Pollution and human health

A mother nurtures her child with love, energy, nutrients, fluids, protection against disease, and physical warmth. In recent years, many women have become concerned that during pregnancy and through breast feeding, they also expose their children to environmental contaminants. This concern is justified. Many contaminants are present in our bodies, and a pregnant or nursing woman will transfer some of these to her child. While the known benefits of breast feeding are still thought to greatly outweigh the possible risk, we know that human health can be affected by contaminants. Because our health is intimately connected with the food we eat, the water we drink, and the air we breathe, we pay a price when the environment around us and our sources of nourishment become tainted. The presence of contaminants in umbilical cord blood, in human milk, in food, air, and water presents a political, social, and public health challenge.

In the context of environmental health and with special attention to the role of traditional foods in the Arctic, this chapter presents an assessment of contaminants and human health, including the first results of AMAP's Human Health Monitoring Program.

AMAP's circumpolar human health assessment addresses eight persistent organic pollutants, three heavy metals, several radionuclides, and ultraviolet radiation. In addition, national reports present detailed discussions of contaminants issues in specific regions.

Mother and child. Quartzite sculpture by Kovinatilliak Parr

Environmental health – an introduction

Many factors contribute to health and illness in the Arctic: socioeconomic conditions, health services, societal and cultural factors, individual lifestyles and behaviors, and genetics. Contaminants enter this already complex scene, with the capacity to have physical, mental, and social impacts on health. For example, fear of contaminants and changes in traditional ways of living can affect both community social structure and individual mental well-being.

This report focuses on the role of contaminants in people's physical health. The major concerns are long-term, subtle effects, such as how contaminants might influence our ability to conceive and carry children, reduce our defense against diseases, affect children's mental development, or increase the risk of cancer.

The growing fetus and the new-born child are especially sensitive to the toxic effects of many persistent organic pollutants and heavy metals. Several of these substances move from mother to fetus via the umbilical cord and to the child via mother's milk.The levels of such contaminants in the mother's blood give an indication of the risk her child faces.

Contaminant burden is high enough to justify international action

Observations indicate that most regions of the Arctic are far from pristine. In fact, long-range transport and biomagnification of some substances in Arctic food webs have led to contaminant levels in people that can be 10 to 20 times higher than in most temperate regions. Indigenous people who rely on traditional diets are likely to be more exposed to several toxic substances than the majority of people elsewhere in the world.

Constraints of epidemiology

Epidemiology examines the causes and risks of disease in a population. By studying large groups of people, it is possible to identify important risk factors that increase the occurrence of certain health effects. Sometimes it is possible to identify a major cause, for example a particular bacterium or an industrial chemical. By themselves, however, the results from epidemiology can only rarely establish a conclusive link between a disease in an individual and a specific cause. In studying environmental health in Arctic communities, the lack of evidence from epidemiological studies cannot be used to rule out the presence of actual health effects. There are several important limitations to these epidemiological studies:

The population groups in the Arctic are small, making it difficult to involve enough people to confirm statistically valid associations between risk factors and health effects. It is also difficult to find a 'control group' that has similar important ethnic, social, or economic characteristics but that has not been exposed to the same contaminants.

Not enough is known about the toxicology of many contaminants to ensure that an epidemiological study looks for the most sensitive health effects. For example, some studies may look only for higher cancer rates associated with higher contaminant exposure, while subtle effects on the immune system go undetected.

Epidemiological studies provide only part of the information necessary to establish a connection between cause and effect. Health assessments also have to take into account results from controlled animal studies and knowledge about each contaminant's mechanism of action on the body.

For epidemiological studies to be effective, health effects must already have occurred in the population. These studies are not good predictors of disease. Rather, they report illness that has already occurred.

There are no illnesses yet reported in the Arctic for which contaminants are known to be a direct cause. However, a lack of readily-visible illness does not mean that the exposure of indigenous peoples in the Arctic is without medical consequence. Moreover, the exposure situation is highly complex as many stressors interact with one another. As described in the box on this page, it is difficult to scientifically prove the connection between contaminants and disease in small population groups, even when such connections are known to exist from studies of larger groups. For these reasons, high levels of contaminants in blood and tissue or subtle biochemical changes in the body should be taken as significant health warnings. Listening to these warning signals may be the only way to avoid illness from contaminants. The information to date already provides a strong reason to aggressively seek international agreement on the reduction or elimination of the manufacture and release of persistent organic pollutants and some toxic metals.

Public health advice must include insight about local culture

In the Arctic, formulating public health advice about contaminants in food is complicated by the key role that indigenous foods play in people's social, spiritual, and cultural identity. Indigenous foods also provide excellent nourishment, vitamins, and minerals, and help protect against several diseases. Public health advice must therefore include insight about native cultures and local lifestyles. Moreover, these aspects of health and well-being need to be given an equal hearing in any discussion of overall public health. Dialogue with local people, not just among scientists, becomes essential in this process, and communication must be based on both respect and knowledge.

Such insight and communication is best developed at the local level. One aim of this chapter is to provide a source of basic information. Then, local and regional authorities can use the information to address the specific needs of their communities.

Toxicology of contaminants

Several of the previous chapters describe the toxicology of contaminants in some detail. Often the main concerns are summarized in catch words such as 'neurological effects', 'reproductive effects', 'immunosuppression', or 'carcinogenic effects'. The following are short explanations of what these terms mean for human health.

Neurological effects

Neurological or neurobehavioral effects of contaminants mostly concern effects on the brain. The brain of a fetus or a young child is

rapidly growing and thus especially sensitive to environmental contaminants. In the context of environmental contaminants, the damage may be subtle, and the effects have to be studied using complex psychological and behavioral tests. Such tests of groups of newborns as well as older children can reveal a higher occurrence of slight handicaps in memory or in the ability to learn or to pay attention. Some studies have also looked at school performance.

Reproductive effects

Reproductive effects cover an array of different problems, and the connections between the contaminant and the effects are not always clear. A major concern is that some substances interfere with or mimic sex hormones. For the growing fetus, a high burden of such contaminants might disturb the balance that steers the development of sex organs. Lower sperm count, and thus reduced fertility, is one of the suspected effects on men. For women, the same contaminants might make it difficult to become pregnant or to carry a pregnancy to term. The contaminant levels at which reproductive effects may occur in humans are poorly understood. As with all other aspects of human health, contaminants are hardly the only factor affecting fertility. For example, lifestyle choices such as smoking and alcohol consumption have well-documented and profound effects on reproduction.

The hormone-disrupting effects of contaminants may also increase or decrease the risk of some forms of cancer.

Immunosuppression

Several contaminants can damage the body's immune system, its defense against disease. When the immune system is suppressed, the body is less able to fight infectious agents such as bacteria and viruses. Moreover, there are suggestions that immunosuppression is involved in an increased risk for cancer. Effects on the immune system are often studied by looking at subtle changes in the cells that are involved in the body's defense against disease. Although it is difficult to connect the immunosuppressive effects of contaminants with any particular disease, they may lead to increases in the rates and duration of infections.

Cancer

Several contaminants can cause cancer and these are referred to as carcinogens. Some of them directly damage the hereditary material of cells and are called initiators. These initiators potentially turn normal cells into cancer cells. Others act as cancer promoters. Promoters do not start a cancer by themselves but enhance the risk that cells that have been initiated will grow into tumors. Most of the findings concerning carcinogens come from studies in animals.

Tolerable daily intakes include a safety factor

Most of the knowledge about toxic effects of contaminants comes from laboratory studies where animals are fed high doses of a single substance. There are also some epidemiological studies of people who have been exposed to high doses of a single compound at work or following accidents. In the environment, the situation is quite different. People are exposed to a mixture of many different compounds at the same time, often at low levels and over their whole lives. In spite of the difficulties in translating current knowledge about toxic effects into public health advice, there have been several attempts to define exposure levels below which people should not have to be concerned about health effects. One example is tolerable daily intake (TDI).

Differences between humans and experimental animals and between the different exposure situations are sources of uncertainty in estimating health effects of contaminants on humans. Therefore, tolerable daily intake figures for people usually include substantial safety factors. For example, if the highest daily exposure that is known not to cause effects in animals is 100 micrograms of a substance per kilogram body weight, a safety factor of 100 would make the tolerable daily intake for humans 1 microgram per kilogram body weight. The greater the uncertainty in the toxicology, the larger the safety factor.

The safety factor is an attempt to account for the unknown, and as such it might exaggerate the perceived risk. Nevertheless, when the intake of contaminants in food exceeds tolerable daily intakes or other similar 'action levels', it is a warning that health effects cannot be ruled out and that the situation has to be examined more closely.

The tolerable daily intake values for persistent organic pollutants and tolerable weekly

Tolerable daily intake for persistent organic contaminants.

Substance	TDI in µg/kg body weight	Reference
DDT	20	WHO 1984
Total PCB	1.0	Provisional TDI, Health Canada 1996
Chlordane	0.05	Health Canada 1996
Hexachlorocyclohexane	0.3 (total HCH) 8 (gamma-HCH)	Provisional TDI, Health Canada 1996 WHO 1989
Dioxin (2,3,7,8-TCDD)	0.00001 (10 pg)	WHO 1992
Toxaphene	0.2	Provisional TDI, Health Canada 1996
Mirex	0.07	Provisional TDI, Health Canada 1996

Tolerable weekly intake for heavy metals

Substance	TDI in µg/kg body weight	Reference
Total mercury	5	WHO
Methyl mercury	3.3	WHO
Cadmium	7	WHO
Lead	50	WHO

intake values for metals are summarized in the tables below. Note that tolerable daily or weekly intake values should by multiplied by the body weight of a person to determine the maximum daily or weekly intake. The values can change when new and better toxicological information becomes available.

Health benefits of traditional food

While this report focuses on contaminants in the circumpolar region, it is important to remember the benefits that traditional diets provide. The most striking example is that marine mammals and fish are rich in polyunsaturated fatty acids. In both Greenland and Canada, a diet high in these fatty acids has been associated with lower risk for heart disease. Among Inuit living in Greenland and on the shore of Hudson Bay in Canada, death from heart disease is uncommon.

Marine foods, especially whale skin, are also rich in selenium. This is important because selenium may reduce the toxic effects of metallic compounds such as arsenic, cadmium, mercury, and lead. Selenium is especially important in the body's antioxidant defense and may protect against cancer and possibly against heart disease

While some selenium in the diet is good, high selenium intake may, in some cases, cause negative health effects. For some Arctic populations, especially in northern Greenland, the local diet contains very high amounts of selenium, which has raised concern that the selenium could become toxic. However, there are no signs of chronic selenium poisoning among Greenlanders. This might be because the selenium is bound in animal proteins in the food.

The traditional diet of all Arctic groups is high in animal foods, which are rich sources of protein as well as many vitamins and essential elements. For example, a study in Canada showed that Inuit and Dene/Métis get most of their protein from traditional foods and more than adequate amounts of iron, zinc, vitamins D and E, and several of the B-vitamins. High levels of vitamin A are found in animal liver and blubber.

Traditional foods also provide a substantial portion of peoples' energy requirements. For example, they account for 47 percent of the daily requirement for people along Hudson Bay, 29 percent on Baffin Island, and 19 percent in central Arctic Canada.

Traditional diets are low in a few essential substances, providing barely enough to meet nutritional requirements. They include calcium, vitamin C, and vitamin B_6. People who depend mostly on land-based mammals rather than marine mammals may have marginal deficits of selenium in the diet. However, there have been no documented overt deficiencies of individual vitamins or minerals in the traditional diets of Arctic people.

In general, traditional diets provide a strong nutritional base for the health of Arctic peoples. Market foods from outside the Arctic often have less protein and iron, but more fat and carbohydrates. Moreover, changes in food habits are often accompanied by tendencies to a more sedentary life style, in which people spend less time hunting. Therefore, a move away from traditional foods could contribute to poor health, and specifically to a higher risk of diabetes and cardiovascular diseases.

The circumpolar study

In the first-ever circumpolar study of contaminants in people, AMAP has analyzed blood samples from mothers in ten regions of the Arctic. The following countries have participated so far: Canada, Denmark, Finland, Iceland, Norway, Russia, and Sweden. The information from Finland is not yet available. Discussions with the United States are on-going.

The maternal blood level reflects what the mother can potentially transfer to her fetus in the womb or to her child during breast feeding. The reported values are averages (geometric means). There will thus be women with both higher and lower contaminant levels. Even if the mean value is below known effect limits, a proportion of the women may still have levels that are high enough to cause concern.

To date, the results are preliminary, and little of the supporting demographic information has been analyzed. The next step will be to confirm the findings with additional samples and to assess whether traditional foods are responsible for these high levels.

Persistent organic pollutants

DDT

DDT is a pesticide. In humans, animals, and the environment, it is converted to DDE. Both substances accumulate in fat. People may be exposed through the food they eat or directly when the pesticide is sprayed. The human body can only get rid of DDT and DDE very slowly, mostly via urine and feces. DDT and DDE can cross the placenta to a growing fetus. A nursing mother also excretes these substances in her breast milk and can pass them on to her child in this way as well.

DDT and DDE have a range of effects, the most serious of which relate to reproduction, development, the nervous systems, and cancer. DDT can mimic the effects of estrogen (a female hormone), and DDE can be anti-androgenic (counteracting the male hormone). The effects of these contaminants may only be seen later, during an individual's reproductive years.

Total DDT (DDT+DDE) in maternal blood, geometric mean.

Region	µg total DDT/ liter blood plasma
Western Northwest Territories, Canada	0.9
North-central Northwest Territories, Canada	1.4
Nunavik (northern Quebec) Canada	4.6
Northwest Greenland	4.0
Northern Sweden	0.9
Northern Norway	0.7
Iceland	0.9
Nikel, Russia	3.4
Salekhard, Russia	0.7
Norilsk, Russia	0.9

Total PCBs in maternal blood, geometric mean.

Region	µg total PCBs/ liter blood plasma
Western Northwest Territories, Canada	1.6
North-central Northwest Territories, Canada	4.3
Nunavik (northern Quebec), Canada	10.0
Northwest Greenland	14.8
Northern Sweden	6.1
Northern Norway	3.6
Iceland	4.6
Nikel, Russia	4.2
Salekhard, Russia	4.8
Norilsk, Russia	6.4

There is some evidence that breast milk with DDE levels as low as 4 micrograms per gram lipid can suppress reflexes in newborns. Similar DDE levels have also been correlated with a shorter breast-feeding period. However, in neither of these cases is it completely clear that DDE is the cause.

The table above shows the levels of total DDT (including both DDT and DDE) in mothers' blood in different Arctic regions. Along the west coast of Greenland, in Nunavik, Canada, and in Nikel on the Kola Peninsula of Russia, blood levels are only a factor of ten lower than the levels that are known to cause neurological effects in babies. Reproductive effects and an increasing risk for breast cancer may be associated with these levels, but the links have not been proven.

A closer analysis of the components of total DDT points to different sources of contamination in Greenland and Nunavik than in Nikel. In Greenland and Nunavik, the break-down product DDE dominates, indicating that the DDT has accumulated in the food chain. In Nikel, there is relatively more DDT than in the other samples, which is a pattern that indicates a direct exposure to DDT through the local use of pesticides or indirect exposure via food contaminated by current use of DDT in other parts of Russia.

PCBs

PCBs are a family of compounds similar to one another and all called polychlorinated biphenyls. PCBs were produced and sold as mixtures. They have been used in a variety of applications, for example as electrical transformer fluids, lubricants, and plasticizers. PCBs are highly persistent and accumulate in fatty tissues. PCBs are only slowly excreted, mainly via breast milk.

Some PCBs have dioxin-like effects. PCBs have been implicated in effects on the liver, reproduction, birth weight of infants, neurobehavioral development, and the immune system. PCBs may also cause cancer.

The table above the right column shows the preliminary results from the circumpolar study of maternal blood. Women from an area that includes western Greenland and the eastern Canadian Arctic have the highest levels of PCBs, which most likely reflects their diet of sea mammals, fatty fish, and perhaps eggs from seabirds.

According to other studies, neurobehavioral effects in children can occur when the mother has a blood level of approximately 10 micrograms per liter blood. This indicates that there might be a concern for fetal and childhood development in some regions of the Arctic. Even in areas other than Greenland and the eastern Canadian Arctic, a proportion of the population is likely to be in this risk range.

A study of Inuit boys in Canada showed that their birth weight was lower if the mother had high levels of PCBs in her breast milk. Moreover, ear infections and other infectious diseases were much more common among 1-year-old Inuit who had been exposed to high levels of PCBs in the womb, which might indicate that their immune systems were weaker than those of other children.

Chlordane

Chlordane is a mixture of several components and is used as a pesticide. In the environment and in the body, chlordane can break down to other toxic substances. Its major effects are on the liver, the nervous system, and the immune system. It is also a probable human carcinogen. The body can excrete chlordane through feces and breast milk.

The table below shows that the geographical pattern of chlordane exposure is similar to that of PCBs. The majority of the chlordane is

Concentration of chlordanes in maternal blood, geometric mean.

Region	µg total clordanes/ liter blood plasma
Western Northwest Territories, Canada	0.1
North-central Northwest Territories, Canada	0.7
Nunavik (northern Quebec), Canada	1.4
Northwest Greenland	1.6
Northern Sweden	0.1
Northern Norway	0.1
Iceland	0.1
Nikel, Russia	0.1
Salekhard, Russia	0.5
Norilsk, Russia	0.5

in the form of the break-down product trans-nonachlor. Very little is known about the long-term effects of chlordane, especially of trans-nonachlor. It is therefore difficult to assess the health risks from elevated levels of total chlordane found in people in some Arctic regions.

Dietary studies from Canada together with measurements of elevated levels of chlordane in animals suggest that some indigenous groups are exposed to levels that are significantly above tolerable daily intakes.

Hexachlorobenzene

Hexachlorobenzene (HCB) is a pesticide and is also used as an industrial chemical. It has a range of toxic effects in laboratory animals, including damage to the liver, the skin, and the immune system. It can also cause neurological changes, cardiovascular effects, and reproductive effects.

Hexachlorobenzene in maternal blood, geometric mean.

Region	µg total hexachlorobenzene/ liter blood plasma
Western Northwest Territories, Canada	0.2
North-central Northwest Territories, Canada	0.5
Nunavik (northern Quebec), Canada	0.7
Northwest Greenland	0.9
Northern Sweden	0.2
Northern Norway	0.2
Iceland	0.3
Nikel, Russia	0.5
Salekhard, Russia	0.4
Norilsk, Russia	0.4

The circumpolar study of mother's blood finds the highest levels in Greenland, followed by intermediate levels in the Canadian and Russian Arctic. Also, concentrations of hexachlorobenzene in the blood of newborn Inuit from Arctic Canada are two to three times higher than those seen in southern Canadian population groups.

Hexachlorocyclohexane/lindane

Hexachlorocyclohexanes are a group of compounds that are primarily used as pesticides. They accumulate in fatty tissues and people are exposed via food. The body excretes them slowly via breast milk, feces, and urine. The most toxic form, gamma-hexachlorocyclohexane, also called lindane, can affect the liver, the nervous system, the kidneys, the reproductive system, and perhaps also the immune system. Lindane is a possible human carcinogen.

Beta-hexachlorocyclohexane in maternal blood, geometric mean

Region	µg beta-HCH/ liter blood plasma
Western Northwest Territories, Canada	0.1
North-central Northwest Territories, Canada	0.1
Nunavik (northern Quebec), Canada	0.1
Northwest Greenland	0.1
Northern Sweden	0.1
Northern Norway	0.1
Iceland	0.3
Nikel, Russia	1.7

Due to its persistence, beta-hexachlorocyclohexane has been measured in the circumpolar study of maternal blood, see table below left. One of the regions, Nikel, stands out with much higher levels than any other region. These blood values would lead to higher levels in breast milk and higher exposure of nursing infants.

Dioxins and furans

Dioxins and furans are two related families of substances. Some dioxins are extremely toxic to animals. The major concerns are effects on the development of the fetus and the newborn, reproduction, and the immune system. Another concern is cancer.

There are several studies of how dioxins and furans affect people. Levels found in most populations have not been associated with any excess disease incidence. However, workers who have been exposed during accidents have developed a skin disease called chloracne. High exposure in the workplace has also been associated with some types of cancer. Recent studies of infants who have been exposed in the womb or via breast milk show that dioxins and furans can affect some hormone-regulating systems.

Different dioxins and furans can vary more than ten-thousand-fold in toxicity. To adjust for these differences, the different compounds are assigned toxic equivalence factors (TEFs), relating them to the most toxic dioxin. For estimates of risk, the amount of each dioxin and furan is multiplied by its specific TEF, and the results are then added together. The final sum is expressed as toxic equivalents (TEQ).

Current exposure to dioxins and furans is at or just below tolerable daily intakes in most circumpolar nations. Some PCBs also have dioxin-like activity and can be included in the total TEQ values. This pushes the combined exposure well above tolerable daily intakes.

The average levels of dioxins and furans in breast milk are similar for Arctic and non-Arctic populations: 0.00001 to 0.00002 micrograms (10 to 20 picograms) per gram lipid in the milk.

Toxaphene

Toxaphene, also known as camphechlor, is a complex mixture of chemicals used as a pesticide. It enters the Arctic through long-range transport. People ingest it via their food, and the highest levels occur in marine mammals. The body can break down some components of toxaphene, but other components are very persistent and accumulate in fatty tissues.

In animals, high doses of toxaphene affect the nervous system, the liver, and the kidneys. Some components of the toxaphene mixture

bind to the estrogen receptor and can interfere with hormones important for reproduction. Intermediate and long-term exposure may affect the adrenal glands, the immune system, and the developing fetus. It is also a possible carcinogen.

There are very few measurements of toxaphene in people, but current intake scenarios suggest that some indigenous groups are exposed to levels that are significantly above the tolerable daily intake.

Mirex

Mirex is a pesticide that has entered the Arctic via long-range transport. It is highly persistent. Sensitive body organs include the liver, the kidneys, the eyes, and the thyroid. It is also a possible human carcinogen and is toxic to the growing fetus.

Mirex is present at low levels in human tissues throughout North America and Greenland. Because it is persistent and accumulates in the aquatic food chain, Mirex levels in breast milk are above average in communities that consume large amounts of fish, seabird eggs, or marine mammals. There is not enough information on the toxicology of Mirex to allow an accurate assessment of the implications for human health.

PAH

Polycyclic aromatic hydrocarbons (PAHs) are of concern because they can cause cancer. The important sources for humans are local, with tobacco smoke as the main exposure route. Wood smoke and smoke from other fuel sources also contribute to exposure both indoors and outdoors.

The potential daily exposure for adult males generally averages about 3 micrograms but can be up to 15 micrograms, and for smokers twice that amount. Exposure to PAHs through cigarette smoke has been associated with reduced fertility and with low birth weight in children. PAHs are also a major factor in lung cancer.

For non-smokers, PAHs in smoked or fried foods are by far the most important source. Their concentration depends on how the food is prepared, with barbecuing increasing the levels. Smoked fish also has higher levels than uncooked products. The daily intake from food has been estimated at 2 to 20 micrograms. In spite of the high intake, there appears to be little risk to health from this source.

Benefits of traditional foods have to be weighed against risks from POPs

The current levels of exposure to persistent organic contaminants in the Arctic are clearly of great concern, but it is still not clear what public health measures should be taken. The dilemma is especially difficult in communities where traditional foods are vital to spiritual, cultural, and physical well-being. After weighing the uncertainty of some of the values for tolerable daily intake for POPs against the benefits of traditional food gathering and consumption, most Arctic jurisdictions still advise people to continue to eat as they have before.

To develop better advice, it is necessary to learn more about the quantity and kind of food people consume and the contaminant levels in different food products. There is also an urgent need for an in-depth assessment of the toxic effects of all persistent organic contaminants, including the combined effects of these substances.

Breast feeding should continue in spite of POPs in the milk

Almost all of the organic pollutants studied can be detected in breast milk, sometimes at levels at which the child's short-term exposure is higher than tolerable daily intakes calculated for lifetime adult exposure. The effects of these contaminants on developing babies are poorly understood. Because a child gets breast milk for only a short period, from a few months to a couple of years, this exposure contributes only a little to the total lifetime body burden. Nevertheless, the relative exposure is high at a sensitive stage of growth and development.

Breast feeding has great benefits, including enhancing the bond between mother and child, providing nutrients, and helping the child's immune system get a good start. Breast feeding also reduces the risk that children will get intestinal upsets from contaminated water used to prepare formulas. At this time, the studies that have evaluated the potential effects of persistent organic pollutants in breast milk are limited and not conclusive. Currently, most health agencies advise that the benefits of breast feeding outweigh the known risks from persistent organic contaminants, and that breast feeding should continue.

Mother's life-time burden determines fetal exposure

A growing fetus is exposed to contaminants in the womb, and its dose of persistent organic pollutants will be determined by the levels in the mother's body. By the time a woman is pregnant, she can only partially influence this dose by changing her food habits. Most of the exposure comes from persistent organic pollutants she has accumulated in her body since she was born. The most important way to reduce fetal exposure to POPs is therefore to ensure that contaminant levels in the environment decrease drastically by cutting emissions. In addition, it is important to develop dietary advice for girls, women of child-bearing age, and pregnant women to promote the use of less-contaminated local foods to help reduce POP intake without losing the nutritional, cultural, and spiritual benefits of traditional foods.

Heavy metals

AMAP's circumpolar study of human health includes an assessment the impacts of mercury, cadmium, lead, and nickel. The results are preliminary, but it is already clear that mercury levels in some areas are high enough to put children's health at risk. Cadmium levels are also high enough to cause public health concerns.

In general, metal levels are highest in people who eat large amounts of organ meats, including kidney, liver, and muscle from marine mammals and some freshwater fish, and kidney from terrestrial animals.

Mercury

The major source of mercury is through meat, in which it is found as methyl mercury. Methyl mercury is easily taken up through the intestinal wall, and blood concentrations will reflect the daily intake. The major concern is damage to the brain and to the nervous system.

Methyl mercury easily passes through the placenta and can affect a growing fetus. Such exposure can cause neurological damage in the child, which is evident both from structural changes in the brain and from changes in behavior. The growing brain is much more sensitive than the adult brain.

Mercury in maternal blood, geometric mean.

Region	µg mercury/ liter whole blood
Western Northwest Territories, Canada	1.7
North-central Northwest Territories, Canada	3.5
Nunavik (northern Quebec), Canada	13.7
Northwest Greenland	19.8
Northern Sweden	1.6
Northern Norway	2.3
Iceland	2.9
Nikel, Russia	2.3

The table above summarizes the levels of mercury in maternal blood. The levels are highest among people who eat a lot of marine food, especially in the eastern Canadian Arctic and in Greenland. The range of values shows that the levels in some women indicate daily intakes close to those that cause concern for possible neurological damage in children.

These findings confirm earlier studies that found several groups of people with blood levels above acceptable values. Some of the values in these findings are above those that are associated with a known risk for neurological damage. The most exposed groups include Polar Inuit in North Greenland and Inuit and Cree in the eastern Canadian Arctic. A dietary survey of eastern Canadian Inuit shows that 29 percent of the women have daily intakes of mercury that exceed WHO tolerable daily intake recommendations. While neurological signs have been observed in some highly exposed indigenous people, it has not been possible to prove that methyl mercury is the cause.

Methyl mercury may also affect the immune system, though existing data is not conclusive. Based on the mercury levels found in people from several Arctic communities, immunosuppressive effects cannot be ruled out.

Mercury levels in people living today in Northwest Greenland are up to three times higher than those that can be calculated from archeological hair samples from the late 1400s. Recent time trends are more difficult to assess. Some recent Canadian studies indicate lower levels in the mid 1990s than a decade earlier. Changes in diet or geographical and seasonal differences may also explain the apparent trend.

The high mercury levels in some population groups and in certain marine foods have raised questions about the need for public health measures to protect the growing fetus and the nursing infant. It is recommended that local authorities develop dietary guidelines to help pregnant and nursing women avoid the most contaminated foods. It is important that such guidelines are made within the context of the benefits of traditional foods and local cultures.

Cadmium

Cadmium accumulates in the kidney and the liver. The main concern is its toxic effects on the kidney. Kidney damage leads to a loss of proteins and essential minerals, even at modest exposures. Cadmium-induced kidney damage is irreversible.

The main source of cadmium for people is tobacco. One cigarette contains 1 to 2 micrograms cadmium. Other sources are traditional foods, especially kidney and liver from caribou, reindeer, and whale. The exposure from diet is difficult to estimate, as less than five percent of the cadmium in the food is taken up by the intestine. The iron and protein content of the diet also affects uptake.

Cadmium in maternal blood, geometric mean.

Region	µg cadmium / liter whole blood
Western Northwest Territories, Canada	0.7
North-central Northwest Territories, Canada	1.8
Nunavik (northern Quebec), Canada	3.9
Northwest Greenland	1.3
Northern Sweden	0.1
Northern Norway	0.5
Iceland	0.4
Nikel, Russia	0.1
Salekhard, Russia	0.4
Norilsk, Russia	0.3

The growing fetus is protected from cadmium because the placenta accumulates the metal and acts as a partial biological barrier. However, if cadmium levels are very high, as in a smoker, the placenta will only partially protect the fetus. Cadmium can also have indirect effects by upsetting the uptake of zinc, which could possibly lead to a zinc deficiency in the child.

The circumpolar study of maternal blood shows that cadmium levels are highest in Inuit from Nunavik in the eastern Canadian Arctic; see table on the previous page. Based on the WHO guidelines, these levels should not cause health concerns. However, recent research suggests that effect levels are lower than those used to develop the guideline. The implication is that some people in the eastern Canadian Arctic and Greenland have cadmium levels in their kidneys that are high enough to cause mild damage. To test these suspicions, cadmium and protein levels in urine need to be assessed.

To reduce cadmium exposure, the most important public health advice is to reduce smoking.

Lead

The exposure pathways for lead are not clear, but air, food, and drinking water are probably the major sources. Lead is toxic to the process that builds red blood cells, leading to anemia. The most disconcerting damage, however, is on children's neurological development. The growing brain seems to be highly sensitive to lead, and several studies indicate that children in polluted areas have deficits in speech and language processing, attention, and classroom performance. This effect persists several years after exposure.

Lead concentration in maternal blood, geometric mean.

Region	µg lead/ liter whole blood
Western Northwest Territories, Canada	28.3
North-central Northwest Territories, Canada	36.1
Nunavik (northern Quebec), Canada	82.9
Northwest Greenland	51.4
Northern Sweden	19.7
Northern Norway	12.4
Iceland	16.2
Nikel, Russia	22.8
Salekhard, Russia	24.9
Norilsk, Russia	18.6

The table above shows lead levels in mothers' blood. These levels are similar to levels in southern populations in the northern hemisphere and below guideline values of 100 micrograms per liter blood. Current lead levels do not pose a significant threat to the health of Arctic people. Moreover, lead levels are decreasing, though there are some exceptions in Arctic Russia.

Nickel

For the general public, the main concern with nickel is that it can cause an allergic reaction, especially on the skin. The skin allergies can be exacerbated by nickel in the drinking water or food. Worldwide, 7 to 10 percent of all females and 1 to 2 percent of all males suffer from nickel allergies

Occupational exposure is a problem at the nickel-copper smelters in the Russian Arctic. The major concern is an increased incidence of cancer of the lungs and nose. Nickel can also be toxic to the kidneys, and mild effects have been seen in people exposed in the work environment or by drinking contaminated well water.

Radiation

The health effects of radiation are presented in the chapter *Radioactivity*, including a dose assessment for different population groups. The main concern for public health is that chronic exposure to natural and anthropogenic radionuclides will lead to an increased risk of cancer. In regulating nuclear activities, the dose limit for public exposure to anthropogenic radionuclides is 1 millisievert per year, which corresponds to an estimated increased risk for fatal cancer of one in 20 000.

Anthropogenic radionuclides are declining

The levels of human exposure to anthropogenic radionuclides in the Arctic have declined since the cessation of above-ground tests of nuclear bombs. However, because of the accumulation of some radionuclides in Arctic food chains, the exposure is generally higher in the Arctic than for populations in northern temperate latitudes.

Radiocesium is the most important anthropogenic radionuclide from a human-health perspective. In biological systems, radiocesium behaves in a manner similar to potassium, which is an essential nutrient. The cesium is almost completely absorbed by the intestines and becomes distributed throughout the body. It is cleared from the body with a biological half-life of two to three months. The major biological pathways are lichen to caribou/reindeer to humans, and freshwater to fish to humans.

The average lifetime cumulative dose to Arctic populations is 0.7 to 11 millisieverts. For some groups of people who consume large quantities of caribou, the range is 10 to 150 millisieverts, with the latter being an upper limit for individual lifetime exposure.

Virtually all the cumulative radiocesium dose has already been received. Unless there are new major inputs from accidents or from new atmospheric bomb testing in spite of international bans, the impact on future generations will be minimal.

Strontium-90 is chemically similar to calcium and becomes integrated in the bone. It is concentrated in the food chain from grass to cows to milk to humans. The impact on Arctic people is no greater that on other population groups. The doses are much smaller than for radiocesium, 0.1 to 0.4 millisieverts, with 4 millisieverts as the highest dose in selected groups.

Natural isotopes contribute most to lifetime exposure

Two natural radioactive isotopes, lead-210 and polonium-210, make a greater contribution to present-day exposure of Arctic populations than all the anthropogenic radionuclides combined. They become airborne as a result of the decay of radon gas seeping from the soil.

The isotopes are transported via the air and accumulate in the lichen-caribou/reindeer-human food chain. Some Canadian studies have estimated doses of up to 10 millisieverts per year for Arctic residents. Since these natural isotopes are ubiquitous in the environment, these doses have probably remained the same for the 10 000 to 20 000 years that people have lived in the Arctic.

Ultraviolet radiation

Depletion of ozone will increase the amount of ultraviolet radiation reaching the Earth's surface, in particular the shorter wavelengths that are most damaging to living systems. As discussed in the chapter *Climate change, ozone depletion, and ultraviolet radiation*, reflective snow cover can make the effects especially pronounced in the Arctic. The eyes are most vulnerable, with definite risks of snowblindness, and an increasing concern about the incidence of cataracts. Clothing protects the skin and prevents skin cancer.

Snow blindness and eye disease

The acute effect of excess ultraviolet radiation on the eye is that the surface of the eyeball becomes inflamed. In severe cases, this causes snow blindness. This painful condition has been known since ancient times in the Arctic and is usually linked to the strong light of spring, when snow reflects the solar rays. Fortunately, the eyes heal after only a few days. Repeated episodes of snowblindness, however, may lead to an increased risk of other eye diseases.

RIKKE CLAESSON

Traditional Inuit slit goggles from Greenland that protect the eyes against ultraviolet radiation.

Because the diffusely-reflected ultraviolet radiation comes from all sides, it is difficult to protect the eyes, though tight-fitting, UV-absorbing sunglasses with side flaps may help significantly. Traditional Inuit slit goggles provide very effective protection and allow less than one percent of the damaging ultraviolet radiation to reach the eye.

The chronic exposure of the eyes to excess ultraviolet radiation can increase the risk of some types of cataracts, a clouding of the lens in the eye. Cataracts can eventually lead to blindness.

Skin and immune effects

The acute effect of ultraviolet radiation on the skin is that too much can cause a sunburn. A more serious concern is that chronic exposure to ultraviolet radiation increases the risk of skin cancer. A person's total lifetime exposure to sun is the most important factor for the two most common skin cancers, basal cell carcinoma and squamous cell carcinoma. These are usually treatable. The more dangerous skin cancer, malignant melanoma, has been connected to sunburns, especially during childhood.

The risk for skin cancer depends very much on natural skin complexion. Light-skinned people who sunburn easily are much more sensitive than those with naturally darker skin. Lifestyle is another important factor, especially the extent to which the body is protected by clothing. Greenlanders only have 15 percent of the incidence of tumors found among Danes in Denmark. The major reasons are probably their darker complexion, greater protection from clothing, and that they are less likely to vacation in southern sunny areas.

Sunlight also plays an important role in aging the skin, making it less elastic and causing wrinkles. Such changes are common in the faces of Inuit hunters, whose skin is smooth and unblemished where it has been protected by clothing.

Ultraviolet radiation can suppress the immune system, especially in the skin. This suppression makes the body less able to recognize tumor cells and may thus be a factor in the increased risk of skin cancer. Immunosuppression related to ultraviolet exposure has also been connected to outbreaks of cold sores caused by the *Herpes simplex* virus and in the development of a wart virus that gives rise to flat benign tumors in the exposed skin.

National reports

As a complement to the overall assessment, this chapter also provides national reports about regional and local environmental health issues.

Canada

In response to concern about contaminants in traditional foods, the Canadian government launched the Arctic Environmental Strategy, Northern Contaminants Program in 1992. A general conclusion from this initiative is that the indigenous peoples of Canada's North are

exposed to higher levels of persistent organic contaminants and metals than the general population in Canada. Moreover, some groups of people have high enough body burdens of contaminants to cause health concerns.

Persistent organic pollutants

The immediate sources of persistent organic pollutants are marine mammals and fish in the diet. The major concern is that these contaminants are passed on to the developing fetus and to breast-feeding children. The figure to the right shows the levels of hexachlorobenzene, DDE, and PCBs in the cord blood of newborns. For some Inuit populations, the levels are two to four times higher than for the southern population of Canada.

In breast milk, the concentration of DDE is four to five times higher in Inuit women in northern Quebec than women in southern Canada, reflecting the fact that the Inuit women's food includes animals high in the food web. People from the north shore of the Gulf of St. Lawrence, who eat large amounts of fish and gull eggs, have intermediate levels. There is too little data to analyze time trends, but so far there is no indication that the DDT/DDE levels are going down, as they have in southern Canada. In the late 1960s, DDT levels in breast milk from women in southern Canada were three times higher than they are in the Arctic today.

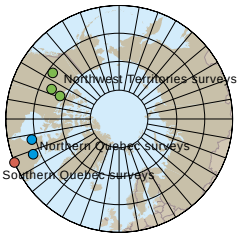
Several studies also point to elevated levels of PCBs. Most of the dioxin-like activity in the milk samples seems to come from dioxin-like PCBs. A large Dutch study of contaminants in breast milk and child development has shown that similar levels of dioxin-like activity, but from other sources, have subtle effects on the immune systems and the neurological development of children. A preliminary report from a study on Canadian Inuit children showed an association between increasing PCB/dioxin/furan levels and immune system deficits, which could lead to an increased susceptibility to disease.

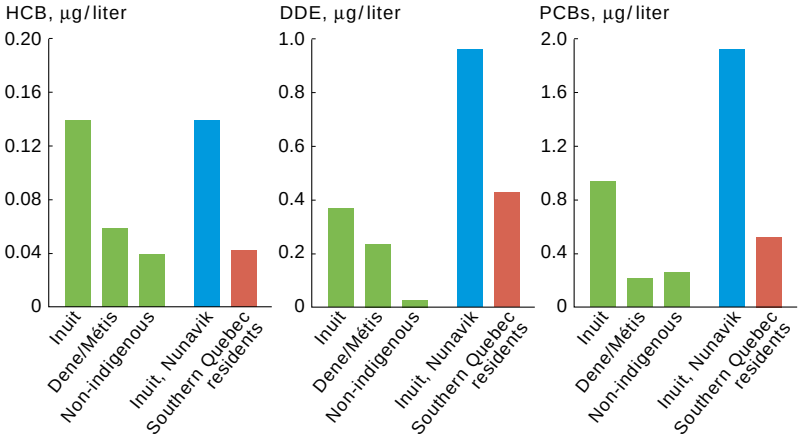
Several other POPs are also five to ten times higher in the breast milk of Inuit women than in that of women from southern Canada. These include Mirex, chlordane, and hexachlorocyclohexane.

A few studies have also tried to estimate the intake of persistent organic pollutants by using diet surveys. The figure to the right shows the intake for a group of Inuit from Baffin Island, who rely heavily on marine mammals and fish, compared to Sahtu Dene/Métis, who rely heavily on caribou and fish. For the Inuit group, intakes of chlordane and toxaphene exceed the tolerable daily intakes. The intakes of hexachlorobenzene, hexachlorocyclohexane, and PCBs are below but within a factor of ten of the tolerable daily intakes. For the Sahtu Dene/Métis, the values for toxaphene and chlordane are approximately one tenth of the tolerable daily intakes, while the other contaminants are well below these limits.

Another study of Inuit women showed that the intake of chlordane, toxaphene, and to a lesser extent PCBs may also exceed tolerable daily intakes. This is in contrast to people living in southern Canada, where market foods have negligible levels of persistent organic pollutants.

One of the least studied contaminants is toxaphene. The intake depends completely on

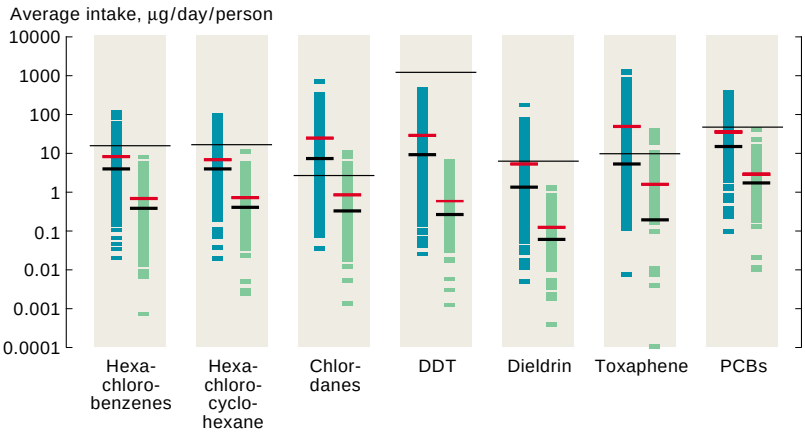




Levels of persistent organic pollutants in blood plasma from different populations in Canada.

food: narwhal and beluga blubber in the eastern Canadian Arctic are the most contaminated. A recent analysis of dietary surveys from the late 1980s shows that the daily intake of toxaphene often exceeded the tolerable daily intake. However, there is a large uncertainty factor in the tolerable daily intake value (TDI) for toxaphene due to the lack of information on its toxicity.

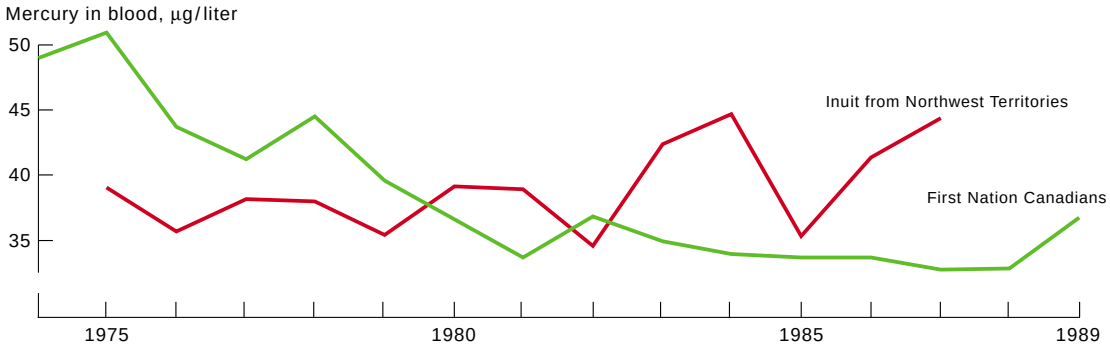
For all the persistent organic contaminants there is as yet very little scientific information linking harmful effects to these levels of exposure. When weighing this uncertainty against the known benefits of traditional foods, the recommendation is usually to continue eating traditional foods, though a recent health evaluation has recommended that women of reproductive age should consume less contaminated traditional food, e.g. more caribou and less beluga. Women are also advised to continue breast feeding.



Ranges of intake of persistent organic pollutants as estimated by diet surveys among Baffin Inuit and Sahtu Dene/Métis in relation to tolerable daily intake levels.

Heavy metals

High mercury exposure is common in the Canadian Arctic. In a large survey of people in more than 500 aboriginal communities across Canada, 57 percent of the Inuit and 20 percent of



Time trend of mercury concentrations in blood from Inuit in Northwest Territories and First Nation Canadians.

the Dene had blood mercury levels above the acceptable limit. The highest levels occur among Inuit from the eastern Northwest Territories and Nunavik and among northern Quebec Cree. In general, the levels of methyl mercury are higher in northern and eastern Inuit communities, where people eat large amounts of fish and sea mammals. Two recent dietary surveys indicate that Inuit women's daily intake of mercury exceeds the tolerable daily intake.

Cadmium is a concern for smokers and for people who eat large amounts of liver and kidney from hoofed animals, especially caribou and muskox. A recent risk assessment suggests that mild kidney damage may occur at intake levels that were previously considered safe. This may mean that even some non-smokers are at risk of mild kidney damage. Cadmium levels in smokers are as much as 20 times higher than in non-smokers, and are high enough that they may have some impact on kidney function.

Some indigenous communities in Canada have already addressed the health issues connected with cadmium. For northern Quebec Cree, food intake puts cadmium levels close to the tolerable daily intake, and one pack of cigarettes a day pushes it above the limit. The Cree Regional Authority has recommended that the use of traditional food does not have to be changed if smoking habits can be modified.

Caribou in the Yukon herd and in the herds between Great Slave Lake and Hudson Bay in the Northwest Territories also have very high levels of cadmium in their kidneys. A risk assessment that has been endorsed by community leaders concludes that the most important action is to reduce tobacco smoking, which leads to excessive cadmium levels regardless of the contribution from traditional foods.

Current levels of lead do not cause any immediate concern in Canada, but because lead can have such severe effects on children, monitoring should continue in order to detect any increases.

Radioactivity

The levels of radiocesium in freshwater fish and caribou are below internationally-agreed acceptable levels in meat. Whole body measurements of radioactivity show that the radiation dose from radiocesium is about 0.4 millisieverts per year. This can be compared with 5 millisieverts per year in the 1960s and also with a natural background radiation from all radioisotopes of 2 millisieverts per year.

The major source of radiation for people in the Canadian Arctic is from naturally occurring isotopes of polonium and lead, which accumulate in the muscle, liver, and kidney of caribou. Some residents in northern communities may be receiving radiation doses up to 10 millisieverts per year from ingested polonium.

Radon in buildings is probably less of a problem in the Arctic than in southern Canada, since permafrost and snow tend to keep radon in the ground. The common practice of building houses on pilings rather than directly on the ground also retards the buildup of radon in indoor air.

Greenland

Exposure to environmental contaminants in Greenland comes mostly from eating marine mammals. For cadmium, smoking is also a major source.

Persistent organic pollutants

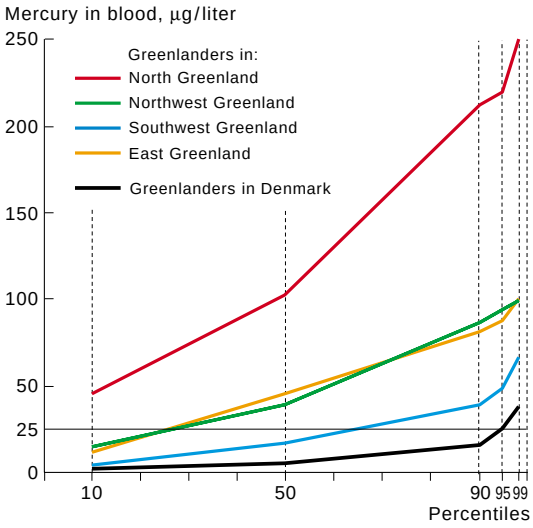
A few studies of levels of organic pollutants, along with dietary surveys, show that exposure to persistent organic pollutants is very high, both compared with other countries and in relation to the levels that may cause effects in people. The table below shows the levels of some organic contaminants in abdominal fat.

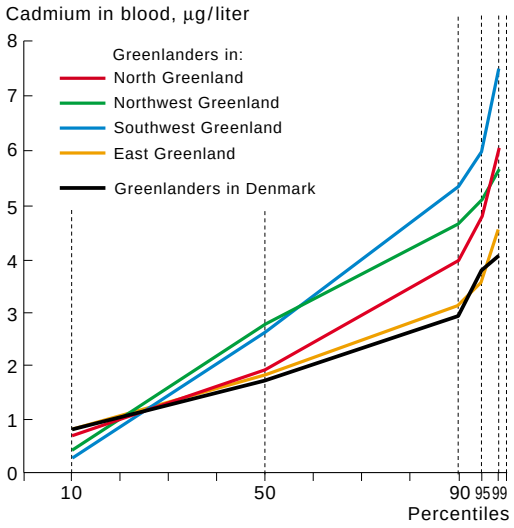
Mean levels of organochlorines in the fat of autopsies from Inuit; Greenland 1993.

Contaminant	µg/kg
beta-HCH	109
Chlordane	874
DDT+DDE	3987
Hexachlorobenzene	676
Mirex	153
PCBs	15 700

Heavy metals

For methyl mercury, high consumption of marine mammal meat leads to a high body burden. In North Greenland, 16 percent of the population have blood concentrations of mercury that exceed the levels at which toxic effects in the most susceptible persons might occur; see graph at opposite page, top left.





Mercury and cadmium in blood from Greenlanders showing the proportion, in percent, of the population that has blood values above a certain level. The left figure shows that all North Greenlanders have levels above the blood concentration that causes concern (approximately 25 micrograms per liter), and that almost all Greenlanders living in Denmark fall below this level. For cadmium, it is difficult to relate level of concern to blood concentrations.

Thus, the body burdens of both persistent organic pollutants and mercury are at levels that might have a negative impact on people's health. Although there are no examples of overt toxic effects from environmental pollutants, the subtle effects likely to exist would be very difficult to detect, easily overlooked, or easily masked by other factors.

In spite of this disconcerting picture, most health professionals with knowledge about Greenland agree that the positive health and social aspects of traditional food far outweigh any negative health effects of pollutants in the diet. More information from dietary surveys and about the contaminant levels in specific animal organs will make it possible to establish more specific dietary guidelines for vulnerable subgroups in the population, such as women of reproductive age, pregnant women, and children.

A few studies have looked for decreases in mercury levels. One study of blood from mothers did not show any time trends. However, maternal and cord blood analyzed within the AMAP monitoring program showed lower levels than have been previously found in northwest Greenland. One explanation might be that pregnant women are eating less marine foods than in past years. Monitoring of selenium levels also points to decreasing consumption of marine food.

Cadmium levels in people from East and North Greenland are the same as those for Greenlanders living in Denmark, whereas West Greenlanders have higher levels; See graph at the top right. The concentrations are lower than have been previously reported, but are still high enough to cause concern about mild kidney damage. To minimize cadmium intake, action should be taken to reduce smoking.

Lead levels among Greenlanders do not differ much from people in industrialized areas of Europe. The levels have decreased since the elimination of lead from gasoline, indicating strongly that the lead in the blood of Greenlanders most probably comes from long-range transport.

Local pollution

A few cases of local pollution have raised health issues in Greenland. The Black Angel zinc mine, situated close to the small village of Ukussissat in northern West Greenland, has contaminated the nearby fjord with zinc, lead, and cadmium. There have been some claims that this has caused an increased incidence of disease in the local population, but this has not been verified.

The second point source is the US Air Force bomber carrying nuclear weapons that crashed on the sea ice and spread radioactive material in the marine sediments near Thule Air Base in 1968. Danish workers employed in the clean-up have claimed that they suffer from higher cancer mortality and reduced fertility as a result of radiation exposure. However, several well-conducted epidemiological investigations have failed to confirm these claims. Only a few Greenlanders were employed in the clean-up and the accident happened far from Inuit villages.

A current source of local contamination is waste disposal and incineration in towns and villages, which is not well controlled.

Faroe Islands

Mercury, PCBs, and DDT are the contaminants of major concerns in the Faroe Islands. The major route of exposure is through high consumption of whale meat.

The median level of mercury in newborn cord blood in a recent study was 24.2 micrograms per liter, and about one fourth of the samples had levels above 40 micrograms per liter. This is higher than the normal acceptable range. Moreover, a very recent study by the Faroe Islands health authorities have shown that of a thousand women examined at childbirth, 15 percent had hair-mercury concentrations above the tolerable limit.

The intake of PCBs and DDE from whale blubber is high. For example, average daily intake of PCBs is estimated to be more than 200 micrograms, which is an order of magnitude higher than in Scandinavia.

Iceland

According to AMAP's circumpolar study, the levels of persistent organic pollutants and heavy metals in Iceland are marginally higher than those in Swedish and Norwegian women and markedly less than in Greenlandic women. This supports some earlier studies of PCBs and organochlorine pesticides in breast milk and in fat tissue collected during autopsies, which also indicate intermediate levels.

Norway, Finland and Russia

The national reports of Norway, Finland, and Russia are partly integrated because of joint efforts to assess the effects of contaminants on human health.

The most severe environmental problems are related to local industrial pollution in the Norilsk region of Siberia and in the Kola Peninsula of Russia, including the regions close to the Norwegian/Russian/Finnish borders. As discussed in the chapters *Acidification and Arctic Haze* and *Heavy Metals*, the air concentrations of sulfur dioxide, nickel, and copper can be extremely high close to the metal-smelter complexes. Locally, sulfur dioxide levels sometimes twenty times higher than permissible limits. The increased incidence of respiratory diseases, asthma, and allergies is probably related to the high sulfur dioxide levels.

The table below summarizes the potential point sources in Russia. In Norway, the only point source has been an iron-producing plant, Syd-Varanger. The plant closed permanently in 1996, but previous releases of dioxins are being investigated.

In industrial areas, occupational exposure to contaminants is a serious concern. In Russia, this includes people in coal and metal mining and in gas and oil production. For example, lung and nasal cancer are recognized as chronic occupational diseases in the nickel industry. One study also raises the concern that the occupational environment in nickel refineries may cause adverse effects on reproduction and development. A thorough follow-up of pregnancies and new-born babies has been initiated.

Indigenous people in Russia are mostly occupied in their traditional activities of herding, hunting, and fishing and thus are more exposed through the food chain than through their workplace.

Industrial cities of the Russian Arctic.

Region	City	Population	Main industrial activity
Murmansk Oblast	Murmansk	473 000	Harbor, ship repair,
	Severodvinsk	66 000	Ship building
	Kandalaksha	54 000	Aluminium industry
	Apatity	89 000	Extraction of apatite
	Kirovsk	43 000	Extraction of apatite
	Monchegorsk	68 000	Nickel industry
	Olenegorsk	47 000	Extraction of iron
	Kovdor	31 000	Extraction of iron
	Zapolyarnyy	23 000	Nickel industry
	Nikel	22 000	Nickel industry
Komi Republic	Vorkuta	117 000	Extraction of coal
	Inta	61 000	Extraction of coal
Yamalo-Nenets Autonomous Okrug	New Urengoy	105 000	Gas extraction
	Nadim	52 000	Gas extraction
Taimyr Autonomous Okrug	Norilsk	169 000	Nickel, copper, cobalt, and other non-ferrous industry

Persistent organic pollutants

There are several studies of persistent organic pollutants, including a survey of maternity patients carried out by AMAP. The results from Nikel on the Kola Peninsula of Russia show very high levels of beta-hexachlorocyclohexane and total DDT in plasma from delivering women. These levels may also be in the range of the lowest-observed-adverse-effect-levels for neurological effects in babies reported from other regions. Reproductive effects and increasing risk of breast cancer may also be associated with these DDT levels. Breast milk from these women is being analyzed.

There are several regional studies of breast milk, summarized in the table on top of opposite page. The levels of persistent organic pollutants in breast milk from Norway are generally very low from a global perspective, and far below the lowest-observed-adverse-effect-level. The concentrations of chlorinated pesticides in breast milk from Eastern Europe are, except for chlordane, generally significantly higher in all the sampling areas. The high concentration of DDT in relation to the breakdown product DDE points to some current source. One source for the high levels of DDT and hexachlorocyclohexane in the Russian samples may be current Russian use of insecticide mixtures that contain concentrated solutions of DDT and hexachlorocyclohexane. Exposure during a woman's stay at the maternity clinic cannot be ruled out since these insecticides are regularly used in hospitals against domestic insects such as cockroaches.

Breast milk samples from Fennoscandia show a slight decrease in persistent organic contaminants over the past decade. The decrease may be the result of bans and other restrictions on the use of several organic pesticides and PCBs in western countries.

Metals

Information about metal levels comes from AMAP's Human Health program presented earlier in this chapter in the circumpolar assessment of heavy metals in the Arctic. Mercury levels do not seem to pose any health risks in the joint Norwegian-Russian study areas, which included Norway, Kola, and Arkhangelsk. Mercury levels in delivering women from the Norwegian town of Hammerfest are moderately higher than elsewhere

in the region and point to fish as the major source of mercury.

Cadmium levels in blood from all three countries are generally very low compared with known effect levels. As expected, smokers have significantly higher levels of cadmium, with a few individuals reaching lowest known effects limits. A Finnish study of reindeer herders showed rather high cadmium levels, and there has been speculation as to whether this could be connected to pollution from the nickel smelters on the Kola Peninsula. More recent studies have not confirmed that the Kola smelters are the source of the cadmium.

Lead levels in the study area were mostly below the health reference values, though lead levels were significantly higher in children and mothers in Russia than in Norway. Russia still uses leaded gasoline, but because it has fewer cars than many other countries, lead levels are lower than those found in Western Europe 20 years ago.

Children are especially sensitive to lead. In some Russian communities, the blood levels in children are high enough to cause concern. This includes the communities of Krasnochelie and Lovozero. Traffic is not a likely source as the levels are higher than in big cities. The lead might come from meat contaminated by lead ammunition.

Nickel levels in urine are significantly higher in the Russian study groups than in the Norwegian groups, and the Russian values are above normal. Compared with the levels of nickel in people working in the nickel smelters, the exposure of the general population is mild to moderate. Although the health consequences are not believed to be of concern, these observations need to be examined more closely. The levels do not correlate with the distance from the nickel smelters, and the possible sources therefore need to be investigated. One source might be contaminated drinking water.

Radionuclides

In northwestern Russia and in Fennoscandia, the Chernobyl accident has resulted in a high dietary intake of radiocesium for some population groups. This is in addition to historical contamination from nuclear weapons tests in Novaya Zemlya.

Levels of radiocesium in placentas collected from the Norwegian and Russian Arctic range from below the detection limit to 83 becquerels per kilogram placenta. The levels seem to correlate with the Chernobyl fallout zone, with the highest counts in people who eat large amounts of traditional food. The Saami population of Finnmark, which is outside the Chernobyl high-fallout zone but consumes large amounts of traditional food, has levels that are similar to the general Norwegian population within the Chernobyl zone.

Based on the most recent literature, radiocesium concentrations in placental fresh tissue would not be expected to have adverse effects until they exceed 200 to 300 becquerels per kilogram, but a thorough cancer-risk assessment for the Norwegian Saami population of Finnmark has not yet been carried out. Figures from the Norwegian Cancer Registry, however, do not point to any increased cancer risk in Finnmark. Unverified data from the Russian city of Naryan Mar, near Novaya Zemlya, show a very high incidence of cancer and congenital malformations in both the indigenous and general populations. These results must be investigated more thoroughly as soon as possible.

Organic pollutants in breast milk from several different studies. The results are in nanograms per gram fat.

Region	HCB	Total HCH	Total chlordane	Total DDT	Ratio DDT/DDE	Total PCB
Russia						
Severodvinsk 1996	95	467	35	1336	0.16	517
Arkhangelsk 1996	99	558	27	2088	0.20	516
Murmansk 1993	129	858	59	1615	0.14	484
Monchegorsk 1993	111	745	33	1154	0.16	535
Norilsk 1995						457
Salekhard 1995						406
Norway						
Tromsø 1993	39	34	42	328	0.06	383

Sweden

Very few studies of contaminants have been carried out in the Swedish Arctic. Therefore, the following conclusions are based on levels in the general Swedish population. A recent report on environmental health listed five priority problem areas. These include asthma and respiratory tract problems from indoor and outdoor air pollution; lung cancer from air pollution, radon, and passive smoking; malignant melanoma (skin cancer) connected with sun bathing habits; accidents; and the accumulation of persistent environmental toxins.

Persistent organic contaminants

In general, the levels of several persistent organic contaminants seem to be declining. Nevertheless, a risk assessment for PCBs concluded that it cannot be ruled out that the current exposure of the Nordic population approximates the level which may give small but measurable effects on children's behavioral and intellectual performance. The most recent measurements of PCBs in breast milk, from 1986, found levels of 580 nanograms per gram lipid.

The high levels of persistent organic contaminants in some foods have prompted the Swedish Food Administration to recommend that Baltic herring, wild salmon, and sea trout from the Baltic and the Gulf of Bothnia should not be eaten more than once a week on average, and that girls and women of reproductive age should limit their consumption to once a month. Liver from cod and burbot should be avoided altogether.

Heavy metals
Mercury levels in Swedish women are very low compared with the levels in fish-eating populations in other parts of the world, and do not cause any health concern. However, to further reduce the risk to the fetus, the Swedish Food Administration advises pregnant women to restrict their intake of mercury by avoiding some freshwater fish.

Lead exposure is low and is unlikely to be a major health problem in Sweden.

Cadmium levels in the Swedish diet are a little less than half of those which can lead to cadmium-related kidney diseases in a small fraction of the population. Cadmium levels in smokers are higher than in non-smokers.

Radioactivity
After the Chernobyl accident, radiocesium has been measured both in breast milk and as whole-body content. The average whole body count for the general population varied between 1100 and 2000 becquerels. For the Saami population the range was 3400 to 25 000. It seems that less of the Chernobyl fallout is taken up by people than was the case with nuclear weapons fallout. The radiocesium might behave differently in the environment, but it might also be a result of effective countermeasures, such as dietary advice and stringent regulations concerning permissible levels of radiocesium in food.

Summary

Several groups of people in the Arctic are highly exposed to environmental contaminants. Persistent contaminants are carried to the Arctic via long-range transport and accumulate in animals that are used as traditional foods.

Traditional foods have known nutritional value and there is as yet little conclusive scientific evidence directly linking effects in adults to the levels of exposure that have been observed in the Arctic. Therefore it is not always clear what public health measures should be taken to reduce the exposure of populations who rely on traditional foods.

The growing brain is particularly sensitive to contaminants, and the influence on fetal development is of special health concern. Methyl mercury and several persistent organic pollutants cross the placental barrier, and in some groups of people PCB and mercury levels in mother's blood approach and exceed those thought to cause developmental effects in children. Preliminary results indicate that the average umbilical cord blood levels of several persistent organic pollutants and methyl mercury are two- to ten-fold higher in newborns from the AMAP region than in newborns from regions farther south.

For a number of persistent organic pollutants, health concerns also include child development, reproductive impacts, and effects on the immune system. Several of these effects may be mediated through the hormone-disrupting properties of some contaminants.

For certain geographic areas, current dietary exposure to persistent organic pollutants, to methyl mercury, and to cadmium are high enough to indicate a need for public health measures. For example, elevated levels of toxaphene, PCBs, and chlordane coupled with current intake scenarios suggest that some indigenous groups are exposed to levels that exceed tolerable daily intakes.

Human exposure to radionuclides has declined since the cessation of above-ground nuclear weapons testing. However, Arctic peoples are exposed to higher levels of radionuclides than people in the temperate zone. Moreover, radiation from natural sources has resulted in certain indigenous groups having higher radiation risks than the general public.

The goal of public health actions should be to reduce exposure to contaminants without threatening the social, cultural, spiritual, and physical well-being that is connected to collecting, sharing, and consuming traditional foods. The current traditional diet of Arctic indigenous people provides a substantial proportion of energy and protein requirements as well as most vitamins, essential elements, and minerals. The high consumption of fish and marine mammals may contribute to the lower incidence of heart disease among indigenous peoples in Alaska, Greenland, and Arctic Canada.

Weighing these known benefits against the suspected, but not yet fully understood, effects of contaminants, the conclusion at present is that consumption of traditional foods should continue. However, consideration should be given to developing dietary advice to promote the use of less-contaminated traditional food items which will also maintain nutritional benefits. Such guidelines should be developed at the local level within the context of local cultures.

Although there is both scientific and public concern that breast feeding will transfer contaminants from the mother to her child, present knowledge clearly indicates that the known benefits of breast feeding outweigh the currently-known risks from contaminants. To date, there have been no proposals to limit the duration of breast feeding.

The long-term reduction of exposure to persistent organic pollutants can only be accomplished through international conventions on bans and restrictions in production and use of these substances. The relative importance of natural and anthropogenic sources of heavy metals in the Arctic needs to be determined, and appropriate controls implemented.