.6, respectively. The decrease may be related to lower concentrations of organochlorine chemicals in the environment as well as to dietary changes. Limited dietary data from Arctic Canada and Greenland suggest that changes are taking place in the traditional diet of Inuit mothers. Consumption of traditional food species that have higher concentrations of contaminants (e.g., marine mammals) is decreasing, while consumption of other species with lower concentrations of contaminants (e.g., fish and caribou) is increasing. This would result in an overall decrease in dietary exposure to contaminants. However, decreasing consumption of these traditional foods is not a positive indicator for human health as there are positive cardiovascular and neurobehavioral benefits to the consumption of these foods.

Guidelines are available for concentrations of PCBs, Hg, and lead (Pb) in blood. Inuit from the high Arctic that consume marine mammals continue to have higher

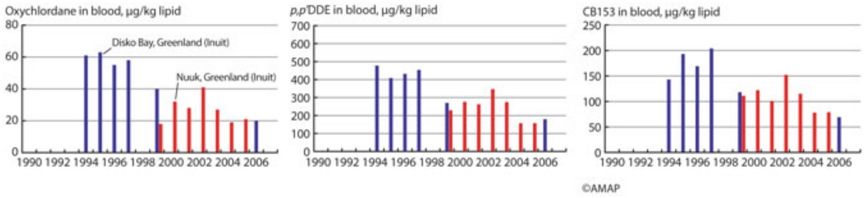

Fig. 7.6 Temporal trends of POPs and metals in maternal blood samples from Nuuk and Disko Bay, Greenland

proportions of the population that exceed these guideline values. In parallel with the decreases in the concentrations of PCBs and Hg in some populations of Arctic mothers, the proportion of mothers exceeding these guidelines is also decreasing.

Both blood and breast milk can be used for monitoring contaminant concentrations. The preference for blood monitoring in the Arctic is based on a need for information on both males and females, multiple age groups (children, adolescents, adults, senior citizens) and both POPs and metals. Several studies and data provided in previous AMAP assessments indicate that contaminant concentrations in blood and breast milk are well correlated and intercomparable.

The results presented in this chapter illustrate the need for continued monitoring of organochlorines and metal concentrations in human populations in the Arctic, especially for mothers or women of reproductive age and children. These data are important to allow a more complete assessment of trends in contaminant concentrations in a broader range of Arctic populations. The issue of decreasing contaminant exposure and decreasing traditional food consumption is very important in a number of circumpolar countries and is specifically addressed in Section "AMAP and Risk Communication."

Emerging Contaminants of Concern for Humans in Arctic Regions

In addition to the legacy POPs discussed in the previous section, a growing number of compounds are being detected in humans from the Arctic regions of the world. Some of these are fairly "new" compounds, whereas others have been around for decades but have only recently been detected due to advances in analytical techniques. The main compounds addressed in this section are the brominated flame retardants and the perfluorinated compounds, in particular the polybrominated diphenylethers (PBDEs), perfluorooctane sulfonate (PFOS), and perfluorooctanoic acid (PFOA). Until recently, there were few data available on human concentrations of these compounds.

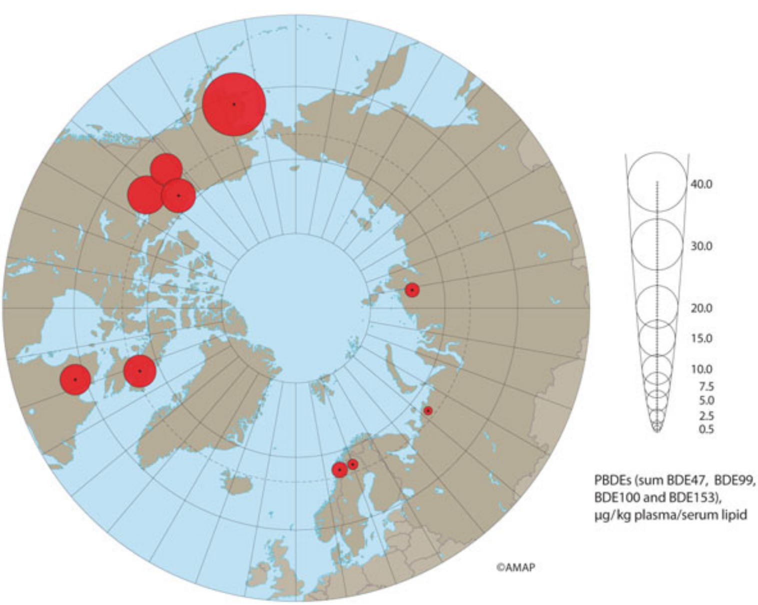

Fig. 7.7 PBDE (sum of BDE47, BDE 99, BDE 100, and BDE153) concentrations in blood of mothers, pregnant women, and women of childbearing age in the circumpolar countries

Concentrations of PBDEs in the Arctic are low in general, with the exception of Alaska where concentrations are much higher. Reported concentrations in Alaska are comparable to, or even higher than, those that have been reported in the US general population. Concentrations in the Canadian Arctic were considerably lower than in Alaska, but higher than in the European Arctic (Fig. 7.7). BDE47 was the predominant PBDE congener. Other brominated flame retardants investigated were tetrabromobisphenol A (TBBPA) and hexabromocyclododecane (HBCD), which showed low exposures based on limited data. Concentrations of PFOS were generally high throughout the Arctic and comparable to concentrations reported in several other heavily populated areas. There were minor intercountry differences, but comparisons were limited by small sample sizes. Concentrations of PFOA were much lower than the concentrations of PFOS but were elevated compared to the legacy POPs, and were clearly distributed throughout the Arctic. Limited data from Nunavik (Canada) showed an increase in ΣPBDE concentrations and a decrease in PFOS concentrations. There is, however, a clear need for ongoing monitoring of these compounds. Several other compounds of concern, such as short-chain chlorinated paraffins (SCCPs), parabens, and siloxanes plus metabolites of PCBs, should also be screened at regular intervals.

Genetics and Contaminants

This chapter describes the concepts of natural and selected gene diversity in relation to different populations, with emphasis on the Inuit and the possible link with and consequences of chemical exposures. Maternal inheritance of mitochondrial DNA (mtDNA) has been used to elucidate the ancestry of the Inuit and has demonstrated a close similarity in the circumpolar region with the hypothesis that the genetic impact of neo-Inuit (Thule groups) interbred with existing Dorset populations in Canada and Greenland.

Differences in the occurrence of diseases between Inuit and Caucasian populations have been reported, and the possible relation to gene polymorphism is speculated but needs further study. Serum lipids and apolipoproteins are risk factors for atherogenesis. Apolipoprotein E (APOE) differs between populations, and APOE polymorphisms were found to be associated with atherosclerosis in US white and black people that seems independent of serum lipids. However, the risk of coronary heart disease in Canadian Inuit was lower despite a higher incidence of disease-related *APOE* alleles. Nor was any association found between *APOE* genotypes and atherosclerotic lesions in Greenlandic Inuit. Studies have supported the hypothesis that the risk of coronary heart disease in Inuit is influenced by inherited genes as well as by diet and lifestyle.

In contrast to their Asian ancestors, the Inuit do not seem to be genetically protected against alcoholism. Co-exposure to alcohol and environmental chemicals might influence metabolism because some of the genes involved in metabolism of both types of exposure are identical. Ethnic differences in lactose tolerance are well known, and a low range of lactose tolerance is found in Inuit. Future studies might elucidate whether changes in diet and lactose tolerance have any impact on health risk.

The balance between xenobiotic absorption and elimination rates in metabolism is important factors in detoxification and prevention of chemical carcinogenesis as illustrated in Fig. 7.8. Approximately 80 % of all cancers have been estimated from epidemiological studies to be related to environmental factors, and cancer susceptibility can result from differences in genetic background for metabolism, DNA repair, and altered gene expressions of tumor-related genes. Thus, gene polymorphism in metabolizing enzymes, for example cytochrome P450, is suspected to influence susceptibility to environmental carcinogens. Studies have suggested a link between gene polymorphism in metabolizing genes, levels of POPs, and the risk of, for example, breast cancer in Caucasians. The incidence of breast cancer in Inuit is low, and the very few studies on polymorphism in metabolizing genes in Inuit await further studies with respect to the risk of breast cancer.

Epigenetics is a new paradigm in toxicology and teratology, a phenomenon that can be hereditary without any change in primary DNA sequence but which reflects a change in control of gene activity that arises from the interplay of DNA methylation, histone modification, and RNA-mediated pathways. Epigenetic regulation is a part of normal development and differentiation; however, by

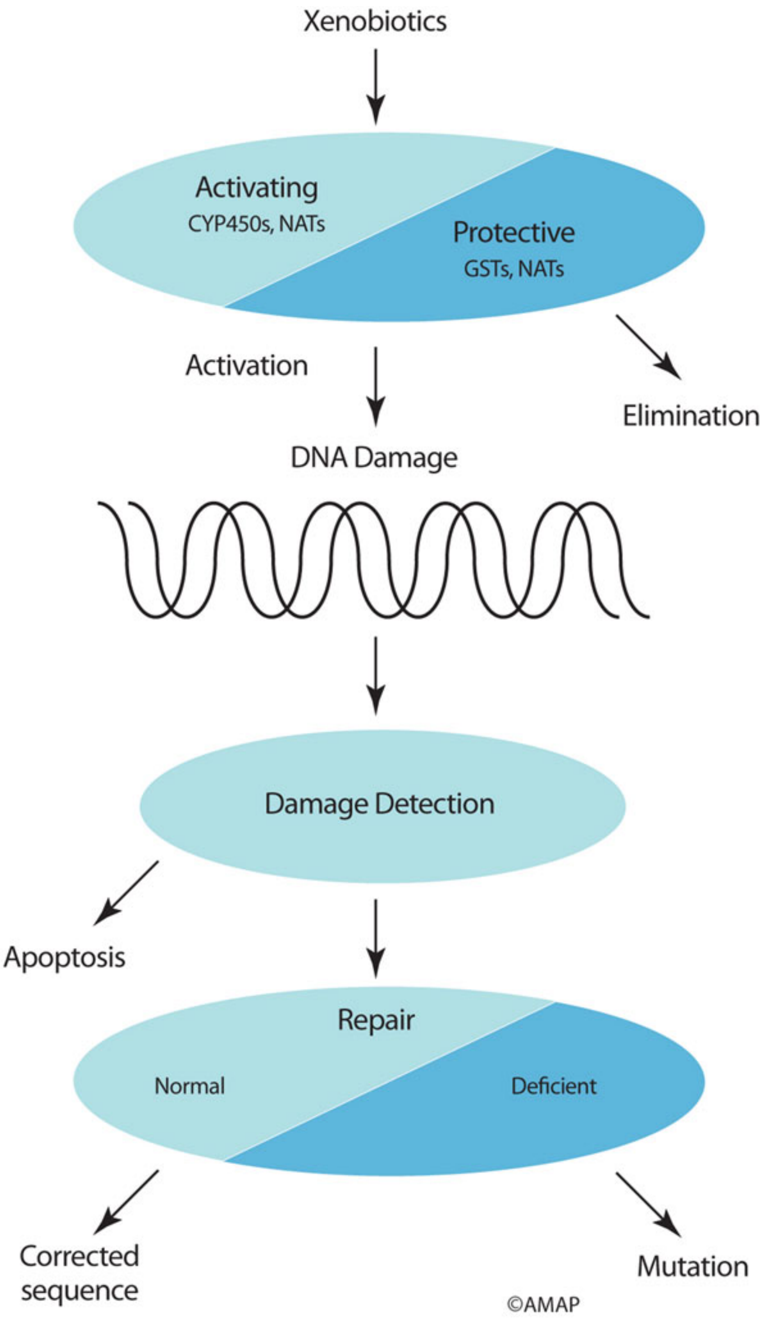

Fig. 7.8 Genetic variability in susceptibility to toxicants. *Source* cited in AMAP (2009a)

misdirection, it can cause diseases including cancer. Environmental exposure to PCBs and polybrominated biphenyls (PBBs), which are effective promoters in two-step-cancer models, implies the involvement of epigenetic mechanisms, and epigenetic hypermethylation of the tumor suppressor breast cancer *BRAC1* gene has been related to breast and ovarian tumors. In vitro studies showed that non-coplanar PCBs can decrease the *BRAC1* expression implying epigenetic mechanisms. A link between epigenetic mechanisms, exposure to gamma-hexachlorocyclohexane (HCH), and risk for breast and prostate cancer has also been suggested. Recent data for Greenlandic Inuit showed a link between the levels of serum POPs and the level of "global" DNA methylation, and further studies are needed to elucidate these cellular and biological epigenetic responses in relation to health.

Finally, the chapter describes ethnic gene polymorphism for the aryl hydrocarbon receptor (AHR), the androgen receptor (AR), and the estrogen receptor (ER). For the *AHR* gene, similar polymorphism was found for Caucasians and Inuit and was different to that for Japanese and African populations. Ethnic differences in the *ERα gene* have been reported and related to PCB exposure and breast cancer. However, no report on *ER* polymorphisms was found for Arctic Inuit people. In vitro *studies have shown complex patterns of responses* following exposure to natural as well as to synthetic estrogens (e.g., hydroxyl-PCBs) dependent on the cell context and ER form that must encourage researchers to elucidate the possible interaction between POP exposure, *ER* polymorphism, and health.

In summary, genetic background affects the impact and susceptibility to contaminant exposure and thus health risk. To date, little research on genetic polymorphism especially in relation to diseases has been undertaken on Arctic populations. Future studies should include genetics in parallel with lifestyle and contaminant exposure in order to provide a better insight into individual and population vulnerability to contaminants.

Interactions Between Contaminants and Nutrients

Over the last five decades, increases in the prevalence of obesity and subsequent health problems—metabolic syndrome, diabetes type II, and cardiovascular diseases—have been observed worldwide, including within populations living in the Arctic. These conditions have been regarded as lifestyle-related metabolic disturbances caused by hypercaloric and misbalanced diets in combination with a sedentary lifestyle. However, it has recently been suggested that exposure to contaminants might also play a role as illustrated in Fig. 7.9.

Maintenance of good metabolic health goes, however, beyond weight control. In this connection, the quality of the macronutrients plays a pivotal role. The dietary fat composition is especially important. Some of the saturated fatty acids, for example, palmitate, induce inflammation in adipocytes and will thus promote and exacerbate obesity and insulin resistance. Polyunsaturated fatty acids (PUFAs), both the n-6 and n-3 families, are essential. The two interact in the regulation of

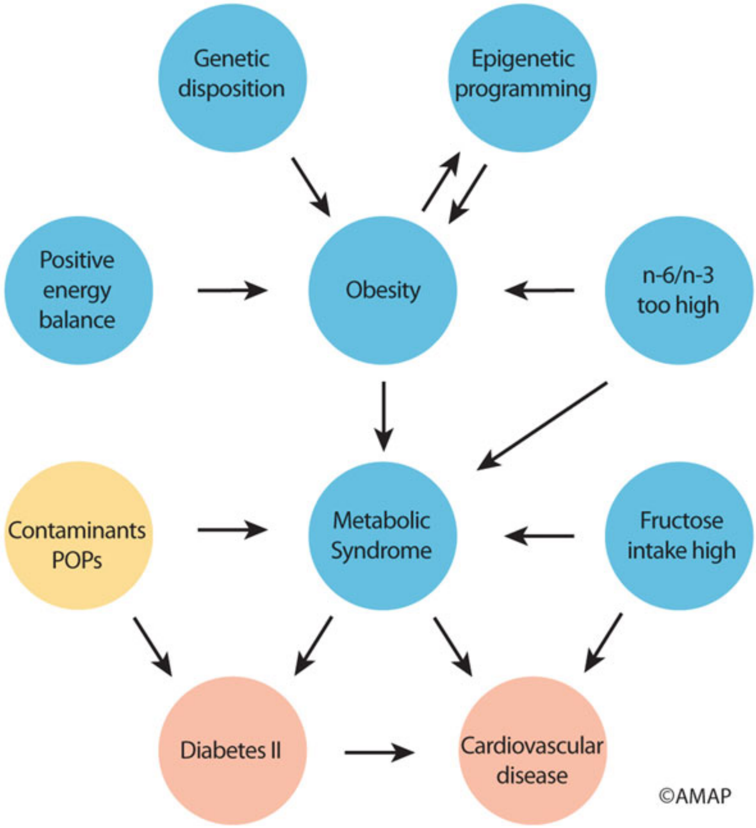

Fig. 7.9 Genetic and environmental factors increase in concert the susceptibility of an individual for public health problems such as type II diabetes and metabolic syndrome. All these conditions may have complications involving the cardiovascular system. *Source* cited in AMAP (2009a)

pro- and anti-inflammatory processes, and for this reason, a balanced dietary intake of n-6 and n-3 fatty acids is very important.

A high n-6:n-3 ratio will tend to be pro-inflammatory, while a very low ratio will induce immunosuppression. Furthermore, there is evidence that n-6, but not n-3, fatty acids act in a lipogenic manner. The optimal ratio is still under debate. The precolonial traditional Inuit diet provided a PUFA ratio of around 1, while a present-day Westernized fast-food diet provides a ratio of 10–20. In relation to cardiovascular health, a n-6:n-3 ratio of ~6:1 has been recommended.

Carbohydrate quality does not seem to play as important a role as does PUFAs, because carbohydrates do not interfere with gene expression of metabolic regulating enzymes. Carbohydrates serve as an energy source, and as long as the total energy supply is eucaloric, even the glycemic index value seems to be of minor importance. An exception is the high intake of fructose prevalent today as a result of the increasing industrialization of food production. Existing literature provides convincing evidence for this to be a major contributor to the increasing prevalence of obesity and metabolic syndrome on a global scale.

A common feature for dietary-induced obesity and metabolic syndrome is induction of oxidative stress at a cellular level and thus development of inflammation. This is also a characteristic effect of environmental xenobiotic exposure through the diet.

As a consequence, it is reasonable to speculate on an interaction between an unbalanced diet and concomitant exposure to xenobiotic compounds, where the contaminants may play a role as aggravating factors. Early findings from studies in the 1980s of a PCB-related and persistent increase in serum triglyceride concentrations clearly support a connection to xenobiotic exposure. Similarly, recent findings from Greenland were that the risk factor for cardiovascular diseases (TG/HDL ratio) increased with increasing body mass index, as expected, but that there was an additional increase in the TG/HDL ratio related to the POP exposure concentration. This indicates that in relation to obesity and metabolic syndrome, neither dietary imbalances nor exposure to contaminants should be evaluated separately, but should be addressed as a single entity.

Except for some Inuit populations, the general exposure level in the Arctic is below the guidelines for safe exposure to contaminants (AMAP 2003). The question is whether these relatively low exposures can have an influence on metabolic disorders. From the existing literature, it seems reasonable to speculate that in an organism already susceptible to developing a state of metabolic disorder, a concomitant exposure to dietary contaminants will, even at a relatively low level, be able to accelerate the processes, in an additive manner. At the moment, there is not much epidemiological evidence for this; however, experimental evidence indicates that this potential interaction is a public health issue that should be accounted for in future studies.

Divergent scientific and regulatory agency perspectives on contaminants in food have lead to contradictory advice and often to confusing public messages. It is, however, widely recognized that owing to the multifactorial character of the problems “cancer and non-cancer health impacts associated with environmental exposures generally cannot be directly isolated and measured,” and for this reason, the discipline of risk assessment was established. A risk assessment approach using the formal tools established for this purpose is likely to be the most helpful approach for establishing risk and facilitating suitable risk management strategies (including dietary advice).

The concept that nutrition can modulate the toxicity of environmental pollutants, and vice versa, is a new way of thinking in the area of environmental health. Nutritional awareness in environmental toxicology is critical because of the opportunities to develop guidelines which specifically target exposed populations. In this way, nutrition may provide the most sensible means to develop primary prevention strategies for diseases associated with environmental toxicology.

To improve the understanding of the health effects associated with exposure to contaminants in the Arctic, it is recommended that circumpolar studies, including both nutritional and toxicological aspects, should be implemented on a large scale. Methylmercury- and POPs-related effects are still the key issues. However, the role

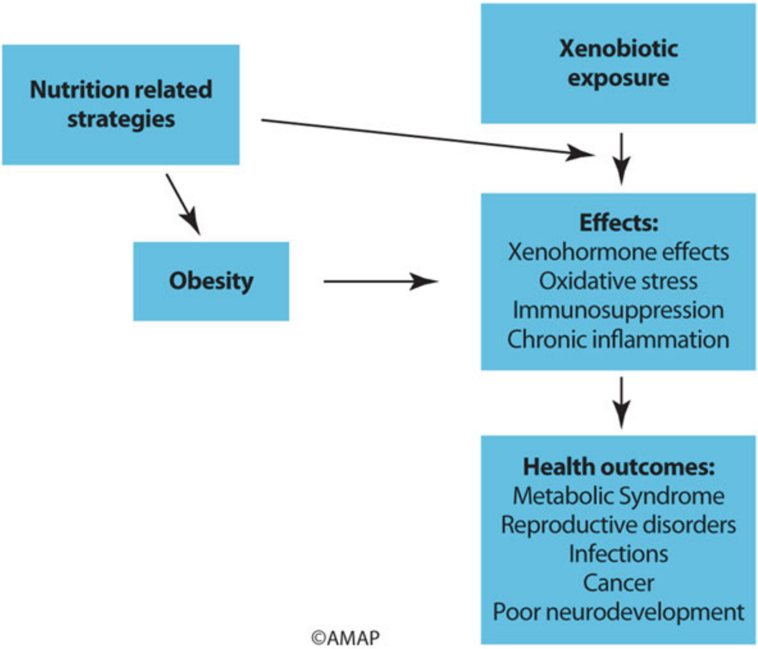

Fig. 7.10 Potential methods for improving public health. *Source* cited in AMAP (2009a)

of newly discovered contaminants, such as PBDEs, polychlorinated naphthalenes, and phthalates, should also be investigated. For exposure estimates, mixtures of contaminants and nutritional benefits of foods should be incorporated in the risk assessment profile. There is a need for better understanding of the interactions between nutrients and xenobiotic compounds, and risks should be evaluated in accordance with this interaction. Figure 7.10 provides a schematic representation of the relationship between nutrition and toxicology in the development of disease prevention strategies targeted at specific exposure populations.

It is essential that a better understanding is achieved of the health consequences of the dietary (and thus, nutritional) transition taking place within indigenous populations and the nutrient/contaminant interaction in Arctic populations, and that this information is communicated to the Arctic populations in a correct and understandable manner.

Public Health and the Effects of Contaminants

General Health of Arctic Populations

Human populations in the Arctic, especially indigenous populations, have comparatively poorer health status than populations from non-Arctic regions of the

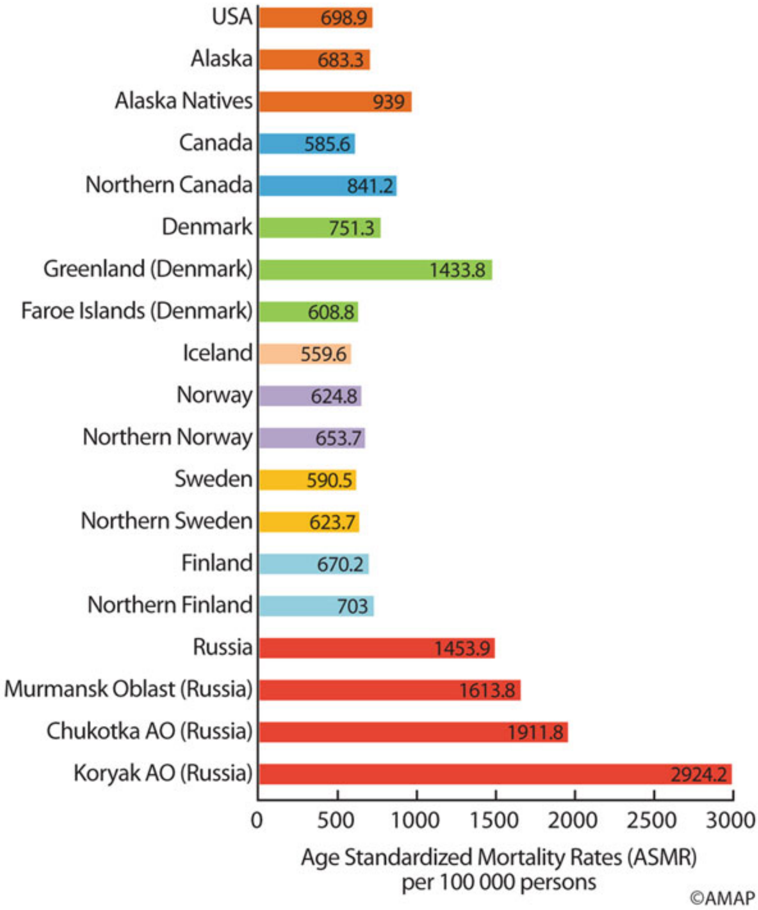

Fig. 7.11 Circumpolar age-standardized mortality rates by cause per 100,000 persons; standardized to European standard population. *Source* cited in AMAP (2009a)

same eight circumpolar countries as can be seen in age-standardized mortality rates in Fig. 7.11. Although infant death rates are lower and population longevity has improved, rates of several chronic diseases have been increasing. These changes are not uniform across the Arctic and are influenced by a number of determinants of health related to socioeconomic, dietary, and cultural influences. It is very likely that the higher prevalence of tobacco use, less active lifestyles, and consumption of more calorie-rich and nutrient-poor store-bought foods among some indigenous populations in the Arctic have contributed to an increasing burden of chronic diseases.

Health intervention strategies and population health in the Arctic will only improve with better information and better cooperation between all players. A full understanding of ethnic-specific health status can only arise if common health status indicators are selected and then monitored, reported, and analyzed consistently. This will require that indigenous peoples' organizations, tribal governments, and other levels of government in each Arctic country work together and support the establishment and/or active utilization of indigenous status identifiers for ethnic-specific public health surveillance.

While contaminants certainly play a role in the current health status of indigenous populations in many areas of the Arctic, it is also certain that other determinants of health are involved, including education, economic well-being, cultural strength, community engagement in shaping its present and future, lifestyle choices, genetic susceptibility, and availability of public health services.

Conducting epidemiological studies in the Arctic is difficult due to a variety of limiting factors: exposure to complex contaminant mixtures, small population size, contaminant–nutrient interactions, genetic factors, confounding factors, and health priorities. For this reason, epidemiological studies conducted in other parts of the world on POPs and metals-induced toxicity should be used as much as possible for risk assessment. However, different factors may limit the applicability of findings from these studies for Arctic populations.

Indigenous populations in the Arctic are exposed to mixtures of contaminants and primarily through food. Investigating the toxicological properties of environmentally relevant mixtures of POPs in laboratory species is essential for determining the biological plausibility of associations identified in epidemiology studies between exposure to these compounds and adverse health effects. It is clear from studies of chemical mixtures that data derived from single chemical experiments cannot be used to predict the risk resulting from exposure to complex mixtures of POPs. Interactions between components of the mixture not only modify the disposition of individual components but also their dose–response relationship for various developmental endpoints. These interactions, coupled with differences in nutrient levels, could explain some of the differences between the findings of the Faroe Islands and Seychelles Islands cohort studies.

New and promising techniques that evaluate the overall xenohormone activity in human blood are useful screening tools and can identify blood samples from population studies which warrant more expensive chemical analysis. The results from xenobiotics studies clearly indicate that the use of single or a few POPs proxy markers cannot alone be used for assessment of either bioactivity or possible adverse effects of POP mixtures on human populations.

Environmental POPs and Health

Many POPs, including PCBs, PCDDs, PCDFs, and pesticides, can mimic hormone activities. As potential endocrine disrupters, they are suspected to be capable of increasing the risk of cancer, birth defects, and reproductive and neuroimmune disorders. To date, no clear evidence for adverse endocrine-related human health effects of POPs has been obtained at the individual or population level. However, data from studies on wildlife species, laboratory animals, and biomarker effects in vitro have strengthened the need for further research to address the potential impacts of endocrine disruptors on human populations.

Although there have been associations found in individual cohort studies between fish consumption or POP exposure and newborn head circumference, birth weight, duration of pregnancy, and infant growth, the relationships observed differ between studies. It is clear that different contaminant levels, different mixtures of chemicals, diet, maternal susceptibility factors, and other confounding factors play a significant role in changing the associations found from one study to the next. It is also clear that exposure to POPs can adversely affect prenatal and postnatal development in human populations.

Results from the PCB studies conducted in the Faroe Islands and Nunavik to date suggest that prenatal exposure to PCBs is related to a relatively specific profile of cognitive impairments in children. Among the cognitive functions assessed, effects have been most clearly demonstrated on executive functions and speed of information processing and those effects can be responsible for the small decreases in IQ observed in most studies. Verbal abilities and visual recognition memory are also likely to be impaired.

Several recent studies in Arctic Canada confirm and support the relationship between exposure to certain contaminants and depressed immunity. Both PCBs and DDE are associated with a higher incidence rate of acute otitis media and respiratory tract infections in Inuit children during the first six months of life. Concentrations of lymphocytes and immunoglobulin A have been found depressed in comparative studies of breast-fed babies and bottle-fed babies. The effectiveness of vaccination programs among Inuit children and children from the Faroe Islands appear to be compromised by perinatal exposure to PCBs (as a marker of POPs). New research with piglets supports these findings and indicates that transplacental POP exposure leads to a reduction in antibody response.

Preliminary findings from a large Russian Arctic cohort adds evidence to the findings identified earlier that higher levels of maternal blood serum PCBs might be associated with more frequent occurrences of low birth weight, premature births, stillbirths, and menstrual irregularities. These possible adverse reproductive health effects of POPs and metals will require more in-depth evaluation. Detailed analyses of all available data and systematic epidemiological studies, which take into account relevant confounders and other contaminants, must be undertaken before conclusive statements can be made.

POP exposures have been suggested as the reason for observed alterations in birth sex ratios in animal populations and occasionally in human studies. New research results with pigs, which have a similar reproductive system to humans, indicate that exposure of sperm to environmentally pertinent organochlorine mixtures in vitro adversely affects oocyte development, polyspermy, sperm fertility, and embryonic development. However, a comparison of existing population studies, one including Arctic countries, did not reveal any definitive or consistent relationship between POPs, sperm X:Y ratios, or male-to-female birth ratios. Emerging data from a relatively small cohort in the Russian Arctic indicate that increasing maternal PCB concentrations may be associated with an initial effect of increasing the male-to-female newborn ratio; however, causality has not been determined and the increase in the ratio appears to disappear in the highest concentration group. The possible effects of other contaminants have not been determined. Systematic epidemiological studies, including all possible confounders and other relevant contaminants, must be performed before any conclusive statements can be made about contaminants and sex ratios in Arctic populations.

A large international study indicated some links between POP exposure and biomarkers of male reproductive function. Associations were found between high PCB153 serum levels and low sperm counts, decreased sperm motility, and damage to sperm chromatin integrity in some of the subpopulations studied. In spite of these effects, fertility was not related to POPs except in Inuit. Definitive conclusions cannot be derived from these studies, in part because the two POP proxy markers measured did not represent the biological activity of the entire POP mixtures. There are also open questions related to the role of genetic background, lifestyle, and/or diet nutrition factors such as trace elements/antioxidants (e.g., selenium) that may interfere with the possible adverse health effects of POPs.

Exposure to POPs may contribute to the development of metabolic syndrome. The endocrine-disrupting properties of several contaminants, especially dioxin-like compounds, can affect glucose and lipid metabolism, which in turn affect the onset of metabolic syndrome. Genetic factors and lifestyle are also important determinants of metabolic syndrome. The dramatic increase in the rate of diabetes among Inuit and Alaskan Natives may be affected by multiple factors; however, the role played by contaminants in obesity, metabolism, and diabetes warrants urgent study.

Environmental mixtures may also be able to affect bone density (diminished bone cortical area and bone mineral content) in male and female rat pups. These findings may be significant for humans as indications of a negative association between PCB plasma levels and quantitative ultrasound bone parameters have been reported in a group of peri- and postmenopausal women from Greenland.

Environmental Metals and Health

The growing fetus and newborn children are especially sensitive to the toxic effects of environmental Hg and Pb. Animal studies indicate that exposure to environmentally relevant mixtures of POPs and metals has significant effects on reproduction. Exposures led to decreases in maternal weight gain, weight gain in offspring, and increased mortality rates in pups prior to weaning. Interactions between MeHg and POPs in mixtures warrants further study as lower levels of MeHg administered alone have been found to lead to more pup mortality than found in mixture studies containing higher levels of MeHg.

Potential neurobehavioral effects associated with MeHg exposure have been found in the Faroe Islands in the domains of verbal function, visuomotor integration, and attention. However, the most consistent marker of prenatal MeHg exposure is delayed auditory processing assessed from brain stem auditory event potentials. Because of the inconsistencies between studies, there is a need for additional well-conducted prospective studies to elucidate the specific growth and neurobehavioral effects of MeHg and to assess the impacts of differences in maternal diet during pregnancy on susceptibility to MeHg exposure.

Recent studies in the Faroe Islands, Greenland, and Nunavik all indicate that Hg can affect circulatory parameters such as pulse pressure, heart rate and heart rate variability, blood pressure, hypertension, and atherosclerosis. Prenatal exposures to MeHg may also affect the development of cardiovascular homeostasis. If these preliminary findings are confirmed, the estimated attributable burden of diseases due to contaminant exposure might increase. Even small relative risks have a large impact on diseases having high incidence and mortality and could affect policy development on safe levels of exposure. Confirmation of these findings in other studies is needed as the current findings have potentially significant implications for Hg intervention policies. In addition, more research is needed to determine the relationship between changes in risk of cardiovascular disease and changes in diet among Arctic indigenous populations.

It is highly likely that oxidative stress is a significant underlying biochemical mechanism in MeHg neurotoxicity. MeHg neurotoxicity can be inhibited by various antioxidants, including Se. New studies in Arctic Canada indicate that Hg exposure may diminish defense mechanisms against oxidative stress by limiting the availability of glutathione, while Se may afford protection by favoring the destruction of hydrogen peroxide. It will be important to continue to assess oxidative stress in adult residents of Nunavik and to further understand interactions which affect the mechanisms of Hg toxicity.

Lead is well known to adversely affect neurodevelopment and behavior in children. Until recently, studies of behavioral effects of Pb in children have only confirmed effects from postnatal exposure, not from prenatal exposure. New studies with children from Nunavik have shown that cord blood Pb concentrations were related to observational measures of inattention even at cord blood Pb concentrations below 10 microg/dL. The new data indicate that behavioral effects of low prenatal Pb exposure are likely to be observed when testing protocols include sensitive measures of behavior.

Some new associations have been reported in Arctic Russia between spontaneous abortions and Hg levels in blood. No negative associations were found between maternal exposure to nickel and the risk of delivering a newborn with malformations of the genital organs. Further study to confirm the associations between Hg exposure and abortion rates is warranted.

AMAP and Risk Communication

AMAP was established by the Arctic Council to investigate the spread and effects of pollution from the industrial regions in the temperate zones to the Arctic. AMAP's main role has been to harmonize the compilation of data to establish the levels and extent of contamination in the circumpolar area and also to initiate research into the correlation between contaminants and the health status of these areas.

Because all Arctic circumpolar areas are represented within the Arctic Monitoring and Assessment Programme, the present assessment provides a reasonably reliable picture of the status of human exposure to heavy metals and legacy POPs within the Arctic. Furthermore, because the exposure measurements have been repeated over time, it is possible to comment on the development of trends with regard to pollution in many areas. Effects studies have also been undertaken. By comparing documented levels of exposure to the effect studies from the Arctic area and the toxicological literature in general, it may be concluded that in several places, it is possible that exposure via food has adverse implications on the health of populations. Studies have demonstrated that the main source of exposure to contaminants in the Arctic is traditional food, especially marine animals.

The benefit/risk management process for traditional foods in circumpolar countries has been challenged by the issue of environmental contaminants entering the Arctic food chain for many decades. Although a framework for risk management has been adopted in many countries, no common process to integrate all benefits and risks, qualitative and quantitative information, and to assess and direct decision making on this topic has yet been developed.

In societies with a wide range of alternative dietary choices and broad cultural means of existence, dietary adjustments are easy to implement. This is not the case in the Arctic area, however, where communities depend heavily on marine food, especially marine mammals. Many populations in the circumpolar area experience real food insecurity. Will there be enough food? Will the healthy food be available?

Marine mammals are the focus for many Arctic cultures. It has been possible to achieve some significant reductions in exposure to heavy metals and POPs by eliminating the most contaminated species and organs from the diet. It is feared, however, that a change in food choices and lifestyle will alter community culture to such a degree that some of the cultures will not survive. Another reason for caution when communicating adverse effects of certain pollutants is that, theoretically, contaminated food also contains compounds that have a positive impact on health, such as marine fatty acids (see Sections "Food, Diet, Nutrition and Contaminants" and "Interactions between Contaminants and Nutrients").

All these considerations constitute "The Arctic Dilemma" that traditional food items have both positive and negative properties and that the management and communication of this dilemma are complicated and dependent on geographic, demographic, cultural, and social conditions (Sections "Food, Diet, Nutrition and Contaminants" and "Interactions between Contaminants and Nutrients").

Dietary guidelines for individual communities are principally the responsibility of the national/local health authorities. The aim of the communication is to provide balanced information allowing people to make informed rational choices about how to reduce their exposure to toxic substances and at the same time ensure that their food has satisfactory nutritional and aesthetic properties. Information alone is not enough, however. There is also an obligation on local authorities to make healthy food available even in small communities, so that people can actually carry out these informed rational dietary choices. This is more of a political and logistic issue.

Because AMAP is able to contribute data and information on exposure status in local areas over time and because such information is of general interest to populations living in the Arctic, it has to some extent initiated and participated in public health assessments of both the beneficial and adverse effects resulting from the various sources of exposure, such as marine mammals.

Communication Strategies and Problems in the Arctic

Information presented in this chapter highlights how risk communication has been conducted differently in different countries and regions. In most countries, risk communication has been undertaken by national authorities, seldom or never by communication professionals. Communication of information resulting from AMAP's activities has been given much consideration from the start, and on some occasions, professional communicators have been used to ensure that the information is communicated as effectively as possible. Nevertheless, the goal of giving clear but nuanced information on the sometimes complicated conclusions arising from its work has not been totally satisfactory in all cases. This may be partly due to none of the Arctic countries having an official strategy for the communication of the results.

In the Faroe Islands, risk communication has had measurable positive effects on both the food choices of target groups (children and young woman) and health parameters. In Norway, Sweden, Finland, and Iceland, human health issues resulting from the accumulation of contaminants from Arctic food chains have been very limited and so the need for dietary advice to the populations has also been limited.

It is communities in northern Alaska, Canada, Russia, and Greenland that are subject to "The Arctic Dilemma" where risk communication has been complicated and often unsuccessful. The difficulty is to convey insights to all citizens of exposed populations that will enable them to weigh the benefits against the drawbacks in their dietary choices.

One particular difficulty has been in identifying the receiver for the risk communication. Is it the health professionals of a given country or is it the entire, affected population? Another difficulty is the form of the communication. A simple message may be easy to communicate, but equally easy to misunderstand, for example, that all seafood is considered contaminated. On the other hand, balanced and targeted risk communication would only reach a specific and narrow receiver population.

Another difficulty has been that toxicological terms are relatively alien to the general population. It is assumed that the majority of a population wants questions about the negative impacts of contaminants answered by a yes or no and not by a number of statistical variations which they can interpret to fit their own personal preferences. However, it is likely that a substantial proportion of the communicated messages with regard to contaminants in the circumpolar area have not been fully understood.

Risk perception research has been valuable in showing the local perspectives and understanding of the issue; surveys and other qualitative assessments have shown that while the majority of the population is aware of the issue of "contaminants," some confusion with regard to the "chemical-only" nature of the use of terms by the research community exists and may create barriers to understanding the messages given out by northern health professionals and researchers.

In the Canadian Arctic, it appears that women of childbearing age have received and understood the least regarding this issue, yet may be the most at risk to contaminant exposure because of the sensitivity of the developing fetus. This is therefore the most important target audience around which to develop risk reduction strategies and messages.

Research conducted in the Canadian Arctic indicates that contaminants are not direct determinants influencing food choice among northern residents; however, indirect impacts of food choice and hunting catch rejection may be taking place in some regions.

A circumpolar assessment of communication efficiency should be established. New studies on risk communication result in new materials for better communication. More work is, however, needed on the effectiveness and effects of risk–benefit communication. The dissemination of AMAP assessment reports and information, both to the public and to health authorities in the Arctic, should be improved.

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